第 37/2018 號行政長官公告

國際海事組織海上安全委員會於二零一四年五月二十二日透過第MSC.370（93）號決議通過了《國際散裝運輸液化氣體船舶構造和設備規則》（IGC規則）的修正案，該修正案於二零一六年一月一日在國際法律秩序上生效，包括對中華人民共和國及澳門特別行政區生效；

基於此，行政長官根據第3/1999號法律《法規的公佈與格式》第五條（一）項和第六條第一款的規定，命令公佈包含上指修正案的第MSC.370（93）號決議的中文及英文正式文本。

上指《國際散裝運輸液化氣體船舶構造和設備規則》（IGC規則）已透過第116/2015號行政長官公告公佈於二零一五年八月十四日第三十二期《澳門特別行政區公報》第二組副刊。

二零一八年六月二十日發佈。

行政長官　崔世安

Aviso do Chefe do Executivo n.º 37/2018

Considerando que, em 22 de Maio de 2014, o Comité de Segurança Marítima da Organização Marítima Internacional, através da sua resolução MSC.370(93), adoptou emendas ao Código Internacional para a Construção e Equipamento de Navios que Transportam Gases Liquefeitos a Granel (Código IGC), e que tais emendas entraram em vigor na ordem jurídica internacional, incluindo a República Popular da China e a sua Região Administrativa Especial de Macau, em 1 de Janeiro de 2016;

O Chefe do Executivo manda publicar, nos termos da alínea 1) do artigo 5.º e do n.º 1 do artigo 6.º da Lei n.º 3/1999 (Publicação e formulário dos diplomas), a resolução MSC.370(93) que contém as referidas emendas, nos seus textos autênticos em línguas chinesa e inglesa.

O *supra* mencionado Código IGC encontra-se publicado através do Aviso do Chefe do Executivo n.º 116/2015 no *Boletim Oficial da Região Administrativa Especial de Macau* n.º 32, II Série, Suplemento, de 14 de Agosto de 2015.

Promulgado em 20 de Junho de 2018.

O Chefe do Executivo, *Chui Sai On*.

海安會MSC.370（93）號決議

（2014年5月22日通過）

《國際散裝運輸液化氣體船舶構造和設備規則》

（《IGC規則》）修正案

海上安全委員會，

憶及《國際海事組織公約》關於本委員會職能的第28（b）條，

注意到以第MSC.5（48）號決議決議通過的《國際散裝運輸液化氣體船舶構造和設備規則》（以下稱“《IGC規則》”），根據《1974年國際海上人命安全公約》（《SOLAS》）（以下稱“公約”）第VII章已成為強制性文件，

還注意到公約關於《IGC規則》修正程序的第VIII（b）條和第VII/11.1條，

在其第93屆會議上**審議了**按公約第VIII（b）（i）條提出和分發的《IGC規則》修正案，

1. 按公約第VIII（b）（iv）條規定，**通過**《IGC規則》的修正案，其文本載於本決議附件；

2. 按公約第 VIII（b）（vi）（2）（bb）條規定，**決定**該修正案於 2015 年 7 月 1 日應視為已被接受，除非在此日期之前，有三分之

一以上的公約締約國政府或擁有商船合計噸位數不少於世界商船總噸數 50%的締約國政府通報其反對該修正案；

3. **提請**各締約國政府注意，按公約第VIII（b）（vii）（2）條規定，該修正案在按上述2被接受後，應於2016年1月1日生效；

4. **要求**秘書長按公約第VIII（b）（v）條規定，將本決議及其附件中修正案的核准無誤副本分發給所有公約締約國政府；

5. **還要求**秘書長將本決議及其附件的副本分發給非公約締約國的本組織成員。

附件

《國際散裝運輸液化氣體船舶構造和設備規則》

（《IGC規則》）修正案

《IGC規則》的完整文本由下列替代：

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第2章 船舶殘存能力和液貨艙位置

第3章 船舶佈置

第4章 貨物圍護

第5章 處理用受壓容器及液體、蒸氣和壓力管系

第6章 構造材料和質量控制

第7章 貨物壓力/溫度控制

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附錄1 《IGC規則》貨品數據報告格式

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前言

1 本規則的目的是為第19章所列的散裝液化氣體和某些其他物質的海上安全運輸提供一個國際標準；在考慮到所載貨品的情況下，規定了相關船舶的設計和建造標準及其所應裝配的設備，以便使其對船舶、船員和環境所造成的危險減至最少。

2 本規則的基本原則是根據其所涉及貨品的危險性，確定運輸所需的某種船型。每一種貨品可能具有一個或多個危險特性，包括易燃性、毒性、腐蝕性和反應性。由於某些貨品在低溫或者壓力狀態下進行運輸，有可能進一步產生其他危險。

3 嚴重的碰撞或擱淺可能導致液貨艙破損，並導致貨品不受控的排放。此種排放可能引起貨品的蒸發和擴散，在某些情況下可能導致船體的脆性斷裂。本規則的要求是根據現有的知識和技術，儘可能減少這種危險性。

4 在制定本規則的整個過程中，認識到本規則必須基於完善的造船和工程學原理，以及對本規則所涉及的貨品的危險性的徹底了解。液化氣體船舶的設計建造不僅是一門複雜的技術，而且還在迅速發展，故本規則也不應保持不變。本組織持續考慮到經驗和技術的進一步發展，將定期地對本規則進行審核。

5 對新貨品及其運輸條件的要求，在本組織海上安全委員會通過後，將根據1974年國際海上人命安全公約第VIII條的規定，在適當的修正案生效前，暫作建議案進行分發。

6 本規則主要是針對船舶設計和設備的規定。為了確保能安全運

輸貨品，必須對整個系統進行評估。至於保證貨品安全運輸的其他方面，例如培訓、操作、交通控制和港口裝卸等，本組織正在進行或將作進一步審核。

7 本規則的制定得到許多具有諮詢地位的組織的大力協助，例如國際氣體運輸船和碼頭經營者協會（SIGTTO）和其他組織，例如國際船級社協會（IACS）成員。

8 本規則第18章涉及液化氣體運輸船舶的操作，突出了其他章節中屬於操作性質的規則，並提到氣體運輸船安全操作特有的其他重要方面。

9 本規則的編排與海上安全委員會第48屆會議通過的《國際散裝運輸危險化學品船舶構造和設備規則》（IBC規則）相一致。如《IGC規則》所述，氣體運輸船也可散裝運輸IBC規則涉及的液體化學品。

10 設計成裝卸散裝液化氣體的浮式生產儲存和卸貨（FPSO）設施不列入《IGC規則》。但是，在《IGC規則》提供裝置操作最適當的風險減輕措施的範圍內，該裝置的設計者可考慮使用《IGC規則》。如果確定的更適當的風險減輕措施與本規則不一致，這些措施應優先於本規則。

第1章

總則

目的

為散裝液化氣體的海上安全運輸提供一個國際標準；在考慮到貨品性質（包括易燃性、毒性、窒息、腐蝕性、反應性以及低溫和蒸氣壓力）的情況下，規定了這類運輸船舶的設計和建造標準及其所應裝配的設備，以便使其對船舶、船員和環境所造成的危險減至最少。

1.1 適用範圍和實施

1.1.1 本規則適用於各種尺度（包括500總噸以下）從事散裝運輸本規則第19章所列的溫度為37.8℃時其蒸氣壓力超過0.28MPa（絕對壓力）的液化氣體和其他貨品的船舶。

1.1.2.1 除另有規定外，本規則適用於在2016年7月1日或以後安放龍骨或處於類似建造階段的船舶。類似建造階段係指：

.1 可辨認出船舶建造開始；和

.2 該船業已開始的裝配量至少為50t，或為所有結構材料估算重量的1%，取其小者。

1.1.2.2 就本規則而言，“建造的船舶”係指安放龍骨或處於類似建造階段的船舶。

1.1.2.3 除另有明文規定外，對於1986年7月1日或以後和2016年7月1日以前建造的船舶，主管機關應確保符合MSC.5（48）決議通過並經MSC.17（58）、MSC.30（61）、MSC.32（63）、MSC.59（67）、

MSC.103（73）、MSC.177（79）和MSC.220（82）決議修正的本規則適用要求。

1.1.3 不論何時建造的船舶，凡在2016年7月1日或以後改建成氣體運輸船後，應視作在開始改建之日建造的氣體運輸船。

1.1.4.1 當液貨艙內裝有本規則要求用1G型船舶載運的貨品時，位於本規則2.4.1.1所述保護區域內的液貨艙內不應裝載閃點為60℃（閉杯試驗）或低於60℃的易燃液體，也不應裝載本規則第19章中所列的易燃貨品。

1.1.4.2 同樣，當液貨艙內裝有本規則要求用2G/2PG型船舶載運的貨品時，則位於本規則2.4.1.2所述保護區域內的液貨艙內不應裝載1.1.4.1中所述易燃液體。

1.1.4.3 當液貨艙內裝有本規則要求用1G或2G/2PG型船舶載運的貨品時，在每一種情況下，上述限制僅適用於貨艙處所的縱向範圍內的保護區域。

1.1.4.4 當液貨艙內裝有本規則要求用1G或2G/2PG型船舶載運的貨品時，如果其數量僅限於供冷卻、循環或作燃料之用，則在這些保護區域內可以載運1.1.4.1中所述易燃液體和貨品。

1.1.5 除1.1.7.1的規定外，擬載運本規則涉及的貨品以及MSC.4（48）決議通過、並可能經本組織修正的《國際散裝運輸危險化學品船舶構造和設備規則》（IBC規則）涉及的貨品的船舶，應符合適於所載貨品的兩個規則的要求。

1.1.6.1 如果擬載運的貨品可能被認為是屬於本規則的範圍，但在

本規則第19章中尚未被列出，則主管機關和涉及這種載運的港口主管當局應根據臨時評定制定三方協議並根據本規則的原則制定初步的適當載運條件。

1.1.6.2 對於這類貨品的評估，貨品製造商應向主管機關提交完成的評定表（見附錄1），包括建議的船舶類型和載運要求。

1.1.6.3 如果純的貨品或技術上純的貨品的臨時評定已完成並經其他方同意，主管機關應向本組織的分委會提交評定表和《IGC規則》中新增完整條目的建議（見附錄1）。

1.1.6.4 已按三方協議進行臨時評定並已達成明確的或默認的協議後，可簽發相關船舶證書的附錄（見附錄3）。

1.1.7.1 當船舶設計和建造成載運下列貨品時，首先應滿足本規則的要求：

.1 本規則第19章中專門列出的貨品；和

.2 既在本規則中又在IBC規則中列出的一種或幾種貨品。對這些貨品，在規則第19章中表的“a”欄內用星號予以標記。

1.1.7.2 當船舶擬專門載運1.1.7.1.2所述的一種或幾種貨品時，應符合經修正的IBC規則的要求。

1.1.8 當船舶符合《IGC規則》的要求時，應在本章1.4規定的《國際散裝運輸液化氣體適裝證書》中予以註明。如符合本規則的修正案，適用時，也應在《國際散裝運輸液化氣體適裝證書》中予以註明。

1.1.9 如果本規則提及某段，該段所有分段的規定應適用。

1.1.10 如果船舶擬在固定場所以再氣化和排氣模式或氣體接收、處理、液化和儲存模式營運一段時間，營運涉及的主管機關和港口主管當局應採取適當的措施確保本規則中適用於其預定任務安排的相關要求的實施。此外，應基於本規則的原則針對其他未涵蓋在本規則原則中的特定風險的公認標準制定附加要求。風險可包括但不限於：

.1 火災和爆炸；

.2 撤離；

.3 危險區域的延伸；

.4 受壓氣體排放至岸上；

.5 高壓氣體排放；

.6 貨物處理中的翻滾狀況；

.7 易燃制冷氣體的儲存和處理；

.8 貨物圍護系統外貨物液體和蒸氣的持續存在；

.9 液貨艙過壓和低壓；

.10 液體貨物的船至船駁運；和

.11 停泊期間的碰撞風險。

1.1.11 如在本規則內使用風險評估或類似研究，結果也應包括但不限於下列作為有效證據：

.1 使用的方法和標準的說明；

.2 情景分析說明可能存在的變化或研究中錯誤的來源；

.3 獨立和適當的第三方對風險評估過程的驗證；

.4 制定風險評估依據的質量系統；

.5 評估中使用的數據的來源、適合性和有效性；

.6 評估中相關人員的知識基礎；

.7 結果與相關方關聯的分佈系統；和

.8 獨立和適當的第三方對結果的驗證。

1.1.12 儘管根據SOLAS公約，本規則法律上視作強制性文件，但本規則4.28和附錄1、3和4的規定為建議性或資料性。

1.2 定義

除另有明文規定外，下列定義適用於本規則。附加定義見本規則的各章。

1.2.1 *起居處所*係指公共處所、走廊、盥洗室、居住室、辦公室、醫務室、電影室、遊戲和娛樂室、理髮室、沒有炊事用具的配膳室及類似處所。

1.2.2 *A級分隔*係指SOLAS公約第II-2/3.2條中所定義的分隔。

1.2.3 *主管機關*係指船旗國政府。對於主管機關（港口），見港口主管當局。

1.2.4 *周年日*係指相應於《國際散裝運輸液化氣體適裝證書》到期日期的每年的月和日。

1.2.5 *沸點*係指貨品呈現蒸氣壓力等於大氣壓力時的溫度。

1.2.6 *船寬（B）*係指船舶的最大寬度，對於金屬殼體的船舶，在船中部量至肋骨型線，對於殼體為其他任何材料的船舶，量至殼體外表面。船寬（B）應以m計。

1.2.7 *貨物區域*係指船上設有貨物圍護系統、貨泵艙和壓縮機艙的部分，並包括在這些處所上方的船上該部分的整個長度和寬度範圍內的甲板區域。對於在最後一個貨艙處所後面或最前一個貨艙處所前面所設的隔離艙，壓載艙或留空處所，不應算作貨物區域。

1.2.8 *貨物圍護系統*係指用於圍護貨物的裝置，包括所設的主屏壁和次屏壁以及附屬的絕熱層和屏壁間處所，還包括必要時用於支持這些構件的鄰接結構。如果次屏壁是船體結構的一部分，則他可以是貨艙處所的邊界。

1.2.9 *貨物控制室*係指用於控制貨物裝卸作業的處所。

1.2.10 *貨物機器處所*係指貨物壓縮機或貨泵、貨物處理裝置所在的處所，包括向機艙提供氣體燃料的裝置所在的處所。

1.2.11 *貨泵*係指用於輸送液體貨物的泵，包括主泵、增壓泵、噴淋泵等。

1.2.12 *貨物*係指由符合本規則的船舶散裝運輸的並在第19章中所列的貨品。

1.2.13 *貨物服務處所*係指貨物區域內的工作間、面積大於2m2的的儲物間和儲藏室等處所。

1.2.14 *液貨艙*係指被設計成貨物的主容器的液密殼體，包括不管其是否具有絕熱層或/和次屏壁的所有這類圍護系統。

1.2.15 *閉環取樣*係指通過在取樣期間將貨品返回貨艙從而將貨物蒸氣逸入大氣降至最少的貨物取樣系統。

1.2.16 *隔離艙*係指兩相鄰鋼質艙壁或甲板之間的隔離處所。該處所可為留空處所或壓載處所。

1.2.17 *控制站*係指設有船舶無線電、主要航行設備或應急電源的處所，或火警記錄或失火控制設備集中的處所。其中不包括通常在貨物區域內設置的專用失火控制設備。

1.2.18 *易燃貨品*係指本規則第19章的表中“f”欄內標有“F”的貨品。

1.2.19 *可燃性極限*係指在給定的試驗裝置中，對燃料氧化劑混合物施以一個足夠強的着火源後，使其正好能產生燃燒的條件。

1.2.20 *FSS規則*係指消防安全系統規則，即本組織海上安全委員會MSC.98（73）決議通過並經修正的國際消防安全系統規則。

1.2.21 *液化氣體船*係指建造或改建成用於散裝運輸本規則第19章表中所列的任何液化氣體或其他貨品的貨船。

1.2.22 *氣體燃燒裝置（GCU）*係指通過熱氧化處理過量的貨物蒸氣的裝置。

1.2.23 *用氣設備*係指船上使用貨物蒸氣作為燃料的任何裝置。

1.2.24 *危險區域*係指爆炸性氣體環境出現或預期可能出現的數量達到足以要求對電氣設備的結構、安裝和使用採取特殊預防措施的區域。如果存在氣體環境，也可能存在下列危險：毒性、窒息、腐蝕性、反應性和低溫。也應考慮到這些危險，並需考慮對處所通風和保護船員的附加預防措施。危險區域包括但不限於下列區域：

.1 貨物圍護系統內部和液貨艙壓力釋放管路或其他的液貨艙透氣系統，以及任何含有貨物的管路和設備；

.2 屏壁間處所；

.3 要求次屏壁的貨物圍護系統所在的貨艙處所；

.4 不要求次屏壁的貨物圍護系統所在的貨艙處所；

.5 以單層鋼質氣密界限與要求次屏壁的貨物圍護系統所在的貨艙處所相隔離的處所；

.6 貨物機器處所；

.7 距離氣體釋放的可能來源（例如貨物閥門、貨物管法蘭、貨物機器處所通風出口）3m以內的開敞甲板區域或開敞甲板上半圍蔽處所；

.8 距離貨物機器處所入口、貨物機器處所通風入口1.5m以內的開敞甲板區域或開敞甲板上半圍蔽處所；

.9 在貨物區域內開敞甲板上和在開敞甲板上貨物區域前後3m內、至露天甲板以上2.4m範圍內的區域；

.10 距該貨物圍護系統露天表面2.4m範圍內的區域；

.11 內部含有貨物管路的圍蔽或半圍蔽處所，但含有用於蒸發氣體燃料燃燒系統的貨物管路的處所除外；

.12 其開口直接通向任何危險區域的圍蔽處所或半圍蔽處所；

.13 鄰近貨物圍護系統或直接在貨物圍護系統之上或之下的留空處所、隔離艙、管隧、通道和圍蔽或半圍蔽處所；

.14 在垂直通氣管出口向上或附近，以該出口為中心的6m半徑、無限高度的垂直圓柱內；以及自該出口向下，以6m為半徑的半球面內的開敞甲板區域，或開敞甲板上的半圍蔽處所；和

.15 在貨物集管閥周圍的泄漏承接容器範圍內，以及以該範圍為界向外水平延伸3m，且距甲板以上2.4m範圍內的開敞甲板區域。

1.2.25 *非危險區域*係指危險區域以外的區域。

1.2.26 *貨艙處所*係指由船舶結構所圍蔽、其內部設有貨物圍護系統的處所。

1.2.27 《*IBC規則*》係指本組織海上安全委員會MSC.4（48）決議通過並經修正的國際散裝運輸危險化學品船舶構造和設備規則。

1.2.28 *獨立*係指不以任何方式與其他系統相連接的如管系或透

氣系統，也不存在任何可能與其他系統連接的設施。

1.2.29 *絕熱處所*係指其全部或部分由絕熱材料所填充的處所，其可以是或可以不是屏壁間處所。

1.2.30 *屏壁間處所*係指不論是其全部還是部分由絕熱材料或其他材料所填充的主屏壁和次屏壁之間的處所。

1.2.31 *船長（L）*係指現行的國際載重線公約中定義的船長。

1.2.32 *A類機器處所*係指裝有下列設施的處所以及通往這些處所的圍蔽通道：

.1 用於主推進的內燃機；或

.2 作其他用途的合計總輸出功率不小於375kW的內燃機；或

.3 任何燃油鍋爐或燃油裝置，或鍋爐以外的任何燃油設備，例如惰性氣體發生器、焚燒爐等。

1.2.33 *機器處所*係指A類機器處所和其他有推進機械、鍋爐、燃油裝置、蒸汽機和內燃機、發電機和主要電動機、加油站、製冷機、減搖裝置、通風機和空調機的處所，以及類似處所；並連同通往這些處所的圍蔽通道。

1.2.34 *MARVS*係指液貨艙釋放閥的最大允許調定值（錶壓力）。

1.2.35 *指定的驗船師*係指主管機關指定/任命用於執行SOLAS公約關於檢查和檢驗以及免除規定的驗船師。

1.2.36 *燃油裝置*係指被用於為燃油鍋爐輸送燃油或被用於為內燃機輸送加熱燃油的設備，並包括被用於處理油壓超過0.18MPa錶壓力的任何油泵、過濾器和加熱器。

1.2.37 *本組織*係指國際海事組織（IMO）。

1.2.38 *滲透率*係指在某一處所內假定會被水浸佔的容積與該處所總容積之比。

1.2.39 *港口主管當局*係指船舶裝卸港口的國家有關當局。

1.2.40 *主屏壁*係指當貨物圍護系統含有2層界限面時被用於裝貨的內層構件。

1.2.41 *貨品*係指用於包含本規則第19章中所述氣體清單的集合術語。

1.2.42 *公共處所*係指起居處所中用作大廳、餐室、休息室以及類似的固定圍蔽處所的部分。

1.2.43 *被認可組織*係指由主管機關按SOLAS公約第XI-1/1條規定授權的組織。

1.2.44 *公認標準*係指為主管機關所接受的適用的國際或國家標準，或由被認可組織制定和維護的標準。

1.2.45 *相對密度*係指一定體積貨品的質量與等體積淡水的質量之比。

1.2.46 *次屏壁*係指貨物圍護系統中被設計成能暫時容納可能從主屏壁泄漏的液貨的液密外層構件，同時也為了防止船體結構的溫度

會下降至不安全的程度。對於次屏壁的型式，在本規則第4章中有更完整的定義。

1.2.47 *獨立系統*係指不互相連接的貨物管系和透氣系統。

1.2.48 *服務處所*係用作廚房、配有烹調設備的配膳室、儲物間、郵件間和貴重物品室、儲藏室，不構成機器處所部分的工作間以及類似處所，包括通往這些處所的圍蔽通道。

1.2.49 *SOLAS公約*係指經修正的1974年國際海上人命安全公約。

1.2.50 *液貨艙罩*係指用於保護突出於露天甲板以上的貨物圍護系統免受損壞的結構或用來保證甲板的連續性和完整性的防護。

1.2.51 *液貨艙氣室*係指液貨艙的向上延伸部分。如貨物圍護系統位於甲板以下時，液貨艙氣室應伸出於露天甲板或液貨艙罩之上。

1.2.52 *熱氧化措施*係指符合第16章規定的使用貨物蒸發氣作為船上燃料的系統或作為一個廢熱回收的系統或符合本規則的不使用貨物蒸發氣作為燃料的系統。

1.2.53 *有毒貨品*係指本規則第19章表中“f”欄內標有“T”的貨品。

1.2.54 *轉塔艙*係指包含用於回收和釋放可斷開的轉塔繫泊系統、高壓液壓操作系統、消防裝置和貨物輸送閥的設備和機器的處所和圍蔽通道。

1.2.55 *蒸氣壓力*係指在規定溫度下液體上方飽和蒸氣的平衡壓

力（絕對壓力），以帕斯卡（Pa）計。

1.2.56 *留空處所*係指在貨物區域內的貨物圍護系統外部的圍蔽處所，但不包括貨艙處所、壓載艙、燃油艙、貨泵艙、壓縮機艙或人員正常使用的任何處所。

1.3 等效

1.3.1 凡本規則要求船上應裝設或配備的特定的附件、材料、器具、儀器、設備的部件或其型號，或應採取的任何特別措施，或應符合的任何程序或佈置，主管機關可允許在該船上裝設或配備任何其他的附件、材料、器具、儀器、設備的部件或其型號，或採取任何其他的措施，或符合任何其他的程序或佈置，但須通過試驗或其他方法，確認其至少與本規則要求者具有同等效能。然而，主管機關不能允許用操作方法或程序替代本規則規定的特定的附件、材料、器具、儀器、設備的部件或其型號，除非該替代經本規則特別准許。

1.3.2 當主管機關准許以任何的附件、材料、器具、儀器、設備的部件或其型號，或措施、程序或佈置或新穎設計或適用範圍進行替代時，應將其細節連同驗證報告送交給本組織，以便本組織能將這些文件分發給SOLAS公約的其他締約國政府，供其官員參考。

1.4 檢驗和發證

1.4.1 *檢驗程序*

1.4.1.1 為執行本規則規定和給予免除而對船舶進行的檢驗，應由主管機關的官員進行。但主管機關可將這些檢驗委託給為此目的而指定的驗船師或經其認可的組織。

1.4.1.2 1.2.43中所述的被認可組織應符合SOLAS公約的規定和被認可組織（RO）規則。

1.4.1.3 指定驗船師或認可組織執行檢驗的主管機關，應至少對任何指定的驗船師或被認可組織授權，使其能：

.1 要求船舶進行修理；和

.2 應港口國有關當局要求進行檢驗。

主管機關應將授權給指定的驗船師或被認可組織的具體職責和條件通知本組織，以便分發給各締約國政府。

1.4.1.4 當指定的驗船師或被認可組織判定該船舶或其設備的狀況與《國際散裝運輸液化氣體適裝證書》的內容在實質上不相符或其狀況會對船舶或船上人員產生危險或會對海洋環境造成不當的危害威脅，因而該船舶不適於出海航行時，則驗船師或被認可組織應能立即確保採取糾正措施並及時通知主管機關。如未採取此種糾正指施，應撤回證書並立即通知主管機關。如果船舶係在另一締約國政府的港口內，則亦應立即通知該港口國的有關當局。主管機關的官員在指定的驗船師或被認可組織通知該港口國的有關當局後，有關港口國的政府應向該官員、驗船師或被認可組織按本條規定履行義務時向其提供任何所必需的幫助。必要時，有關的港口國政府應採取措施，確保該船在未具備不危及船舶或船上人員、或對海洋環境不造成不當的危害威脅的條件前，不得開航或離港駛往最近的可進行修理的修船廠。

1.4.1.5 在所有情況下，主管機關均應保證檢驗的完整性和有效性，確保為履行這一職責作出必要安排。

1.4.2 *檢驗要求*

液化氣體船舶的結構、設備、附件、裝置和材料(不包括簽發SOLAS公約要求的貨船構造安全證書、貨船設備安全證書和貨船無線電安全證書或貨船安全證書所需檢驗方面的項目)應進行下述檢驗：

.1 初次檢驗。應在船舶投入營運前或在第一次簽發《國際散裝運輸液化氣體適裝證書》前進行此類檢驗。該檢驗應包括對結構、設備、附件、裝置和材料的全面檢查。該檢驗應確保結構、設備、附件、佈置和材料完全符合本規則中適用的規定。

.2 換證檢驗。對此類檢驗的間隔期，應由主管機關規定，但除1.4.6.2.1、1.4.6.5、1.4.6.6或1.4.6.7的適用者外，不得超過5年。換證檢驗時應確保結構、設備、附件、裝置和材料完全符合本規則中適用的規定。

.3 中間檢驗。應在證書的第2個周年日前或後的3個月內或在此證書的第3個周年日前或後的3個月內進行此類檢驗，並應取代1.4.2.4中規定的其中一次年度檢驗。中間檢驗應確保安全設備和其他設備以及附屬的泵和管系完全符合本規則中適用的規定並處於良好的工作狀態。對此種檢驗，應在按1.4.4或1.4.5簽發的證書上簽署。

.4 年度檢驗。應在證書的每個周年日前或後3個月內進行此類檢驗，包括對1.4.2.1中所述的結構、設備、附

件、裝置和材料的總體檢查，以確保按1.4.3的規定進行了維護並滿足船舶的預定用途。對於此種年度檢驗，應在按1.4.4或1.4.5的規定簽發的證書上簽署。

.5 附加檢驗。在經過1.4.3.3規定的調查後有要求時或在任何重大修理或換新後應根據情況進行全面或部分檢驗。此類檢驗時應確保必要的修埋或換新有效，此種修理或換新的材料和工藝應令人滿意，船舶適於出海航行，不會對船舶或船上人員產生危險或不會對海洋環境造成不當的危害威脅。

1.4.3 ***檢驗後狀況的維持***

1.4.3.1 應維持船舶及其設備的狀況，使其符合本規則的規定，確保船舶適於出海航行，不會對船舶或船上人員產生危險或不會對海洋環境造成不當的危害威脅。

1.4.3.2 1.4.2中所述的要求對船舶的任何檢驗完成後，非經主管機關許可，經檢驗的結構、設備、附件、裝置及材料不得作任何改變，但直接更換者除外。

1.4.3.3 每當船舶發生事故或發現缺陷業已影響船舶安全或影響船舶的救生設備或其他設備的有效性或完整性時，該船的船長或船東應儘快向負責簽發證書的主管機關、指定的驗船師或被認可組織報告，此時主管機關、驗船師或被認可組織應着手進行調查，以確定是否需要進行1.4.2.5所要求的檢驗。如果船舶係在另一締約國政府的港口內，則船長或船東亦應立即向港口國有關當局報告，而指定的驗船師或被

認可組織應查明該報告確已提交。

1.4.4 *《國際散裝運輸液化氣體適裝證書》的簽發或簽署*

1.4.4.1 符合本規則有關規定從事國際航行的液化氣體船，經初次檢驗或換證檢驗後，應給予簽發《國際散裝運輸液化氣體適裝證書》。

1.4.4.2 證書應按附錄2所示樣本相一致的格式寫成。如所用語言既不是英文，又不是法文或西班牙文，則其文本應包括其中一種語言的譯文。

1.4.4.3 按本節規定簽發的證書應存放在船上，供隨時檢查。

1.4.4.4 雖有海上安全委員會MSC.17（58）決議通過的本規則修正案的任何其他規定，但對在這些修正案生效時正在使用的任何《國際散裝運輸液化氣體適裝證書》，在按修正案生效前的本規則規定的證書到期日之前，仍屬有效。

1.4.5 *由他國政府簽發或簽署的《國際散裝運輸液化氣體適裝證書》*

1.4.5.1 SOLAS公約的締約國政府應另一締約國政府要求，可有權對懸掛該締約國國旗的船舶進行檢驗；如果確認該船符合本規則的要求，可向該船簽發或授權簽發《國際散裝運輸液化氣體適裝證書》，並在適當時，也可按本規則對船上的證書進行簽署或授權簽署。在如此所簽發的任何證書上應聲明：該證書係應船旗國政府要求簽發的。

1.4.6 *《國際散裝運輸液化氣體適裝證書》的有效期限*

1.4.6.1 《國際散裝運輸液化氣體適裝證書》的有效期限，應由簽

發證書的主管機關規定，但不得超過5年。

1.4.6.2.1 雖有1.4.6.1的規定，但如果換證檢驗在現有證書期滿之日前3個月內完成，則新證書應從換證檢驗完成之日起，至現有證書期滿之日後不超過5年的日期內有效。

1.4.6.2.2 如果換證檢驗在現有證書期滿之日後完成，則新證書應從換證檢驗完成之日起，至現有證書期滿之日後不超過5年的日期內有效。

1.4.6.2.3 如果換證檢驗在現有證書期滿之日的前3個月前完成，則新證書應從換證檢驗完成之日起不超過5年的日期內有效。

1.4.6.3 如果所發證書的有效期限少於5年，主管機關可將證書有效期自期滿日延長至1.4.6.1規定的最長期限，條件是在簽發5年期的證書時進行了1.4.2.3和1.4.2.4所述的相應的檢驗。

1.4.6.4 如果換證檢驗已完成，而新證書在現有證書期滿之日前不能簽發或不能存放船上，主管機關授權的人員或組織可在現有證書上簽署，簽署後的證書自期滿日起不超過5個月的期限內應視為繼續有效。

1.4.6.5 如果證書期滿時船舶不在應進行檢驗的港口，主管機關可延長該證書的有效期，但此項展期僅以能使該船完成其駛抵應進行檢驗的港口的航次為限，並且僅在正當和合理的情況下才能如此辦理。

1.4.6.6 簽發給短程航行船舶的證書未按本條前述之規定展期時，主管機關可給予自該證書所示的期滿之日起至多1個月的寬限期。換證檢驗完成後，新證書的有效期應自現有證書展期前的期滿日起不超

過5年。

1.4.6.7 在特殊情況下(由主管機關確定),新證書無需按1.4.6.2.2、1.4.6.5或1.4.6.6的要求從現有證書的期滿之日起計算日期。在此特殊情況下,新證書的有效期應自換證檢驗完成之日起不超過5年。

1.4.6.8 如果年度檢驗或中間檢驗在1.4.2規定的期限之前完成,則:

.1 證書上所示的周年日應予以簽署修正,修正後的周年日應不多於檢驗完成之日起3個月;

.2 按1.4.2要求的其後的年度檢驗或中間檢驗應使用新的周年日按該節規定的間隔期完成;和

.3 如進行一次或多次相應的年度檢驗或中間檢驗,以使1.4.2規定的最大檢驗間隔期不被超過,則該期滿日可保持不變。

1.4.6.9 對於按1.4.4或1.4.5的規定所簽發的證書,在下列任何情況下應終止有效:

.1 如果相關檢驗未在1.4.2規定的期限內完成;

.2 如果證書未按1.4.2.3或1.4.2.4的要求進行簽署;和

.3 船舶變更船旗國。只有當換發新證書的政府確信該船符合1.4.3.1和1.4.3.2的要求時,才能簽發新的證書。如果變更船旗係在SOLAS公約締約國之間進行,則在變更後的3個月內,前船旗國政府如收到申請,應儘

快將變更船旗前該船所攜證書的副本以及相關的檢驗報告副本（如備有）送交該船新的主管機關。

第2章
船舶殘存能力和液貨艙位置

目的

在發生較小船體破損時，確保液貨艙處於保護位置且船舶能在假定浸水條件下殘存。

2.1 通則

2.1.1 適用本規則的船舶，在船體受到外力作用發生假定破損後引起浸水的靜水力作用下應能殘存。此外，為保護船舶和環境，應將液貨艙佈置於舷內距船舶外板遠於規定的最小距離，以防船舶在與碼頭、拖船等接觸產生較小破損時液貨艙被戳穿，或在碰撞或擱淺時引起液貨艙破壞。對破損的假定和液貨艙與船舶外板間的距離均取決於所載運貨品的危險程度。此外，液貨艙與船舶外板間的距離應取決於液貨艙的容積。

2.1.2 適用本規則的船舶應按下列標準之一進行設計：

.1 1G型船舶是用於載運本規則第19章所列要求採取最嚴格防漏保護措施的貨品的氣體運輸船。

.2 2G型船舶是用於載運本規則第19章所列要求採取相當嚴格防漏保護措施的貨品的氣體運輸船。

.3 2PG型船舶係指長度為150m及以下用於載運本規則第19章所列要求採取相當嚴格防漏保護措施的貨品的氣體運輸船，且該類貨品是被載運於其釋放閥最大設定值（MARVS）至少為0.7MPa錶壓力和其貨物圍護系統的設計溫度為-55℃或以上的C型獨立液貨艙內（見本規則4.23）。船長150m以上的此類船舶應視為2G型船舶。

.4 3G型船舶是用於載運本規則第19章中所列要求採取中等防漏保護措施的貨品的氣體運輸船。

因此，1G型船舶是用於載運具有最大綜合危險性的貨品的氣體運輸船。2G/2PG以及3G型船舶所載運貨品的危險程度則依次減小。相應的1G型船舶應能在最嚴重的破損標準下殘存，並且其液貨艙應位於舷內離船體外板具有最大的規定距離之處。

2.1.3 各種貨品所要求的船型已被列於本規則第19章的表中“C”欄內。

2.1.4 當船舶擬載運1種以上的本規則第19章的表列貨品時，其破艙標準應與要求最嚴格船型的該種貨品相一致。但對各個液貨艙位置的要求，則應按所擬載運的各種貨品所要求的船型而定。

2.1.5 就本規則而言，不同圍護系統的型線位置見圖2.5（a）至（e）。

2.2 乾舷和穩性

2.2.1 適用本規則的船舶，可按現行的《國際載重線公約》核定

最小乾舷。但是，核定乾舷的相關吃水應不大於本規則另行規定的最大吃水。

2.2.2 船舶在其所有航行狀態下和裝卸貨期間的穩性應滿足國際完整穩性規則的要求。這包括在海上部分充裝和裝卸貨(如適用)。壓載水操作期間的穩性應滿足穩性衡準。

2.2.3 對各種裝載工況計算消耗液體自由液面的影響時，應對每種液體假定：至少有1對橫向液艙或1個中心線上的液艙存在自由液面，且所考慮的液艙或液艙組合應是自由液面影響最大者。對於未破損液艙內的自由液面影響應按照國際完整穩性規則中的方法計算。

2.2.4 固體壓載通常不應用於貨物區域的雙層底處所。但是，如為滿足穩性要求而必須在這些處所內進行固體壓載時，對其佈置應能保證能進入檢查且不致於使船底破損引起的衝擊負荷直接傳遞到液貨艙結構。

2.2.5 應向船長提供裝載和穩性資料手冊。該手冊應包括典型的營運狀態、裝卸貨和壓載操作、對估算其他裝載工況的規定以及對船舶殘存能力的總結等詳細資料。該手冊也應有充分的資料，使船長能以安全和適航方式裝載貨物和操縱船舶。

2.2.6 所有適用本規則的船舶，應配備能進行完整和破損穩性的符合性驗證、並經主管機關參照本組織建議的性能標準認可的穩性儀：

.1 2016年7月1日以前建造的船舶應在2016年7月1日以後但不遲於2021年7月1日的初次計劃換證檢驗時符

合本要求；

.2 儘管有2.2.6.1的要求，對於2016年7月1日以前建造的船上配備的穩性儀，如能進行完整和破損穩性的符合性驗證並使主管機關滿意，則不必替換；和

.3 就SOLAS公約第XI-1/4條的控制而言，主管機關應簽發一份穩性儀的認可文件。

2.2.7 主管機關可對下列船舶免除2.2.6的要求，只要用於完整和破損穩性驗證的方法與按批准的工況進行的裝載保持同等安全程度。任何此類免除應在1.4.4中所述的國際適裝證書上適當註明：

.1 按2.2.5提供船長的穩性資料中所有預計的裝載工況已經批准、並且裝載改變量有限的從事專用業務的船舶；

.2 用主管機關認可的方法進行遠程穩性驗證的船舶；

.3 在批准的裝載工況範圍內裝載的船舶；或

.4 2016年7月1日以前建造的、具有滿足所有適用完整和破損穩性要求的批准的極限KG/GM曲線的船舶。

2.2.8 *裝載工況*

應根據提交給主管機關的裝載資料，並考慮所有預計的裝載工況及吃水和縱傾的變化，對破損殘存能力進行審查。這應包括壓載和貨物橫傾（如適用）。

2.3 破損假定

2.3.1 假定的最大破損範圍：

.1	舷側破損		
.1.1	縱向範圍：	$L^{2/3}/3$或14.5m，取小者	
.1.2	橫向範圍： 在夏季水線平面上，從船體外殼型線沿垂直於船體中心線方向量取	B/5或11.5m，取小者	
.1.3	垂向範圍： 從船體外殼型線量取	向上無限制	
.2	船底破損：	距船舶首垂線0.3L範圍	船舶的其他部位
.2.1	縱向範圍：	$L^{2/3}/3$或14.5m，取小者	$L^{2/3}/3$或14.5m，取小者
.2.2	橫向範圍：	B/6或10m，取小者	B/6或5m，取小者
.2.3	垂向範圍：	B/15或2m，取小者，在中心線的船底外板型線量起（見2.4.3）	B/15或2m，取小者，在中心線的船底外板型線量起（見2.4.3）

2.3.2 *其他破損*

2.3.2.1 如任何破損範圍雖小於2.3.1所規定的最大值，但卻將導致更嚴重狀態時，則應考慮此類破損。

2.3.2.2 在貨物區域內任何部位的局部破損延伸到舷內從船體外殼型線垂直量起達2.4.1中規定的距離 *"d"*，則應考慮此類破損。當2.6.1的相關要求適用時，應假定艙壁破損。如破損範圍雖小於 *"d"*，但卻將導致更嚴重狀態時，則應考慮此類破損。

2.4 液貨艙位置

2.4.1 液貨艙應設在舷內下列位置：

.1 1G型船舶距船體外殼型線應不小於2.3.1.1.2規定的橫向破損範圍和在中心線上距船底板型線不小於2.3.1.2.3規定的垂向破損範圍，其任何部位都應不小於 *"d"*， *"d"* 如下：

.1 如果Vc≤1000m^3，d＝0.8m；

.2 如果1000m^3<Vc<5000m^3，d = 0.75+Vc × 0.2/4000m；

.3 如果5000m^3≤Vc<30000m^3，d＝0.8+Vc/25000m；和

.4 如果Vc≥30000m^3，d＝2m，

式中：

— Vc相當於20℃時單個液貨艙的總設計容積的100%，包括氣室和附屬物（見圖2.1和2.2）。就液貨艙保護距離而言，液貨艙容積是具有公共艙壁的液貨艙所有部分的總容積；和

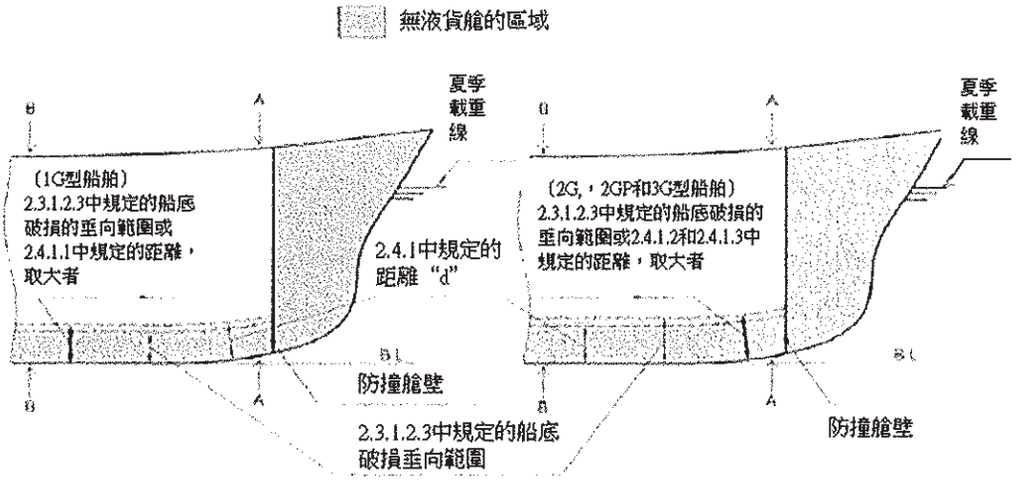
— *"d"* 在與船體外殼型線成直角的任何橫截面處測量。

按照第17章，液貨艙大小限制可適用於1G型船舶貨物。

.2 2G/2PG型船舶在中心線上距船底板型線應不小於2.3.1.2.3規定的垂向破損範圍，其任何部位都應不小於2.4.1.1中所述的“d”（見圖2.1和2.3）。

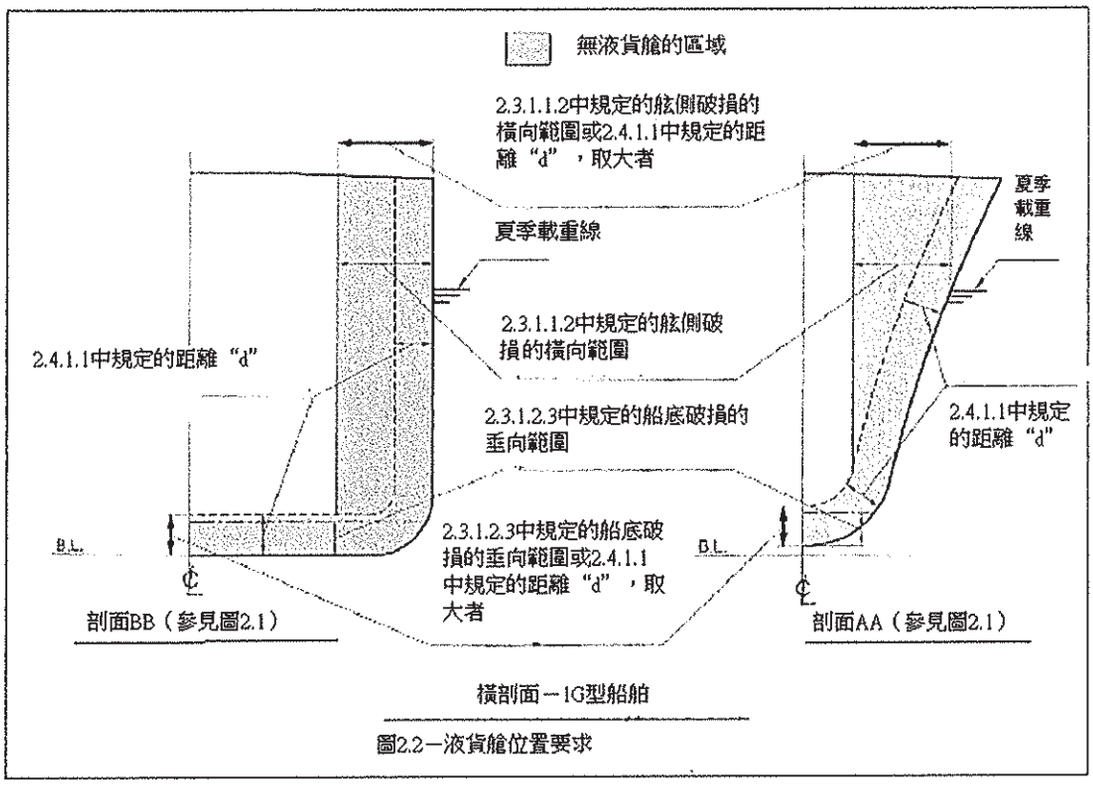
.3 3G型船舶在中心線上距船底板型線應不小於2.3.1.2.3規定的垂向破損範圍，其任何部位都應不小於“d”，“d”＝0.8m，自船底板型線（見圖2.1和2.4）。

2.4.2 對液貨艙位置而言，如採用薄膜或半薄膜液貨艙，船底破損的垂向範圍應量至內底，其他情況則量至液貨艙底；當採用薄膜或半薄膜液貨艙時，舷側破損的橫向破損範圍應量至縱艙壁，其他種類液貨艙應量至液貨艙側壁。2.3和2.4中所述距離應如圖2.5（a）至（e）使用。這些距離應板至板測量，自型線至型線，不包括絕熱。



中縱剖面－1G, 2G, 2PG和3G型船舶

圖2.1－液貨艙位置要求



橫剖面－1G型船舶

圖2.2－液貨艙位置要求

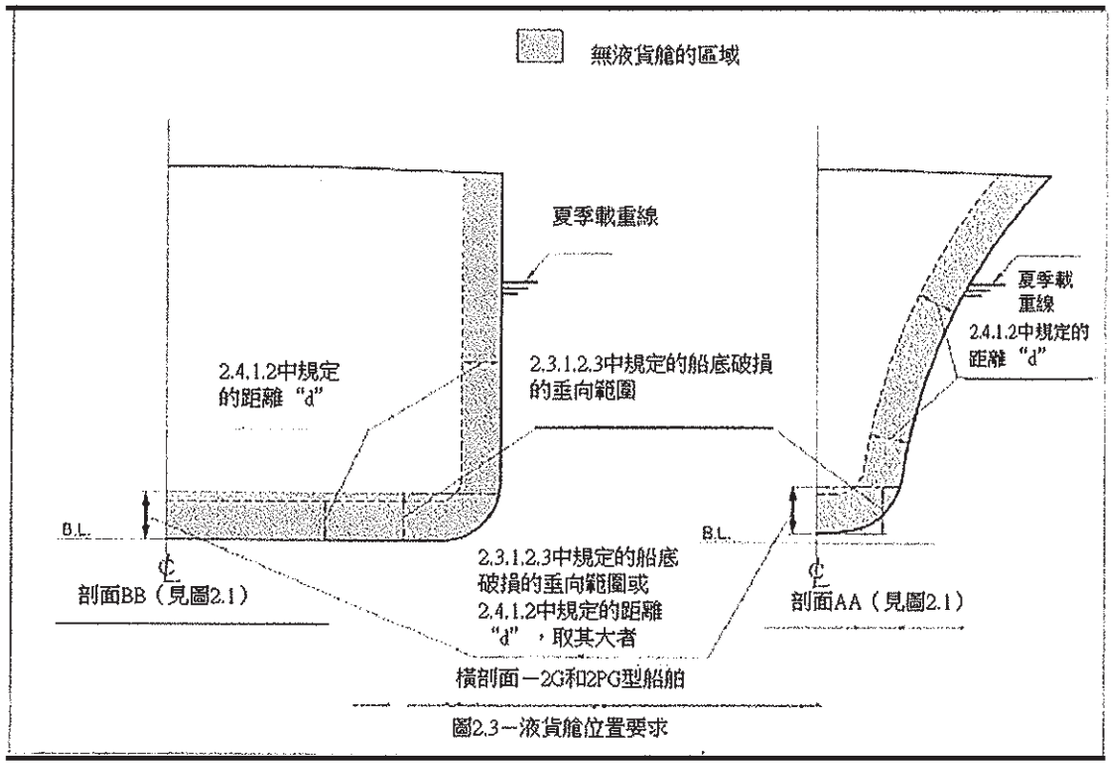


圖2.3－液貨艙位置要求

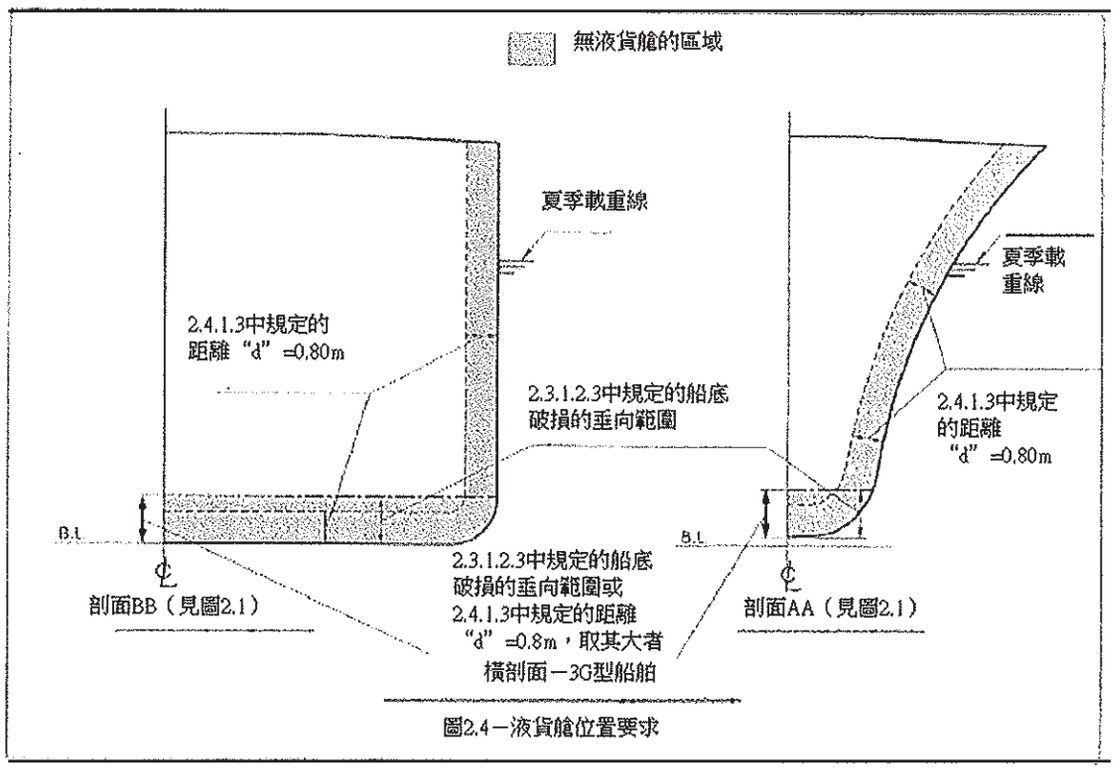
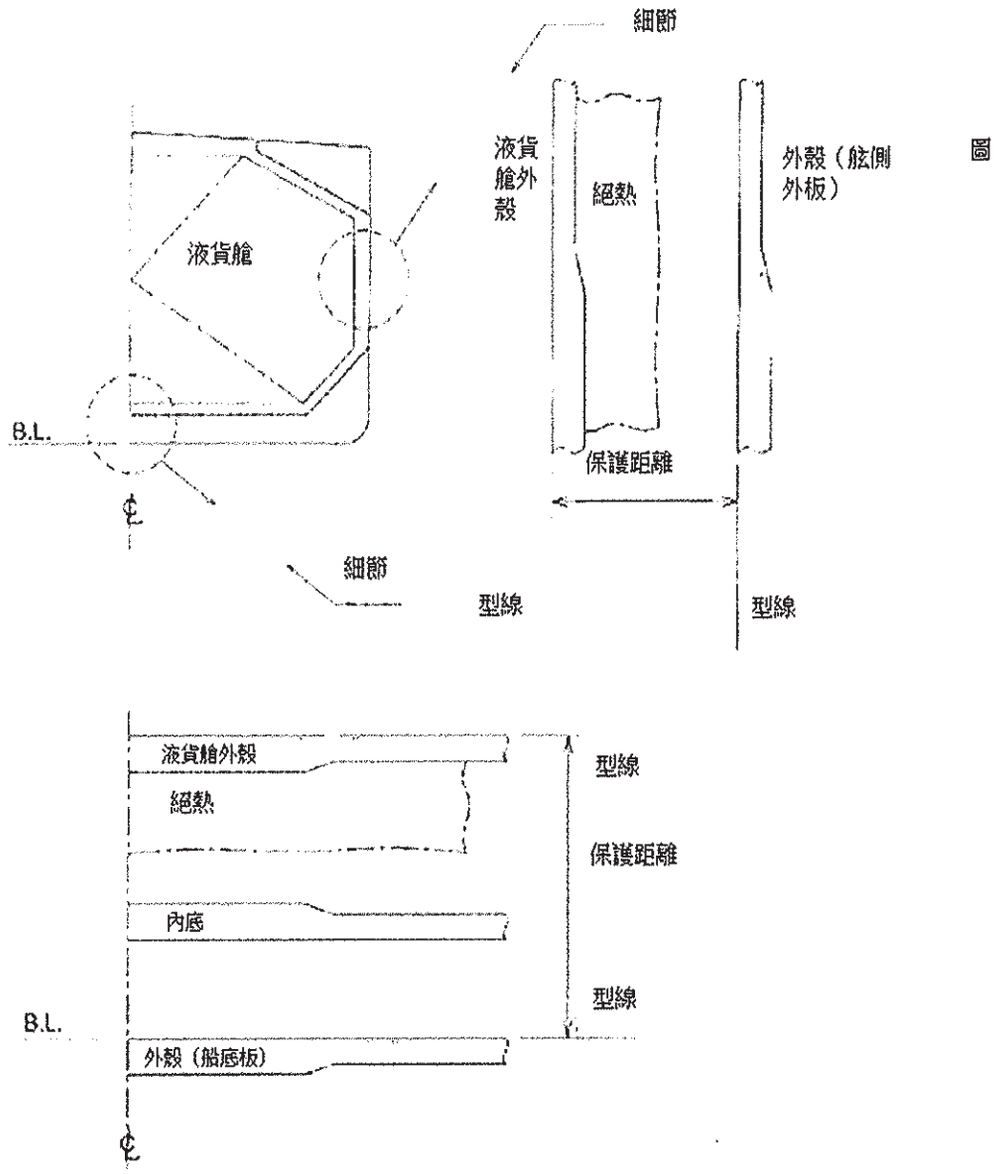


圖2.4－液貨艙位置要求



圖

獨立棱形液貨艙

2.5（a）－保護距離

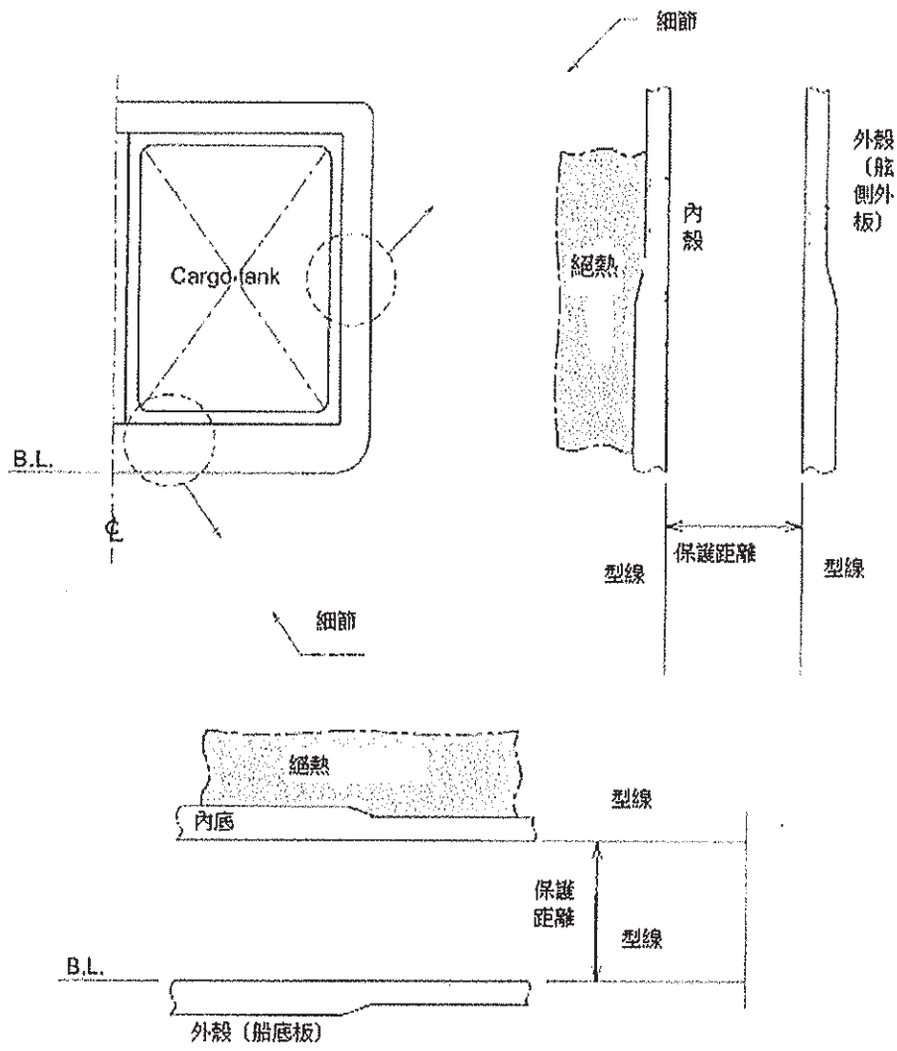

細節
Cargo tank
B.L.
℄
細節
絕熱
內殼
外殼（舷側外板）
型線
保護距離
型線
絕熱
內底
型線
保護距離
型線
B.L.
外殼（船底板）
半薄膜液貨艙

圖2.5（b）－*保護距離*

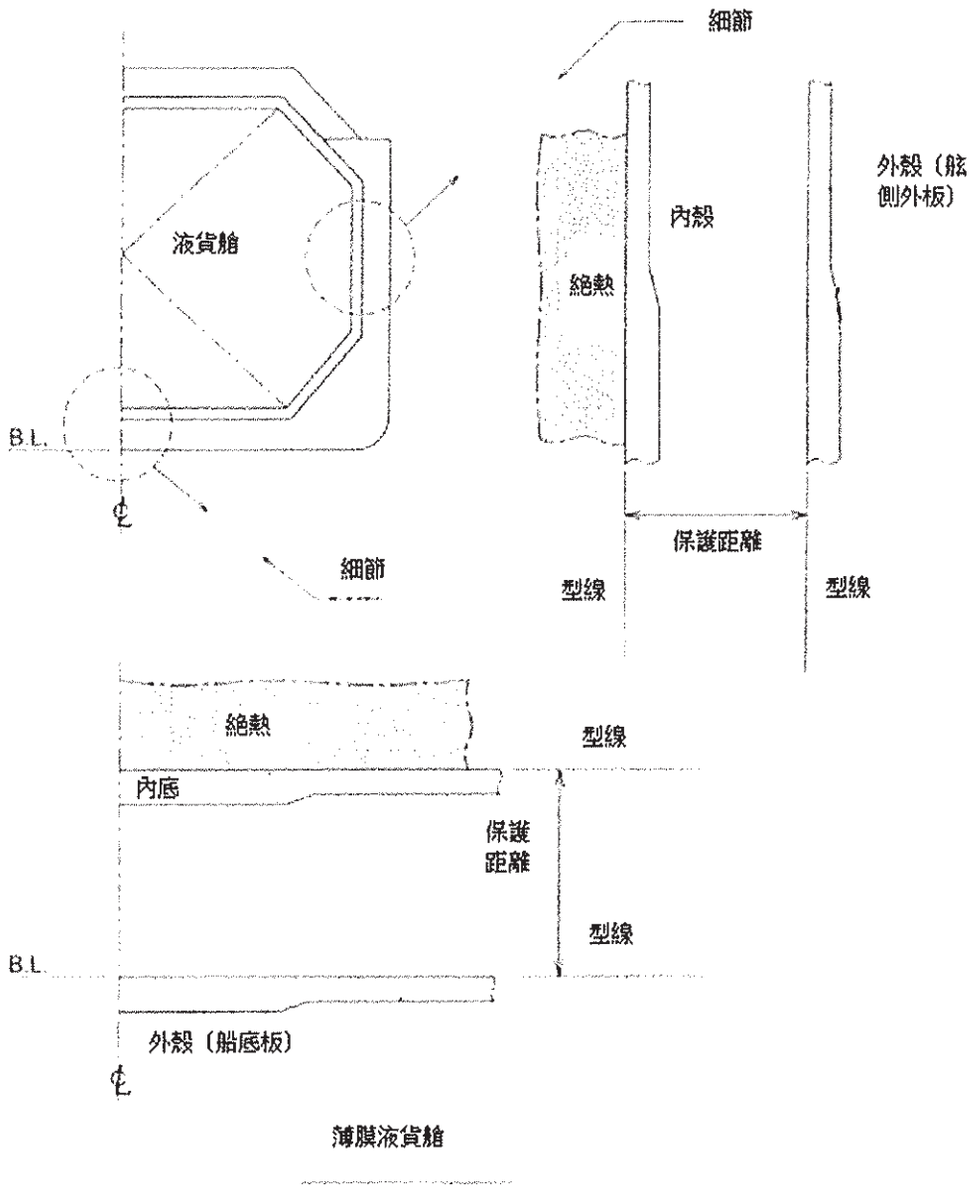

細節
液貨艙
內殼
絕熱
外殼（舷側外板）
B.L.
保護距離
細節
型線
型線
絕熱
型線
內底
保護距離
型線
B.L.
外殼（船底板）
薄膜液貨艙

圖2.5（c）－*保護距離*

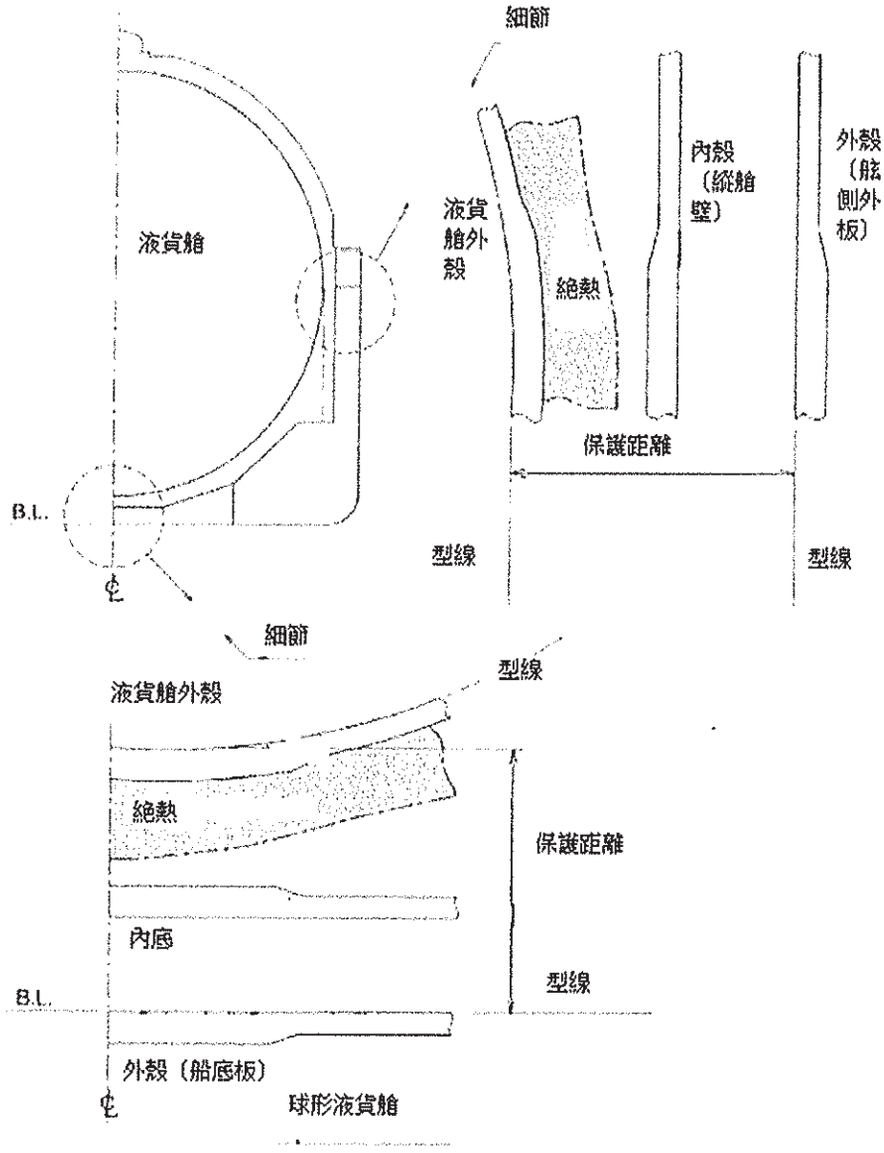

細節
液貨艙
液貨艙外殼
絕熱
內殼（縱艙壁）
外殼（舷側外板）
保護距離
型線
型線
B.L.
細節
液貨艙外殼
型線
絕熱
保護距離
內底
型線
B.L.
外殼（船底板）
球形液貨艙

圖2.5（d）－*保護距離*

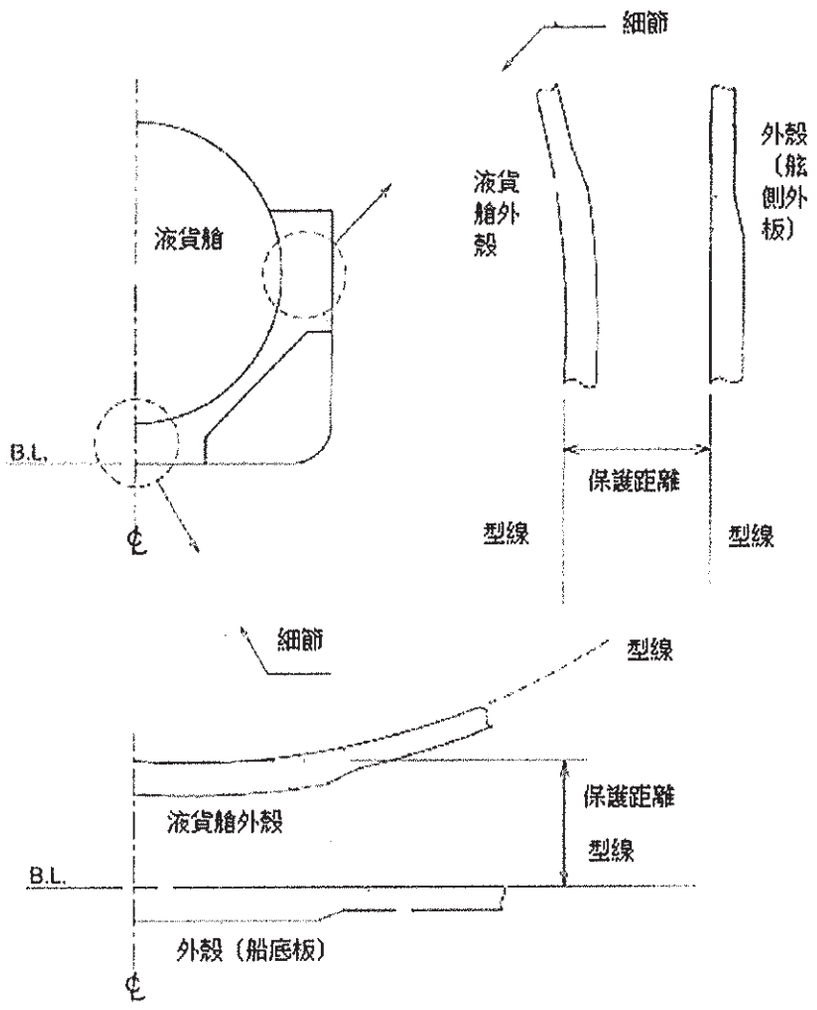

細節
液貨艙
液貨艙外殼
外殼（舷側外板）
B.L.
保護距離
型線
型線
細節
型線
保護距離
液貨艙外殼
型線
B.L.
外殼（船底板）
壓力型液貨艙

圖2.5（e）－*保護距離*

2.4.3 除1G型船舶外，液貨艙內的吸口阱可以延伸至2.3.1.2.3規定的船底垂向破損範圍內，條件是此種阱儘可能小，且伸入內底板以下部分應不超過雙層底深度的25%或350mm，取小者。如無雙層底時，吸口阱伸入船底破損上限以下的部分不應超過350mm。在確定受破損影響的艙室時，按照本條要求所設置的吸口阱，可忽略不計。

2.4.4 液貨艙不應位於防撞艙壁前面。

2.5 浸水假定

2.5.1 應通過計算證實2.7的要求已被滿足，計算應考慮船舶的設計特徵，破損艙室的佈置、形狀和容量，液體的分佈、相對密度和自由液面影響，以及所有裝載工況下的吃水和縱傾。

2.5.2 假定破損處所的滲透率應如下：

處所	滲透率
物料貯存處所	0.6
起居處所	0.95
機器處所	0.85
留空處所	0.95
貨艙處所	0.95[1]
消耗液體	0～0.95[2]
其他液體	0～0.95[2]

註1：滲透率的其他值可基於具體計算。參見SOLAS公約第II-1章B-1部分的解釋（MSC/Circ.651通函）。

註2：部分充裝的艙室的滲透率應與艙室所載運的液體量相一致。

2.5.3 當破損穿透裝有液體的液貨艙，應假設艙內液體從該艙完全流失，並由海水替代直至最終的平衡液面。

2.5.4 如水密橫艙壁之間的破損被假定為2.6.1.4、2.6.1.5和2.6.1.6中所指的範圍，則橫艙壁之間的距離至少應等於2.3.1.1.1規定的縱向破損範圍才被認為有效。如橫艙壁之間的距離小於上述值，則對在此破損範圍內的這種艙壁中的一個或幾個，在確定浸水艙室時應假定為不存在。再則，如水密艙壁邊界是在2.3所要求的垂向或水平向穿透範圍內，則邊艙或雙層底艙的水密橫艙壁邊界處的任何部分應被假定破損。如橫艙壁上有長度超過3m的台階或壁龕位於被假定的破損穿透範圍內，則該橫艙壁亦應被假定破損。由尾尖艙艙壁和尾尖艙艙頂形成的台階在此處不應被視為台階。

2.5.5 通過艙有效的佈置將船舶設計成能使不對稱浸水減至最低。

2.5.6 當所設置機械輔助設備（如閥或橫通調平管）作為平衡裝置時，則該裝置不應視為可用於減小橫傾角或達到最小剩餘穩性範圍以滿足2.7.1的要求。如採用平衡裝置，則應在所有階段仍保持有足夠的剩餘穩性。用大截面導管連通的處所可視為連通處所。

2.5.7 如管路、導管、圍蔽通道或隧道位於2.3規定的假定破損穿透範圍內，其佈置應能在每一破損情況下使連續浸水不會擴展到除被假定浸水艙室外的其他艙室。

2.5.8 直接位於舷側破損範圍上方的任何上層建築的浮力應不予考慮。然而破損範圍之外的上層建築未浸水部分的浮力可予以考慮，

條件是：

.1 其用水密隔壁與破損處所隔開，並滿足2.7.1.1對這些完整處所的要求；和

.2 這些分隔上的開口能用遙控的滑動水密門予以關閉，且未保護的開口在2.7.2.1所要求的最小剩餘穩性範圍內不被浸沒，但對於能水密關閉的其他開口，可允許被浸沒。

2.6 破損標準

2.6.1 船舶應能在2.5所述的假定浸水情況下經受住2.3所述的破損。對於其假定浸水的範圍，應根據船型應符合下列標準：

.1 對於1G型船舶，應假定在其船長範圍內的任何部位均能經受破損；

.2 船長大於150m的2G型船舶，應假定在其船長範圍內的任何部位均能經受破損；

.3 船長等於或小於150m的2G型船舶，應假定在其船長範圍內的任何部位任一艙壁均能經受破損，但不包括鄰接於尾機型機艙邊界壁；

.4 對於2PG型船舶，應假定在其船長範圍內的任何部位的均能經受破損，但不包括間距超過2.3.1.1.1規定的縱向破損範圍的橫向艙壁；

.5 船長等於或大於80m的3G型船舶，應假定在其船長範

圍內的任何部位均能經受破損，但不包括間距超過2.3.1.1.1規定的縱向破損範圍的橫艙壁；和

.6 船長小於80m的3G型船舶。應假定在其船長範圍內的任何部位均能經受破損，但不包括間距大於2.3.1.1.1規定的縱向破損範圍的橫艙壁和尾部機器處所的破損。

2.6.2 對於小型的2G/2PG和3G型船舶不是在所有方面都滿足2.6.1.3、2.6.1.4和2.6.1.6的合適要求，可由主管機關考慮予以特別免除，但應提供能保持同等安全程度的替代措施，對此替代措施的性質應進行認可，並清楚地加以說明，且隨時可提交給港口主管當局。對任何的此種免除應在本規則1.4.4所述的《國際散裝運輸液化氣體適裝證書》內加以適當的註明。

2.7 殘存要求

適用本規則的船舶，應按2.6規定的破損標準經受2.3假定的破損，在穩定平衡條件下，殘存能力應能滿足下列衡準。

2.7.1 在浸水任何階段：

.1 計及下沉、橫傾和縱傾的水線應位於可能產生連續進水或向下（注灌）進水的任何開口的下緣。此類開口應包括空氣管和用風雨密門或艙口蓋關閉的開口，但不包括用水密人孔蓋關閉的開口和水密平艙口、能保持甲板高度完整性的小型水密液貨艙艙口蓋、能遙控操縱的水密滑動門和固定式（非開啟）舷窗；

.2 不對稱浸水引起的最大橫傾角應不超過30°；和

.3 浸水中間階段的剩餘穩性不應小於2.7.2.1所要求的值。

2.7.2 在浸水後的最終平衡階段：

.1 復原力臂曲線在平衡位置應有20°的最小範圍，在20°範圍內最大剩餘復原力臂至少應有0.1m；此範圍內，該曲線下的面積應不小於0.0175m· rad。20°範圍可從平衡位置與25°角（或30°，如果未發生甲板浸沒）之間開始的任何角度測量。在此範圍內未加保護的開口不應被浸沒，除非這些處所是假定浸水。在此範圍內2.7.1.1所列的任何開口及能以風雨密關閉的其他開口可以允許浸沒；和

.2 應急電源應能操作。

第3章
船舶佈置

目的

確保貨物圍護和裝卸系統的位置能將任何貨物排放的後果降至最低，並提供安全通道進行操作和檢查。

3.1 貨物區域的分隔

3.1.1 貨艙處所應與機器處所、鍋爐處所、起居處所、服務處所、

控制站、錨鏈艙、生活用水艙以及儲物艙隔開。貨艙處所應位於A類機器處所的前方。基於SOLAS公約第II-2/17條，在進一步考慮到相關風險（包括貨物排放風險和減輕方式）後，可接受替代佈置，包括使A類機器處所在前方。

3.1.2 如在不要求設有完整或部分次屏壁的貨物圍護系統內載運貨物，則貨艙處所與3.1.1所述處所之間，或與其下面或外側的處所之間，可用隔離艙、燃油艙或形成A-60級分隔的全焊接結構的單層氣密艙壁予以分隔。如果相鄰處所內不存在點火源或火災危險，則可接受氣密A-0級分隔。

3.1.3 如在要求設有完整或部分次屏壁的貨物圍護系統內載運貨物，則貨艙處所與3.1.1所述處所之間，或與其下面或外側存在點火源或火災危險的處所之間，應用隔離艙或燃油艙予以分隔。如果相鄰處所內不存在點火源或火災危險，則可接受氣密A-0級分隔。

3.1.4 轉塔艙與3.1.1中所述處所之間，或與其下面或外側存在點火源或火災危險的處所之間，應用隔離艙或A-60級分隔予以分隔。如果相鄰處所內不存在點火源或火災危險，則可接受氣密A-0級分隔。

3.1.5 此外，從轉塔艙至相鄰處所的火災擴展風險應通過風險分析進行評估（見1.1.11），並應在需要時提供預防措施，例如在轉塔艙周圍佈置隔離艙。

3.1.6 如在要求設有完整或部分次屏壁的貨物圍護系統內載運貨物，則應符合下列規定：

.1 當貨物溫度低於-10℃時，貨物艙處所與海水之間應設

置雙層底；和

.2 當貨物溫度低於-55℃時，貨物艙處所還須設置構成邊艙的縱艙壁。

3.1.7 在露天甲板上貨物圍護系統所設的開口處應設有密封裝置。

3.2 起居、服務和機器處所以及控制站

3.2.1 任何起居處所、服務處所或控制站應不位於貨物區域內。對貨物圍護系統要求設置次屏壁的船舶，應將起居處所、服務處所或控制站面向貨物區域的艙壁佈置成能避免僅因甲板或艙壁的單一破損而使貨物艙的氣體進入這些處所。

3.2.2 為了防止有害蒸氣進入起居處所、服務處所、機器處所和控制站，在確定上述處所的空氣進口/出口和開口的位置時，應考慮貨物管路、貨物透氣系統以及機器處所內氣體燃燒裝置排出的廢氣對上述處所的影響。

3.2.3 非危險區域到危險區域之間，不允許設置氣密或其他型式的門的通道，但當起居處所位於船艉時，通過3.6.1規定的空氣閘而進出貨物區域前面的服務處所所設的通道是允許的。

3.2.4.1 起居處所，服務處所、機器處所和控制站的入口、空氣進口和開口不應面向貨物區域，而應設置在不面向貨物區域的端壁上，或設置在上層建築或甲板室的外側壁上，這些開口離面向貨物區域上層建築或甲板室的端壁之間的距離至少為船長（L）的4%，且不小於3m，但不必超過5m。

3.2.4.2 面向貨物區域和在上述距離內的上層建築或甲板室兩外側壁上的窗和舷窗應是固定(非開啟)型的。駕駛室窗可為非固定型，而駕駛室門可位於上述範圍內，只要其設計能確保駕駛室迅速而有效的氣密和蒸氣密。

3.2.4.3 對於專用於載運既不易燃又無毒性危害貨物的船舶，在執行上述要求時，經主管機關認可後可予以放寬。

3.2.4.4 進入包含點火源的艙樓處所的通道可允許通過面向貨物區域的單扇門，條件是門位於第10章中定義的危險區域外。

3.2.5 面向貨物區域和在3.2.4中規定的限制內的上層建築或甲板室兩外側壁上的窗和舷窗（駕駛室窗除外）應建造成A-60級。駕駛室窗應建造成不小於A-0級（對於外部火載荷）。最上層連續甲板以下外板上的舷窗以及在第1層上層建築或甲板室的舷窗均應為固定（非開啟）型的。

3.2.6 起居處所、服務處所和控制站的所有空氣進口、出口和其他開口均應設置關閉裝置。在載運有毒貨品時，應能從處所內部進行操作。對有毒貨品設置空氣進口和開口從處所內部操作關閉裝置的要求不必適用於非經常有人的處所，例如甲板貯存室、艙樓儲藏室、工作間。此外，本要求不適用於位於貨物區域內的貨物控制室。

3.2.7 轉塔系統的控制室和機器處所可位於具有這類裝置的船上液貨艙前後的貨物區域。進入包含點火源的處所的通道可允許通過面向貨物區域的門，條件是門位於危險區域外或通道通過空氣閘。

3.3 貨物機器處所和轉塔艙

3.3.1 貨物機器處所應位於露天甲板上，且應位於貨物區域內。貨物機器處所和轉塔艙應視作貨泵艙，在防火要求方面按照SOLAS公約第II-2/9.2.4條的要求，而在防止潛在的爆炸方面按照SOLAS公約第II-2/4.5.10條的要求。

3.3.2 當貨物機器處所位於最後貨艙處所的後面或最前貨艙處所的前面時，1.2.7所定義的貨物區域的界限應擴展到包括貨物機器處所在內的整個船寬和船深的範圍以及這些處所上方的甲板區域。

3.3.3 當貨物區域的界限按3.3.2要求擴展時，貨物機器處所與起居處所、服務處所、控制站和A類機器處所之間的分隔艙壁應佈置成能避免氣體通過甲板或艙壁的單一破損進入這些處所。

3.3.4 貨物壓縮機和貨泵可由經艙壁或甲板分隔的相鄰非危險處所中的電動機驅動，條件是艙壁貫穿周圍的密封能確保該兩個處所的有效氣密分隔。作為替代，如果電氣裝置符合第10章的要求，該設備可由相鄰的合格防爆型電動機驅動。

3.3.5 貨物機器處所和轉塔艙的佈置應確保能使穿防護服和帶呼吸器的人員安全無阻地進出，並且在人員受傷時，能及時將昏迷的傷員救出。貨物機器處所內應設有至少2個遠離的脫險通道和門，但至門的最大距離為5m或以下的的情況除外，可接受單個脫險通道。

3.3.6 穿防護服的人員應易於接近裝卸貨物所需的所有閥。在貨泵艙和貨物壓縮機艙內應配備合適的排水裝置。

3.3.7 轉塔艙應設計成在發生爆炸或不可控的高壓氣體排放（過壓和/或脆性斷裂）時，保持其結構完整性，其特徵應基於風險評估

予以證明，並適當考慮到壓力釋放設備的性能。

3.4 貨物控制室

3.4.1 任何貨物控制室均應位於露天甲板以上，且可位於貨物區域內。貨物控制室可設於起居處所，服務所處或控制站內，還應滿足下列條件：

.1 貨物控制室是非危險區域；

.2 如果貨物控制室的入口符合3.2.4.1的要求，則貨物控制室可以設置到上述處所的通道；和

.3 如果貨物控制室的入口不符合3.2.4.1的要求，則貨物控制室不得設置到上述處所的通道，且貨物控制室與這些處所之間的界限面應達到“A-60”級分隔完整性。

3.4.2 如果貨物控制室設計成非危險區域，則貨物控制室內的儀錶設備應儘可能採用間接讀出系統，且儀錶設備應設計成在任何情況下能防止氣體逸至貨物控制室內的空氣中。如氣體探測系統按13.6.11規定安裝，則在貨物控制室內的氣體探測系統設置不會導致該控制室成為危險區域。

3.4.3 對於載運易燃貨物的船舶，如果貨物控制室是危險區域，則應排除點火源，且任何電氣設備應按第10章規定安裝。

3.5 通往貨物區域內各處所的通道

3.5.1 在不移動任何固定結構或裝置的情況下，至少對船體內殼

結構的一側應能進行目測檢查，如這種目測檢查只能檢查內殼的外表面（不論其能否與3.5.2、4.6.2.4或4.20.3.7所要求的檢查同時進行），則此內殼不應成為燃油艙界限的艙壁。

3.5.2 應能對貨艙處所內任何絕熱層的一側進行檢驗。如對於絕熱系統的完整性，能在液貨艙處於營運溫度時通過對貨艙處所界限外側的檢驗予以驗證時，則對貨艙處所內一側絕熱層的檢驗可不要求。

3.5.3 對貨艙處所、留空處所、液貨艙和歸為危險區域的其他處所進行佈置時，應考慮身穿防護服和攜帶呼吸器的人員能進入上述任何處所並進行檢驗，且允許受傷和/或昏迷人員撤離。該佈置應符合下列要求：

.1 應設有下述通道：

.1 直接從露天甲板進入所有液貨艙；

.2 水平開口、艙口或人孔應具有足夠尺寸，能讓攜帶呼吸器的人員上下梯子無阻礙，且應提供1個無阻礙的開口，以便將受傷人員從處所底向上提升；該開口的最小尺寸應不小於600mm×600mm；

.3 在艙內沿長度和寬度方向通道的垂直開口或提供出入這些處所人孔的最小淨開口尺寸應不小於600mm×800mm，其下緣距艙底板的高度應不大於600mm，否則應設有格柵或其他踏步；和

.4 至C型艙的圓形通道開口直徑應不小於600mm。

.2 如能滿足3.5.3的要求並使主管機關滿意，3.5.3.1.2和3.5.3.1.3所要求尺寸可予以減小。

.3 如果貨物在要求次屏壁的圍護系統中載運，3.5.3.1.2和3.5.3.1.3的要求不適用於以單層鋼質氣密界限與貨艙處所相隔離的處所；此類處所應設置僅能從露天甲板直接或間接進入的通道，不包括任何圍蔽的非危險區域。

.4 檢查所需通道應為通過液貨艙上方或下方結構的指定通道，應至少有3.5.3.1.3要求的橫截面。

.5 就3.5.1或3.5.2而言，下列應適用：

.1 如要求通過平的或彎的待檢查表面和結構（例如甲板樑、加強筋、肋骨、縱桁等）之間，該表面與結構件自由邊之間的距離應至少為380mm。待檢查表面和設置上述結構件的表面（例如甲板、艙壁或外殼）之間的距離，對於彎的液貨艙表面（例如C型艙），應至少為450mm，對於平的液貨艙表面（例如A型艙），應至少為600mm（見圖3.1）；

.2 如不要求通過待檢查表面和結構的任何部分之間，為便於看到，該結構件的自由邊和待檢查表面之間的距離應至少為50mm或結構面板寬度的一半，取其大者（見圖3.2）；

.3 如為了檢查曲面，要求通過該表面和另一個未設置結構件的平的或彎的表面之間，2個表面之間的距離應至少為380mm（見圖3.3）。如不要求通過該曲面和另一個表面之間，考慮到曲面的形狀，可接受距離小於380mm；

.4 如為了檢查大致平的表面，要求通過未設置結構件的2個大致平的和大致平行的表面，這些表面之間的距離應至少為600mm。如設有固定通道梯子，應設有至少450mm的間隙供進入（見圖3.4）；

.5 液貨艙集液槽和吸口井處相鄰雙層底結構之間的最小距離不應小於圖3.5中所示距離（圖3.5顯示集液槽平面和井之間的距離最小為150mm，內底板和井的垂直邊之間的邊緣以及球形或圓形表面與液貨艙集液槽之間的接合點之間的間隙至少為380mm）。如無吸口井，液貨艙集液槽和和內底之間的距離應不小於50mm；

.6 液貨艙氣室和甲板結構之間的距離應不小於150mm（見圖3.6）；

.7 應安裝檢查液貨艙、液貨艙支承裝置和固定裝置（例如抗縱搖、抗橫搖和止浮墊塊）、液貨艙絕熱所需的固定式或可攜式腳手架。該腳手架不應減少3.5.3.5.1至3.5.3.5.4中規定的間隙；和

.8 如應安裝固定式或可攜式通風管道以符合12.1.2，這類管道不應減少3.5.3.5.1至3.5.3.5.4要求的距離。

3.5.4 開敞露天甲板至非危險區域的通道應位於第10章中規定的危險區域外，除非通道按3.6使用空氣閘。

3.5.5 轉塔艙應設有2個獨立的通道/出口。

3.5.6 不允許設置從露天甲板下的危險區域至非危險區域的通道。

3.6 空氣閘

3.6.1 開敞露天甲板上的危險區域與非危險處所之間的通道應依靠空氣閘。空氣閘應由兩扇能確保氣密的鋼質門組成，此類門應為自閉式，無任何門背扣裝置，能保持過壓，其距離至少為1.5m，但不大於2.5m。空氣閘處所應從非危險區域機械通風並相對露天甲板上的危險區域保持過壓狀態。

3.6.2 如果這些處所受到加壓保護，通風應按照公認標準設計和安裝。

3.6.3 空氣閘處所的兩側應配備聽覺和視覺報警系統。當一扇門開啟時，應發出視覺報警。當空氣閘兩側的門從關閉位置開啟時應發出聽覺報警。

3.6.4 載運易燃貨品的船上，受空氣閘所保護處所內的非合格防爆型電氣設備，當處所內的過壓狀態消失時應能切斷其供電電器。

3.6.5 位於空氣閘所保護的處所內用於操縱、錨泊和繫泊的電氣設備以及應急消防泵應為合格防爆型。

3.6.6 空氣閘處所內應監測貨物蒸氣（見13.6.2）。

3.6.7 按照現行《國際載重線公約》的要求，空氣閘的門檻高度應不小於300mm。

3.7 艙底水、壓載和燃油裝置

3.7.1 如貨物載運在不要求設有次屏壁的貨物圍護系統，則在貨艙處所內應配備不與機器處所相連的合適的排水裝置，還應設有探測任何泄漏的裝置。

3.7.2 如設有次屏壁，則應配備適當的排水裝置，用於排水通過相鄰船體結構漏入貨艙處所或絕熱處所的污水。吸口不應引向機器處所內的泵。還應設有能探測此類泄漏的裝置。

3.7.3 A型獨立液貨艙的貨艙處所或保護層處所，應設有適當的排水系統，以處理在液貨艙泄漏或破裂時漏出的液貨，這種裝置還應提供將漏出的液貨返回到液貨艙的管路。

3.7.4 上述3.7.3所述的裝置應提供可拆短管。

3.7.5 壓載處所（包括用作壓載水管路的濕箱形龍骨）、燃油艙和非危險處所可與機器處所內的泵相連接。有壓載水管通過的乾箱形龍骨可與機器處所內的泵相連接，條件是連接管直接同泵連接，並從泵直接排出舷外，且從箱形龍骨至非危險處所的每一連接管不裝設閥門或分配閥箱。泵的透氣管的開口不應通向機器處所。

3.8 船艏或船艉裝卸貨物裝置

3.8.1 符合本節和第5章的要求時，可允許設置船艏或船艉裝卸貨物管系。

3.8.2 通過起居處所、服務處所或控制站旁通過的船艏或船艉裝卸管路不得用於輸送要求1G型船舶載運的貨品。如果設計壓力超過2.5MPa，船艏或船艉裝卸管路也不得用於輸送1.2.53所定義的有毒貨品。

3.8.3 不允許採用可攜式裝置。

3.8.4.1 起居處所、服務處所、機器處所和控制站的進入口、空氣進口及開口不應面向船艏或船艉裝卸裝置的貨物通岸接頭所在位置，而應位於上層建築或甲板室的外側，距上層建築或甲板室面向首和尾裝卸貨物通岸接頭至少為船長（L）的4%，但不小於3m，也不必超過5m。

3.8.4.2 面向通岸接頭以及上述距離範圍內的上層建築或甲板室兩側的窗和舷窗應為固定（非開啟）型。

3.8.4.3 此外，首尾裝卸裝置在使用期間，相應的上層建築或甲板室兩側的所有門、舷門以及其他開口均應保持關閉狀態。

3.8.4.4 對於小型船舶，如不可能滿足3.2.4.1至3.2.4.4和3.8.4.1至3.8.4.3要求時，主管機關可同意予以放寬上述要求。

3.8.5 首尾裝卸裝置在使用期間，離貨物通岸接頭10m範圍內各處所的甲板開口和空氣進口應保持關閉狀態。

3.8.6 首尾裝卸區域的消防設備應符合11.3.1.4和11.4.6的要求。

3.8.7 貨物控制站與通岸接頭處之間應配備用於聯絡的通信設備，並在適用時應採用可在危險區域使用的合格防爆型通信設備。

圖3.1

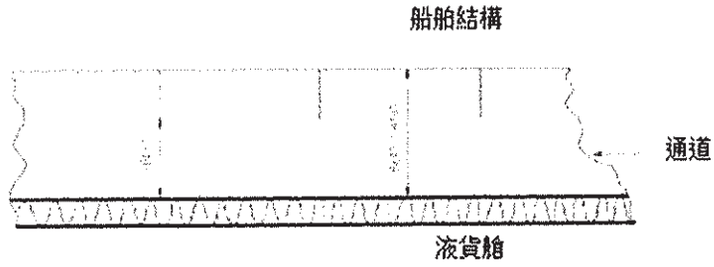


圖3.2

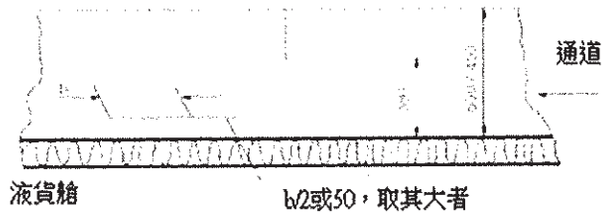


圖3.3

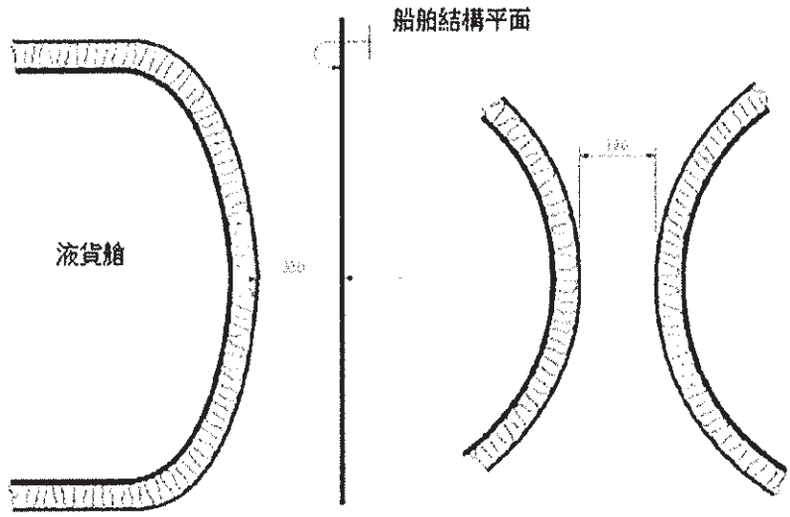


圖3.4

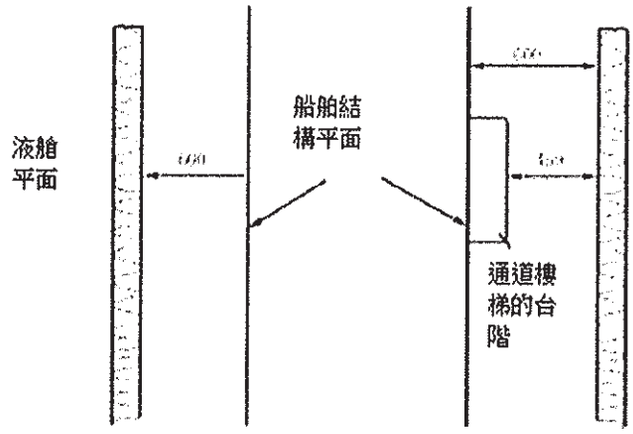


圖3.5

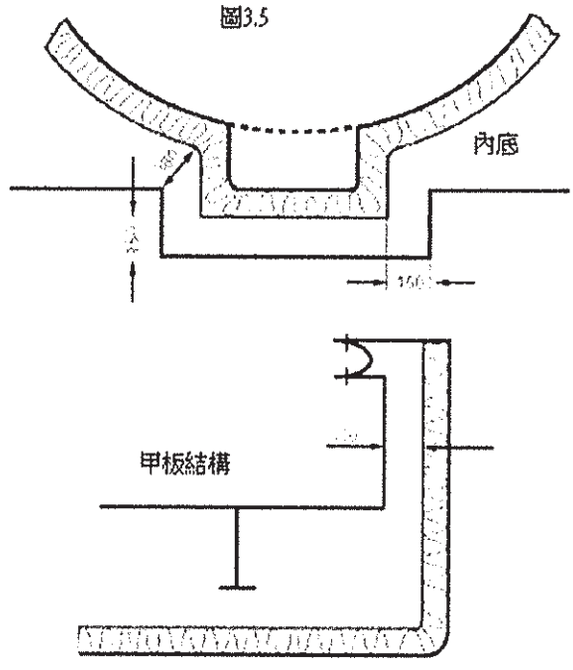


圖3.6

第4章

貨物圍護

目的

確保在所有設計和操作條件下貨物的安全圍護，並考慮到所載貨物的性質。這包括下列措施：

.1 提供承受規定載荷的強度；

.2 使貨物處於液體狀態；

.3 設計成防止船體結構暴露於低溫；和

.4 防止水或空氣進入貨物圍護系統。

4.1 定義

4.1.1 *冷點*係指船體或絕熱表面的一部分，對於船體或相鄰船體結構的許用最低溫度或第7章要求的貨物壓力/溫度控制系統的設計能力，其發生局部溫度降低。

4.1.2 *設計蒸氣壓力“P_o”*係指用於液貨艙設計的液貨艙頂部的最大表壓。

4.1.3 *供選擇材料用的設計溫度*係指可以在液貨艙內裝載或運輸的貨物的最低溫度。

4.1.4 *獨立液貨艙*係指自身支持的液貨艙，其不構成船體結構的一部分，對船體強度不是必需的。獨立液貨艙分為3類，分別在4.21、4.22和4.23中敍述。

4.1.5 *薄膜液貨艙*係指非自身支持的液貨艙，由鄰接的船體結構通過絕熱層支持的一層液體氣密薄膜組成。薄膜液貨艙詳見4.24。

4.1.6 *整體液貨艙*係指構成船體結構的一部分，並且以相同方式與相鄰船體結構一起受到同樣載荷影響的貨艙。整體液貨艙詳見4.25。

4.1.7 *半薄膜液貨艙*係指裝載工況下非自身支持的液貨艙，由一層薄膜組成，該薄膜的大部分是由相鄰船體結構通過絕熱層所支持。半薄膜液貨艙詳見4.26。

4.1.8 除1.2中的定義外，本章中給出的定義還應在本規則中適用。

4.2 適用範圍

除E部分中另有規定外，A至D部分的要求應適用於所有類型的液貨艙，包括F部分涉及的液貨艙。

A部分
貨物圍護

4.3 功能要求

4.3.1 貨物圍護系統的設計壽命應不小於船舶的設計壽命。

4.3.2 貨物圍護系統應根據無限航行北大西洋環境條件和相關長期海況散佈圖設計。對於專門用於有限航行的貨物圍護系統，主管機關可接受與預期使用相一致的較小環境條件。對於在比北大西洋環境更惡劣的條件下運作的貨物圍護系統，可要求較大環境條件。

4.3.3 貨物圍護系統應設計成具有適當的安全裕度，從而：

.1 在完整條件下，經受貨物圍護系統設計壽命預期的環境條件及其適當的裝載工況，包括滿載均勻和部分裝載工況，規定限制範圍內的部分充裝和壓載航行載荷；和

.2 適於載荷、結構建模、疲勞、腐蝕、熱效應、材料可變性、老化和建造公差的不確定性。

4.3.4 應按失效模式評定貨物圍護系統的結構強度，包括但不限於塑性變形、屈曲和疲勞。每個貨物圍護系統設計時應考慮的具體設計條件見4.21至4.26。有3類主要的設計條件：

.1 極限設計條件－貨物圍護系統結構及其結構件應承受建造、試驗和預期投入使用期間可能發生的載荷，不損害結構完整性。設計應考慮下列載荷的適當組合：

.1 內部壓力；

.2 外部壓力；

.3 船舶運動引起的動載荷；

.4 熱載荷；

.5 晃蕩載荷；

.6 船舶變形引起的載荷；

.7 液貨艙和貨物重量在支持構件部位的相應的反作

用力；

.8 絕熱層重量；

.9 作用在塔架和其他附件處的載荷；和

.10 試驗載荷。

.2 疲勞設計條件－貨物圍護系統結構及其結構件不應在累積循環載荷下失效。

.3 貨物圍護系統應滿足下列衡準：

.1 碰撞－貨物圍護系統的保護位置應按照2.4.1，並承受4.15.1中規定的碰撞載荷，且支持構件或支持構件處的液貨艙結構無變形，從而不可能危及液貨艙結構。

.2 失火－貨物圍護系統應在無破裂的情況下，在預期的失火情景時保持8.4.1中規定的內部壓力的增加。

.3 在液貨艙上形成浮力的浸水艙－止浮裝置應保持4.15.2中規定的向上的力，且應無危及船體的塑性變形。

4.3.5 應採取措施確保要求的尺寸滿足結構強度規定並在設計壽命中保持。措施可包括但不限於材料選擇、塗層、腐蝕增量、陰極保護和惰化。除結構分析產生的厚度外，無需要求腐蝕裕量。但是，如果無環境控制（例如液貨艙周圍的惰化），或貨物具有腐蝕性，主

管機關或代表主管機關的被認可組織可要求適當的腐蝕裕量。

4.3.6 應制定貨物圍護系統的檢查/檢驗計劃並由主管機關或代表主管機關的被認可組織認可。檢查/檢驗計劃應確定在貨物圍護系統整個壽命的檢驗期間需要檢查的區域，特別是選擇貨物圍護系統設計參數時假定的所有必需的營運檢驗和維護。貨物圍護系統的設計、建造和配備應提供進入檢查/檢驗計劃中規定的需要檢查區域的適當的通道。貨物圍護系統（包括所有相關內部設備）的設計和建造應確保操作、檢查和維護期間的安全（見3.5）。

4.4 貨物圍護安全原則

4.4.1 圍護系統應設有能安全控制通過主屏壁的所有潛在泄漏的完整的液密次屏壁，並且該次屏壁能與絕熱系統一起防止船舶結構的溫度下降至不安全的程度。

4.4.2 但是，如果按照4.4.3至4.4.5的適用要求證明同等的安全等級，次屏壁的尺寸和形狀或佈置可減小。

4.4.3 已確定結構失效導致臨界狀態的可能性極低但不能排除主屏壁泄漏的可能性的貨物圍護系統應設有能安全處理泄漏的部分次屏壁和小泄漏保護系統。裝置應符合下列要求：

.1 達到臨界狀態前能可靠探測到的失效形成（例如通過氣體探測或檢查）應有足夠長的形成時間以採取補救措施；和

.2 達到臨界狀態前不能安全探測到的失效形成應有比液貨艙預計壽命長得多的預計形成時間。

4.4.4 如果主屏壁的結構失效和泄漏的可能性很低且可忽略不計，貨物圍護系統不要求設次屏壁，例如C型獨立液貨艙。

4.4.5 如果大氣壓力下的貨物溫度不低於-10℃，不要求設次屏壁。

4.5 與液貨艙類型相關的次屏壁

與4.21至4.26中規定的液貨艙類型有關的次屏壁應按下表設置。

大氣壓力下的貨物溫度	-10℃及以上	-10℃至-55℃	-55℃以下
基本液貨艙類型	不要求設次屏壁	船體可作為次屏壁	要求設單獨的次屏壁
整體液貨艙		通常不允許採用此類艙型[1]	
薄膜液貨艙		完整的次屏壁	
半薄膜液貨艙		完整的次屏壁[2]	
獨立液貨艙			
－A型獨立液貨艙		完整的次屏壁	
－B型獨立液貨艙		部分的次屏壁	
－C型獨立液貨艙		不要求次屏壁	

註1： 按4.25.1的規定，允許大氣壓力下貨物的溫度低於-10℃，則通常應要求設完整的次屏壁。

註2： 如半薄膜液貨艙在各方面均能符合適用於B型獨立液貨艙的要求（支持方式除外），經主管機關特別考慮，可同意設置部分的次屏壁。

4.6 次屏壁的設計

4.6.1 如在大氣壓力下貨物溫度不低於-55℃，則基於下列條件船體結構可作為次屏壁：

.1 按4.19.1.4的要求，在大氣壓力下船體材料應能適應於貨物溫度；和

.2 設計時應考慮到不會因溫度而產生不能接受的船體應力。

4.6.2 次屏壁應設計成：

.1 在考慮到4.18.2.6所述的載荷譜後，能使其容納15天時間的任何預計泄漏的貨物。但對航行於特殊航線的船舶可應用不同的衡準；

.2 液貨艙內能導致主屏壁失效的物理、機械或操作事件不應損害次屏壁的功能，反之亦然；

.3 船體結構支持構件或附件的失效不會導致主屏壁和次屏壁液密的喪失；

.4 能以主管機關或代表主管機關的被認可組織接受的方式定期檢查其有效性。這可通過外觀檢查或壓力/真空試驗或按照主管機關或代表主管機關的被認可組織同意的用文件記錄的程序進行的其他合適方式；

.5 上述.4中要求的方法應經主管機關或代表主管機關的被認可組織認可，如適用於試驗程序，應包括：

.1 在危及液密有效性之前，可接受的缺陷尺寸和次屏壁內位置的詳細情況；

.2 上述.1中探測缺陷的建議方法的值的精度和範圍；

.3 確定驗收衡準使用的縮減比例因數（如不進行全尺度模型試驗）；和

.4 熱和機械循環載荷對建議試驗有效性的影響；和

.6 應在靜橫傾角為30°時仍能使次屏壁履行其功能要求。

4.7 部分次屏壁和主屏壁小泄漏保護系統

4.7.1 4.4.3中允許的部分次屏壁應與小泄漏保護系統一起使用並滿足4.6.2的要求。小泄漏保護系統應包括探測主屏壁泄漏的裝置，使任何液體貨物向下進入部分次屏壁的防濺屏障以及通過自然蒸發處理液體的裝置。

4.7.2 應根據相當於在最初探測到主屏壁泄漏後，從4.18.2.6所述的載荷譜中得到的破損範圍所泄漏的貨物量確定部分次屏壁的容量。可適當考慮液體蒸發、泄漏率、泵的排量以及其他有關因素。

4.7.3 要求的液體泄漏探測可通過液體傳感器或有效使用壓力、溫度或氣體探測系統或任何組合進行。

4.8 支持裝置

4.8.1 對於液貨艙，應由船體予以支持，在液貨艙受到4.12至4.15中規定的靜、動載荷作用時（如適用），其支持方式應能防止液貨艙本體的移動，可以允許液貨艙在溫度變化和船體變形時收縮和膨脹，但不能使船體和液貨艙出現過大的應力。

4.8.2 應設置用於液貨艙的止浮裝置，其能承受4.15.2中規定的載荷，而不會產生可能危及船體結構的塑性變形。

4.8.3 支持構件和支持裝置應經受4.13.9和4.15中規定的載荷，但這些載荷無需進行相互間的合成，也不必將這些載荷與波浪引起的載荷進行合成。

4.9 相關結構和設備

4.9.1 貨物圍護系統應設計成能承受相關結構和設備施加的載荷。這包括泵塔、貨物氣室、貨泵和管系、清艙泵和管系、氮氣管系、通道艙口、梯子、管系貫穿件、液位錶、獨立液位報警錶、噴嘴和儀錶系統（例如壓力、溫度和應力錶）。

4.10 絕熱

4.10.1 應按要求設置絕熱層以防止船體溫度降至許用值以下（見4.19.1）並將進入液貨艙的熱流限制在第7章使用的壓力和溫度控制系統能維持的水平。

4.10.2 在確定絕熱性能時，應適當注意與船上的再液化裝置、主推進機械或其他溫度控制系統有關的可接受的蒸發量。

B部分

設計載荷

4.11 通則

本節規定與4.16、4.17和4.18要求有關的應考慮的設計載荷。這包括：

.1 載荷種類（永久、功能、環境和意外的）和載荷描述；

.2 這些載荷應考慮的範圍取決於液貨艙類型，並在下文中更詳細地描述；和

.3 液貨艙連同其支持結構和其他固定裝置，其設計時應考慮下述載荷的相關組合。

4.12 永久載荷

4.12.1 ***重力載荷***

應考慮液貨艙、絕熱層、塔架和其他附件產生的載荷的重量。

4.12.2 ***永久外部載荷***

應考慮外部作用在液貨艙上的結構和設備的重力載荷。

4.13 功能載荷

4.13.1 液貨艙系統操作使用產生的載荷應歸類為功能載荷。應考慮確保在所有設計條件下液貨艙系統完整性所必需的所有功能載荷。在確定功能載荷時，至少應考慮下列適用衡準的影響：

.1 內部壓力；

.2 外部壓力；

.3 熱載荷；

.4 振動；

.5 相互作用載荷；

.6 與結構和安裝相關的載荷；

.7 試驗載荷；

.8 靜橫傾載荷；和

.9 貨物重量。

4.13.2 *內部壓力*

.1 在任何情況下，包括4.13.2.2，P_o均不得小於釋放閥的最大調定值（MARVS）。

.2 對於無溫度控制裝置和其貨物壓力僅由環境溫度支配的液貨艙，P_o應不得低於在溫度為45℃時的貨物蒸氣表壓，但下列除外：

.1 對於航行於限制航區的船舶，主管機關或代表主管機關的被認可組織可以接受更低的環境溫度值。反之，可要求較高的環境溫度值；和

.2 對於在限制期限內航行的船舶，P_o可基於航行期間的實際壓力上升進行計算，並考慮液貨艙的任何絕熱情況。

.3 如經主管機關特別考慮，並符合4.21至4.26規定對各類液貨艙的限制條件，可接受在動載荷降低的場所特定條件下（港口或其他場所），採用高於P_o的蒸氣壓力P_h。任何釋放閥設定應記錄在《國際散裝運輸液化氣體適裝證書》中。

.4 內部壓力P_{eq}源自蒸氣壓力P_o或Ph加最大相關動態液體壓力P_{gd}，但不包括液體晃蕩載荷的影響。對相關動態液體壓力P_{gd}的指導公式，見4.28.1。

4.13.3 *外部壓力*

對於外部壓力載荷，應根據液貨艙的任何部位可被同時承受的最小內部壓力和最大外部壓力之間的差值予以確定。

4.13.4 *熱載荷*

4.13.4.1 對於擬用於載運溫度低於-55℃的貨物的液貨艙，應考慮冷卻期間的瞬態熱載荷。

4.13.4.2 當所設計的支持裝置或附件和營運溫度可能會引起較大的熱應力時，對於這類貨物圍護系統，應考慮穩態熱載荷（見7.2）。

4.13.5 *振動*

應考慮振動對貨物圍護系統潛在的破壞影響。

4.13.6 *相互作用載荷*

應考慮貨物圍護系統和船體結構之間相互作用產生的靜載荷分量以及相關結構和設備產生的載荷。

4.13.7 *與結構和安裝相關的載荷*

應考慮與結構和安裝相關的載荷或條件，例如起重。

4.13.8 *試驗載荷*

應考慮對應於4.21至4.26中所述的貨物圍護系統試驗的載荷。

4.13.9 ***靜橫傾載荷***

應考慮對應於在0°到30°範圍內的最不利的靜橫傾角的載荷。

4.13.10 ***其他載荷***

應考慮未特別提及但對貨物圍護系統有影響的任何其他載荷。

4.14 環境載荷

環境載荷定義為貨物圍護系統上由周圍環境產生且未歸類為永久、功能或意外載荷的載荷。

4.14.1 ***船舶運動產生的載荷***

4.14.1.1 在確定動載荷時應考慮船舶在其使用壽命期間在不規則海浪中船舶運動的長期分佈。由於必要的減速和航向的變化，可考慮減小動載荷。

4.14.1.2 船舶運動可包括縱蕩、橫蕩、垂蕩、橫搖、縱搖和首搖。在估算作用於液貨艙的加速度時，其作用點應在液貨艙的重心處，且包括下列分量：

.1 垂向加速度：垂蕩、縱搖以及可能還有橫搖（垂直於船舶基線）的運動加速度；

.2 橫向加速度：橫蕩、首搖和橫搖的運動加速度；以及橫搖的重力分量；和

.3 縱向加速度：縱蕩和縱搖的運動加速度；以及縱搖的重力分量。

4.14.1.3 應建議預測船舶運動引起的加速度的方法並經主管機關或代表主管機關的被認可組織認可。

4.14.1.4 加速度分量的指導公式見4.28.2。

4.14.1.5 對於限定航區營運的船舶，可給予特別考慮。

4.14.2 ***動態相互作用載荷***

應考慮貨物圍護系統和船體結構之間相互作用產生的動載荷分量，包括相關結構和設備產生的載荷。

4.14.3 ***晃蕩載荷***

4.14.3.1 貨物圍護系統和內部構件上的晃蕩載荷應基於許用充裝高度進行評估。

4.14.3.2 當預計存在較大的晃蕩引起的載荷時，應要求作專門的試驗和計算，包括預定充裝高度的整個範圍。

4.14.4 ***雪和冰載荷***

應考慮雪和結冰（如相關）。

4.14.5 ***冰區航行產生的載荷***

對於擬在冰區航行的船舶，應考慮冰區航行產生的載荷。

4.15 意外載荷

意外載荷定義為在異常和意外情況下施加在貨物圍護系統及其支持裝置上的載荷。

4.15.1 *碰撞載荷*

應基於滿載工況下的貨物圍護系統確定碰撞載荷，向前慣性力為0.5g，向後慣性力為0.25g，其中g為重力加速度。

4.15.2 *船舶浸水產生的載荷*

對於獨立液貨艙，在設計止浮墊塊和支持船體結構時，應考慮浸水至夏季載重吃水的貨艙處所中空艙的浮力產生的載荷。

C部分
結構完整性

4.16 通則

4.16.1 結構設計應確保液貨艙具有足夠的承受所有相關載荷的能力和足夠的安全裕量。應考慮塑性變形、屈曲、疲勞和喪失液密和氣密的可能性。

4.16.2 貨物圍護系統的結構完整性應由符合有關貨物圍護系統類型的4.21至4.26予以證明。

4.16.3 具有新穎設計且與4.21至4.26中所述顯著不同的貨物圍護系統的結構完整性應由符合4.27予以證明以確保保持本章中規定的總體安全等級。

4.17 結構分析

4.17.1 *分析*

4.17.1.1 設計分析應基於接受的靜力學、動力學和材料強度原則。

4.17.1.2 可使用簡化方法或簡化分析計算載荷影響，只要其是保守的。模型試驗可與理論計算一起使用或代替理論計算。如果理論方法不適當，可要求模型或全尺度試驗。

4.17.1.3 確定對動載荷的響應時，應考慮動力影響（如其可能影響結構完整性）。

4.17.2 ***載荷情景***

4.17.2.1 對於應考慮的貨物圍護系統的每個位置或部分和應分析的每個可能的失效模式，應考慮可能同時作用的所有相關載荷組合。

4.17.2.2 應考慮建造、裝卸、試驗和營運期間所有相關階段最不利的情景和條件。

4.17.3 當分別計算靜應力和動應力時，除有其他計算方法能證明其恰當者外，總應力應按下式計算：

$$\sigma_x = \sigma_{x.st} \pm \sqrt{\sum (\sigma_{x.dyn})^2}$$

$$\sigma_y = \sigma_{y.st} \pm \sqrt{\sum (\sigma_{y.dyn})^2}$$

$$\sigma_z = \sigma_{z.st} \pm \sqrt{\sum (\sigma_{z.dyn})^2}$$

$$\tau_{xy} = \tau_{xy.st} \pm \sqrt{\sum (\tau_{xy.dyn})^2}$$

$$\tau_{xz} = \tau_{xz.st} \pm \sqrt{\sum (\tau_{xz.dyn})^2}$$

$$\tau_{yz} = \tau_{yz.st} \pm \sqrt{\sum (\tau_{yz.dyn})^2}$$

式中：

$\sigma_{x.st}$、$\sigma_{y.st}$、$\sigma_{z.st}$、$\tau_{xy.st}$、$\tau_{xz.st}$和$\tau_{yz.st}$為靜應力；和

$\sigma_{x.dyn}$、$\sigma_{y.dyn}$、$\sigma_{x.dyn}$、$\tau_{xy.dyn}$、$\tau_{xz.dyn}$和$\tau_{yz.dyn}$為動應力。

上述各值應從加速度分量和因撓曲和扭轉引起的船體應變分量中分別予以確定。

4.18 設計條件

對於所有相關載荷情景和設計條件，設計時應考慮所有相關失效模式。設計條件見本章前面部分，載荷情景見4.17.2。

4.18.1 ***極限設計條件***

考慮到彈性和塑料材料特性，結構能力可通過試驗或分析、簡化線性彈性分析或本規則規定予以確定。

4.18.1.1 應考慮塑性變形和屈曲。

4.18.1.2 分析應基於的特徵載荷值如下：

永久載荷：	預期值
功能載荷：	規定值
環境載荷：	對於波浪載荷：10^8波浪遭遇時遇到的最可能最大載荷

4.18.1.3 下列材料參數適用於極限強度評估：

.1.1 R_e＝標定的室溫下屈服應力下限值（N/mm^2）。如在應力—應變曲線上無明顯的屈服應力，則可採用0.2

%條件的驗證應力。

.1.2 R_m＝標定的室溫下抗拉強度下限值（N/mm^2）。

對鋁合金焊接接頭，如果低匹配焊縫（即焊接金屬的抗拉強度低於母材的抗拉強度）不可避免，應採用熱處理後Re或Rm的相應值。在這種情況下，橫向焊接抗拉強度應不小於母材的實際屈服強度。如這不能做到，這類材料的焊接結構不應納入貨物圍護系統。

.2 上述性能應與材料標定的機械性能的下限值相一致，包括製造狀態的焊縫金屬。經主管機關或代表主管機關的被認可組織特別考慮後，可考慮提高低溫下的屈服應力和抗拉強度。對於作為材料性能依據的溫度，應在1.4要求的《國際散裝運輸液化氣體適裝證書》內予以註明。

4.18.1.4 相當應力σ_c（Von Mises，Huber）應按下式確定：

$$\sigma_c = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2 - \sigma_x\sigma_y - \sigma_x\sigma_z - \sigma_y\sigma_z + 3\left(\tau_{xy}^2 + \tau_{xz}^2 + \tau_{yz}^2\right)}$$

式中：

σ_x＝x方向的總正應力；

σ_y＝y方向的總正應力；

σ_z＝z方向的總正應力；

τ_{xy}＝x-y平面的總剪應力；

τ_{xz}＝x-z平面的總剪應力；和

τ_{yz}＝y-z平面的總剪應力。

上述值應如4.17.3所述進行計算。

4.18.1.5 除第6章所涉及的材料外，在所有情況下，用於材料的許用應力應得到主管機關或代表主管機關的被認可組織的認可。

4.18.1.6 根據疲勞分析、裂紋擴展分析和屈曲標準，可對應力作進一步的限制。

4.18.2 ***疲勞設計條件***

4.18.2.1 疲勞設計條件是有關累積循環裝載的設計條件。

4.18.2.2 如要求疲勞分析，疲勞載荷的累積效應應符合：

$$\sum \frac{n_i}{N_i} + \frac{n_{Loading}}{N_{Loading}} \leq C_w$$

式中：

n_i = 液貨艙的使用壽命期間每一應力水平的應力循環次數；

N_i = 按照韋勒（S-N）曲線，相應的應力水平在達到斷裂時的循環次數；

$n_{裝載}$ = 液貨艙的使用壽命期間裝卸循環次數，不少於1000。裝卸循環包括完整的壓力和熱循環；

$N_{裝載}$ = 由於裝卸產生的疲勞載荷達到斷裂時的循環次

數；和

C_w = 許用最大累積疲勞破損率。

疲勞破損應基於液貨艙的設計壽命，但不小於10^8波浪遭遇。

4.18.2.3 如要求，考慮到貨物圍護系統預期壽命期間所有疲勞載荷及其適當的組合，貨物圍護系統應進行疲勞分析。應考慮到各種充裝工況。

4.18.2.4.1 分析中使用的設計S-N曲線應適用於材料和焊接件、結構細節、製作程序和預期的適用應力狀況。

4.18.2.4.2 S-N曲線應基於對應於至最終失效的相關實驗數據的平均值減去兩倍的標準差曲線的97.6%的殘存概率。使用通過不同方式得到的S-N曲線要求調整4.18.2.7至4.18.2.9中規定的可接受的C_w值。

4.18.2.5 分析應基於的特徵載荷值如下：

永久載荷：預期值

功能載荷：規定值或規定的過去值

環境載荷：預期載荷過去值，但不小於10^8循環。

如使用簡化動力裝載譜評估疲勞壽命，其應經主管機關或代表主管機關的被認可組織特別考慮。

4.18.2.6.1 如按4.4.3的規定減小次屏壁的尺寸，應進行疲勞裂紋擴大的斷裂力學分析以確定：

.1 結構中的裂紋擴展路徑；

.2 裂紋擴大速度；

.3 裂紋擴展導致液貨艙泄漏所要求的時間；

.4 全厚度裂紋的尺寸和形狀；和

.5 可探測到的裂紋達到臨界狀態所要求的時間。

斷裂力學通常基於試驗數據的平均值加上兩倍的標準差得到的裂紋擴大數據。

4.18.2.6.2 分析裂紋擴展時，應假定使用的檢查方法不能探測到的最大初始裂紋，並考慮到適用的許用無損探傷和目視檢查衡準。

4.18.2.6.3 在4.18.2.7中規定的條件下進行的裂紋擴展分析：可採用為期15天的簡化載荷分佈和順序。該分佈可由圖4.4所示得到。4.18.2.8和4.18.2.9中更長時間的載荷分佈和順序應經主管機關或代表主管機關的被認可組織認可。

4.18.2.6.4 佈置應符合4.18.2.7至4.18.2.9，如適用。

4.18.2.7 能通過泄漏探測可靠探測到的失效：

C_w應小於或等於0.5。

從泄漏探測點至達到臨界狀態，預計剩餘失效發展時間應不少於15天，但對航行於特殊航線的船舶可實施不同的要求。

4.18.2.8 不能通過泄漏探測到但能在營運檢查時可靠探測到的失效：

C_w應小於或等於0.5。

從營運檢查方法不能探測到的最大裂紋至達到臨界狀態，預計剩餘失效發展時間應不少於檢查間隔的3倍。

4.18.2.9 在液貨艙的特定位置，如不能確保有效的缺陷或裂紋擴大探測，應至少使用下列更嚴格的疲勞驗收衡準：

C_w應小於或等於0.1。

從假定的初始缺陷至達到臨界狀態，預計失效發展時間應不少於液貨艙使用壽命的3倍。

4.18.3 ***意外設計條件***

4.18.3.1 意外設計條件是針對發生概率極低的意外載荷的設計條件。

4.18.3.2 分析應基於的特徵值如下：

永久載荷：預期值

功能載荷：規定值

環境載荷：規定值

意外載荷：規定值或預期值

4.18.3.3 不需要將在4.13.9和4.15中所述的載荷進行相互間的合成，也不必將這些載荷與波浪引起的載荷進行合成。

D部分

材料和構造

4.19 材料

目的

確保貨物圍護系統、主屏壁和次屏壁、絕熱層、相鄰船舶結構和貨物圍護系統中的其他材料使用在正常作業和主屏壁失效時（如適用）適於其經受條件的具有適當特性的材料製成。

4.19.1 ***構成船舶結構的材料***

4.19.1.1 為確定船體結構中使用的板和型材的等級，當貨物溫度低於-10℃時，所有液貨艙應進行溫度計算。計算時應進行下列假定：

.1 應假定所有液貨艙的主屏壁處於貨物溫度；

.2 除.1外，如要求設置完整的或部分的次屏壁，僅對任一液貨艙假定其處於大氣壓力下的貨物溫度；

.3 對於環球航行，環境溫度應取空氣為5℃和海水為0℃。對於在限制航區營運的船舶，可允許採用較高的環境溫度。反之，對於在冬季月份預期會有較低溫度的區域航行的船舶，主管機關可規定較低的環境溫度；

.4 應假定空氣和海水為靜止狀態，即無強制對流調節；

.5 應假定船舶整個壽命期間由於諸如4.19.3.6和4.19.3.7中規定的熱和機械老化、壓縮、船舶運動和液貨艙振動等因素而使絕熱性能降低；

.6 應考慮泄漏貨物蒸發所產生的冷卻效應，如適用；

.7 可按照4.19.1.5進行船體加熱，只要加熱裝置符合4.19.1.6；

.8 除4.19.1.5所述外，對於任何加熱方式，均不予認定；和

.9 對於連接內外層殼體的構件，在確定其鋼材級別時可取平均溫度。

本段所述的設計中所選用的環境溫度，應在1.4.4要求的《國際散裝運輸液化氣體適裝證書》內予以註明。

4.19.1.2 船體的外板和甲板以及所有相連的扶強材均應符合公認標準的要求。如果由於貨物溫度的影響使設計條件下的材料計算溫度是在-5℃以下，此時的材料應符合表6.5的規定。

4.19.1.3 由於貨物溫度的影響使設計條件下的計算溫度在0℃以下且未構成次屏壁的所有其他船體結構的材料也應符合表6.5的規定。這包括支持液貨艙的船體結構、內底板、縱艙壁板、橫艙壁板、肋板、強肋骨、桁材以及所有相連的扶強構件。

4.19.1.4 構成次屏壁的船體材料應符合表6.2的要求。如次屏壁是由甲板或舷側外板構成，則表6.2所要求的材料級別應被延伸到鄰接的甲板或舷側外板的適當範圍（如適用時）。

4.19.1.5 可採用對船體結構材料進行加熱的方法，以確保這些材料的溫度不會降到低於表6.5規定的材料等級的最低允許值。在進行4.19.1.1要求的計算時，可按照下列進行加熱：

.1 對於任何橫向船體結構；

.2 如果已規定較低的環境溫度，對於4.19.1.2和4.19.1.3

中所述的縱向船體結構，但要求這些材料在不進行加熱計算時也能適應於空氣為5℃和海水為0℃的溫度條件；和

.3 作為.2的替代，對於液貨艙之間的縱向艙壁，可進行加熱，只要這些材料適應於最低設計溫度-30℃，或比4.19.1.1中確定的溫度低30℃，取小者。在這種情況下，無論這些艙壁是否視作有效，船舶總縱強度應符合SOLAS公約第II-1/3-1條的要求。

4.19.1.6 4.19.1.5中所述的加熱措施應符合下列要求：

.1 應將加熱系統佈置成當該系統的任一部分失效時，備用加熱設備仍能保持不低於100%的理論熱載荷；

.2 應考慮加熱系統是一個必需的輔助設備。至少一個按照4.19.1.5.1設置的系統的所有電氣部件應由應急電源供電；和

.3 主管機關或代表主管機關的被認可組織進行圍護系統認可時應納入加熱系統的設計和構造。

4.19.2 *主屏壁和次屏壁的材料*

4.19.2.1 用於建造不構成船體的主屏壁和次屏壁的金屬材料應適於其可能經受的設計載荷並按照表6.1、6.2或6.3的規定。

4.19.2.2 主屏壁和次屏壁中使用的、但表6.1、6.2或6.3未涉及的非金屬或金屬材料可經主管機關或代表主管機關的被認可組織認可，並

考慮到其可能經受的設計載荷、性能和預定的用途。

4.19.2.3 如果非金屬材料（包括複合材料）用於或納入主屏壁或次屏壁，其應進行下列性能試驗（如適用時），以確保其適合於預定的用途：

.1 與貨物的相容性；

.2 時效；

.3 力學性能；

.4 熱膨脹和收縮；

.5 耐磨性；

.6 凝聚性；

.7 抗振性能；

.8 防火和阻止火焰傳播；和

.9 耐疲勞破壞和裂紋擴展。

4.19.2.4 如適用時，應在營運中預計出現的最高溫度和低於最低設計溫度5℃之間的範圍內對上述性能進行試驗，但不必低於-196℃。

4.19.2.5.1 如果非金屬材料（包括複合材料）用於主屏壁和次屏壁，連接過程也應如上述進行試驗。

4.19.2.5.2 使用非金屬材料建造主屏壁和次屏壁的指導見附錄4。

4.19.2.6 可考慮在主屏壁和次屏壁中使用非防火和阻止火焰傳播

的材料，只要其受適當的系統（例如永久惰性氣體環境）保護或設有耐火屏壁。

4.19.3 ***貨物圍護系統中使用的絕熱和其他材料***

4.19.3.1 貨物圍護系統中使用的承載絕熱和其他材料應適於設計載荷。

4.19.3.2 貨物圍護系統中使用的絕熱和其他材料應具有下列性能（如適用），以確保其適合於預定的用途：

.1 與貨物的相容性；

.2 在貨物中的可溶性；

.3 貨物的吸收作用；

.4 收縮量；

.5 時效；

.6 封閉氣泡含量；

.7 密度；

.8 機械性能，能經受貨物和其他載荷影響，熱膨脹和收縮；

.9 耐磨性；

.10 凝聚性；

.11 熱傳導性；

.12 抗振性能；

.13 防火和阻止火焰傳播；和

.14 耐疲勞破壞和裂紋擴展的性能。

4.19.3.3 如適用時，應在營運中預計出現的最高溫度和低於最低設計溫度5℃之間的範圍內對上述性能進行試驗，但不必低於-196℃。

4.19.3.4 由於所處位置或環境條件的不同，如適用時，絕熱材料應具有適當的防火和阻止火焰傳播的性能，並應受到足夠的保護，以防止水蒸汽的滲透和機械損傷。如果絕熱層位於露天甲板或以上並在液貨艙罩貫穿處，其應有符合公認標準的適當的耐火性能或覆蓋具有低播焰性並形成有效認可蒸氣密封的材料。

4.19.3.5 未永久惰化的貨艙處所可使用不滿足公認的耐火標準的絕熱層，只要其表面覆蓋具有低播焰性並形成有效認可蒸氣密封的材料。

4.19.3.6 應在適當老化的樣品上進行絕熱層的熱傳導性試驗。

4.19.3.7 當採用粉末或顆粒狀絕熱層時，應採取措施減少營運中的材料壓實，保持要求的熱傳導性，同時防止對貨物圍護系統增加任何不適當的壓力。

4.20 建造過程

目的

規定適當的建造過程和試驗程序以儘實際可能確保貨物圍護系統按照設計階段的假定在營運中具有令人滿意的性能。

4.20.1 *焊縫設計*

4.20.1.1 對獨立液貨艙殼體的所有焊接接頭，均應採用全焊透型的平面內對接焊。僅對於氣室和殼體的連接，可根據焊接工藝認可試驗的結果採用全焊透型T型焊接。除氣室上的小型貫穿件外，一般也應將噴管焊縫設計成全焊透型。

4.20.1.2 C型獨立液貨艙和主要以曲面構成的B型獨立液貨艙液密主屏壁的焊接接頭的細節應滿足以下要求：

.1 所有縱向和環形接頭均應為對接、全焊透、雙面V型坡口或單面V型坡口形式，對於全焊透的對接焊縫，應採用雙面焊或使用襯墊環。如使用襯墊環，則焊後應除去襯墊環，很小的處理用壓力容器除外。根據對焊接工藝認可試驗的結果，亦可採用其他的坡口形式；和

.2 對於液貨艙本體和氣室之間以及氣室和有關的附件之間的連接接頭的斜坡口，應按主管機關或代表主管機關的被認可組織可接受的標準進行設計。容器上連接噴管、氣室或其他貫通件的焊縫以及法蘭與容器或噴管連接的所有焊縫均應為全焊透型焊縫。

4.20.1.3 如適用，所有建造過程和試驗（4.20.3中規定的除外）應按照第6章的適用規定進行。

4.20.2 *黏合和其他連接過程的設計*

黏合（或用除焊接外的一些其他過程連接）接頭的設計應考慮連

接過程的強度特徵。

4.20.3 ***試驗***

4.20.3.1 所有液貨艙和處理用壓力容器應按照適用於液貨艙類型的4.21至4.26進行水壓或水壓-氣動壓力試驗。

4.20.3.2 所有液貨艙應進行密性試驗，該密性試驗可與4.20.3.1中所述的壓力試驗一起進行。

4.20.3.3 關於對次屏壁的檢查要求，在所有情況下，均由主管機關或代表主管機關的被認可組織確定，並考慮到屏壁的可達性（見4.6.2）。

4.20.3.4 對於設有新穎B型獨立液貨艙或按照4.27設計的液貨艙的船舶，主管機關可要求至少應在一個原型液貨艙及其支持結構上使用應變儀或其他適當的設備進行測量，以確認其應力水平。對於C型獨立液貨艙，根據其形狀及其支持構件和附件的佈置，也可要求作類似的測量。

4.20.3.5 應按照檢驗程序和1.4的要求以及主管機關或代表主管機關的被認可組織的要求，在首次滿載及卸貨期間驗證貨物圍護系統的整體性能符合設計參數。對於驗證設計參數所必要的部件和設備性能的記錄，應予以保存，並可供主管機關使用。

4.20.3.6 如果按4.19.1.5和4.19.1.6的規定設有加熱裝置，則應對所要求的熱量輸出和熱量分佈進行試驗。

4.20.3.7 在第1次載貨航行時或之後，應對貨物圍護系統冷點進行

檢查。不能進行目視檢查的絕熱表面的完整性檢查應按照公認標準進行。

E部分

液貨艙類型

4.21 A型獨立液貨艙

4.21.1 *設計依據*

4.21.1.1 A型獨立液貨艙係指按照公認標準，應用傳統的船舶結構分析程序進行設計的液貨艙。如果這種液貨艙主要是由平面構成，則其設計蒸氣壓力P_o應小於0.07MPa。

4.21.1.2 如在大氣壓力下貨物溫度低於-10℃，則應按4.5要求設置完整的次屏壁。次屏壁應按照4.6設計。

4.21.2 *結構分析*

4.21.2.1 考慮到4.13.2中所述的內部壓力和與支持和鍵固系統以及船體的適當部分相互作用的載荷，應進行結構分析。

4.21.2.2 對於在本規則要求中沒有包括的某些部件，如支持結構，在儘可能計及4.12至4.15所述的載荷和支持結構處的船舶變形後，應採用直接計算法確定其應力。

4.21.2.3 應將具有支持構件的液貨艙設計成能承受4.15中規定的意外載荷。無需將這些載荷進行相互間的合成，也不必將這些載荷與環境載荷進行合成。

4.21.3 *極限設計條件*

4.21.3.1 對於由平面構成主要結構的液貨艙，主要構件和次要構件（扶強材、強肋骨、縱桁、桁材）的公稱薄膜應力，如按經典的分析方法進行計算，採用鎳鋼、碳錳鋼、奧氏體鋼和鋁合金時，應不超過R_m/2.66或R_e/1.33的較小值，其中，對於R_m和R_e，見4.18.1.3的定義。然而，如對主要構件進行了詳細計算，4.18.1.4的等效應力σ_c可超過上述數值，增加到主管機關或代表主管機關的被認可組織可接受的應力值；計算時應考慮到彎曲、剪切、軸向和扭轉變形，以及由於雙層底和液貨艙底的變形而引起的船體和液貨艙的相互作用力的影響。

4.21.3.2 液貨艙界限的結構尺寸至少應滿足主管機關或代表主管機關的被認可組織對深艙的要求，並考慮到4.13.2規定的內部壓力和4.3.5要求的任何腐蝕裕量。

4.21.3.3 液貨艙結構應檢查是否有潛在的屈曲。

4.21.4 ***意外設計條件***

4.21.4.1 液貨艙和液貨艙支持構件應設計成能承受4.3.4.3和4.15中規定的相關意外載荷和設計條件。

4.21.4.2 經受4.15中規定的意外載荷時，在計及其較低的發生概率的同時，應力應符合經修訂的4.21.3中規定的的驗收衡準。

4.21.5 ***試驗***

應對所有A型獨立液貨艙應進行水壓或水壓-氣動試驗。進行這種試驗時，應使其應力儘可能接近設計應力，並使液貨艙頂的壓力至少相當於釋放閥的最大調定值。當進行水壓－氣動試驗時，其試驗條件應儘可能模擬液貨艙及其支持結構的設計載荷情況，包括動態分量，

同時避免應力水平引起永久變形。

4.22 B型獨立液貨艙

4.22.1 *設計依據*

4.22.1.1 B型獨立液貨艙係指採用模型試驗、精確分析手段和分析方法確定應力水平、疲勞壽命和裂紋擴展特性進行設計的液貨艙。如果這類液貨艙主要由平面構成（棱鏡液貨艙），則其設計蒸氣壓力P_o應小於0.07MPa。

4.22.1.2 如在大氣壓力下貨物溫度低於-10℃，則應按4.5要求設置具有小泄漏保護系統的部分次屏壁。小泄漏保護系統應按照4.7設計。

4.22.2 *結構分析*

4.22.2.1 在確定結構對下列情況的適應性時，應考慮所有動、靜載荷的影響：

.1 塑性變形；

.2 屈曲；

.3 疲勞破壞；和

.4 裂紋擴展。

應進行有限元分析或類似方法的分析和斷裂力學分析或其他等效的分析。

4.22.2.2 應採用三維分析法評估應力水平，包括與船體的相互作用。

該分析模型應包括液貨艙及其支持和鍵固系統以及船體的適當部分。

4.22.2.3 對在不規則波浪中特定的船舶加速度和運動以及船舶及其液貨艙對這些力和運動的響應均應進行完整的分析，除非這些數據可從類似的船舶中獲得。

4.22.3 ***極限設計條件***

4.22.3.1 塑性變形

4.22.3.1.1 對於由回轉體構成主要結構的B型獨立液貨艙，其許用應力應滿足：

$$\sigma_m \leq f$$

$$\sigma_L \leq 1.5f$$

$$\sigma_b \leq 1.5F$$

$$\sigma_L + \sigma_b \leq 1.5F$$

$$\sigma_m + \sigma_b \leq 1.5F$$

$$\sigma_m + \sigma_b + \sigma_g \leq 3.0F$$

$$\sigma_L + \sigma_b + \sigma_g \leq 3.0F$$

式中： σ_m = 等效總體主膜應力；

σ_L = 等效局部主膜應力；

σ_b = 等效主彎曲應力；

σ_g = 等效二階應力；

f = R_m/A或R_e/B，取其小者；和

F = R_m/C和R_e/D，取其小者。

Rm和Re見4.18.1.3中的定義。σ_m、σ_L、σ_b和σ_g參見4.28.3中應力分類的定義。對於A和B值，應在《國際散裝運輸液化氣體適裝證書》內予以註明，且至少應為下表中所列的最小值：

	鎳鋼和碳錳鋼	奧氏體鋼	鋁合金
A	3	3.5	4
B	2	1.6	1.5
C	3	3	3
D	1.5	1.5	1.5

上述數字可經修改，並考慮到主管機關接受的設計條件。

4.22.3.1.2 對於由平面構成主要結構的B型獨立液貨艙，用於有限元分析的許用膜等效應力應不超過：

.1 對於鎳鋼和碳錳鋼，$R_m/2$或$R_e/1.2$，取其小者；

.2 對於奧氏體鋼，$R_m/2.5$或$R_e/1.2$，取其小者；和

.3 對於鋁合金，$R_m/2.5$或$R_e/1.2$，取其小者。

上述數字可經修正，並考慮到應力的位置、應力分析方法和主管機關接受的設計條件。

4.22.3.1.3 殼板的厚度和扶強材的尺寸應不小於對A型獨立液貨艙

的要求。

4.22.3.2 *屈曲*

承受外部壓力和引起壓縮應力的其他載荷的液貨艙應按照公認標準進行屈曲強度分析。方法應充分考慮到理論和實際屈曲應力值之間的差別；此差別是由於板邊對中失誤、缺乏平直、橢圓度以及在規定弧長或弦長範圍內存在的失圓度而引起的。

4.22.4 *疲勞設計條件*

4.22.4.1 應按照4.18.2進行疲勞和裂紋擴展評估。根據缺陷的可探測性，驗收衡準應符合4.18.2.7、4.18.2.8或4.18.2.9。

4.22.4.2 疲勞分析應考慮建造公差。

4.22.4.3 如主管機關認為有必要，可要求做模型試驗，以確定應力集中係數和結構單元的疲勞壽命。

4.22.5 *意外設計條件*

4.22.5.1 液貨艙和液貨艙支持構件應設計成能承受4.3.4.3和4.15中規定的適用意外載荷和設計條件。

4.22.5.2 經受4.15中規定的意外載荷時，在計及其較低的發生概率的同時，應力應符合經修訂的4.22.3中規定的的驗收衡準。

4.22.6 *試驗*

B型獨立液貨艙應按下列要求進行水壓或水壓－氣動試驗：

.1 應按4.21.5中對A型獨立液貨艙的要求進行試驗；和

.2 此外，在試驗條件下，主要構件中的最大主膜應力或最大彎曲應力應不超過材料（製造狀態）在試驗溫度下的屈服強度的90%。為確保滿足上述條件、當計算表明此應力超過材料屈服強度的75%時，應採用應變儀或其他合適的設備對原型試驗加以監測。

4.22.7 *標記*

壓力容器作任何標記時，所用的方法應不致於使其產生不能接受的局部應力的升高。

4.23 C型獨立液貨艙

4.23.1 *設計依據*

4.23.1.1 C型獨立液貨艙的設計依據為經修訂納入斷裂力學和裂紋擴展衡準的壓力容器衡準。4.23.1.2中規定的最小設計壓力旨在確保動應力足夠低，從而在液貨艙使用壽命期間，初始表面裂紋不會擴展超過外殼厚度的一半。

4.23.1.2 設計蒸氣壓力應不小於：

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

式中：

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

其中：

σ_m = 設計主膜應力；

$\Delta\sigma_A$＝許用動態膜應力（雙振幅，當概率水平為Q＝10^{-8}），

－55N/mm^2，對鐵素體（珠光體）/馬氏體和奧氏體鋼。

－25N/mm^2，對鋁合金（5083-0）；

C＝液貨艙的特性尺度，取下列各值中的最大者：

h，$0.75b$或$0.45I$

其中：

h＝液貨艙高度（沿船舶的垂向量取），m；

b＝液貨艙寬度（沿船舶的橫向量取），m；

I＝液貨艙長度（沿船舶的縱向量取），m；

ρ_r＝設計溫度下貨物的相對密度（淡水：ρ_r＝1）。

當液貨艙的規定設計壽命長於10^8波浪遭遇，$\Delta\sigma_A$應予以修改以得出對應於設計壽命的等效裂紋擴展。

4.23.1.3 根據液貨艙的形狀及其支承裝置和附件的佈置，主管機關可將符合4.23.1.2中C型液貨艙最小設計壓力標準的液貨艙歸屬為A型或B型。

4.23.2 *殼體厚度*

4.23.2.1 殼體厚度應如下：

.1 按4.23.2.4規定計算得到的壓力容器的殼體厚度應視為沒有任何負公差的加工成形後的最小厚度。

.2 加工成形後的壓力容器的殼體和封頭的最小厚度（包括腐蝕裕量）應為：

對於碳錳鋼和鎳鋼，應不小於5mm；對於奧氏體鋼應不小於3mm；對於鋁合金，應不小於7mm。

.3 當進行6.5.6.5所述的檢驗和無損探傷時，按4.23.2.4的規定進行的計算中所用的焊接有效係數應為0.95。如考慮了其他因素，諸如所使用的材料、接頭型式、焊接方法以及載荷類型等，則焊接有效係數可以增大到1。對於處理用壓力容器，主管機關或代表主管機關的被認可組織在考慮了諸如所使用的材料、設計溫度、材料製造時的零韌性轉變溫度，接頭型式和焊接方法等因素，可以接受不小於6.5.6.5規定的局部無損探傷，但在這種情況下，所採用的焊接有效係數應不大於0.85。對於特殊材料，根據焊接接頭的標定機械性能，上述係數應減小。

4.23.2.2 在內部壓力計算中應考慮4.13.2所定義的設計液體壓力。

4.23.2.3 用於驗證壓力容器屈曲的設計外部壓力P_e應不小於按下式計算所得值：

$P_e = P_1 + P_2 + P_3 + P_4$（MPa），

式中：

P_1= 真空釋放閥的調定壓力，對未配備真空釋放閥的容器，應作特別考慮，但一般應取不小於0.025MPa；

P_2= 安放壓力容器或壓力容器部件的全封閉處所的壓力釋放閥（PRV）的調定壓力；對其他處所，$P_2=0$；

P_3= 由於絕熱層的重量和收縮、殼體重量（包括腐蝕裕量）以及壓力容器可能承受的其他外部載荷所引起的作用在殼體中或殼體上的壓力。這些壓力還包括（但不限於）氣室、塔架和管路的重量、部分充裝工況下的貨品的作用、加速度和船體變形所引起的壓力。此外，還應考慮外部壓力或內部壓力或兩者的局部作用；和

P_4= 由水壓頭引起的作用於露天甲板上的壓力容器或壓力容器部件的外部壓力；對其他住所，$P_4=0$。

4.23.2.4 對於液貨艙的結構尺寸，應根據液貨艙的內部壓力按下述規定進行計算：應確定承受4.13.2中定義的內部壓力的壓力容器的受壓部件的厚度和形狀，包括法蘭在內。在所有情況下，應根據公認的壓力容器的設計原理進行這些計算。對於壓力容器中的受壓部件的開口，應按公認標準予以加強。

4.23.2.5 對於靜、動載荷的應力分析，應按下述規定進行：

.1 對於壓力容器的結構尺寸，應按4.23.2.1至4.23.2.4和4.23.3的規定予以確定。

.2 應對支持構件及其殼體連接件處的載荷和應力進行計算。如適用時，應採用4.12至4.15所述的載荷，支持結構處的應力應符合主管機關或代表主管機關的被認可組織所接受的公認標準。在特殊情況下，主管機關或代表主管機關的被認可組織可要求作疲勞分析。

.3 如主管機關或代表主管機關的被認可組織要求，應特別考慮二階應力和熱應力。

4.23.3 ***極限設計條件***

4.23.3.1 塑性變形

對於C型獨立液貨艙，其許用應力應滿足：

$\sigma_m \quad \leq f$

$\sigma_L \quad \leq 1.5f$

$\sigma_b \quad \leq 1.5f$

$\sigma_L + \sigma_b \quad \leq 1.5f$

$\sigma_m + \sigma_b \quad \leq 1.5f$

$\sigma_m + \sigma_b + \sigma_g \quad \leq 3.0f$

$$\sigma_L + \sigma_b + \sigma_g \quad \leq 3.0f$$

式中：

σ_m＝等效總體主膜應力；

σ_L＝等效局部主膜應力；

σ_b＝等效主彎曲應力；

σ_g＝等效二階應力；

$f = R_m/A$或R_e/B，取其小者；

R_m和R_e見4.18.1.3中的定義。σ_m、σ_L、σ_b和σ_g參見4.28.3中應力分類的定義。A和B值應在《國際散裝運輸液化氣體適裝證書》內予以註明，且至少應為下表中所列的最小值：

	鎳鋼和碳錳鋼	奧氏體鋼	鋁合金
A	3	3.5	4
B	1.5	1.5	1.5

4.23.3.2 屈曲衡準應為如下：對於承受外部壓力和引起壓縮應力的其他載荷的壓力容器，其厚度和形狀應基於使用公認的的壓力容器屈曲理論進行的計算，並應充分考慮到理論和實際屈曲應力值之間的差別；此差別是由於板邊對中失誤、橢圓度以及在規定弧長（或弦長）範圍內存在的失圓度而引起的。

4.23.4 *疲勞設計條件*

對於大型C型獨立液貨艙，如在大氣壓力下貨物溫度低於-55℃，

主管機關或代表主管機關的被認可組織可要求附加驗證以核查其是否符合4.23.1.1關於靜應力和動應力的要求。

4.23.5 ***意外設計條件***

4.23.5.1 液貨艙和液貨艙支持構件應設計成能承受4.3.4.3和4.15中規定的適用意外載荷和設計條件。

4.23.5.2 經受4.15中規定的意外載荷時，在計及其較低的發生概率的同時，應力應符合經修訂的4.23.3.1中規定的驗收衡準。

4.23.6 ***試驗***

4.23.6.1 每一壓力容器應進行水壓試驗，試驗時在液貨艙頂測得的壓力應不小於$1.5P_o$。在壓力試驗期間的任何情況下，對任意艙計算所得的主膜應力應不超過材料屈服應力的90%。為了確保滿足上述條件，如計算表明主膜應力超過屈服強度的75%，則在原型試驗時，應採用應變儀或其他合適的設備加以監測，但對於簡單的圓柱型或球型的壓力容器，可予以除外。

4.23.6.2 試驗時所採用的水溫至少應比製成的材料的零韌性轉變溫度高出30℃。

4.23.6.3 每25mm厚度，壓力應保持為2小時，但在任何情況下不得少於2小時。

4.23.6.4 如為貨物壓力容器所需要，可在4.23.6.1和4.23.6.3所述的條件下進行水壓氣動試驗。

4.23.6.5 採用較高許用應力液貨艙的試驗，將根據其工作溫度可予

以特別考慮。但4.23.6.1的要求應完全滿足。

4.23.6.6 在裝配和完工後，應對每一壓力容器及其有關的附件進行適當的密性試驗，該試驗可與4.23.6.1中所述的壓力試驗一起進行。

4.23.6.7 對於除液貨艙以外的壓力容器的氣壓試驗，只能根據各種情況分別予以考慮。僅在下述情況時，才允許對那些容器進行氣壓試驗：容器的設計或其支持結構不能使容器被安全地注滿水，或不能對容器進行乾燥，以及在使用容器時不允許在容器內留有試驗介質的痕跡。

4.23.7 *標記*

壓力容器作標記時，所用的方法應不致於使其產生不能接受的局部應力的升高。

4.24 薄膜液貨艙

4.24.1 *設計依據*

4.24.1.1 薄膜圍護系統的設計依據為使熱膨脹和其他膨脹或收縮得到補償，以免出現喪失薄膜密性的不當風險。

4.24.1.2 基於分析和試驗的系統方法應用於證明考慮到4.24.2.1中規定的營運中發生的事件，系統會提供預期功能。

4.24.1.3 如在大氣壓力下貨物溫度低於-10℃，應按4.5的要求設置完整的次屏壁。次屏壁應按照4.6進行設計。

4.24.1.4 設計蒸氣壓力P_o通常應不超過0.025MPa。如果船體構件尺寸相應加大並適當考慮支持絕熱層的強度，P_o亦可相應增加到一較高

值，但應小於0.07MPa。

4.24.1.5 薄膜液貨艙的定義並不排除設計非金屬薄膜或其薄膜被包括或被合併在絕熱層中的液貨艙。

4.24.1.6 薄膜厚度一般應不超過10mm。

4.24.1.7 按照9.2.1，惰性氣體在主要絕熱處所和次要絕熱處所中的循環應足以允許有效的氣體探測。

4.24.2 ***設計考慮***

4.24.2.1 應評估能在薄膜的壽命期間導致喪失液密的潛在事件。這包括但不限於：

.1 極限設計事件：

.1 薄膜的拉力失效；

.2 絕熱層的壓縮破壞；

.3 熱時效；

.4 絕熱層和船體結構之間喪失連接；

.5 薄膜與絕熱系統喪失連接；

.6 內部結構及其支持結構的結構完整性；和

.7 支持船體結構的破損。

.2 疲勞設計事件：

.1 薄膜疲勞，包括船體結構的接頭和附件；

.2 絕熱層的疲勞裂紋；

.3 內部結構及其支持結構的疲勞；和

.4 導致壓載水進入的內殼的疲勞裂紋。

.3 意外設計事件：

.1 意外機械破損（例如營運時液貨艙內掉落的物體）；

.2 絕熱處所的意外過壓；

.3 液貨艙的意外真空；和

.4 內殼結構進水。

不接受會導致2個薄膜同時或級聯失效的單個內部事件的設計。

4.24.2.2 按照4.24.1.2進行設計時，應確定建造貨物圍護系統時使用的材料的物理性能（機械的、熱的、化學的等）。

4.24.2.3 ***載荷和載荷組合***

對於因屏壁間處所的超壓、液貨艙可能出現真空、液體晃蕩的影響、船體振動的影響或這些事件的組合而可能造成液貨艙完整性的喪失，應給予特別注意。

4.24.4 ***結構分析***

4.24.4.1 應進行為確定極限強度而進行的貨物圍護和相關結構（例如4.9中定義的結構）的結構分析和/或試驗以及疲勞評估。結構分析應提供評估已確定對貨物圍護系統而言關鍵的每個失效模式所要求

的數據。

4.24.4.2 船體結構分析應計及4.13.2中所述的內部壓力。應特別注意船體的變形以及船體與薄膜和船體與其相關的絕熱層的相容性。

4.24.4.3 4.24.4.1和4.24.4.2中所述的分析應基於船舶和貨物圍護系統特有的運動、加速度和響應。

4.24.5 *極限設計條件*

4.24.5.1 應按照4.24.1.2確定在營運條件下各關鍵部件、子系統或組件的結構阻力。

4.24.5.2 貨物圍護系統、船體結構附件和內部液貨艙結構的失效模式的強度驗收衡準的選擇應反映與所考慮的失效模式相關的結果。

4.24.5.3 內殼尺寸應滿足深艙的要求，並考慮到4.13.2中所述的內部壓力和4.14.3中規定的晃蕩載荷的適當要求。

4.24.6 *疲勞設計條件*

4.24.6.1 如果連續監測不能探測到失效發展，液貨艙內的結構（即泵塔）以及部分薄膜和泵塔附件應進行疲勞分析。

4.24.6.2 應按照4.18.2進行疲勞計算，並根據下列相關要求：

.1 結構部件關於結構完整性的重要性；和

.2 檢查的有效性。

4.24.6.3 對於可經試驗和/或分析證明裂紋不會導致2個薄膜同時或級聯失效的結構單元，*Cw*應小於或等於0.5。

4.24.6.4 如果無人照看的疲勞裂紋會造成2個薄膜同時或級聯失效，經定期檢查的結構單元應滿足4.18.2.8中所述的疲勞和斷裂力學要求。

4.24.6.5 如果疲勞裂紋會在無預兆的情況下造成2個薄膜同時或級聯失效，不能進行營運檢查的結構單元應滿足4.18.2.9中所述的疲勞和斷裂力學要求。

4.24.7 *意外設計條件*

4.24.7.1 圍護系統和支持船體結構應設計成能承受4.15中規定的意外載荷。無需將這些載荷進行相互間的合成，也不必將這些載荷與環境載荷進行合成。

4.24.7.2 應基於風險評估確定附加相關意外情景。應特別考慮液貨艙內的繫固設備。

4.24.8 *設計開發試驗*

4.24.8.1 4.24.1.2中要求的設計開發試驗應包括既有主屏壁又有次屏壁的一系列分析和物理模型（包括角和接頭），經試驗以驗證其能承受由靜、動和熱載荷引起的預期的組合應變。這用於建造完整的貨物圍護系統的原型模型。分析和物理模型中考慮的試驗條件應代表貨物圍護系統在其使用壽命中可能遇到的最極端的營運狀態。4.6.2中要求的次屏壁的定期試驗的建議驗收衡準可基於原型模型的試驗結果。

4.24.8.2 薄膜材料和薄膜中有代表性的焊接或連接接頭的疲勞性能應通過試驗確定。將絕熱系統繫固至船體結構的裝置的極限強度和

疲勞性能應通過分析或試驗確定。

4.24.9 ***試驗***

4.24.9.1 當船上設有薄膜貨物圍護系統時，所有液貨艙和在正常情況下可能裝有液體並鄰接於支持薄膜的船體結構的其他處所，均應進行水壓試驗。

4.24.9.2 安裝貨物圍護系統前，支持薄膜的所有貨艙結構應進行密性試驗。

4.24.9.3 不必對管隧和在通常情況下不裝液體的其他艙室進行水壓試驗。

4.25 整體液貨艙

4.25.1 ***設計依據***

構成船體結構的一部分並與相鄰船體結構一起受到載荷影響的的整體液貨艙應符合下列要求：

.1 按4.1.2所確定的設計蒸氣壓力P_o通常應不超過0.025MPa。如果船體構件尺寸相應加大，P_o亦可相應增加到一較高值，但應小於0.07MPa；

.2 整體液貨艙可用於載運沸點不低於-10℃的貨品。經主管機關或代表主管機關的被認可組織特別考慮，也可同意更低的溫度，但在這種情況下，應設有完整的次屏壁；和

.3 第19章要求的1G型船舶載運的貨品不應載於整體液

貨艙。

4.25.2 ***結構分析***

整體液貨艙的結構分析應按照公認標準。

4.25.3 ***極限設計條件***

4.25.3.1 液貨艙界限的結構尺寸應滿足對深艙的要求，並考慮到4.13.2規定的內部壓力。

4.25.3.2 對於整體液貨艙，其許用應力通常應為按照主管機關或代表主管機關的被認可組織對船體結構的要求。

4.25.4 ***意外設計條件***

4.25.4.1 液貨艙和液貨艙支持構件應設計成能承受4.3.4.3和4.15中規定的相關意外載荷。

4.25.4.2 經受4.15中規定的意外載荷時，在計及其較低的發生概率的同時，應力應符合經修訂的4.25.3中規定的的驗收衡準。

4.25.5 ***試驗***

應對整體液貨艙進行水壓或水壓氣動試驗。對這種試驗，應儘可能使其應力接近設計應力，並使液貨艙頂的壓力至少相當於釋放閥的最大調定值（MARVS）。

4.26 半薄膜液貨艙

4.26.1 ***設計依據***

4.26.1.1 半薄膜液貨艙係指裝載工況下非自身支持的液貨艙，由一

層薄膜組成，該薄膜的大部分是由相鄰船體結構通過絕熱層所支持，但對與上述受支持部分相連接的薄膜層圓形部分應設計成能承受熱膨脹和其他膨脹或收縮。

4.26.1.2 設計蒸氣壓力P_o通常應不超過0.025MPa。如船體構件尺寸相應加大，並且對支持絕熱層的強度作了適當考慮，則P_o可相應增加到一較高值，但應小於0.07MPa。

4.26.1.3 用於獨立液貨艙或薄膜液貨艙的有關要求，如合適時，亦適用於半薄膜液貨艙。

4.26.1.4 如半薄膜液貨艙在各方面均能符合適用於B型獨立液貨艙的要求（支持方式除外），經主管機關特別考慮，可同意設置部分的次屏壁。

F部分

新穎形狀的貨物圍護系統

4.27 新穎概念的極限狀態設計

4.27.1 不能使用4.21至4.26節進行設計的新穎形狀的貨物圍護系統應使用本節以及本章的A部分和B部分以及適用的C部分和D部分進行設計。按照本節進行的貨物圍護系統的設計應基於極限狀態設計的原則，該結構設計方法可用於確定設計解決方案和新穎設計。該更通用的方法保持的安全等級與使用4.21至4.26進行設計的已知圍護系統達到的安全等級類似。

4.27.2.1 極限狀態設計是系統方法，對每個結構單元進行與4.3.4中確定的設計條件相關的可能的失效模式評估。極限狀態可定義為超

出後結構或部分結構不再滿足要求的狀態。

4.27.2.2 對於每個失效模式，一個或多個極限狀態可能相關。考慮到所有相關極限狀態，結構單元的極限載荷為所有相關極限狀態產生的最小極限載荷。極限狀態分為以下3類：

.1 最終極限狀態（ULS），在完整（無破損）條件下，對應於最大承載能力或在某些情況下，對應於最大適用應變或變形；

.2 疲勞極限狀態（FLS），對應於由於隨時間變化（循環）裝載的影響造成的降級；和

.3 意外極限狀態（ALS），與結構的抗意外狀況能力有關。

4.27.3 極限狀態設計的程序和相關設計參數應符合附錄5中所載的新穎形狀的貨物圍護系統設計中極限狀態方法的使用標準（LSD標準）。

G部分

指導

4.28 第4章的指導性說明

4.28.1 *為靜載設計而進行內部壓力詳細計算的指導*

4.28.1.1 本節為相關動態液體壓力的計算提供指導以進行靜載設計計算。該壓力可用於確定4.13.2.4中所述的內部壓力，其中：

.1 $(P_{gd})_{max}$是使用最大設計加速度確定的相關液體壓

力。

.2 （P_{gd}site）$_{max}$是使用場所特定加速度確定的相關液體壓力。

.3 P_{eq}應為如下計算得出的P_{eq1}和P_{eq2}的大者：

$$P_{eq1} = P_o + (P_{gd})_{max} \quad \text{MPa}$$

$$P_{eq2} = P_h + (P_{gd}\text{site})_{max} \quad \text{MPa}$$

4.28.1.2 內部液體壓力是由於4.14.1所述的船舶運動所引起的貨物重力加速度所產生的壓力。對於由重力和動力加速度的聯合作用所引起的內部液體壓力P_{gd}，應按下式計算：

$$P_{gd} = \alpha_\beta Z_\beta \frac{\rho}{1.02\times10^5} \text{MPa}$$

式中：

a_β = 在任意的β方向上由重力和動載荷引起的無因次加速度（即相對於重力加速度）（見圖4.1）。

對於大型液貨船，考慮到橫向垂直和縱向加速度，應使用加速度橢球。

Z_β = 從所決定的壓力點沿β方向向上量至液貨艙殼板的最大液柱高度（見圖4.2）。

在確定Z_β時，除非液貨艙氣室的總容積V_d不超過按下列公式所得值，否則液貨艙氣室應考慮作為所同意的液貨艙總容積的一部分：

$$V_d = V_t \left(\frac{100 - FL}{FL} \right)$$

式中：

V_t＝無任何氣室的液貨艙容積；和

FL＝按第15章規定的充裝極限。

ρ＝設計溫度時的最大貨物密度，kg/m^3。

應考慮給出最大值（P_{gd}）$_{max}$或（P_{gd}site）$_{max}$的方向。上述公式僅適用於注滿的液貨艙。

4.28.1.3 也可以採用等效的計算方法。

4.28.2 ***加速度分量的指導公式***

4.28.2.1 下列公式是作為計算由於船舶在北大西洋中以相當於概率水平為10^{-8}的運動而產生的加速度分量的指導公式，且適用於船長超過50m並以或接近營運速度航行的船舶。

— 4.14.1中定義的垂向加速度：

$$a_z = \pm a_0 \sqrt{1 + \left(5.3 - \frac{45}{L_0}\right)^2 \left(\frac{x}{L_0} + 0.05\right)^2 \left(\frac{0.6}{C_B}\right)^{1.5} + \left(\frac{0.6yK^{1.5}}{B}\right)^2}$$

— 4.14.1中定義的橫向加速度：

$$a_y = \pm a_0 \sqrt{0.6 + 2.5\left(\frac{x}{L_0} + 0.05\right)^2 + \mathrm{K}\left(1 + 0.6K\frac{z}{B}\right)^2}$$

— 4.14.1中定義的縱向加速度：

$$a_x = \pm a_0 \sqrt{0.06 + A^2 - 0.25A}$$

式中：

$$a_0 = 0.2\frac{V}{\sqrt{L_0}} + \frac{34 - (\frac{600}{L_0})}{L_0}$$

L_0＝船長按公認標準所定義確定結構尺寸，m；

C_B＝方形係數；

B＝ 船舶最大型寬，m；

X＝ 船中到裝貨的液貨艙重心之間的縱向距離，m；船中前，X為正值，船中後，X為負值；

Y＝ 中線到裝貨的液貨艙重心之間的橫向距離，m；

Z＝船舶的實際水線到裝貨的液貨艙重心之間的垂向距離，m；水線以上，Z為正值，水線以下，Z為負值；

K＝*通常為1。對於特殊的裝載工況和船型，K值可按下式確定：*

$K=13GM/B$，此時：$K\geq1$和GM＝靜穩心高度，m；

$A = (0.7 - \frac{L_0}{1200} + 5\frac{z}{L_0})(\frac{0.6}{C_B})$；和

V＝ *營運速度，kn；*

a_x、a_y、a_z＝ 為相應方向上的最大無因次加速度（即相對於重力加速度）。計算時可視其為分別作用，a_z不包括靜重力分量，a_y包括橫搖在橫方向上引起靜重力分量，a_x包括縱搖在縱方向上引起靜重力分量。上述公式得出的加速度只適用於以或接近營運速

度航行的船舶，而不是錨泊或在暴露場所幾乎靜止的船舶。

4.28.3 ***應力分類***

4.28.3.1 就應力評估而言，本節對應力分類作如下定義。

4.28.3.2 正應力係指垂直於基準平面的應力分量。

4.28.3.3 膜應力係指在考慮的截面厚度範圍內，均勻分佈且等於應力平均值的正應力的分量。

4.28.3.4 彎曲應力係指在所考慮的截面厚度範圍內，減去膜應力後的變應力。

4.28.3.5 剪切應力係指作用在基準平面內的應力分量。

4.28.3.6 主應力係指由施加的載荷所產生的應力，需要與外力和外力矩相平衡。主應力的基本特性係呈非自身限制的（自身無平衡能力的）。明顯超過屈服強度的主應力將導致構件破壞或至少出現嚴重變形。

4.28.3.7 總體主膜應力係指這樣一種主膜應力，即當結構發生屈服時，在結構中分佈的主膜應力不會導致載荷的重新分佈。

4.28.3.8 局部主膜應力係指由於壓力或其他機械載荷及有關的初始的或不連續的效應所形成的膜應力的載荷的傳遞中對結構的其他部位所產生的過度變形而引起的應力。這種應力雖具有二階應力的特性，但仍應將其歸類於局部主膜應力。如果滿足下列條件，則可認為應力區域是局部的：

$S_1 \leq 0.5\sqrt{Rt}$和

$S_2 \geq 2.5\sqrt{Rt}$

式中：

S_1= 在子午線方向內，等值應力超過1.1*f*的距離；

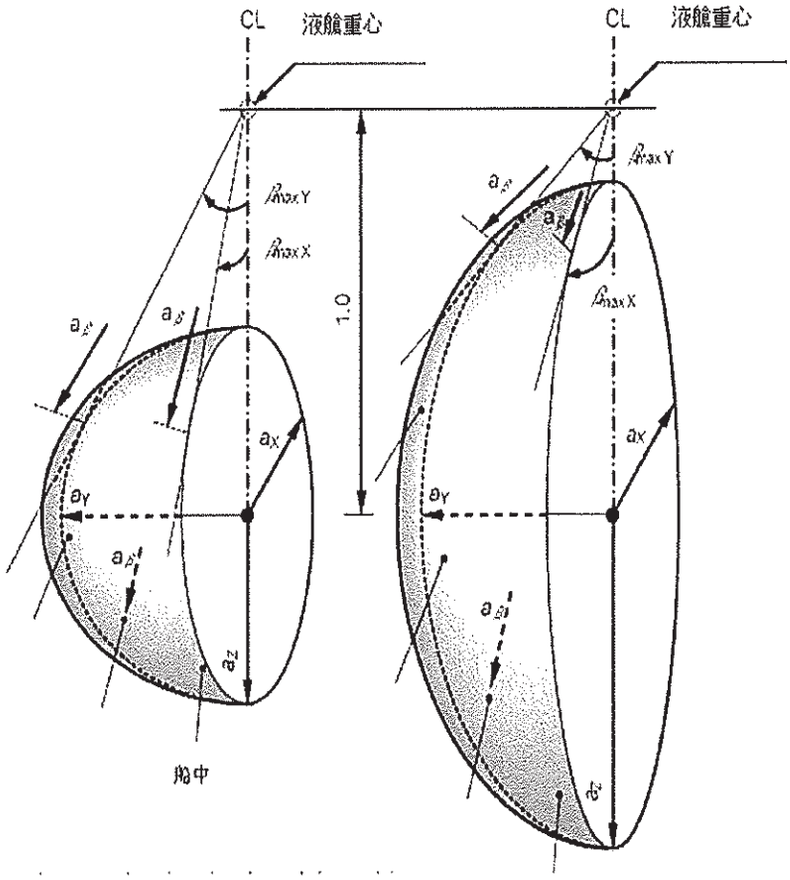
S_2= 在子午線方向內，到超過總體主膜應力極限的另一區域的距離；

R= 容器的平均直徑；

t= 超過總體主膜應力極限處的容器壁厚；和

f= 許用總體主膜應力。

4.28.3.9 二階應力係指由相鄰部件的約束或由結構自身約束產生的正應力或剪應力。二階應力的基本特性是呈自身限制（自身有平衡能力）。導致產生這種應力的條件是局部屈服和較小的變形。



a_β = 在任意β方向上的合成加速度（靜載和動載）

a_X = 加速度縱向分量　　距首垂線0.05L處：

a_Y = 加速度橫向分量

a_Z = 加速度垂向分量

圖4.1－加速度橢圓

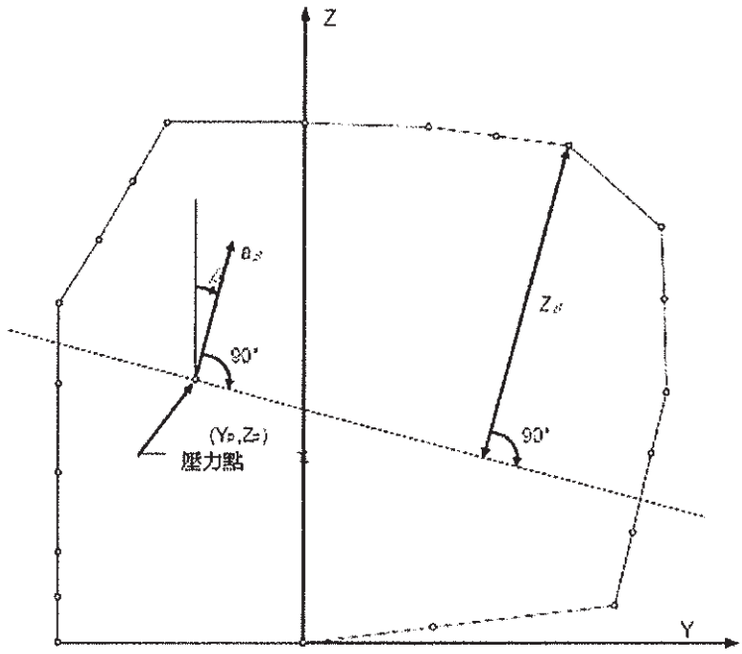


圖4.2－內部壓頭的確定

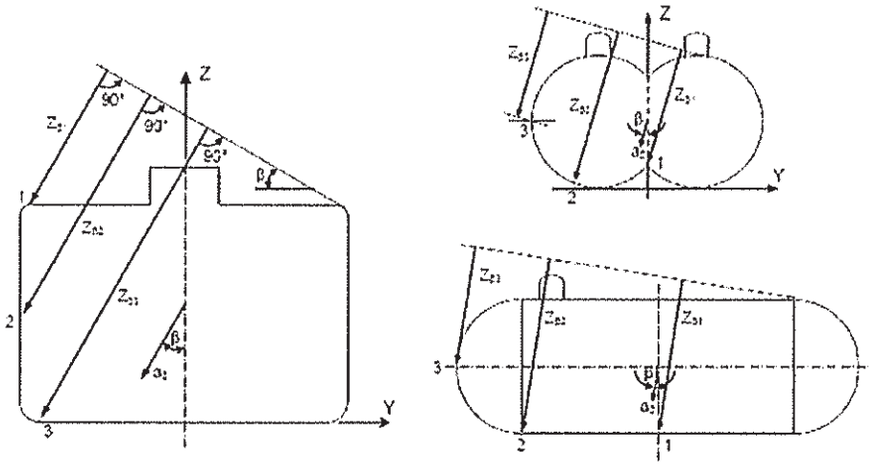
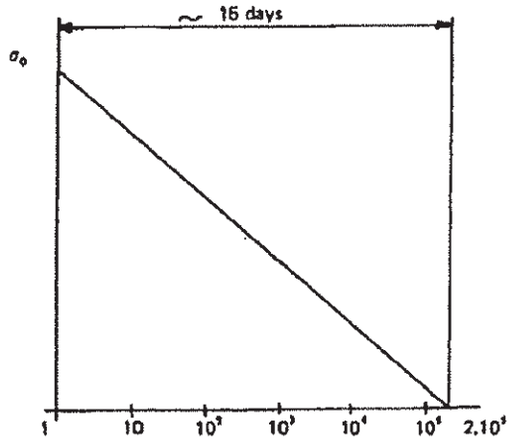


圖4.3－點1、2和3的液體高度Zβ的確定



響應循環次數

σ_0＝船舶使用壽命中最可能出現的最大應力響應循環次數，以對數計；給出的2×10^5值作為一個估算算例

圖4.4－簡化的載荷分佈

第5章

處理用受壓容器及液體、蒸氣和壓力管系

目的

確保所有貨物和處理用液體和蒸氣在所有營運狀態下的安全裝卸，考慮到所涉及貨品的性質，將對船舶、船員和環境的風險降至最低。這將：

.1 確保處理用受壓容器，管系和貨物軟管的完整性；

.2 防止貨物的不受控駛運；

.3 確保填充和排空圍護系統的方式可靠；和

.4 防止貨物圍護系統的壓力或真空偏移在貨物過駁作業中超過設計參數。

5.1 一般要求

5.1.1 本章要求應適用於包括蒸氣管系，氣體燃料管系和安全閥透氣管路或類似管路在內的貨物管系和處理管系。對不含有貨物的輔助管系免除本章的一般要求。

5.1.2 第4章中對C型獨立液貨艙的要求也可適用於處理用受壓容器。按此要求，第4章中所使用的“受壓容器”一詞可包括C型獨立液貨艙和處理用受壓容器。

5.1.3 處理用受壓容器包括收集或處理液體或蒸氣貨物的緩沖罐、熱交換器和蓄能器。

5.2 系統要求

5.2.1 貨物裝卸系統和貨物控制系統的設計應考慮到下列方面：

.1 防止異常狀態導致液體或蒸氣貨物泄漏；

.2 泄漏貨物液體的安全回收和處理；

.3 防止易燃混合物的形成；

.4 防止泄漏的易燃液體或氣體和蒸氣的點燃；和

.5 限制人員暴露於火災和其他危險中。

5.2.2 ***佈置：一般要求***

5.2.2.1 可能含有貨物液體或蒸氣的任何管系應符合下列規定：

.1 該類管系應與其他管系隔離，與貨物有關的作業如驅氣、除氣或惰化要求的內部連接管除外。對於防止貨物的回流，應考慮9.4.4的要求。在此情況下，應採取預防措施，確保貨物或貨物蒸氣不會通過內部連接管進入其他管系；

.2 除第16章中的規定以外，此類管系不得通過任何起居處所、服務處所、控制站或除貨物機器處所以外的機器處所；

.3 除安裝在垂向圍壁通道或等效裝置內的管路橫穿貨物圍護系統上面的留空處所外，以及除排水、透氣或驅氣用的管路橫穿隔離艙外，該類管系應從露天甲板直接通至貨物圍護系統；

.4 除3.8規定的船艏或船艉裝卸裝置，5.3.1規定的貨物應急投棄管系，5.3.3規定的轉塔艙系統以及除第16章的規定以外，上述管系應位於貨物區域內露天甲板的上方；和

.5 除在航行中不受內部壓力的橫向接岸管路或貨物應急投棄管系外，上述管系應位於2.4.1所規定的液貨艙的橫向位置以內。

5.2.2.2 應有適當措施，在斷開連接前，釋放管路中的壓力並排空裝卸的橫向匯管（同樣，最外集管閥和裝卸臂或貨物軟管之間的任何

管路）中的液貨至液貨艙或其他適當的處所。

5.2.2.3 輸送用於直接加熱或冷卻貨物的液體的管系不應通向貨物區域以外，除非有適當措施用以防止或探測貨物蒸氣向貨物區域外擴散（見13.6.2.6）。

5.2.2.4 應將從管系的釋放閥排出的液貨排入液貨艙內；或者，如設有能探測和處理可能流入透氣系統中的任何液貨的措施，則也可將液貨排入透氣總管內。如要求防止下游管路過壓，貨泵的釋放閥排出的液貨應排至泵的吸口。

5.3 貨物區域外貨物管系的佈置

5.3.1 *貨物應急投棄*

貨物應急投棄管系（如設置）應符合5.2.2的有關規定，可以引至起居處所、服務處所、控制站或機器處所後部的外面，但不應穿過這些處所。如貨物應急投棄管系為固定設置，則應在貨物區域內設有合適的措施將投棄管系與貨物管系隔離。

5.3.2 *船艏或船艉裝載佈置*

5.3.2.1 符合3.8、本節和5.10.1的要求時，可允許設置船艏或船艉裝卸貨物管系。

5.3.2.2 應配備能對使用後的管系進行驅氣和除氣的裝置。當不使用時，應拆去可拆短管，管端用盲板法蘭封住。與驅氣管相連接的透氣管應位於貨物區域內。

5.3.3 *轉塔艙駁運系統*

對於通過位於貨物區域外的內部轉塔裝置駁運的液體或蒸氣貨物，用於該目的的管路應符合5.2.2（如適用），5.10.2和如下規定：

.1 除與轉塔的連接處，管系應位於露天甲板上方；

.2 不允許採用可攜式裝置；和

.3 應配備能對使用後的管系進行驅氣和除氣裝置。當不使用時，應拆去用於隔離貨物管系的可拆短管，管端用盲板法蘭封住。與驅氣管相連接的透氣管應位於貨物區域內。

5.3.4 ***氣體燃料管系***

機器處所內的氣體燃料管路除應符合第16章的要求外，還應符合本章所有適用部分。

5.4 設計壓力

5.4.1 用於確定管路和管系部件最小尺寸的設計壓力P_o應不小於系統在工作中可能承受的最大表壓。最小設計壓力應不小於1MPa（表壓），但對管端敞開的管路或壓力釋放閥的排放管路，其設計壓力應不小於0.5MPa（表壓）或壓力閥調定壓力的10倍（取較小者）。

5.4.2 對於管路、管系和部件，根據所載運的貨物，應取下列設計情況中的較大者：

.1 對於可能與其釋放閥隔離並可能含有一些液體的蒸氣管系或部件，應為設計溫度45℃時的飽和蒸氣壓力。可使用較高或較低的值（參見4.13.2.2）；或

.2 對於可能與其釋放閥隔離並在任何時候僅含有蒸氣的管系或部件，應為45℃時的過熱蒸氣壓力。可使用較高或較低的值（參見4.13.2.2），此時，假定系統中飽和蒸氣的初始狀態是處於該系統的工作壓力和工作溫度；或

.3 液貨艙和貨物處理系統的MARVS；或

.4 相關的泵或壓縮機的釋放閥的調定壓力；或

.5 考慮到所有可能的泵佈置，在裝卸貨時貨物管系的最大總壓頭，或管路系統的釋放閥的調定壓力。

5.4.3 液體管系中可能承受峰值壓力的部分應設計為能承受這種壓力。

5.4.4 氣體燃料系統的外管或管道的設計壓力應不小於氣體內管的最大工作壓力。或者，對於工作壓力大於1MPa的氣體燃料管系，考慮到破斷處的局部即時峰值壓力和通風佈置，外管道的設計壓力應不小於環形處所內的最大積聚壓力。

5.5 貨物系統閥門要求

5.5.1.1 每一液貨艙和管系應設有本節規定的用於隔離的手動操作閥。

5.5.1.2 此外，還應視情況設置遙控閥作為緊急切斷（ESD）系統的一部分，ESD系統的目的是當貨物液體或蒸氣在駁運時出現緊急情況時，停止貨物流動或泄漏。ESD系統旨在將貨物系統回歸到安全的

靜態狀態，以便可以採取補救行動。ESD系統的設計應對避免貨物駁運管路內產生衝擊壓力予以充分考慮。ESD啟動時切斷的設備包括裝卸貨時的集管閥，任何在船舶內部或外部（如至岸上或另一船舶/駁船）駁運貨物的泵或壓縮機等和液貨艙閥（如MARVS超過0.07MPa）。

5.5.2 ***液貨艙連接管***

5.5.2.1 除安全釋放閥和液位測量裝置以外，在所有液體和蒸氣的連接管上均應設截止閥。應將這些閥儘可能地靠近液貨艙。這些閥應能完全關閉並應能就地手動操作。這些閥還應能遙控。

5.5.2.2 對MARVS超過0.07MPa的液貨艙，上述連接管上還應設有遙控ESD閥。應將這些閥儘可能地靠近液貨艙。如1個單獨的閥符合18.10.2的要求，並能將管路完全關閉，則可用1個單獨的閥代替2個分開的閥。

5.5.3 ***貨物總管連接管***

5.5.3.1 在使用的每一貨物駁運連接管均應設置1個遙控ESD閥，以停止液體和蒸氣駁入或駁出船舶。對於不使用的駁運連接管，應用合適的盲板法蘭予以隔斷。

5.5.3.2 如液貨艙MARVS超過0.07MPa，應為使用的每一駁運連接管設置一1個額外的手動閥，該閥可在ESD閥的內側或外側以適應船舶的設計。

5.5.4 當受保護管路的直徑不超過50mm時，可用超流量閥代替ESD閥。超流量閥在達到製造廠規定的蒸氣或液體的額定關閉流量時應自動關閉。包括附件、閥和由超流量閥保護的附屬設備的管路應具

有比超流量閥的額定關閉流量大的容量。應將超流量閥設計成具有1個直徑不超過1mm的圓形旁通孔，以便在超流量閥關閉後能使壓力保持平衡。

5.5.5 對於儀錶或測量裝置的液貨艙連接管，不必設置超流量閥或ESD閥，但這些裝置的結構應能保證液貨艙內貨物的外流量不超過通過直徑為1.5mm圓孔的流量。

5.5.6 在充滿液體情況下，對能被隔斷的所有管路或部件均應裝設釋放閥以應對熱膨脹和蒸發。

5.5.7 對於可能由於火災被自動隔斷的所有管路或部件，如其內部的液體容積超過0.05m^3，PRV的排量應適應火情。

5.6 貨物駁運佈置

5.6.1 當使用貨泵駁運貨物，且在液貨艙處於營運狀態又不能接近貨泵進行修理時，則至少應設有2套獨立裝置，以便能駁運每個液貨艙的貨物，同時應設計成當1台貨泵或駁運裝置發生故障時，不致妨礙使用另外1台泵或泵組，或其他貨物駁運裝置駁運貨物。

5.6.2 採用氣體加壓駁運貨物時，在駁運過程中應防止釋放閥開啟。氣體加壓可以被作為用於液貨艙駁運貨物的一種方法。但在設計這些液貨艙時，應考慮使其在貨物駁運作業期間不致降低液貨艙的設計安全係數。如為此改變液貨艙釋放閥或設定壓力（8.2.7和8.2.8允許這種作法），新的設定壓力不應超過4.13.2所定義的P_h。

5.6.3 ***蒸氣回路接頭***

應設置通向岸上裝置的蒸氣回路接頭。

5.6.4 ***液貨艙透氣管系***

應將壓力釋放系統與透氣管系相連接，對透氣管系的設計應使貨物蒸氣積聚在甲板上或進入居住處所、服務處所和控制站以及機器處所或可能造成危險狀態的其他處所的可能性減少至最低限度。

5.6.5 ***貨物取樣連接管***

5.6.5.1 連接至貨物管系並用於貨物液體取樣的連接管應清晰標記，其設計應將貨物蒸氣的釋放降至最低。對於允許載運有毒貨品的船舶，取樣系統應為閉環設計，以確保貨物液體和蒸氣不揮發至大氣。

5.6.5.2 液體取樣系統應在取樣入口設有兩個閥，其中之一應為多回轉閥門以防止意外開啟，並且兩者之間的距離應足夠遠以確保如遇諸如冰或水合物造成堵塞可隔斷管路。

5.6.5.3 在閉環系統中，回流管上的閥還應符合5.6.5.2。

5.6.5.4 取樣容器的連接管應符合公認標準，並應有支撐，以能承受取樣容器的重量。螺紋接頭應為定位焊，或採用其他方式鎖閉，以防止其在取樣容器的正常連接和斷開時被擰開。取樣連接管應設有封閉塞或法蘭以防止連接管不用時發生泄漏。

5.6.5.5 僅用於蒸氣取樣的取樣連接管可按5.5，5.8和5.13設有單閥，並且還應設有封閉塞或法蘭。

5.6.5.6 取樣作業應按18.9規定的程序進行。

5.6.6 *貨物濾器*

貨物液體和蒸氣系統應能設置濾器以免受異物損壞。此類濾器可為固定或臨時，過濾標準應與碎片等進入貨物系統的風險相適應。應設有設施能顯示濾器正被堵住，還應設有將濾器隔斷、減壓和安全清潔的措施。

5.7 安裝要求

5.7.1 *膨脹和收縮設計*

應採取措施保護管路、管系和部件和液貨艙免受由於熱變形及液貨艙和船體構件的移動而引起的過大應力的影響。液貨艙外宜使用補償管、彎管或環形管，但如補償管、彎管或環形管不可行，可使用多層波紋管。

5.7.2 *防低溫措施*

必要時，應對低溫管路與其鄰接的船體構件進行熱隔離。以防止船體溫度降低到船體材料的設計溫度以下。當液體管路需經常被拆開或預計其可能有液體泄漏時（如通岸接頭處和貨泵軸封處等），則應對其下方的船體部分提供保護措施。

5.7.3 *水幕*

如貨物溫度低於-110℃，應在通岸接頭下的船體處安裝供水系統，提供低壓水幕為船體鋼材和舷側結構提供額外保護。該系統是對11.3.1.4的要求的補充，並且應在貨物駁運時工作。

5.7.4 *電氣連接*

當在液貨艙或貨物管路和管路設備與船體結構之間採用熱隔離時，則對管路和液貨艙均需採取電氣接地措施。對所有具有密封墊片的管接頭和軟管接頭也均需作電氣連接。除使用搭接片的情況外，應證明每一接頭或連接處的電阻小於1MΩ。

5.8 管路製造和連接細節

5.8.1 *一般要求*

本節要求適用於液貨艙的內、外管路。對於液貨艙內部管路和端部敞開的管路，可按照認可的標準同意放寬這些要求。

5.8.2 *直接連接*

可以考慮採用下列無法蘭的管段直接連接：

.1 根部完全焊透的對接焊連接均可被用於各種用途。當設計溫度低於-10℃時，對接焊應為雙面焊或與雙面焊等效的對接焊，這可以通過採用在第一焊道上加襯墊、自耗嵌補或惰性氣體封底等方法予以實現，當設計壓力超過1MPa及設計溫度為-10℃或更低時，焊接後應將襯墊除去；

.2 具有符合認可標準的尺寸的套筒焊接接頭只能被用於外徑小於或等於50mm和設計溫度不低於-55℃的設備管路和端部敞開的管路；和

.3 符合認可標準的螺紋連接只能被用於外徑小於或等於25mm的次要管路和儀錶管路。

5.8.3 *法蘭接頭*

5.8.3.1 對於法蘭接頭中的法蘭焊接，應採用頸焊、套焊或插入焊等型式。

5.8.3.2 法蘭的型式及其製造和試驗均應符合公認標準。對於除端部敞開管路以外的所有管路，均應遵守下列限制：

.1 設計溫度低於-55℃時，只應採用頸焊法蘭；和

.2 設計溫度低於-10℃，對於公稱尺寸大於100mm者，不得採用套焊法蘭，而對於公稱尺寸大於50mm者，不得採用插入焊法蘭。

5.8.4 *膨脹接頭*

如按5.7.1設置波紋管和膨脹接頭，下列要求適用：

.1 如果需要，應採取措施，防止波紋管結冰；和

.2 除位於液貨艙內者外，不應採用套筒接頭。

5.8.5 *其他接頭*

管路接頭應按5.8.2至5.8.4連接，但對於其他特殊情況，主管機關可考慮替代佈置。

5.9 焊接、焊後熱處理和無損探傷

5.9.1 *一般要求*

應按6.5進行焊接。

5.9.2 *焊後熱處理*

對碳鋼、碳錳鋼和低合金鋼鋼管的所有對接焊縫均應進行焊後熱處理。主管機關或代表主管機關的被認可組織根據相關管系的設計溫度和設計壓力可以免除對壁厚小於10mm的管子進行消除熱應力的要求。

5.9.3 *無損探傷*

除在焊接前和焊接期間進行正常控制以及對完工焊縫進行目視檢查外，為證明已按本要求正確地進行焊接，還應進行下列試驗：

.1 對設計溫度低於-10℃且內徑大於75mm或壁厚大於10mm的管系的對接焊接頭應作100%射線或超聲波檢查；

.2 當管路截面的此種對接焊接頭係用主管機關或代表主管機關的被認可組織認可的自動焊接工藝焊接時，射線或超聲波檢查的範圍可逐漸減少，但在任何情況下，均不能小於所有接頭的10%。如發現有缺陷，則應進行100%檢查，其中還應包括以前已經被認可的焊縫。只能在具備合適的質量保證程序文件和記錄以評估製造商生產合格的焊接產品的能力時才能授予該許可；和

.3 對於5.9.3.1和5.9.3.2中未包括的其他管子的對接焊接頭，應根據其用途、位置和材料進行抽樣射線或超聲波檢查或其他的無損探傷。通常，至少應對10%的管

子對接焊接頭進行射線或超聲波檢查。

5.10 貨物區域外貨物管系的安裝要求

5.10.1 *船艏或船艉裝載裝置*

下列要求適用於貨物區域以外的貨物管系及有關的管系設備：

.1 貨物區域以外的貨物管系及有關的管系設備只准採用焊接連接。貨物區域以外的管系應敷設在露天甲板上，且應位於舷側以內至少為0.8m，但橫貫船寬的通岸連接管系除外。此種管系應能被明顯地識別，並在貨物區域內的貨物管系連接處應設置截止閥。當不使用時，此位置還應採用可拆的短管和盲板法蘭進行隔離；和

.2 管系應採用全焊透對接焊，不論其管徑和設計溫度如何，均應進行全部射線或超聲波探傷。只允許在貨物區域內以及通岸接頭處的管路採用法蘭連接。

5.10.2 *轉塔艙駁運系統*

如液體和蒸氣貨物管系位於貨物區域以外，下列要求對其適用：

.1 貨物區域以外的貨物管系及有關的管系設備只準採用焊接連接；和

.2 管系應採用全焊透對接焊，不論其管徑和設計溫度如何，均應進行全部射線或超聲波探傷。只允許在貨物區域內以及貨物軟管接頭處和轉塔接頭處的管路採

用法蘭連接。

5.10.3 ***氣體燃料管路***

氣體燃料管路應儘可能採用焊接接頭。對於未被包圍在16.4.3所要求的通風管或管道內的氣體燃料管路，以及位於貨物區域以外的露天甲板上的氣體燃料管路，均應採用全焊透對接焊接頭並應進行全部的射線或超聲波檢查。

5.11 管系部件要求

5.11.1 管路尺寸。管系應按公認標準設計。

5.11.2.1 應使用下列衡準確定管壁厚度。

5.11.2.2 管壁厚度應不小於：

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

式中：

t_o＝理論壁厚，由下式確定：

$$t_0 = \frac{P \cdot D}{2K \cdot e + P} \text{（mm）}$$

其中：

P＝設計壓力，MPa，參見5.4的規定；

D＝外徑，mm；

K $\frac{P \cdot D}{2K \cdot e + P}$ ＝許用應力，N/mm^2，參見5.11.3的

規定；

e＝有效係數。對於無縫鋼管以及由認可的焊接管製造廠供應的縱向焊或螺旋焊焊接管，在按公認標準進行無損探傷後認為等效於無縫鋼管者，則取1；在其他情況下，按公認標準並根據製造工藝，可要求有效係數小於1；

b＝彎曲餘量，mm。對b值的選取，應使僅受內壓的彎曲部分的計算應力不超過材料的許用應力。如未做出此種證明，則b值應為：

$$b = \frac{D \cdot t_0}{2.5r}(mm)，$$

其中：

r＝平均彎曲半徑，mm；

c＝腐蝕餘量，mm。如果預計受到腐蝕或浸蝕，則管壁厚度應比其他設計要求的值有所增加。此餘量應與管子的預期壽命相一致；和

a＝用於壁厚的製造負公差，%。

5.11.2.3 最小壁厚應符合公認標準。

5.11.2.4 為防止附加載荷造成管子的損壞、破斷和過度下垂或失穩，而需要一定的機械強度時，管壁厚度應比5.11.2.2要求的值有所增加。如增加管壁厚度不現實或反而會使管子產生過大的局部應力，則應採

取其他的設計方法，以減小、防止或消除上述載荷。此類附加載荷可能是由於支撐結構、船舶變形、駁運作業時的液壓升高、懸掛閥的重量、對裝卸臂連接處的反作用力或其他原因產生的。

5.11.3 *許用應力*

5.11.3.1 對於管子，5.11.2的公式中的許用應力K是下列值中的較小者：

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

式中：

R_m＝標定的室溫下抗拉強度下限值，N/mm^2；和

R_e＝標定的室溫下屈服應力下限值，N/mm^2。如在應力—應變曲線上無明顯的屈服應力，則可採用0.2%條件的驗證應力。

對於A和B的值，應在1.4.4中規定的《國際散裝運輸液化氣體適裝證書》內予以註明，且至少A＝2.7，B＝1.8。

5.11.4 *高壓氣體燃料外管或管道尺寸*

如燃氣管系的設計壓力大於臨界壓力，當承受5.4規定的設計壓力時，管子或管道筆直段的薄膜切應力應不超過抗拉強度除以1.5（R_m/1.5）。所有其他管路部件的額定壓力應反映出與筆直管子同一水平的強度。

5.11.5 *應力分析*

當設計溫度為-110℃或更低時，對管系的每一分支，應向主管機關提交一份考慮到由於管子的重量，包括加速度載荷（如較大）、內部壓力、熱收縮以及船舶中拱和中垂引起的載荷等所產生的所有應力的完整的應力分析資料。當設計溫度高於-110℃時，主管機關所要求的應力分析資料的內容可為諸如管系的設計或剛度，以及材料的選擇等。在任何情況下，即使不提交計算書，也應考慮熱應力。對上述的應力分析可按主管機關所接受的常用規則進行。

5.11.6 ***法蘭、閥件和附件***

5.11.6.1 對於法蘭、閥件和其他附件，應考慮到所選的材料和5.4規定的設計壓力符合公認標準。對於蒸氣管路中的波紋管膨脹接頭，可同意採用較低的設計壓力。

5.11.6.2 對於不符合認可標準的法蘭，其尺寸和其螺栓的尺寸均應使主管機關或代表主管機關的被認可組織滿意。

5.11.6.3 所有應急截止閥應為“遇火關閉”型（參見5.13.1.1和18.10.2）。

5.11.6.4 波紋管膨脹接頭的設計和安裝應符合公認標準，並設有裝置防止過度拉伸或壓縮造成的損壞。

5.11.7 ***船用貨物軟管***

5.11.7.1 對於貨物駁運的液體和蒸氣軟管，應能與貨物相容並能與貨物溫度相適應。

5.11.7.2 對於承受液貨艙壓力的軟管，或承受貨泵或蒸氣壓縮機排

放壓力的軟管，應按其爆破壓力進行設計，此壓力應不小於貨物駁動期間軟管可能承受的最大壓力的5倍。

5.11.7.3 配有端部附件的每一新型貨物軟管，應進行原型試驗，該試驗應在正常環境溫度和從零到至少兩倍於規定的最大工作壓力下，進行200次壓力循環。經循環壓力試驗後，還應進行爆破試驗以確認爆破壓力在最高和最低極端營運溫度下至少為5倍於規定的最大工作壓力。原型試驗用過的軟管應不再用於輸送貨物。然而，在每段新製成的貨物軟管被投入使用之前，均應在環境溫度下對其進行靜水壓力試驗，試驗壓力應不小於1.5倍的規定的最大工作壓力，但不大於其爆破壓力的2/5。根據適用情況，軟管應用模板噴刷或其他方法標出試驗日期和規定的最大工作壓力。對於不是在環境溫度下使用的軟管，還應標出其最高和最低使用溫度。軟管規定的最大工作壓力應不小於1MPa（表壓）。

5.12 材料

5.12.1 對於管系中所用材料，應按其最低的設計溫度進行選擇和試驗並應符合第6章的要求。但是，當貨物在壓力釋放閥調定值時的溫度為-55℃或更高些時，以及當不會發生液體流至透氣管路的情況時，對於端部敞開的透氣管路的材料質量，可予以放寬。在相同溫度條件下，對於液貨艙內的端部敞開的管路，也可允許予以同樣的放寬，但排放管路及薄膜液貨艙和半薄膜液貨艙內的所有管路除外。

5.12.2 不應將熔點低於925℃的材料用於液貨艙以外的管路，但與液貨艙連接的短管除外。此時，應設置耐火絕熱層。

5.12.3 ***貨物管系絕熱系統***

5.12.3.1 貨物管系應設有要求的絕熱系統以在駁運作業中將泄漏至貨物的熱量降至最低並保護人員避免直接接觸寒冷的表面。

5.12.3.2 由於所處位置或環境條件的不同，如適用時，絕熱材料應具有適當的防火和阻止火焰傳播的性能，並應受到足夠的保護，以防止水蒸氣的滲透和機械損傷。

5.12.4 如貨物管系所用的材料在含鹽大氣易受應力腐蝕開裂，應採取充分措施（選擇材料、避免暴露於鹽水和/或經常檢查）避免此類情況發生。

5.13 試驗要求

5.13.1 ***管路部件的型式試驗***

5.13.1.1 閥

應對擬用於工作溫度低於-55℃的每種型式的閥進行下列型式試驗：

.1 每種尺寸和每種型式的閥應每隔一段時間雙流向在不超過閥的額定設計壓力的全部作業壓力和溫度範圍下進行閥座密性試驗。允許的泄漏率應滿足主管機關或代表主管機關的被認可組織的要求。在試驗期間，應驗證閥具有良好的工作性能；

.2 每種尺寸和每種型式的閥應按公認標準對流量進行認證；

.3 受壓部件應至少按額定壓力的1.5倍進行壓力試驗；和

.4 對於熔點低於925℃的應急截止閥，型式試驗應包括按主管機關接受的標準進行的防火試驗。

5.13.1.2 波紋管膨脹接頭

對於擬用於液貨艙以外的貨物管路上的每種波紋管膨脹接頭如主管機關或代表主管機關的被認可組織有要求時，應對設置在液貨艙內的波紋管膨脹接頭進行下列型式的試驗：

.1 未經預先壓縮的波紋管元件應經受不小於5倍設計壓力的壓力試驗而不破裂，試驗持續時間應不少於5min；

.2 對於帶有所有附件如法蘭、拉杆和鉸接件等的原型膨脹接頭，應在最低設計溫度和製造廠推薦的最大位移條件下，使其經受2倍設計壓力的壓力試驗而不產生永久變形；

.3 對完整的膨脹接頭應進行循環試驗（熱運動），在壓力、溫度、軸向運動、旋轉運動和橫向運動等條件下，完整的膨脹接頭應能承受至少為與實際使用中所遇到的同樣多的循環次數。當這些試驗與在營運溫度下的試驗一樣嚴格時，則允許在室溫下進行試驗；和

.4 對完整的膨脹接頭應在無內壓的情況下進行循環疲勞試驗（船體變形），即用模擬相當於補償管段的波紋管運動的方式，在不高於5Hz的頻率下，至少進行

2,000,000次循次。但只有當由於管路的佈置實際上會經受船體變形載荷作用時，才要求進行這種試驗。

5.13.2 ***系統試驗要求***

5.13.2.1 本節要求適用於液貨艙內、外管路。

5.13.2.2 在裝配後，應使用適當的流體對所有貨物管路和處理用的管路進行強度試驗。液體管路的試驗壓力應至少為1.5倍設計壓力（當試驗流體可壓縮時，1.25倍設計壓力），蒸氣管路的試驗壓力應至少為1.5倍系統最大工作壓力（當試驗流體可壓縮時，1.25倍系統最大工作壓力）。當完成對管系或系統部件的製造並對其配齊所有附件時，可在其被裝船之前對其進行試驗。對在船上焊接的接頭應進行至少為1.5倍設計壓力的試驗。

5.13.2.3 對於每一貨物管系和處理用管系，在船上將其安裝完工之後，均應使用空氣或其他適當介質進行泄漏試驗，其試驗壓力取決於所採用的檢測泄漏的方法。

5.13.2.4 在雙層壁氣體燃料管系中，外管或管道也應進行壓力試驗，以證明其可承受氣體管路破斷時預計的最大壓力。

5.13.2.5 在首次裝載作業之前，應按公認標準，對用於貨物或蒸氣操作的所有管系，包括閥、附件及附屬設備進行正常工作狀態下的功能試驗。

5.13.3 ***應急截止閥***

對用於液貨管系的應急截止閥的關閉特性應進行試驗，以證明其

符合18.10.2.1.3。該試驗可在閥門安裝後在船上進行。

第6章

構造材料和質量控制

目的

確定金屬和非金屬材料要求的特性，試驗標準和穩性以及貨物圍護和管路系統建造中使用的製造工藝以確保其具有第4章和第5章中要求的功能。

6.1 定義

6.1.1 本章涉及的A、B、D、E、AH、DH、EH和FH級的船體結構鋼均為公認標準船體結構鋼的等級。

6.1.2 *軋製件*係指從單板或坯或從單錠軋製而成的產品（如果直接軋製成板、條、型材或塊）。

6.1.3 *批*係指基於取樣試驗一起接受或拒絕的件數。批的大小見公認標準。

6.1.4 *控制軋製（CR）*係指在正火溫度範圍內進行最終變形，並導致材料狀況等效於正火獲得的材料狀況的軋製程序。

6.1.5 *溫度－形變控制軋製（TMCP）*係指包括對鋼的溫度和軋製變形均嚴格控制的程序。與CR不同，TMCP的性能不能通過隨後的正火或其他熱處理進行複製。經主管機關批准，也可接受TMCP完成後加速冷卻。同樣適用於TMCP完成後進行回火。

6.1.6 *加速冷卻（AcC）*係指在最終TMCP操作後立即通過以比空氣冷卻更快的速度進行控制冷卻以改善力學性能的過程。加速冷卻不包括直接淬火。經TMCP和AcC後給出的材料性能不能通過隨後的正火或其他熱處理進行複製。

6.2 範圍和一般要求

6.2.1 本章給出用於貨物系統構造的金屬和非金屬材料的要求。這包括連接工藝、生產工藝、人員資格、NDT和檢查和試驗（包括生產試驗）的要求。對軋製材料、鍛件和鑄件的要求見6.4和表6.1至6.5。對焊接件的要求見6.5，非金屬材料的指導見附錄4。應執行質量保證/質量控制計劃以確保符合6.2的要求。

6.2.2 有關製造、試驗、檢查以及文件應按照公認標準和本規則的特殊要求。

6.2.3 如規定或要求作焊後熱處理。其母材性能應在熱處理條件下按照本章適用的表列要求予以確定，而焊縫性能應按照6.5的規定的熱處理條件予以確定。如果採用焊後熱處理，則上述試驗的要求，可由主管機關酌情修改。

6.3 一般試驗要求和說明

6.3.1 ***抗拉試驗***

6.3.1.1 抗拉試驗應按照公認標準進行。

6.3.1.2 抗拉強度、屈服應力和伸長率應使主管機關滿意。對具有明顯屈服點的碳錳鋼和其他材料，應考慮其屈強比的限制。

6.3.2 ***韌性試驗***

6.3.2.1 除主管機關另有規定外，金屬材料的驗收試驗應包括夏比V型缺口衝擊韌性試驗。規定的夏比V型缺口衝擊能量值的要求為3個全尺寸（10mm×10mm）試樣的最小平均衝擊能量值和對最小的單個試樣衝擊能量。夏比V型缺口試樣的尺寸和公差應符合公認標準。對尺寸小於5mm的試樣的試驗和要求應符合公認標準。小尺寸試樣的最小平均值見下表：

夏比V型缺口試樣尺寸（mm）	**3個試樣的最小平均衝擊能量（J）**
10×10	KV
10×7.5	5/6KV
10×5	2/3KV

表中：

KV＝表6.1至表6.4中規定的衝擊能量值（J）。

僅允許有個試樣的衝擊能量可低於規定的平均值，但不得低於該平均值的70%。

6.3.2.2 對於母材，應儘可能按材料厚度截取最大尺寸的夏比V型缺口試樣，應儘量使試樣位於材料表面和其厚度中心之間的中點位置，並使缺口的長度方向垂直於材料表面（見圖6.1）。

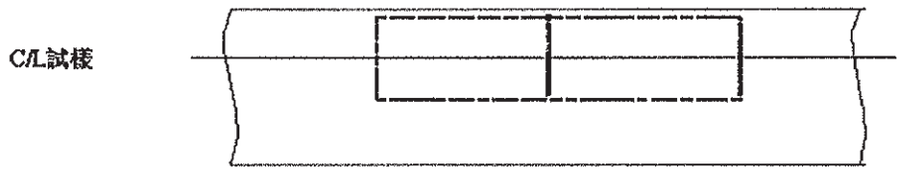


圖6.1－母材試樣的方向性

6.3.2.3 對於焊接試驗試樣，儘可能按材料厚度截取最大尺寸的夏比V型缺口試樣，應儘量使試樣接近材料表面和其厚度中心之間的中點位置，在各種情況下，從材料表面至試樣邊的距離應不小於1mm。此外，對於雙V型坡口的對接焊縫，應在接近於第2個焊接面處截取試樣。試樣一般應取在下列位置，即焊縫的中線上、熔合線上和距離熔合線1mm、3mm和5mm處，見圖6.2。

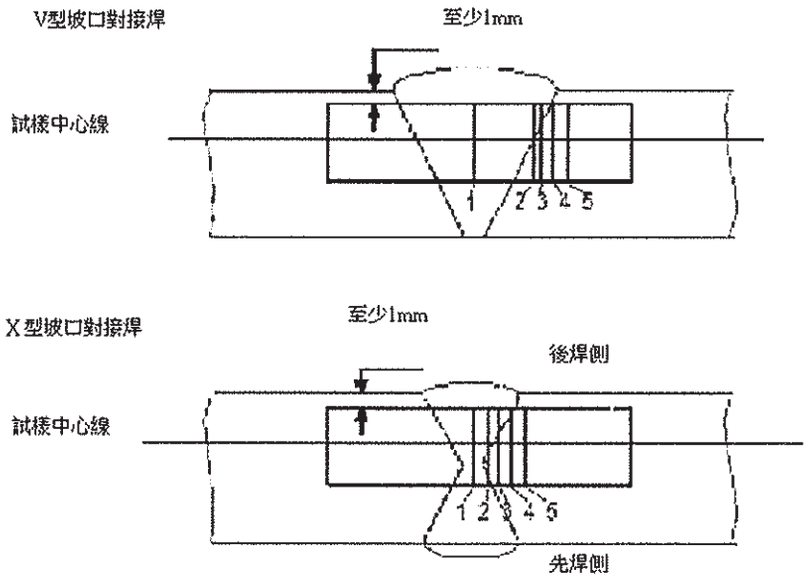


圖6.2－焊接試樣的方向性

圖6.2中的缺口位置：

.1 位於焊縫中心。

.2 位於熔合線上。

.3 在熱影響區（HAZ），距熔合線1mm。

.4 在熱影響區（HAZ），距熔合線3mm。

.5 在熱影響區（HAZ），距熔合線5mm。

6.3.2.4 如果3個最初的夏比V型缺口試樣的平均衝擊能量沒有達到規定的要求，或1個以上試樣的衝擊能量低於規定的平均值，或者僅有1個試樣的衝擊能量低於所允許的單個試樣的最小衝擊能量值時，則可以從同一材料中再取3個附加試樣進行試驗。將所得的結果與原先獲得的試驗結果組成1個新的平均值。如果這個新的平均值符合要求，而且，低於要求的平均值的個別結果不多於2個且低於單個試樣要求值的試樣結果不多於1個，則可以接受此件或這批材料。

6.3.3 ***彎曲試驗***

6.3.3.1 作為材料驗收試驗，彎曲試驗可予以免除，但對焊接試驗仍要求彎曲試驗。如進行彎曲試驗，應按照公認標準進行。

6.3.3.2 焊接試驗應為橫向彎曲試驗，主管機關可酌情決定進行正彎、反彎或側彎試驗。如母材和焊縫金屬具有不同的強度級，則可要求以縱向彎曲試驗替代橫向彎曲試驗。

6.3.4 ***斷面觀察和其他試驗***

主管機關也可要求按照公認標準對焊縫做宏觀斷面、微觀斷面觀察以及硬度試驗。

6.4 對金屬材料的要求

6.4.1 ***對金屬材料的一般要求***

6.4.1.1 構造材料要求見下列各表：

.1 表6.1：適用於設計溫度不低於0℃的液貨艙和處理用壓力容器所用的板材、管材（無縫管和焊接管）、型材和鍛件。

.2 表6.2：適用於設計溫度低於0℃至-55℃的液貨艙、次屏壁和處理用壓力容器所用板材、型材和鍛件。

.3 表6.3：適用於設計溫度低於-55℃至-165℃的液貨艙、次屏壁和處理用壓力容器中所用板材、型材和鍛件。

.4 表6.4：適用設計溫度低於0℃至-165℃的貨物管系和處理用管系所用管材（無縫管和焊接管）、鍛件和鑄件。

.5 表6.5：適用於4.19.1.2和4.19.1.3要求的船體結構所用板材和型材。

表6.1

<table>
<tr><td colspan="3">設計溫度不低於0℃的液貨艙和處理用壓力容器所用板材、管材
（無縫管和焊接管）見註1和2、型材和鍛件</td></tr>
<tr><td colspan="3">化學成分和熱處理</td></tr>
<tr><td colspan="3">◆碳錳鋼</td></tr>
<tr><td colspan="3">◆全鎮靜細晶粒鋼</td></tr>
<tr><td colspan="3">◆經主管機關同意可添加少量的合金元素</td></tr>
<tr><td colspan="3">◆化學成分的範圍應經主管機關認可</td></tr>
<tr><td colspan="3">◆正火或淬火加回火見註4</td></tr>
<tr><td colspan="3">強度和韌性（衝擊）試驗要求</td></tr>
<tr><td colspan="3">取樣頻率</td></tr>
<tr><td>◆板材</td><td colspan="2">按“軋製件”試驗</td></tr>
<tr><td>◆型材和鍛件</td><td colspan="2">按批試驗</td></tr>
<tr><td colspan="3">力學性能</td></tr>
<tr><td>◆抗拉性能</td><td colspan="2">規定最低屈服應力不超過410N/mm²見註5</td></tr>
<tr><td colspan="3">韌性（夏比V型缺口衝擊試驗）</td></tr>
<tr><td>◆板材</td><td colspan="2">橫向試樣，最小平均衝擊能量值（KV）為27J</td></tr>
<tr><td>◆型材和鍛件</td><td colspan="2">縱向試樣，最小平均衝擊能量值（KV）為41J</td></tr>
<tr><td rowspan="3">◆試驗溫度</td><td>厚度t（mm）</td><td>試驗溫度（℃）</td></tr>
<tr><td>t≤20</td><td>0</td></tr>
<tr><td>20<t≤40見註3</td><td>-20</td></tr>
<tr><td colspan="3">註：
1 無縫管和附件，應採用正常的製造工藝。縱向焊接和螺旋焊接的管材，應經主管機關或代表主管機關的被認可組織特別認可。
2 管道不要求進行夏比V型缺口衝擊試驗。</td></tr>
</table>

3	本表一般適用於厚度不超過40mm的材料。更大厚度的提議應經主管機關或代表主管機關的被認可組織認可。
4	控制軋製工藝或TMCP可用於替代。
5	規定的最低屈服應力超過410N/mm^{2}的材料可由主管機關或代表主管機關的被認可組織認可。這些材料的焊縫和熱影響區的硬度應予以特別注意。

表6.2

<table>
<tr><td colspan="6">設計溫度低於0℃和至-55℃的液貨艙，次屏壁和處理用壓力容器所用板材、型材和鍛件[見註1]最大厚度為25mm[見註2]</td></tr>
<tr><td colspan="6">化學成分和熱處理</td></tr>
<tr><td colspan="6">◆碳錳鋼</td></tr>
<tr><td colspan="6">◆全鎮靜、鋁處理的細晶粒鋼</td></tr>
<tr><td colspan="6">◆化學成分（爐罐分析）</td></tr>
<tr><td>C</td><td colspan="2">Mn</td><td>Si</td><td>S</td><td>P</td></tr>
<tr><td>≤0.16%[見註3]</td><td colspan="2">0.7～1.60%</td><td>0.1～0.50%</td><td>≤0.025%</td><td>≤0.025%</td></tr>
<tr><td colspan="6">選擇的添加元素：合金化元素和晶粒細化元素一般按下列要求：</td></tr>
<tr><td>Ni</td><td>Cr</td><td>Mo</td><td>Cu</td><td>Nb</td><td>V</td></tr>
<tr><td>≤0.8%
最大</td><td>≤0.25%最大</td><td>≤0.08%最大</td><td>≤0.35%最大</td><td>≤0.05%最大</td><td>≤0.1%最大</td></tr>
<tr><td colspan="6">Al總含量最少≤0.02%（酸溶性最少0.015%）</td></tr>
<tr><td colspan="6">◆正火或淬火加回火[見註4]</td></tr>
<tr><td colspan="6">強度和韌性（衝擊）試驗要求</td></tr>
<tr><td colspan="6">取樣頻率</td></tr>
<tr><td colspan="2">◆板材</td><td colspan="4">按“軋製件”試驗</td></tr>
<tr><td colspan="2">◆型材和鍛件</td><td colspan="4">按批試驗</td></tr>
<tr><td colspan="6">力學性能</td></tr>
<tr><td colspan="2">◆抗拉性能</td><td colspan="4">規定最低屈服應力不超過410N/mm^2[見註5]</td></tr>
<tr><td colspan="6">韌性（夏比V型缺口衝擊試驗）</td></tr>
<tr><td colspan="2">◆板材</td><td colspan="4">橫向試樣，最小平均衝擊能量值（KV）為27J</td></tr>
<tr><td colspan="2">◆型材和鍛件</td><td colspan="4">縱向試樣，最小平均衝擊能量值（KV）為41J</td></tr>
</table>

◆試驗溫度	比設計溫度低5℃，或-20℃，取其低者

註：

1 對鍛件的夏比V型缺口衝擊試驗和化學成分的要求，可由主管機關特別考慮。

2 對厚度超過25mm的材料，夏比V型缺口衝擊試驗應按下列要求進行：

材料厚度（mm）	試驗溫度（℃）
25<t≤30	比設計溫度低10℃，或-20℃，取其低者
30<t≤35	比設計溫度低15℃，或-20℃，取其低者
35<t≤40	比設計溫度低20℃
40<t	經主管機關或代表主管機關的被認可組織認可的溫度

衝擊能量值應按所用試樣種類符合表列的要求。

用於液貨艙和液貨艙部件的材料，如焊後熱應力完全消除，可在比設計溫度低5℃或-20℃（取其低者）的溫度進行試驗。

對於已消除熱應力的加強構件和其他構件，其試驗溫度應與鄰接液貨艙殼體厚度所要求的試驗溫度相同。

3 如設計溫度不低於-40℃，經主管機關特別同意，材料的含碳量最大可增至0.18%。

4 控制軋製工藝或TMCP可用作替代。

5 規定的最低屈服應力超過410N/mm^{2}的材料可由主管機關或代表主管機關的被認可組織認可。這些材料的焊縫和熱影響區的硬度應予以特別注意。

指導：

厚度超過25mm的材料，如其試驗溫度為-60℃或更低者，需採用符合本章表6.3規定鋼材或經特殊處理的鋼材。

表6.3

設計溫度低於-55℃至-165℃[見註2]的液貨艙，次屏壁和處理用受壓容器所用板材、型材和鍛件[見註1]最大厚度為25mm[見註3和4]		
最低設計溫度（℃）	化學成分[見註5]和熱處理	衝擊試驗溫度（℃）
-60	1.5%鎳鋼—正火或正火加回火或淬火加回火或TMCP，見註6	-65
-65	2.25%鎳鋼—正火或正火加回火或淬火加回火或TMCP，見註6和7	-70
-90	3.5%鎳鋼—正火或正火加回火或淬火加回火或TMCP，見註6和7	-95
-105	5%鎳鋼—正火或正火加回火或淬火加回火，見註6、7和8	-110
-165	9%鎳鋼—二次正火加回火或淬火加回火，見註6	-196
-165	奧氏體鋼，如304，304L，316，316L，321和347等，固溶處理，見註9	-196
-165	鋁合金，如5083，退火	不要求
-165	奧氏體鐵－鎳合金（含36%Ni），按經同意的熱處理方法	不要求

抗拉和韌性（衝擊）試驗要求	
取樣頻率	
◆板材	按“軋製件”試驗
◆型材和鍛件	按批試驗
韌性（夏比V型缺口衝擊試驗）	
◆板材	橫向試樣，最小平均衝擊能量值（KV）為27J
◆型材和鍛件	縱向試樣，最小平均衝擊能量值（KV）為41J

註：

1 使用在臨界條件鍛件的衝擊試驗的要求，須提交主管機關特別考慮。

2 設計溫度低於-165℃時的要求，應經主管機關特別同意。

3 含1.5%Ni、2.25%Ni、3.5%Ni和5%Ni的材料厚度超過25mm，應按下述要求進

行衝擊試驗：

材料厚度（mm）	試驗溫度（℃）
25<t≤30	比設計溫度低10℃
30<t≤35	比設計溫度低15℃
35<t≤40	比設計溫度低20℃

衝擊能量值，應根據所用試樣型式按照表列值。對厚度超過40mm的材料的夏比V型缺口衝擊能量值應予以特別考慮。

4 可採用厚度超過25mm的9%Ni鋼、奧氏體不鏽鋼和鋁合金。

5 化學成分的範圍應按照公認標準。

6 TMCP鎳鋼應經主管機關接受。

7 淬火加回火的鋼材，經主管機關特別考慮，可用於較低的最低設計溫度。

8 經特殊熱處理的5%鎳鋼，例如經三級熱處理的5%鎳鋼，可被用於最低溫度為-165℃的場合，但應在-196℃下對其進行衝擊試驗。

9 經主管機關同意，可免除衝擊試驗。

表6.4

設計溫度低於0℃和至-165℃[見註3]的貨物管系 和處理用管系所用的管子（無縫管和焊接管）[見註1] 鍛件[見註2]和鑄件[見註2]最大厚度為25mm			
最低設計溫度（℃）	化學成分[見註5]和熱處理	衝擊試驗	
		試驗溫度（℃）	最小平均衝擊能量（KV）
-55	碳錳鋼：應為全鎮靜細晶粒，正火或經同意的熱處理方法[見註6]	見註4	27
-65	2.25%鎳鋼。正火，正火加回火或淬火加回火[見註6]	-70	34
-90	3.5%鎳鋼。正火，正火加回火或淬火加回火[見註6]	-95	34
-165	9%鎳鋼[見註7]。二次正火加回火或淬火加回火	-196	41
	奧氏體鋼，如304，304L，316，316L、321和347。固溶處理[見註8]	-196	41
	鋁合金，如5083，退火		不要求
抗拉和韌性（衝擊）試驗要求			
取樣頻率			
◆應按批試驗。			
韌性（夏比V型缺口衝擊試驗）			
◆衝擊試驗：縱向試樣			

註：

1 如使用縱向焊接和螺旋焊接的管子，應經主管機關特別認可。

2 對鍛件和鑄件的要求可由主管機關特別考慮。

3 設計溫度低於-165℃的要求應經主管機關特別同意。

4 試驗溫度應比設計溫度低5℃，或為-20℃，取其低者。

5 化學成分的範圍應按照公認標準。

6 對於經淬火加回火的材料，經主管機關特別同意，可採用較低的設計溫度。

7 化學成分不適用於鑄件。

8 經主管機關同意，可免除衝擊試驗。

表6.5

用於按4.19.1.2和4.19.1.3要求的船體結構用板材和型材								
船體結構的最低設計溫度（℃）	各鋼級的最大厚度（mm）							
	A	B	D	E	AH	DH	EH	FH
0℃及以上[見註1] -5℃及以上[見註2]	按公認標準							
0至-5℃	15	25	30	50	25	45	50	50
-5至-10℃	×	20	25	50	20	40	50	50
-10至-20℃	×	×	20	50	×	30	50	50
-20至-30℃	×	×	×	40	×	20	40	50
低於-30℃	按表6.2規定，但表6.2及該表註2中所指的厚度範圍不適用							

註：

“×”係指不應採用的鋼級。

1 適用於4.19.1.3。

2 適用於4.19.1.2。

6.5 金屬材料的焊接和無損探傷

6.5.1 *通則*

6.5.1.1 本節應僅適用於主屏壁和次屏壁，包括構成次屏壁的內殼。碳鋼、碳錳鋼、鎳合金鋼和不鏽鋼應進行驗收試驗，但這些試驗也可適用於其他材料。主管機關可決定對不鏽鋼和鋁合金的焊接件免做衝擊試驗，也可對任何材料特別要求做其他的試驗。

6.5.2 *焊接材料*

6.5.2.1 用於液貨艙的焊接材料應符合公認標準。所有焊接材料應

要求進行熔敷金屬試驗和對接焊縫試驗。拉伸試驗和夏比V型缺口衝擊試驗中所得的結果應符合公認標準。熔敷金屬的化學成分應作記錄以供查詢。

6.5.3 ***液貨艙和處理用壓力容器的焊接工藝試驗***

6.5.3.1 所有液貨艙和處理用壓力容器的對接焊縫要求作焊接工藝試驗。

6.5.3.2 焊接試件應能代表：

.1 每種母材；

.2 每種焊接材料和焊接方法；和

.3 每種焊接位置。

6.5.3.3 板材的對接焊試驗，試板的制備應使板材軋製方向平行於焊接方向。每種焊接工藝試驗所規定的材料厚度範圍應符合公認標準。射線檢查或超聲波檢查可由製造廠選擇決定。

6.5.3.4 液貨艙和處理用壓力容器的以下焊接工藝試驗應按6.3進行（從每個試件製作試樣）：

.1 焊縫橫向拉力試驗；

.2 公認標準要求的縱向全焊接試驗；

.3 焊接橫向彎曲試驗，可進行正彎、反彎或側彎試驗。如母材和焊縫金屬具有不同的強度級，則可要求以縱向彎曲試驗替代橫向彎曲試驗；

.4 一組3個的夏比V型缺口衝擊試驗，一般應在下列每個位置上截取，如圖6.2所示：

.1 焊縫的中心線；

.2 熔合線；

.3 距熔合線1mm；

.4 距熔合線3mm；和

.5 距熔合線5mm；和

.5 也可要求對焊縫做宏觀斷面、微觀斷面以及硬度進行測定的檢驗。

6.5.3.5 每個試驗應滿足下列要求：

.1 拉力試驗：焊縫橫向抗拉強度應不低於相應母材的最低抗拉強度。對於鋁合金，應參見4.18.1.3關於低匹配焊縫的焊縫金屬強度要求（如焊縫金屬的抗拉強度低於母材的抗拉強度）。在每種情況下，應提供試樣破斷位置報告以供備查；

.2 彎曲試驗：試樣經直徑為4倍試樣厚度的彎芯彎曲180°後，不應斷裂；和

.3 夏比V型缺口衝擊試驗：應在對連接母材規定的溫度下進行衝擊試驗。焊縫金屬衝擊試驗的結果，其最小平均衝擊能量（KV）應不低於27J。焊縫金屬小尺寸試樣和單個衝擊能量的要求應按6.3.2的規定。熔合線

和熱影響區的衝擊試驗結果的最小平均衝擊能量（KV）應符合母材橫向或縱向要求（視適用而定），而小尺寸試樣，最小平均衝擊能量（KV）應符合6.3.2的規定。如果材料的厚度不允許截取全尺寸試樣或標準小尺寸試樣，則試驗方法和驗收標準應符合公認標準。

6.5.3.6 用於填角焊的工藝試驗應符合公認標準。在這種情況下，應選擇具有良好衝擊性能的焊接材料。

6.5.4 *管材的焊接工藝試驗*

管材焊接工藝試驗應與6.5.3對液貨艙規定的細節相似。

6.5.5 *產品焊縫試驗*

6.5.5.1 除整體液貨艙和薄膜液貨艙外，所有液貨艙和處理用壓力容器通常按每50m左右的對接焊縫進行一次產品焊縫試驗，並應能代表各個焊接位置。對次屏壁應作相同型式的產品焊縫試驗，但經主管機關同意可減少試驗數量。除6.5.5.2至6.5.5.5規定的試驗外，可要求對液貨艙或次屏壁進行其他試驗。

6.5.5.2 對A型和B型獨立液貨艙以及半薄膜液貨艙的產品焊縫試驗應包括每50m的焊縫進行彎曲試驗，以及當要求時還應進行以一組3個夏比V型缺口的衝擊試驗。夏比V型缺口衝擊試驗試樣的缺口應分別位於焊縫中心或熱影響區（根據焊接工藝試驗的結果來確定的最危險的位置）。對於奧氏體不鏽鋼，所有的缺口應位於焊縫的中心處。

6.5.5.3 對於C型獨立液貨艙和處理用壓力容器，除6.5.5.2所列的試驗外，還要求進行焊縫橫向拉力試驗。拉力試驗應滿足6.5.3.5的要

求。

6.5.5.4 質量保證/質量控制計劃應確保材料製造商的質量手冊中規定的產品焊縫持續符合性。

6.5.5.5 整體液貨艙和薄膜液貨艙的試驗要求與6.5.3中所列的適用試驗要求一致。

6.5.6 ***無損探傷試驗***

6.5.6.1 所有試驗程序和驗收標準應按公認標準，除非設計方規定更高的標準以滿足設計假定。原則上應使用射線檢查發現內部缺陷。但是，認可的超聲波檢查可替代射線檢查，但應增選部分位置進行射線檢查以驗證結果。應保存射線和超聲波檢查結果。

6.5.6.2 設計溫度為-20℃以下的A型獨立液貨艙和半薄膜液貨艙以及不論設計溫度如何的B型獨立液貨艙，所有液貨艙殼板的全焊透對接焊縫應進行適於在其整個長度範圍內發現內部缺陷的無損探傷試驗。可在與6.5.6.1中規定的相同條件下進行替代射線檢查的超聲波檢查。

6.5.6.3 如設計溫度高於-20℃的液貨艙，在結構焊縫交叉處的所有全焊透對接焊縫和剩餘的全焊透對接焊縫至少10%應在與6.5.6.1中規定的相同條件下進行射線檢查或超聲波檢查。

6.5.6.4 在所有情況下，液貨艙結構的其餘焊縫，包括扶強材以及其他附件和連接件的焊縫應在必要時用磁粉或着色滲透法進行檢查。

6.5.6.5 對於C型獨立液貨艙，無損探傷的範圍應按公認標準定其為全部或部分，但檢驗範圍應不少於如下的規定：

.1 有關4.23.2.1.3中的全部無損探傷：

射線檢查：

.1 整個長度範圍內的所有對接焊縫；

用於表面裂紋檢查的無損探傷：

.2 10%長度範圍內的所有焊縫；

.3 整個長度範圍內的開孔和噴管等周圍的加強環。

可以用6.5.6.1中所述的超聲波檢查代替部分射線檢查。此外，主管機關可要求對開孔周圍的加強環和噴嘴焊縫進行全部超聲波檢查。

.2 部分無損探傷按4.23.2.1.3規定：

射線檢查：

.1 所有對接焊交叉處的接頭和對接焊縫全部長度上均勻選取至少10%的長度；

用於表面裂紋檢查的無損探傷：

.2 整個長度範圍內的開孔和噴管等周圍的加強環；

超聲波檢查

.3 主管機關或代表主管機關的被認可組織可根據每

一具體情況提出要求。

6.5.6.6 質量保證/質量控制計劃應確保材料製造商的質量手冊中規定的焊縫無損探傷的持續符合性。

6.5.6.7 管道檢查應按照第5章的要求進行。

6.5.6.8 當認為必要時，次屏壁應進行無損探傷以發現內部缺陷。如船體外殼為次屏壁部分，則對所有舷側頂列板的對接焊縫以及舷側外板上的所有環縫和縱縫的交叉處應進行射線檢查。

6.6 金屬材料構造的其他要求

6.6.1 *通則*

6.6.1.1 焊縫的檢查和無損探傷應按照6.5.5和6.5.6的要求。如在設計中假定更高的標準或公差，其也應能滿足。

6.6.2 *獨立液貨艙*

6.6.2.1 對於由回轉體構成主要結構的C型和B型液貨艙，關於製造的公差，例如失圓、局部偏離正確形狀、焊接接頭的對中以及不同厚度板的削斜等，均應符合公認標準。這些公差都是與4.22.3.2和4.23.3.2所述的屈曲分析有關的。

6.6.2.2 對於用碳鋼和碳錳鋼製造的C型獨立液貨艙，如設計溫度低於-10℃，則應在焊接後進行焊後熱處理。其他各種情況下的焊後處理以及當所用材料不同於上述材料時的焊後熱處理均應符合公認標準。熱處理的加熱溫度和保溫時間也應符合公認標準。

6.6.2.3 對用碳鋼或碳錳鋼製成的C型液貨艙和大型受壓容器進行

熱處理有困難時，在下列條件下，可以採用充壓方法進行機械應力消除，以替代熱處理；

.1 對於受壓容器的複雜焊接部件，如帶有噴管的貯槽或氣室連同其相鄰的殼板，在將其焊接到受壓容器的更大部件上之前應進行熱處理；

.2 對於機械應力消除方法，最好應在4.23.6所要求的靜水壓力試驗期間採用施加一個高於4.23.6.1所要求的試驗壓力的方式進行，加壓的介質應是水；

.3 對於水溫，可採用4.23.6.2的要求；

.4 當液貨艙由其常規的鞍座或支承結構支持時，應對其進行應力消除。當不能在船上對其進行應力消除時，液貨艙的支持方式應能達到與由常規的鞍座或支承結構支持時同樣的應力和應力分佈；

.5 每25mm厚度，應保持最大應力消除的壓力為2h，但在任何情況下均不能少於2h；

.6 在應力消除期間，計算所得的應力水平上限應為：

.1 等效總體主膜應力：$0.9Re$；

.2 主彎曲應力加上膜應力的合成相同應力：$1.35Re$，其中Re是在用於液貨艙的鋼材的試驗溫度下標定的最低屈服應力的下限或0.2%條件驗證應力；

.7 為了驗證這些限度，通常要求至少對相繼建造的一系

列同樣液貨艙中的第一個液貨艙進行應變測量。在按照6.6.2.3的要求需提交的機械應力消除的程度中應包括應變測量儀的位置；

.8 試驗程度應證明：在應力消除過程結束後，當壓力再次升高到設計壓力時，在壓力和應變之間應達到一種線性關係；

.9 在進行了機械應力消除後，應採用染色滲透劑或磁粉檢驗對幾何形狀不連續處（如噴管和其他開口）的高應力區域進行有關裂紋的檢查。應特別注意厚度超過30mm的板材；

.10 對屈服應力與極限抗拉強度之比大於0.8的鋼材，通常不進行機械應力消除。如果採用一種提高鋼材延展性的方法，以提高鋼材屈服應力，則在對具體情況進行考慮後可接受略高的比值；

.11 如果冷成形度超出要求作熱處理的限度，則不能用對液貨艙冷成形部件的熱處理替代機械應力消除；

.12 液貨艙的殼板的封頭的厚度不超過40mm。如對部件進行過熱應力消除，則可以接受較高的厚度；

.13 當液貨艙和氣室的封頭為準球形時，應特別注意防止局部屈曲；和

.14 機械應力消除程序應符合公認標準。

6.6.3 次屏壁

建造期間，次屏壁的試驗和檢查要求應經主管機關或代表主管機關的被認可組織認可或接受（見4.6.2.5和4.6.2.6）。

6.6.4 半薄膜液貨艙

6.6中用於獨立液貨艙或薄膜液貨艙的有關要求，如合適時，亦適用於半薄膜液貨艙。

6.6.5 薄膜液貨艙

質量保證/質量控制計劃應確保焊接工藝條件、設計細節、材料、結構、檢驗和部件的生產試驗的持續符合性。這些標準和工藝應在實施原型試驗計劃期間制定。

6.7 非金屬材料

6.7.1 *通則*

根據目前為止的經驗對這些材料的選擇和使用的指導見附錄4中的信息。

第7章
貨物壓力/溫度控制

目的

使液貨艙壓力和溫度保持在圍護系統設計限制和/或貨物載運要求範圍內。

7.1 控制方法

7.1.1 除設計成在最高設計環境溫度條件下能承受貨物的最大蒸氣錶壓力的液貨艙外，液貨艙的壓力和溫度應通過下列一種或幾種方法一直保持在設計範圍內：

.1 貨物蒸氣的再液化；

.2 蒸氣的熱氧化；

.3 壓力積聚；和

.4 液貨冷卻。

7.1.2 對於第17章要求的某些貨物，不論是否設有能處理貨物蒸氣的任何系統，其貨物圍護系統應能承受在最高環境設計溫度條件下的貨物最大蒸氣壓力。

7.1.3 除緊急情況外，不應接受排放貨物以保持液貨艙的壓力和溫度。主管機關可允許在海上將貨物蒸氣排放至大氣中以達到控制某些貨物的目的。經港口主管當局准許，此方法也可在港內採用。

7.2 系統設計

對於正常的營運，其最高的環境設計溫度應為：

— 海水：32℃

— 空氣：45℃

對於在特熱或特冷區域營運的船舶，這些設計溫度應作適當的增減並使主管機關滿意。系統的總容量應能在不向大氣排放的情況下將壓力

控制在設計條件內。

7.3 貨物蒸氣的再液化

7.3.1 *通則*

可以按下列方式之一對再液化系統進行佈置：

.1 直接冷卻系統：對氣化的貨物進行壓縮、冷凝並將其輸回到液貨艙；

.2 間接冷卻系統：用製冷劑對貨物或氣化的貨物進行冷卻或冷凝，而不對其壓縮；

.3 混合系統：將氣化的貨物壓縮後，在貨物/製冷劑的熱交換器中加以冷凝，然後再將其輸回到液貨艙；和

.4 如果在壓力控制操作期間並在設計條件範圍內，再液化系統產生包含甲烷的污水流，這些廢氣儘實際可行在不向大氣排放的情況下進行處理。

註：

第17和19章的要求可排除使用1個或多個系統或可規定使用特定系統。

7.3.2 *相容性*

用於再液化的製冷劑應與其相接觸的貨物相容。此外，如使用多種製冷劑應可能接觸，其應彼此相容。

7.4 蒸氣的熱氧化

7.4.1 *通則*

按1.2.52和16.2的規定通過貨物蒸氣的熱氧化以保持液貨艙壓力和溫度應只適用於LNG貨物。一般來說：

.1 熱氧化系統應呈現無外部可見火焰，並應保持上煙道排放溫度低於535℃；

.2 氧化系統所在處所的佈置應符合16.3，供應系統應符合16.4；和

.3 如果任何其他系統產生的廢氣會燃燒，氧化系統應設計成能承受所有預計的原料氣體成分。

7.4.2 *熱氧化系統*

熱氧化系統應符合下列要求：

.1 每個熱氧化系統應具有一個獨立的上煙道；

.2 每個熱氧化系統應具有專門的強力通風系統；和

.3 熱氧化系統的燃燒室和上煙道應設計成能防止氣體的任何積聚。

7.4.3 *燃燒器*

燃燒器應設計成能在所有設計着火條件下保持穩定的燃燒。

7.4.4 *安全*

7.4.4.1 應裝有適當的設備，對其佈置應確保：在沒有實現和保持良好的點火動作時，能切斷流向燃燒器的氣體。

7.4.4.2 每個氧化系統應能從安全可及的位置手動隔離氣體燃料供應。

7.4.4.3 應設有在燃燒器熄火後能使用惰性氣體清洗燃燒器的供氣管路的裝置。

7.4.4.4 在所有氣體、油類或油和氣燃燒器熄滅的情況下，氧化系統燃料室應能自動進行點火前的驅氣。

7.4.4.5 應採取能對燃燒室進行人工驅氣的措施。

7.5 壓力積聚系統

圍護系統絕熱層、設計壓力或兩者均應為所涉及的操作時間和溫度提供適當的餘量。不要求附加壓力和溫度控制系統。驗收條件應在1.4.4中要求的《國際散裝運輸液化氣體適裝證書》中予以記錄。

7.6 液貨冷卻

散裝貨物液體可由通過液貨艙內部或液貨艙外表面上的盤管流通的冷卻劑製冷。

7.7 隔離

如果同時載運2種或2種以上能起危險化學反應的貨物時，對於每種貨物，均應設有1.2.47中規定的獨立系統，每個系統符合7.8中規定的可用衡準。如果同時載運2種或2種以上不互相反應但由於其蒸氣的特性而需要單獨系統的貨物時，可通過隔離閥進行隔離。

7.8 可用性

系統的可用性及其支持輔助服務應：

.1 如果機械非靜止部件或控制系統部件發生單項故障，能使液貨艙的壓力和溫度保持在其設計範圍內而不影響其他必需的服務；

.2 不要求冗餘管系；

.3 使液貨艙的壓力和溫度保持在其設計範圍內所需的熱交換器應有備用熱交換器，除非其容量超過最大要求的壓力控制容量的25%並能在無外部幫助的條件下在船上進行修理。如液貨艙壓力和溫度控制的附加和單獨方法不依靠單獨的熱交換器，不要求備用熱交換器；和

.4 對於任何貨物加熱或冷卻介質，應設有按照13.6探測有毒或易燃蒸氣泄漏至非危險區域或舷外的裝置。泄漏探測裝置的任何透氣出口應至非危險區域並設有防火網。

第8章

貨物圍護的透氣系統

目的

使貨物圍護系統一直免受有害過壓或低壓。

8.1 通則

所有液貨艙均應具有與貨物圍護系統的設計以及所裝載的貨物相適應的壓力釋放系統。對於所承受的壓力可能超過其設計能力的貨艙處所和屏壁間處所，也應具有合適的壓力釋放系統。本規則第7章所規定的壓力控制系統應獨立於壓力釋放系統。

8.2 壓力釋放系統

8.2.1 液貨艙（包括甲板液貨艙）應設有最少2個壓力釋放閥（PRV），每個大小相等，在製造商的公差範圍內並適當設計和建造以滿足規定的服務。

8.2.2 屏壁間處所應設有壓力釋放裝置。對於薄膜系統，設計方應證明屏壁間處所壓力釋放閥具有足夠的尺寸。

8.2.3 壓力釋放閥的調定壓力應不高於設計該液貨艙時所採用的最大蒸氣壓力。當安裝兩個以上壓力釋放閥時，具有不超過總釋放能力50%的閥可調到MARVS以上5%的壓力以允許隨後的開啟，並將不必要的蒸氣釋放降至最低。

8.2.4 下列溫度要求適用於安裝至壓力釋放系統的壓力釋放閥：

.1 將應設計溫度低於0℃的液貨艙上的壓力釋放閥設計和佈置成能防止閥由於結冰而失靈；

.2 對於壓力釋放閥的結構和佈置，應考慮由於環境溫度結冰的影響；

.3 壓力釋放閥應由熔點高於925℃的材料構成。可接受

對對內部結構和密封使用低熔點材料，只要不損害壓力釋放閥的自動防故障操作；和

.4 先導式壓力釋放閥上的感應導管和排氣管應足夠堅固以防止破損。

8.2.5 ***閥試驗***

8.2.5.1 壓力釋放閥應進行型式試驗。型式試驗應包括：

.1 釋放能力的驗證；

.2 在設計溫度低於-55℃情況下操作的低溫試驗；

.3 閥座密性試驗；和

.4 受壓部件按至少為設計壓力1.5倍的壓力進行壓力試驗。

壓力釋放閥應按照認可標準進行測試。

8.2.5.2 每個壓力釋放閥應經試驗以確保：

.1 在規定的調定壓力下能開啟。對於0～0.15MPa者，開啟壓力的允許偏差不超過±10%；對於0.15～0.3MPa者，允許偏差不超過±6%；對於0.3MPa及以上者，允許偏差不超過±3%；

.2 閥座密性可接受；和

.3 受壓部件能承受至少1.5倍的設計壓力。

8.2.6 對於壓力釋放閥，應由主管機關或代表主管機關的被認可

組織進行調定和鉛封，而此項工作的記錄，包括閥的調定壓力，應被保存在船上。

8.2.7 在下列情況下，允許液貨艙有1個以上的釋放閥調定壓力：

.1 安裝2個或2個以上經正確調定並被鉛封的壓力釋放閥，並設有必要的裝置，將不用的閥與液貨艙隔離；或

.2 安裝可以改變調定壓力的釋放閥。對於其調定壓力，可以通過使用預先認可的不要求進行壓力試驗即能驗證新的調定壓力的設備予以改變。所有其他的閥調節機構均須鉛封。

8.2.8 按8.2.7的規定改變調定壓力和相應地重新設定13.4.2所述的報警，應在船長的監督下，按照認可程序和船舶操作手冊的規定進行。應將改變後的調定壓力記錄在船舶航行日誌內，並在貨物控制室內（如設有時）張貼標記，然後在每個釋放閥上標明其調定壓力。

8.2.9 如果液貨艙安裝的壓力釋放閥發生故障，應有緊急隔離安全裝置：

.1 應有程序並納入貨物操作手冊（見18.2）。

.2 程序應只允許隔離1個液貨艙安裝的壓力釋放閥。

.3 壓力釋放閥的隔離應在船長的監督下進行。該行動應記錄在船舶航行日誌內，並在貨物控制室內（如設有

時）和壓力釋放閥處張貼標記。

.4 在總釋放能力恢復前，液貨艙不應載貨。

8.2.10 安裝在液貨艙上的每個壓力釋放閥應與透氣系統相連接。

.1 此系統的構造應能使氣體排放不受阻礙且垂直引向上方出口；

.2 並佈置成能使水或雪進入透氣系統的可能性減少至最低限度；

.3 透氣管出口的高度應高出露天甲板不小於B/3或6m，取其大者；和

.4 高出工作區域和走道6m。

8.2.11.1 應將液貨艙壓力釋放閥排氣管出口佈置成使其與最近的通向起居處所、服務處所和控制站或其他非危險區域空氣進口或開口之間的距離至少為*B*或25m，取其小者。對船長小於90m的船舶，可允許採用較小的距離。

8.2.11.2 應將所有與貨物圍護系統相連的其他透氣管出口佈置成使其與最近的通向起居處所、服務處所和控制站或其他非危險區域的空氣進口、出口或開口之間的距離至少為10m。

8.2.12 對在其他各章中未涉及的所有其他的貨物透氣管出口的佈置均應按照8.2.10、8.2.11.1和8.2.11.2的規定。應設有裝置防止由於相連處所的靜水壓力造成液體從透氣管桅出口溢流。

8.2.13 如果同時載運幾種相互間會起危險反應的貨物，則對所載運的每種貨物均應設置一個獨立的壓力釋放系統。

8.2.14 在透氣管系中，應設有能從可積聚液體的地方排放液體的設施。應將壓力釋放閥和管路佈置成在任何情況下不會使液體積聚在壓力釋放閥內或其附近。

8.2.15 在透氣管出口端，應裝設網孔不大於13mm^{2}的適當的防護網，以防異物進入，並不會對流量造成不利影響。載運特定貨物時，防護網的其他要求適用（見17.9和17.21）。

8.2.16 應將所有透氣管路設計和佈置成不致於因其受到溫度的變化、流產生的力或船體的運動而使其損壞。

8.2.17 應將壓力釋放閥連接至甲板平面以上的液貨艙最高部分。壓力釋放閥在液貨艙上的位置應使得在第15章中規定的充裝極限*FL*下當船舶處於橫傾15°和縱傾0.015*L*（對於*L*的定義，見1.2.31）的情況下，壓力釋放閥處仍保持蒸氣狀態。

8.2.18 按照15.5.2的要求裝載的液貨艙上的透氣系統，應由主管機關驗證其適用性，並考慮到本組織制定的建議案。有關的證書應永久保留在船上。就本條而言，透氣系統係指：

.1 液貨艙出口和通向壓力釋放閥的管路；

.2 壓力釋放閥；和

.3 從壓力釋放閥到排向大氣部位的管路，並包括於其他液貨艙相通的連接件和管路。

8.3 真空保護系統

8.3.1 對於未設計成能承受最大外壓差為0.025MPa的液貨艙，或不能承受在最大卸貨速率下無蒸氣返回液貨艙時，或由於貨物製冷系統工作時或熱氧化時可能產生的最大外壓差，則均應設置：

.1 兩個獨立的壓力開關，以能在足以低於液貨艙的最大設計外壓差時的壓力下，採取適當的措施，按順序報警並隨後停止從液貨艙內抽吸貨物液體或蒸氣，同時關閉製冷設備（如設有時）；或

.2 真空釋放閥，其氣體流量至少等於每個液貨艙的最大卸貨速率，且調定在足以低於液貨艙的設計外壓差時的壓力下能開啟。

8.3.2 按照第17章的要求，真空釋放閥應能允許惰性氣體、貨物蒸氣或空氣進入液貨艙，同時應佈置成使水或雪進入液貨艙的可能性為最小。如果允許貨物蒸氣進入液貨艙，則所進入的貨物蒸氣應為來自除貨物蒸氣管路以外的蒸氣源。

8.3.3 應能對真空保護系統進行試驗，以保證其在達到規定的壓力時能動作。

8.4 壓力釋放系統的排量

8.4.1 ***壓力釋放閥的排量***

每個液貨艙的壓力釋放閥應具有一個聯合的釋放量，以便能排放下列情況中較大數量的蒸氣，使液貨艙中的壓力升高不超過釋放閥的

最大允許調定值（MARVS）的20%：

8.4.1.1 如果液貨艙惰化系統最大可達到的工作壓力超過液貨艙的MARVS，則取液貨艙惰化系統的最大排量；或

8.4.1.2 用下式算得的火災波及時的蒸氣生成量：

$$Q = FGA^{0.82} \qquad (m^3/s)$$

式中：

Q = 在273.15K和0.1013MPa的標準狀態下所要求的空氣最小排放率；

F = 用於不同類型液貨艙的火災波及係數：

— 1，對於甲板上無絕熱層的液貨艙；

— 0.5，對於甲板以上其絕熱層係經主管機關認可的液貨艙。應根據所使用的防火材料、絕熱層的熱傳導性能及其在火災波及時的穩定性進行此項認可；

— 0.5，對於安裝在貨艙處所內非絕熱的獨立液貨艙；

— 0.2，對於安裝在貨物處所內絕熱的獨立液貨艙（或安裝在絕熱貨艙處所內的非絕熱獨立液貨艙）；

— 0.1，對於惰化貨艙處所內的絕熱獨立液貨艙（或惰化、絕熱貨艙處所內非絕熱獨立液貨艙）；

— 0.1，對於薄膜或半薄膜液貨艙。對於部分突出於開敞甲板上的獨立液貨艙的火災波及係數，應根據甲板上、下部分的表面積予以決定。

G＝氣體係數：

$$G = \frac{12.4}{LD}\sqrt{\frac{ZT}{M}}$$

其中：

T＝在釋放狀態下的絕對溫度（K），即在120%的釋放閥調定壓力下的溫度；

L＝在釋放狀態下，物質被氣化時的潛熱，kJ/kg；

D＝根據比熱*k*決定的常數，用下列公式計算：

$$D = \sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

式中：

K＝釋放狀態下的比熱率，其值在1和2.2之間。如果*k*為未知數時，應取*D*＝0.606；

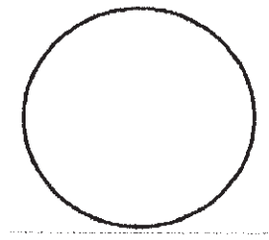
Z＝在釋放狀態下，氣體的壓縮係數；如此係數為未知數，則取Z＝1；和

M＝貨品分子量。

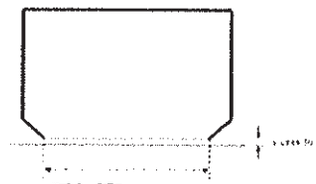
應確定載運的每個貨物的氣體因數，最高值應用於

PRV排量。

A＝1.2.14中規定的液貨艙外表面面積（m^2）。對於不同類型的液貨艙，如圖8.1所示。

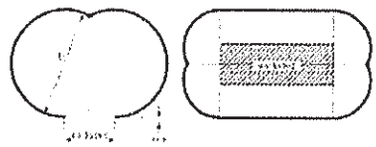


具有球形、半球或半橢圓形封頭的圓柱形液貨艙或球形液貨艙

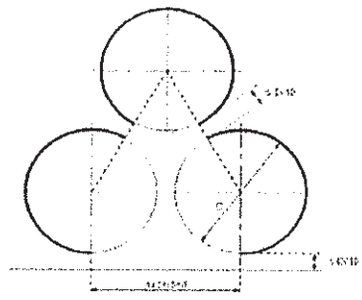


不包括L

棱形液貨艙



雙耳式液貨艙



水平圓柱形液貨艙佈置

圖8.1

8.4.1.3 釋放狀態下要求的空氣質量流由下列公式得出：

$$M_{空氣} = Q\,\rho_{空氣} \quad (\mathrm{kg/s})$$

式中：

空氣密度($\rho_{空氣}$)= 1.293kg/m^3(空氣273.15K，0.1013MPa)。

8.4.2 ***透氣管系統排量***

確定壓力釋放閥的排量時，應考慮壓力釋放閥上流和下流的壓力損失以確保8.4.1要求的流量。

8.4.3 ***上流壓力損失***

8.4.3.1 按照8.4.1，透氣管路中從液貨艙到壓力釋放閥入口處的壓降，應不超過計算流速時該閥釋放調定壓力的3%。

8.4.3.2 如果先導式壓力釋放閥感應導管直接引自液貨艙氣室，則壓力釋放閥應不受進入管壓力損失的影響。

8.4.3.3 對於流動型導閥，應考慮感應導管中的壓力損失。

8.4.4 ***下流壓力損失***

8.4.4.1 如設有公用透氣管聯箱和透氣管桅，計算應包括所有相關壓力釋放閥的流量。

8.4.4.2 透氣管中從壓力釋放閥出口至排放至大氣的位置的背壓，

包括與其他液貨艙相連的任何透氣管連接，應不超過下列值：

.1 對非平衡壓力釋放閥： MARVS的10%；

.2 對平衡壓力釋放閥： MARVS的30%；和

.3 先導式壓力釋放閥： MARVS的50%；

可接受壓力釋放閥製造商提供的替代值。

8.4.5 為確保壓力釋放閥的穩定運作，排氣應不少於進口壓力損失和額定排量時0.02MARVS的總和。

第9章
貨物圍護系統的環境控制

目的

監控圍護系統的完整性並確保系統和貨艙處所內的大氣在船舶營運期間一直處於安全狀態。

9.1 貨物圍護系統內的環境控制

9.1.1 應設有一個管路系統，以便能對每個液貨艙安全地除氣以及在除氣後的狀態下用貨物蒸氣安全地充氣。應將系統佈置成能在氣體環境改變後使氣體或空氣存留死角的可能性降至最低限度。

9.1.2 對於易燃貨物，應將系統設計成在利用惰性的介質對液貨艙進行氣體環境改變作業的中間步驟時，消除易燃氣體混合物存在於

液貨艙內的可能性。

9.1.3 可能含有易燃貨物的管路系統應符合9.1.1和9.1.2。

9.1.4 應對每個液貨艙和貨物管路系統設置足夠數量的採樣點，以能充分地監測氣體環境改變的進程。氣體採樣連接管應在主甲板以上設有單個閥，並用適當的蓋板或盲板密封（見5.6.5.5）。

9.1.5 在上述作業過程中所使用的惰性氣體，可由岸上或船上供給。

9.2 貨艙處所（除C型獨立液貨艙以外的貨物圍護系統）內的環境控制

9.2.1 對於要求全部或部分設次屏壁的用於易燃氣體的貨物圍護系統的屏壁間處所和貨艙處所，均應使用適當的乾燥惰性氣體進行惰化，並用船上惰性氣體發生系統或用船上儲存的惰性氣體提供補充的惰性氣體以保持惰化。船上儲存的惰性氣體應至少能滿足30天的正常消耗。

9.2.2 另一方面，因受第17章規定的限制，可用乾燥空氣充填9.2.1所述的只要求部分次屏壁的處所，但船上仍應保持有一定貯量的惰性氣體或在船上設有足以惰化上述處所中最大處所的惰性氣體發生系統。同時，對於上述處所的形狀以及有關的蒸氣探測系統連同惰化裝置的能力，應保證能迅速探測到液貨艙的任何泄漏以及在可能發展成危險狀態之前能完成惰化。應設有能產生足夠的合適質量的乾燥空氣的設備，以滿足預期的需要。

9.2.3 當載運非易燃氣體時，9.2.1和9.2.2所述的處所可用合適的

乾燥空氣或惰性氣體予以保持。

9.3 C型獨立液貨艙周圍處所的環境控制

對於未設置次屏壁的液貨艙周圍處所，應充填適當的乾燥惰性氣體或乾燥空氣，並應用船上惰性氣體發生系統或貯存的惰性氣體提供補充的惰性氣體或用合適的乾燥空氣設備提供的乾燥空氣，以保持上述處所的環境。如果貨物在環境溫度下載運，乾燥空氣或惰性氣體的要求不適用。

9.4 惰化

9.4.1 惰化是指提供一個不燃環境的過程。在處所內所有可能出現的溫度下，此惰性氣體與貨物在化學性質方面和操作方面均應是相容的。並應考慮惰性氣體的露點。

9.4.2 如果船上還儲存用於滅火的惰性氣體，則應將其儲存在獨立的容器內，且不得用於貨物作業。

9.4.3 當惰性氣體在0℃以下儲存時，無論其是液體還是蒸氣，均應將儲存和供應系統設計成使船舶構件的溫度不致下降到其所能承受的極限值以下。

9.4.4 應設有用以防止貨物蒸氣倒流至適合於所載運貨物的惰性氣體系統的佈置。如果將該惰性氣體裝置設於機器處所或貨物區域之外的其他處所時，應在貨物區域內的惰性氣體總管上安裝2個止回閥或等效裝置以及1個可拆短管。除了與貨艙處所或屏壁層處所的連接外，惰性氣體系統在不使用時應與貨物區域的貨物系統分隔開。

9.4.5 所採用的佈置應使每個被惰化的處所都能被隔離，並在這些處所設置必要的壓力控制和釋放閥等，以控制處所內的壓力。

9.4.6 如果絕熱處所持續獲得惰性氣體作為泄漏檢查系統的一部分，應設有裝置監測各處所獲得的氣體數量。

9.5 船上惰性氣體的製造

9.5.1 製造惰性氣體的設備應能產生含氧量（按體積）在任何時間都不超過5%的惰性氣體，且應符合第17章的特殊要求。從惰性氣體製造設備引出的惰性氣體供應管路上應安裝一個能連續讀數的含氧量測定表和一個調定在最高含氧量（按體積）為5%時報警的報警裝置，且也應滿足第17章的要求。

9.5.2 惰性氣體系統應具有適合於貨物圍護系統的壓力控制裝置和探測裝置。

9.5.3 裝有惰性氣體發生裝置的處所不得有通往起居處所、服務處所或控制站的直接通道，但惰性氣體發生裝置可位於機器處所內。惰性氣體管路不得通過起居處所、服務處所或控制站。

9.5.4 製造惰性氣體用的燃燒設備不得位於貨物區域內。對於使用催化燃燒方法的惰性氣體發生設備的安裝位置，可給予特別考慮。

第10章

電氣裝置

目的

確保電氣裝置設計成能使易燃貨品失火和爆炸的危險降至最低程度，且設有與貨物液體和蒸氣的安全載運、裝卸和調節相關的發電和配電系統。

10.1 定義

就本章而言，除另有規定外，下列定義應適用。

10.1.1 危險區域係指爆炸性氣體環境出現或預期可能出現的數量達到足以要求對電氣設備的結構、安裝和使用採取特殊預防措施的區域。

10.1.1.1 0區危險區域係指持續或長期存在爆炸性氣體環境的區域。

10.1.1.2 1區危險區域係指正常運行時可能出現爆炸性氣體環境的區域。

10.1.1.3 2區危險區域係指正常運行時不可能出現爆炸性氣體環境（如出現，也只是偶爾或短時間出現）的區域。

10.1.2 非危機區域係指爆炸性氣體環境預期出現的數量不足以要求對電氣設備的結構、安裝和使用採取特殊預防措施的區域。

10.2 一般要求

10.2.1 所配備的電氣裝置應能使易燃貨品失火和爆炸的危險降至最低程度。

10.2.2 電氣裝置應按照公認標準。

10.2.3 電氣設備或電纜不得安裝在危險區域內，除非為作業目的或提高安全性所必需時。

10.2.4 當電氣設備安裝在10.2.3所規定的危險區域內時，其應按照不低於本組織可接受的標準選擇、安裝和維護。危險區域的設備應由經認證的試驗當局或經主管機關認可的機構進行評估和發證或列舉。不合格易燃氣體探測設備的自動隔離不能替代合格設備的使用。

10.2.5 為便於選擇適當的電氣設備和設計合適的電氣裝置，危險區域按照公認標準分區。

10.2.6 發電和配電系統及相關控制系統應設計成單個故障不會導致7.8.1要求的液貨艙壓力和4.19.1.6要求的船體結構溫度保持在正常營運限制內的能力喪失。應按照不低於主管機關接受的標準對故障模式和影響進行分析和記錄。

10.2.7 危險區域內的照明系統至少應有2個分支線路。所有開關和保護電器均應能分斷全部的極或相，並應位於非危險區域內。

10.2.8 電測深儀或計程儀以及外加電流陰極保護系統的陽極或電極。這些設備均應置於氣密圍阱內。

10.2.9 可將深潛式貨泵電動機及其供電電纜安裝在貨物圍護系統內。應設有能在低液位時自動停止電動機運轉的裝置。這可通過檢測泵的低排放壓力、電動機的低電流或低液位予以實現。電動機停止運轉時，應在貨物控制站進行報警。在除氣作業期間，應能切斷貨泵電動機的供電電源。

第11章

防火與滅火

目的

確保設有合適的系統在貨物區域發生火災時保護船舶和船員。

11.1 防火安全要求

11.1.1 SOLAS公約第II-2章中對液貨船的要求應適用於本規則所涉及的船舶不論其噸位大小，包括小於500總噸的船舶，但是：

.1 第4.5.1.6條和第4.5.10條的規定不適用；

.2 第10.4條和第10.5條應適用於2000總噸及以上的液貨船；

.3 第10.5.6條應適用於2000總噸及以上的船舶；

.4 SOLAS公約第II-2章中有關對液貨船的下列規定不適用，由本規則的有關章節替代，詳細如下：

公約條文：	由本規則替代的條文號：
10.10	11.6
4.5.1.1和4.5.1.2	第3章
4.5.5	本規則的相關章節
10.8	11.3和11.4
10.9	11.5
10.2	11.2.1至11.2.4

.5 第13.3.4條和第13.4.3條應適用於500總噸及以上的船舶。

11.1.2 除本規則第10章和第16章另有規定外，所有點火源應從可能存在易燃蒸氣的處所排除。

11.1.3 本條規定應與本規則第3章一起適用。

11.1.4 為了滅火，應將在最後面的貨艙處所後端或在最前面的貨艙處所前端處的隔離艙、壓載艙或留空處所上方的任何開敞甲板區域都包括在貨物區域內。

11.2 消防總管和消防栓

11.2.1 對於載運受本規則約束的貨品的船舶，不論其尺度大小，均應滿足SOLAS公約第II-2/10.2條對貨船的要求。但是，當消防泵用於供給本規則11.3.3規定的水霧系統時，則所要求的消防泵的排量以及消防總管和消防水管的直徑應不受SOLAS公約第II-2/10.2.2.4.1條和第II-2/10.2.1.3條規定的限制。消防泵的排量應在具有19mm噴嘴的消防水帶在至少0.5MPa的壓力下同時提供2股水柱時使這些區域得到保護。

11.2.2 對水滅火系統的佈置，應至少使2股水柱能噴射到貨物區域內的甲板的任何部分以及甲板以上的貨物圍護系統和液貨艙艙口蓋等部位。應設置必要數量的消火栓，以滿足上述佈置的需要並滿足SOLAS公約第II-2/10.2.1.5.1條和第II-2/10.2.3.3條的要求，消火栓所配備的消防水帶的長度按第II-2/10.2.3.1.1條的規定。此外，SOLAS公約第II-2/10.2.1.6條所要求的壓力至少應達到0.5MPa（表壓）。

11.2.3 在進入貨物區域前並以確保能隔斷總管上任何損壞的單個管段的間隔，應在所設的任何管路的交叉處和保護位置的消防總管或總管組上設置截止閥，以從最近的消防栓使用不超過2個水帶長度來滿足11.2.2的要求。向服務於貨物區域的消防總管供水應為主消防泵供水的環狀總管或由位於貨物區域前後的消防泵供水的單個總管，其中一個應獨立驅動。

11.2.4 水槍應為經認可的設有關閉裝置的兩用型（水霧/水柱型）。

11.2.5 安裝後，管子、閥、附件和組裝系統應進行密性和功能試驗。

11.3 水霧系統

11.3.1 在載運易燃和/或有毒貨品的船上，應安裝用於冷卻、防火以及船員防護的水霧系統，其範圍應包括：

.1 裸露的液貨艙氣室、液貨艙的任何裸露部分和含有貨物的相鄰設備着火時暴露於熱的液貨艙蓋的任何部分(例如裸露的增壓泵/加熱器/再氣化或再液化裝置，以下稱為露天甲板上的氣體處理裝置）；

.2 在甲板上裸露的用於易燃或有毒貨品儲存容器；

.3 甲板上的氣體處理裝置；

.4 貨物液體和蒸氣的裝卸連接，包括法蘭及其控制閥所在的區域，其範圍至少等於所設滴盤的區域；

.5 貨物液體和蒸氣管中所有裸露的應急關閉(ESD)閥，包括向用氣裝置供氣的總閥；

.6 面向貨物區域的暴露限界面，例如經常有人的上層建築和甲板室的艙壁、貨物機器處所、裝有高度失火危險物品的儲藏室和貨物控制室。這些區域暴露的水平限界面不要求保護，除非在其上面或下面佈置可拆卸的貨物管路連接。對不存放高度失火危險物品或設備的無人首樓結構的限界面，不要求水霧保護；

.7 面向貨物區域的裸露救生艇、救生筏和集合站，不論至貨物區域的距離；和

.8 任何半圍蔽貨物機器處所和半圍蔽貨物機艙。

應特別考慮擬按1.1.10所述進行營運的船舶（見11.3.3.2）。

11.3.2.1 水霧系統應能覆蓋11.3.1.1至11.3.1.8所述的所有區域，用於最大水平投影面的噴射率應至少為每分鐘10ℓ/m^2的均勻分佈水霧；用於垂直表面，應至少為每分鐘4ℓ/m^2。對於不能明確劃分水平面或垂直面的結構，水霧系統的排量應不小於水平投影面積乘以每分鐘10ℓ/m^2。

11.3.2.2 在垂直表面上，確定用於保護較低區域的噴嘴的間距時，可估算從較高區域流下的水量。為了隔斷損壞的管段，在水霧系統總管上應每隔不超過40m安裝1個截止閥。或者將系統分成2個或多個區段，可以對每個區段進行獨立操作，但應將必要的控制裝置集中安裝在貨物區域外易於到達的位置。用於保護包括11.3.1.1和.2所述區域的

任何區域的區段應能至少覆蓋該區域的整個橫向液貨艙群。11.3.1.3中包括的任何氣體處理裝置可由1個獨立的區段服務。

11.3.3 除11.3.1.4至11.3.1.8所述的表面之外。水霧泵排量應能同時保護下列的大者：

.1 任何2個完整的橫向液貨艙群，包括該區域內的任何氣體處理裝置；或

.2 對於按1.1.10所述進行營運的船舶，按照11.3.1需特別考慮任何附加失火危險的必要保護和相鄰橫向液貨艙群，

也可將主消防泵用作水霧系統供水泵，但其總排量中應增加水霧系統所需水量。不論在哪種情況下，在貨物區域外的消防總管和水霧系統總管之間，都應設有帶截止閥的連接管。

11.3.4 如果1個艙失火會使2個消防泵失效，經常有人的上層建築和甲板室的限界面和面向貨物區域的救生艇、救生筏和集合區域也應能由1個消防泵或應急消防泵服務。

11.3.5 通常被用作其他用途的水泵也可向水霧系統總管供水。

11.3.6 水霧系統中的所有管子、閥、噴嘴和其他附件均應能耐海水腐蝕。貨物區域內管路、附件和相關構件（襯墊除外）應設計成經受925℃。水霧系統應佈置成具有管線過濾器以防止管道和噴嘴堵塞。此外，應設有裝置用海水反沖系統。

11.3.7 對於水霧系統供水泵的遙控起動裝置和該系統中任何常

閉閥門的遙控操作裝置，應將其佈置在貨物區域外鄰近起居處所的合適位置，並能在被保護區域發生火災時易於進入和對其操作。

11.3.8 安裝後，管道、閥、附件和組裝系統應進行密性和功能試驗。

11.4 化學乾粉滅火系統

11.4.1 對凡擬載運易燃貨品的船舶，均應安裝經主管機關基於本組織制定的指南認可的固定式化學乾粉滅火系統，以便用其撲滅貨物區域甲板上的火災（包括甲板上任何貨物液體和蒸氣排放和裝載連接），如適用時，也可用其撲滅首尾貨物裝卸區域的火災。

11.4.2 該系統具有至少能用2個手持軟管或乾粉炮與手持軟管的聯合裝置將乾粉噴灑到暴露貨物液體和蒸氣管路、裝卸連接和暴露氣體處理裝置的任何部分。

11.4.3 化學乾粉滅火系統應設計成具有不少於2個獨立裝置。11.4.2要求的任何被保護部件應能從不少於2個獨立裝置及其控制裝置、加壓介質固定管路、乾粉炮或手持軟管達到。對於其液貨艙容量小於1000m^3的船舶，可設一套上述裝置。乾粉炮應佈置成能保護任何裝卸連接區域，且能對其進行就地和遙控啟動和噴灑。如果乾粉炮能從一個位置將所需的乾粉噴灑到整個覆蓋區域，則不要求乾粉炮具有遙控瞄準的能力。面向起居處所並隨時可進入的貨物區域末端左舷和右舷處應設有1個軟管。

11.4.4 乾粉炮的排量不得小於10kg/s。對於手持軟管，不應被扭曲，並應設有個能夠開和關的噴嘴，其噴射速率不小於3.5kg/s。當噴

嘴以最大噴射速率噴射時，應能允許由人進行操作，手持軟管的長度不應超過33m。如果乾粉容器與手持軟管或乾粉炮之間設有固定管路，則對管路的長度，應以不超過其在持續使用或間斷使用中能使乾粉保持流動狀態所需的長度為限，而且在系統關閉之後，應能驅除管路中的乾粉。對於手持軟管和噴嘴，應為耐風雨結構或儲存在耐風雨的箱子內或罩蓋下，並應易於取用。

11.4.5 應認為手持軟管的最大有效覆蓋距離是等於軟管本身的長度。如果被保護區域顯著地高於乾粉炮或手持軟管捲筒所在位置，則應予以特別考慮。

11.4.6 對於設有首尾裝卸連接的船舶，應在貨物區域前後設有獨立的乾粉裝置，通過符合11.4.1至11.4.5要求的覆蓋船艏/船艉裝卸的軟管和1個乾粉炮保護貨物液體和蒸氣管路。

11.4.7 應特別考慮按1.1.10所述進行營運的船舶。

11.4.8 安裝後，管子、閥、附件和組裝系統應進行遙控和就地釋放釋放站的密性試驗和功能試驗。初次試驗也應包括排放足夠數量的化學乾粉以驗證系統處於適當的工作狀態。所有分配管道應用乾燥空氣輸氣以確保管道無障礙物。

11.5 設有貨物裝卸設備的圍蔽處所

11.5.1 滿足1.2.10中貨物機器處所衡準的圍蔽處所和任何船舶貨物區域內的貨物機艙應設有符合FSS規則規定的固定滅火系統，並考慮到氣體滅火所要求的必要的濃縮/施放比率。

11.5.2 專門從事運載有限數量貨物的船舶的貨物區域內滿足第

3.3章中貨物機器處所衡準的圍蔽處所應由合適的針對所載運貨物的滅火系統予以保護。

11.5.3 任何船舶的轉塔艙應由最大被保護水平面施放率不小於10ℓ/m²/min的內部水霧予以保護。如果通過轉塔的氣流壓力超過4MPa，施放率應增至20ℓ/m²/min。系統應設計成保護所有內表面。

11.6 消防員裝備

11.6.1 對於載運易燃貨品的每艘船舶，均應按下述規定配備符合SOLAS公約第II-2/10.10條要求的消防員裝備：

貨艙總容量	裝備的數量
5000m³及以下	4
5000m³以上	5

11.6.2 對於安全設備的附加要求，見第14章的規定。

11.6.3 對於作為消防員裝備組成部分所必需的任何呼吸器，均應為至少具有1200ℓ自由空氣容量的自給式壓縮空氣呼吸器。

第12章

貨物區域內的機械通風

目的

確保貨物區域內的圍蔽處所設有控制易燃和/或有毒蒸氣積聚的裝置。

範圍

本章要求替代經修正的SOLAS公約第II-2/4.5.2.6條和第4.5.4.1條的要求。

12.1 正常裝卸貨物作業中需要進入的處所

12.1.1 對於電動機艙、貨物壓縮機艙和貨泵艙、裝有貨物裝卸設備的處所以及貨物蒸氣可能積聚的其他圍蔽處所，均應安裝能在上述處所外面進行控制的固定式機械通風系統。應連續通風以防止有毒和/或易燃蒸氣積聚，並設有主管機關接受的監控設備。在此類艙室外面設有“進入前需要進行通風”的警告牌。

12.1.2 機械通風的進風口和出風口的佈置應能確保有足夠的空氣流經該處所，以避免易燃、有毒或窒息蒸氣的積聚，同時保證有一個安全的工作環境。

12.1.3 根據該處所的總容積，通風系統的換氣次數應不少於30次/h。作為例外，非危險貨物控制室的換氣次數可為8次/h。

12.1.4 如果處所有進入相鄰更危險處所或區域的開口，其應保持在過壓狀態。其可按照公認標準由過壓保護進入較少危險處所或非危險處所。

12.1.5 服務於機械通風系統的通風管道、空氣進口和廢氣出口的位置應按照公認標準。

12.1.6 服務於危險區域的通風管道，除本規則第16章所允許的情況外，均不得通過起居處所、服務處所和機器處所或控制站。

12.1.7 應將驅動風機的電動機安裝在可能含有易燃蒸氣的通風

管之外。不能使風機在通風處所內或與該處所相連的通風系統內產生着火源。對於危險區域，通風機風扇和鄰近風扇的通風管道應為按如下規定的非火花結構：

.1 非金屬結構的葉輪或機殼，對消除靜電應予以適當注意；

.2 有色金屬材料的葉輪和機殼；

.3 奧氏體不鏽鋼葉輪和機殼；和

.4 鐵質葉輪和機殼，其設計的葉梢間隙不小於13mm。

對於鋁合金或鎂合金的固定或旋轉部件與鐵質的固定或旋轉部件的任何組合，不論其葉梢間隙大小，均視為有產生火花的危險，故不能用於這些處所。

12.1.8 本章要求的風機，應在任何1個風機發生故障後，仍能對每個處所提供本章要求的全部通風量，或應設有由電動機、起動裝置備件和完整的轉動部件（包括各種軸承）組成的備件。

12.1.9 在通風管的外部開口處，應設置其方形網孔不大於13mm的防護網。

12.1.10 如通過增壓保護處所，通風應按照公認標準進行設計和安裝。

12.2 通常不進入的處所

12.2.1 可能積聚貨物蒸氣的圍蔽處所應能進行通風，以確保在需要進入該處所時有一個安全的環境。可在無需人員預先進入的情況下

進行該處所的通風。

12.2.2 對於固定式通風裝置，換氣次數應為8次/h，對於便攜式通風系統，換氣次數應為16次/h。

12.2.3 風扇或風機應遠離人員的通道口，並應符合本章12.1.7的規定。

第13章
儀錶和自動化系統

目的

確保儀錶和自動化系統提供貨物液體和蒸氣的安全載運，裝卸和調節。

13.1 通則

13.1.1 對每個液貨艙都應設有顯示貨物的液位、壓力和溫度的裝置。在液體和蒸氣管系以及貨物製冷裝置中均應裝設壓力錶和溫度指示器。

13.1.2 如果船舶的裝卸貨通過遙控的閥和泵進行，則應將與該液貨艙相關的所有控制裝置和指示器集中在一個控制位置。

13.1.3 對儀錶應進行試驗，以保證其在工作條件下的可靠性，並應對其進行定期校準。儀錶的試驗方法和重新校準的時間間隔應按照製造商的建議。

13.2 用於液貨艙的液位指示器

13.2.1 每個液貨艙應安裝液位測量裝置，其佈置應確保只要液貨艙處於運作狀態，一直能獲得液位讀數。設備應設計成能在液貨艙的設計壓力範圍內以及在貨物操作溫度範圍內的溫度下進行工作。

13.2.2 如果僅安裝1個液位錶，則應將其佈置成能一直處於操作狀態而無需清空液貨艙或對液貨艙進行除氣。

13.2.3 按照第19章表“g”欄中所列特種貨物的任何特殊要求，其液貨艙的液位錶可為下列型式：

.1 間接式裝置，即用諸如秤重或在線流量測量的方法確定貨物的數量；

.2 閉式裝置，此種裝置不穿透液貨艙，例如使用放射性同位素的裝置或超聲波裝置等；

.3 閉式裝置，此種裝置需穿透液貨艙，而且是封閉系統的組成部分，並能防止貨物溢出，如浮筒式系統、電子探頭、磁性探頭和氣泡管式指示器等。如果閉式測量裝置不是直接裝在液貨艙上，則應在儘可能靠近液貨艙的位置設一個截止閥；和

.4 限制式裝置，此種裝置需穿透液貨艙，而且在使用時允許有少量貨物蒸氣或液體逸入大氣，如固定管式和滑動管式液位錶即屬此類裝置。在不使用時，這種裝置應被保持完全關閉。對此種裝置的設計和安裝，應能保證在打開裝置時，不致發生貨物外溢的危險。除

非設有超流量閥，否則，設計此種裝置時其最大開口的直徑應不超過1.5mm或等量的面積。

13.3 溢流控制

13.3.1 除13.3.4的規定外，每個液貨艙均應裝設一個獨立於其他液位指示器的高液位報警裝置，並在動作時發出聽覺和視覺報警。

13.3.2 對於獨立於高液位報警裝置的附加傳感器，應能自動啟動1個截止閥，以避免裝貨管路中產生過大的液體壓力，及防止液貨艙內被注滿液體。

13.3.3 在5.5和18.10中所述的應急截止閥可用於此目的。如果將另一閥用於此目的，則船上應備有18.10.2.1.3所述的相同資料。在裝貨期間，每當這些閥的使用可能在裝貨系統中產生潛在的過大壓力波動時，應使用諸如限制裝貨速率的替代措施。

13.3.4 當液貨艙屬於下述兩種情況之一時，不要求在液貨艙中設高液位報警裝置和液貨艙充裝的自動關閉裝置：

.1 容積不超過200m^3的壓力艙；或

.2 將液貨艙設計成能經受在裝貨作業期間可能出現的最大壓力，但該壓力應低於液貨艙釋放閥的設定壓力。

13.3.5 液貨艙中傳感器的位置應能在交付使用前確認。在交船後和每次乾塢後第一次滿載，應通過提升液貨艙中的貨物液位至報警點進行高位報警試驗。

13.3.6 高位報警和溢出報警的所有構件（包括電路和傳感器）應

能進行功能試驗。在按照18.6.2進行貨物操作前應進行系統試驗。

13.3.7 如設有裝置越控溢流控制系統，其應能防止不當操作。如進行越控，應在相關控制站和駕駛室給出連續視覺指示。

13.4 壓力監控

13.4.1 每一液貨艙的蒸氣空間均應設有一個直接讀數壓力錶。此外，在13.1.2要求的控制位置應設有間接指示。應清晰標出最高和最低的允許壓力。

13.4.2 應在駕駛室內設有一個高壓報警裝置，以及如需要真空保護時，在駕駛室和13.1.2要求的控制位置還應設有一個低壓報警裝置。在達到設定壓力之前，應觸發報警。

13.4.3 對裝有按8.2.7可設定一個以上設定壓力的壓力釋放閥的液貨艙，每個設定壓力應設有高壓報警。

13.4.4 在每一貨泵排放管路上和每個液體和蒸氣貨物的集合管上，應至少各設1個壓力指示器。

13.4.5 應設有就地讀數的集合管壓力指示，以指示船舶集管閥和通岸軟管之間的壓力。

13.4.6 未設通向大氣開口的貨艙處所和屏壁間處所均應設置壓力指示。

13.4.7 所有壓力指示應能在操作壓力範圍內進行指示。

13.5 溫度指示裝置

13.5.1 每個液貨艙應至少設2個貨物溫度指示裝置，一個位於液貨艙底部。另一個接近液貨艙頂部且低於最高允許液面。1.4.4要求的《國際散裝運輸液化氣體適裝證書》上顯示的液貨艙的設計最低溫度應通過溫度指示設備上或溫度指示設備附近的標記清晰指示。

13.5.2 溫度指示設備應能提供越過液貨艙預計貨物操作溫度的溫度指示。

13.5.3 如設有熱電偶，其應設計成能將正常作業中的疲勞導致的故障降至最低。

13.6 氣體探測

13.6.1 應按本節要求安裝氣體探測設備以監測貨物圍護、貨物裝卸和輔助系統的完整性。

13.6.2 下列處所內應設有固定的氣體探測系統和聽覺和視覺報警裝置：

.1 包含氣體管道、氣體設備或用氣設備的所有圍蔽貨物和貨物機器處所（包括轉塔艙）；

.2 可能積聚貨物蒸氣的其他圍蔽或半圍蔽處所，包括除C型獨立液貨艙之外的獨立液貨艙的屏壁間處所和貨艙處所；

.3 空氣閘；

.4 16.7.3.3中所述的氣體燃料內燃機中的處所；

.5 第16章要求的通風罩和氣體管道；

.6 7.8.4要求的冷卻/加熱電路；

.7 惰性氣體發生器供應總管；和

.8 用於貨物裝卸機械的電動機艙。

13.6.3 氣體探測設備應按照公認標準進行設計、安裝和試驗並應按照第19章表中“f”欄適於所載貨物。

13.6.4 如第19章表中“f”欄中指出船舶適於載運不燃貨品，應在貨物機器處所和液貨艙貨艙處所設有缺氧監控。此外，缺氧監控設備應安裝在含有可能導致缺氧環境的設備（例如氮氣發生器、惰性氣體發生器或氮氣循環製冷系統）的圍蔽或半圍蔽處所。

13.6.5 在載運有毒或既有毒又易燃的貨品的情況下，除第19章表中“i”欄內涉及到17.5.3者以外，在對有毒氣體進行探測時，可以使用可攜式設備以替代固定式安裝的系統。在人員進入13.6.2中所列的處所之前以及人員在處所內停留期間的每隔30min均應使用可攜式設備進行探測。

13.6.6 對於歸為有毒貨品的氣體，應對貨艙處所或屏壁間處所設置能從該類處所得到氣體樣品的固定安裝的管系。應對這些處所內的氣體進行取樣和分析（對每個取樣點）。

13.6.7 固定安裝的氣體探測應為連續探測型，能立即響應。如不用於啟動13.6.9和第16章要求的安全關閉功能，可接受取樣型探測。

13.6.8 如使用取樣型氣體探測設備，應滿足下列要求：

.1 氣體探測設備應能在不超過30min的時間間隔期內，

依次從每個取樣點取樣和分析；

.2 應設置從取樣點通向探測設備的單個取樣管路；和

.3 除13.6.9所允許者外，從取樣器引出的管子不得穿過非危險處所。

13.6.9 氣體探測設備可位於非危險處所，只要氣體探測設備（例如採樣管路、採樣泵、電磁閥和分析單元）位於一個具有密封門的全封閉鋼質箱中。應連續監測全封閉鋼質箱內的氣體。當該鋼質箱中的可燃氣體的聚集達到最低可燃性極限的30%時，整個可燃氣體分析設備應自動關斷。

13.6.10 如全封閉鋼質箱不能直接安裝在前艙壁上，取樣管應用鋼或等效材料製成，並設定最短路線。不允許可拆連接，但13.6.11中要求的隔離閥的連接點和分析裝置除外。

13.6.11 如氣體取樣設備位於非危險處所，每個氣體取樣管應設置火焰清除器和手動隔離閥。隔離閥應在非危險側。危險和非危險區域之間取樣管的艙壁穿透部位應保持穿透分隔的完整性。廢氣應排至非危險區域的開敞空氣。

13.6.12 對於每套探測設備，在確定探測點的數量和位置時，應適當考慮艙室的大小和佈局、擬載運貨品的成分和密度、由於艙室內換氣或通風所造成的稀釋度以及不流動區域。

13.6.13 本節要求的氣體探測系統內的任何報警狀況應在下列位置發出聽覺和視覺報警：

.1 駕駛室；

.2 記錄連續監測氣體水平的相關控制站；和

.3 氣體探測器的讀數裝置所在的位置。

13.6.14 對於易燃貨品，要求惰化的貨艙處所或屏壁間處所設置的氣體探測設備應能測量從0至100%的氣體濃度（按容積）。

13.6.15 當蒸氣濃度達到在空氣中的可燃下限的30%等效值時，報警裝置應被觸發。

13.6.16 對於薄膜圍護系統，主絕熱處所和次絕熱處所應能惰化並單獨分析其氣體含量。次絕熱處所的報警按照13.6.15設定，主處所設定為主管機關或代表主管機關的被認可組織認可的值。

13.6.17 對於13.6.2所述的其他處所，當蒸氣濃度達到最低可燃性極限的30%時，報警裝置應被觸發，第16章要求的安全功能應在蒸氣濃度達到最低可燃性極限的60%前被觸發。使用氣體燃料的內燃機的曲軸箱應佈置成在達到最低可燃性極限的100%前報警。

13.6.18 氣體探測設備應設計成能易於試驗。應能定期進行試驗和校準。為此，船上應備有適當的設備並按照製造商的建議使用。應對這些設備設固定連接管。

13.6.19 對每艘船舶應至少設有2套滿足13.6.3或可接受的國家或國際標準要求的可攜式氣體探測設備。

13.6.20 應設有一台能測量惰性氣體中含氧量的合適儀器。

13.7 要求次屏壁的圍護系統的附加要求

13.7.1 ***屏壁的完整性***

如果要求設有次屏壁，則應配備固定式安裝的儀錶，以監測主屏壁的任何部位的液密失效或次屏壁的任何部位接觸液貨。這種儀錶應為符合13.6中規定的合適的氣體監測裝置。但是，不要求該儀錶能確定出主屏壁泄露液貨的區域或次屏壁接觸液貨的區域。

13.7.2 ***溫度指示裝置***

13.7.2.1 溫度指示裝置的數量和位置應適合圍護系統的設計和貨物操作要求。

13.7.2.2 當貨物以低於-55℃的溫度裝運在具有次屏壁的貨物圍護系統內，在絕熱層內或貨物圍護系統鄰接船體的結構上應設置溫度指示裝置。此裝置應定期顯示讀數。如合適時，在溫度達到船體鋼材許可的最低溫度時還應發出報警。

13.7.2.3 如應在溫度低於-55℃的狀態下載運貨物且對貨物圍護系統的設計仍為合適時，液貨艙界限面應安裝足夠數量的溫度指示裝置，以核實未出現不良的溫度梯度。

13.7.2.4 為了設計驗證和確定單個或系列船上初始變冷程序的有效性，1個液貨艙應設有超過13.7.2.1要求的設備。這些設備可為臨時設備或固定設備，對於系列船，只需裝在第1艘船上。

13.8 自動化系統

13.8.1 如使用自動化系統進行控制、監控/報警或本規則要求的安全功能，本節要求應適用。

13.8.2 自動化系統應按照公認標準進行設計、安裝和試驗。

13.8.3 硬件應能經證明通過型式認可或其他方式適合在海上環境使用。

13.8.4 軟件應設計成並經證明易於使用，包括試驗、操作和維護。

13.8.5 用戶界面應設計成控制的設備能一直以安全有效的方式操作。

13.8.6 自動化系統應佈置成硬件故障或操作員的失誤不會導致不安全的狀況。應提供足夠的安全措施防止不正確的操作。

13.8.7 控制、監控/報警和安全功能之間應保持適當的分隔以限制單個故障的影響。這應包括要求提供指定功能的自動化系統的所有部分，包括連接設備和供電。

13.8.8 自動化系統應佈置成保護軟件配置和參數免受未經授權或非預期的改變。

13.8.9 變更過程的管理應用於防護修改未預期的後果。結構變化和認可的記錄應保持在船上。

13.8.10 綜合系統的制定和維護過程應按照公認標準。這些過程應包括適當的風險標識和管理。

13.9 系統綜合

13.9.1 必要的安全功能應設計成在正常營運和故障情況下，對人員傷害或對設備或環境破壞的風險降至主管機關可接受的程度。功能

應設計成具有故障安全性。系統綜合的作用和職責應清晰定義並經相關方同意。

13.9.2 每個組件子系統的功能要求應清晰定義以確保綜合系統滿足功能和規定的安全要求，並考慮到受控設備的任何限制。

13.9.3 應使用適當的風險技術確定綜合系統關鍵的危險。

13.9.4 綜合系統應有適當的反向控制設備。

13.9.5 綜合系統一部分的故障不應影響其他部分的功能，直接依靠缺陷部分的功能除外。

13.9.6 綜合系統的操作應至少與與單個設備或系統一起使用一樣有效，

13.9.7 應證明正常操作和故障情況下必要的機器或系統的完整性。

第14章
人員保護

目的

確保為船上人員提供保護設備，並考慮到日常操作或緊急情況和裝卸貨品可能的短期或長期影響。

14.1 保護設備

14.1.1 為了保護從事正常貨物作業的船員，在考慮了所載貨品的

特性後，應對船員提供包括符合公認的國家或國際標準的眼睛保護在內的合適的保護設備。

14.1.2 應將本章要求的個人保護和安全設備適當地保存在位於容易接近的處所且具有明顯標誌的櫃子內。

14.1.3 對於壓縮空氣設備，應由負責的高級船員至少每月進行1次檢查。並將檢查結果記錄在航行日誌內。該設備也應由適任人員至少每年進行1次檢查和試驗。

14.2 急救設備

14.2.1 應在易於接近之處放置一副擔架，以便能從甲板以下的處所用其抬起受傷人員。

14.2.2 對於附錄2中所示的《國際散裝運輸液化氣體適裝證書》中所列的貨物，基於醫療急救指南（MFAG）的要求，應在船上配備醫藥急救設備，包括氧氣復甦設備。

14.3 安全設備

14.3.1 除按11.6.1所要求的消防人員的裝備以外，還應提供足夠的且不少於3整套的安全設備。每套應提供足夠的人員保護以允許進入充滿氣體的處所內工作。該設備應考慮到附錄2中所示的《國際散裝運輸液化氣體適裝證書》中所列的貨物的性質。

14.3.2 每整套安全設備應包括：

.1 1具不用儲存氧氣的自給式正壓空氣呼吸器（包括整個面罩），其容量至少為1200ℓ的自由空氣。每套應

與11.6.1中的要求相容；

.2 符合公認標準的保護服、長靴和手套；

.3 配有腰帶的鋼芯援救繩；和

.4 防爆燈。

14.3.3 應配備能提供足量的壓縮空氣的設施，並應由下列設施組成：

.1 14.3.1要求的至少1具呼吸器配套充滿空氣的備用空氣瓶；

.2 1台適於供應所需純度的高壓空氣並具有足夠容量且能連續操作的空氣壓縮機；和

.3 1個能對被用於14.3.1所要求的呼吸器的備用空氣瓶進行充氣的充氣閥箱。

14.4 用於各種貨品的人員保護要求

14.4.1 本節要求應適用於載運第19章表中“i”欄內所列貨品的船舶。

14.4.2 應對船上每一人員提供適宜於在應急逃生時用的呼吸防毒面具和眼睛保護設備，但需符合下列要求：

.1 不能接受過濾式呼吸防毒面具；

.2 自給式呼吸器應具有至少能持續工作15min的能力；和

.3 應急逃生呼吸防毒面具不應被用作滅火或貨物裝卸，並應將這一要求作出標誌。

14.4.3 應在甲板上設置1個或多個標有適當標誌的洗除污染的噴淋頭和眼睛沖洗設備，並考慮到船舶的大小和佈置。噴淋頭和眼睛沖洗設備應在所有環境條件下均可予以使用。

14.4.4 14.3.2.2要求的保護服應氣密。

第15章
液貨艙的充裝極限

目的

確定能裝載的貨物的最大數量。

15.1 定義

15.1.1 *充裝極限（FL）*係指當液體貨物達到基準溫度時，液貨艙的最大液體體積與整個液貨艙體積之比。

15.1.2 *裝載極限（LL）*係指最大許可的液體體積與液貨艙可裝載體積之比。

15.1.3 僅在本章範圍內，*基準溫度*係指：

.1 當未配備第7章所述的貨物蒸氣壓力/溫度控制設施時，在壓力釋放閥調定壓力下與貨物蒸氣壓力相應的溫度；和

.2 當配備第7章所述的貨物蒸氣壓力/溫度控制設施時，可以是在裝貨終止時、運輸期間或卸貨時的溫度，取最高者。

15.1.4 *無限航區的環境設計溫度*係指海水溫度32℃和空氣溫度45℃。然而，對於航行於限制航區或在限制期限內航行的船舶，並且在考慮了其液貨艙的任何絕熱情況後，主管機關可接受更低的溫度值。反之，對於一直在較高環境溫度區域航行的船舶，可要求較高的溫度值。

15.2 一般要求

液貨艙的最大充裝極限應確定為蒸氣處所在基準溫度下具有最小體積以允許：

.1 儀器的公差，例如液位和溫度錶；

.2 壓力釋放閥調定壓力和8.4中所述的最大允許上升之間貨物的體積膨脹；和

.3 操作裕量，並考慮到裝載完成後回流至液貨艙的液體、操作員的反應時間和閥的關閉時間，見5.5和18.10.2.1.4。

15.3 默認充裝極限

液貨艙充裝極限（FL）的默認值應為在基準溫度下98%。例外值應符合15.4的要求。

15.4 增加的充裝極限的確定

15.4.1 在8.2.17規定的橫傾和縱傾條件下可允許大於15.3中規定的98%極限的充裝極限，只要：

.1 在液貨艙內無隔開的蒸氣存留死角；

.2 壓力釋放閥進口佈置應留在蒸氣處所；和

.3 下列各項需有裕量：

.1 按照8.4.1，液體貨物由於壓力從MARVS增加至全流釋放壓力造成體積膨脹：

.2 最小0.1%液貨艙體積的操作裕度；和

.3 儀器（例如液位和溫度錶）的公差。

15.4.2 絕不允許在基準溫度下超過99.5%的充裝極限。

15.5 最大裝載極限

15.5.1 對於液貨艙的最大裝載極限L_L由下式確定：

$$LL = FL\frac{\rho_R}{\rho_L}$$

式中：

LL= 15.1.2中規定的裝載極限，用百分數表示；

FL= 15.3或15.4中規定的充裝極限，用百分數表示；

ρ_R= 在基準溫度下貨物的相對密度；和

ρ_L= 在裝載溫度下貨物的相對密度。

15.5.2 如果液貨艙的透氣系統已按8.2.18批准，則主管機關可允許C型獨立液貨艙按15.5.1中的公式裝載，相對密度ρ_R定義如下：

ρ_R= 貨物在裝貨終止、運輸期間或卸貨時，在15.1.4的環境設計溫度狀態下，可能達到的最高溫度下的貨物相對密度。

本條不適用於要求用1G型船舶運輸的貨品。

15.6 向船長提供的資料

15.6.1 應向船舶提供一份文件，規定每個液貨艙和貨品在每種適用的裝載溫度以及最高基準溫度下的最大許可裝載極限。該文件中的信息應經主管機關或代表主管機關的被認可組織認可。

15.6.2 壓力釋放閥已經調定的壓力也應列於文件中。

15.6.3 上述文件的副本應由船長負責長期保存在船上。

第16章
用貨物作燃料

目的

確保安全使用貨物作燃料。

16.1 通則

除16.9的規定外，甲烷（液化天然氣）是其蒸氣或蒸發氣體可被用於A類機器處所的唯一貨物，且僅限用於這些處所中的系統（例如

鍋爐、惰性氣體發生器、內燃機、氣體燃燒裝置和燃氣輪機）。

16.2 用貨物蒸氣作燃料

本節涉及在系統（例如鍋爐、惰性氣體發生器、內燃機、氣體燃燒裝置和燃氣輪機）中用貨物蒸氣作燃料。

16.2.1 對於氣化的液化天然氣，燃料供應系統應符合16.4.1、16.4.2和16.4.3的要求。

16.2.2 對於氣化的液化天然氣，用氣設備應無可見火焰並應保持上煙道排放溫度低於535℃。

16.3 設有用氣設備的處所的佈置

16.3.1 應對用氣設備所在的處所裝設機械通風系統，其佈置成能避免在該區域氣體積聚，並考慮到蒸氣密度和潛在的着火源。應將通風系統與其他處所的通風系統分開。

16.3.2 在這些處所內，特別在空氣循環較差的區域內，應裝設氣體探測器。氣體探測系統應符合第13章的要求。

16.3.3 位於16.4.3中所述的雙層壁管或管道內的電氣設備應符合第10章的要求。

16.3.4 可能含有氣體燃料或被氣體燃料污染的所有透氣管和抽氣管應通至機器處所外的安全位置並裝設防火網。

16.4 氣體燃料供應

16.4.1 ***通則***

16.4.1.1 本節要求應適用於貨物區域外的氣體燃料供應管路。燃料管路不應通過起居處所、服務處所、電氣設備室或控制站。管線佈置應考慮諸如儲藏室或機器裝卸區域等區域中由於機械破損造成的潛在的危險。

16.4.1.2 應提供能對位於機器處所內的氣體燃料管系進行惰化和除氣的設施。

16.4.2 *泄漏探測*

應提供連續監測和報警以指示圍蔽處所中管路系統的泄漏並關閉相關氣體燃料供應。

16.4.3 *燃料供應管路的佈置*

燃料管路可通過或延伸至除16.4.1中所述處所外的圍蔽處所，只要其滿足下列一個條件：

.1 燃料管應為雙層壁設計，同心管之間的空間用惰性氣體加壓至大於氣體燃料的壓力。惰性氣體壓力下降時，16.4.6要求的主氣體燃料閥自動關閉；或

.2 燃料管安裝在通風管或管道內，機械抽風的排量至少為30次/h，並佈置成能維持其壓力低於大氣壓力。機械通風按照第12章。當管路內有燃料時，通風系統始終保持運轉，在排風系統不能產生和維持所要求的空氣流量時，16.4.6要求的主氣體燃料閥自動關閉。進口或管道可來自非危險機器處所，通風出口在安全位置。

16.4.4 ***壓力大於1MPa的氣體燃料要求***

16.4.4.1 高壓燃料泵/壓縮機和消耗裝置之間的燃料輸送管線應用能控制高壓管線故障的雙層壁管系統保護，並考慮到壓力和低溫的影響。可接受貨物區域內至16.4.6要求的隔離閥的單層壁管。

16.4.4.2 也可接受16.4.3.2中的佈置，只要管道或圍壁通道能按照16.4.7的要求控制高壓管線故障，並考慮到壓力和可能的低溫的影響，且外管或圍壁通道的進口和排氣口位於貨物區域。

16.4.5 ***用氣設備的隔離***

每個用氣裝置的供應管路應設有自動雙阻塞和排放的氣體燃料隔離，在正常和緊急操作情況下排放至安全處所。自動閥應佈置成不會在失電時處於關閉位置。在包含多個消耗裝置的處所，一個消耗裝置的關閉不應影響向其他裝置的供氣。

16.4.6 ***設有用氣設備的處所***

16.4.6.1 應有可能用貨物區域內的單獨總閥隔離至設有用氣設備或氣體燃料供應管路通過的每個單獨處所的氣體燃料供應。至處所的氣體燃料供應的隔離不應影響至設有用氣設備（如其位於兩個或以上處所內）的其他處所的氣體供應，且不應造成推進或電力喪失。

16.4.6.2 如果供氣系統周圍的雙屏壁由於空氣進口或其他開口而不連續，或如果有任何點會使單個故障導致泄漏至處所，處所的單獨總閥應在下列情況下：

.1 由以下自動操作：

.1 處所內的氣體探測；

.2 雙層壁管的環形處所中的泄漏探測；

.3 處所內其他艙室中的泄漏探測，包含單層壁氣體管道；

.4 雙層壁管的環形處所中通風失效；和

.5 處所內其他艙室中通風失效，包含單層壁氣體管道；和

.2 從處所內手動操作，且至少一個遠離的位置。

16.4.6.3 如果供氣系統周圍的雙屏壁連續，可向處所內每個用氣設備提供位於貨物區域內的1個單獨總閥。單獨總閥應在下列情況下：

.1 由以下自動操作：

.1 該單獨總閥服務的雙層壁管的環形處所中的泄漏探測；

.2 含有作為由單個總閥服務的供應系統一部分的單層壁氣體管道的其他艙室中的泄漏探測；和

.3 雙層壁管的環形處所中通風失效或壓力失效；和

.2 從處所內手動操作，且至少一個遠離的位置。

16.4.7 ***管道結構***

對於機器處所內的氣體燃料管路，應儘可能符合5.1至5.9中的要求。對於該管路，應儘可能採用焊接接頭。對於在按照16.4.3中要求的通

風管或管道內的氣體燃料管路中的未被封閉部分以及位於貨物區域以外的開敞甲板上的氣體燃料管路，均應採用全焊透對接焊接頭並應進行全部的射線檢查。

16.4.8 *氣體探測*

按照本章要求設置的氣體探測系統應在氣體濃度達到爆炸下限的30%時發出報警，並在未達到爆炸下限的60%時，關閉16.4.6要求的氣體燃料總閥（見13.6.17）。

16.5 氣體燃料裝置和相關儲存容器

16.5.1 *氣體燃料的供應*

所有用作燃料的貨物和/或貨物蒸氣的調節設備(加熱器、壓縮機、濾器等）及任何有關的儲存容器均應位於貨物區域內。如果設備是在圍蔽處所內，則應按照12.1對該處所進行通風，按照11.5配備固定滅火系統並按照13.6配備氣體探測系統（如適用）。

16.5.2 *遠程制動*

16.5.2.1 調節用於燃料的貨物的所有旋轉設備應佈置成從機艙手動遠程制動。附加的遠程制動應位於一直易於接近的區域，特別是貨物控制室、駕駛室和消防控制站。

16.5.2.2 在低吸壓或探火情況下，燃料供應設備應自動停止。除另有明文規定外，18.10的要求無需適用於向用氣設備供氣的氣體燃料壓縮機或泵。

16.5.3 *加熱和冷卻介質*

如果氣體燃料調節系統的加熱或冷卻介質返回至貨物區域外的處所，應配備能對介質中的貨物/貨物蒸氣進行探測和報警的設施。任何透氣管出口應通至安全位置並裝設有效的經認可的防火網。

16.5.4 *管道和壓力容器*

氣體燃料供應系統中裝設的管路或壓力容器應符合第5章的規定。

16.6 對主鍋爐的特殊要求

16.6.1 *佈置*

16.6.1.1 每一鍋爐應具有1個獨立的排氣上煙道。

16.6.1.2 每一鍋爐應具有一個專門的強力通風系統。鍋爐強力通風系統之間的交叉可用於應急使用，只要保持任何相關安全功能。

16.6.1.3 鍋爐燃燒室和鍋爐上煙道應設計成能防止氣體燃料的任何積聚。

16.6.2 *燃燒設備*

16.6.2.1 燃燒器系統應為雙燃料式，以能適合於單獨燃燒油類或氣體燃料或同時燃燒油和氣燃料。

16.6.2.2 燃燒器應設計成能在所有失火條件下保持穩定的燃燒。

16.6.2.3 如果氣體燃料供應中斷，應設有自動系統在不中斷鍋爐燃燒的情況下從氣體燃料作業轉換到油類燃料作業。

16.6.2.4 氣體噴嘴和燃燒器控制系統應使氣體燃料只能由建立的

燃油火焰點燃，除非鍋爐和燃燒設備設計成由氣體燃料點燃並經被認可組織認可。

16.6.3 *安全*

16.6.3.1 應有佈置確保在沒有實現和保持良好的點火動作時，能自動切斷流向燃燒器的氣體。

16.6.3.2 在每個氣體燃燒器的管路上應設置1個手動截止閥。

16.6.3.3 應設有在燃燒器熄火後能使用惰性氣體自動清洗燃燒器的供氣管路的裝置。

16.6.3.4 16.6.2.3要求的自動燃料轉換系統應用報警器進行檢測以確保連續可用。

16.6.3.5 應採取措施，以便在所有燃燒器熄滅的情況下，使鍋爐燃料室能自動進行點火前的驅氣。

16.6.3.6 應採取能對鍋爐進行人工驅氣的措施。

16.7 對氣體燃燒的內燃機的特殊要求

雙燃料發動機係指使用氣體燃料（調節油）和燃油的發動機。燃油可包括蒸餾和殘留燃料。只用氣的發動機係指只使用氣體燃料的發動機。

16.7.1 *佈置*

16.7.1.1 如果氣體以空氣混合物的形式通過公用集管，在每個氣缸頭前應安裝防焰器。

16.7.1.2 每個發動機應有其自身獨立的排氣。

16.7.1.3 排氣應能防止未燃氣體燃料的任何積聚。

16.7.1.4 除非設計成強度能承受由於點燃的氣體泄漏造成的最壞情況的過壓，空氣進氣集管、掃氣處所、排氣系統和曲軸箱應設有合適的壓力釋放系統。壓力釋放系統應通往安全位置，遠離人員。

16.7.1.5 對於曲軸箱、集液槽和冷卻系統，每個發動機應設有獨立於其他發動機的透氣系統。

16.7.2 ***燃燒設備***

16.7.2.1 充裝氣體燃料前，應驗證正確使用每個裝置上的調節油噴射系統。

16.7.2.2 對於火花點火發動機，如果在打開氣體供應閥後，發動機檢測系統未在發動機規定的時間內探測到點燃，應自動關閉發動機並終止起動順序。應確保任何未點燃的氣體混合物從排氣系統驅氣。

16.7.2.3 對於設有調節油噴射系統的雙燃料發動機，應設有自動系統在發動機功率波動最小的情況下從氣體燃料作業轉換到油類燃料作業。

16.7.2.4 如果按照16.7.2.3的佈置在氣體燃燒時發動機操作不穩定，發動機應自動轉換至燃油模式。

16.7.3 ***安全***

16.7.3.1 發動機停止期間，氣體燃料應在着火源前自動關閉。

16.7.3.2 應設有裝置確保在點燃前排放氣體系統中無未燃燒的氣

體燃料。

16.7.3.3 曲軸箱、貯槽、掃氣處所和冷卻系統透氣管應設有氣體探測（見13.6.17）。

16.7.3.4 發動機設計中應規定允許連續監控曲軸箱內可能的着火源。曲軸箱內設置的儀器應按照第10章的要求。

16.7.3.5 應設有裝置監控和探測操作期間可能導致排氣系統中未燃氣體燃料的不良燃燒或未着火。如果探測到該情況，應關閉氣體燃料供應。排氣系統內設置的儀器應按照第10章的要求。

16.8 對燃氣輪機的特殊要求

16.8.1 *佈置*

16.8.1.1 每個渦輪機應有其自身獨立的排氣。

16.8.1.2 排氣應能防止未燃氣體燃料的任何積聚。

16.8.1.3 除非設計成強度能承受由於點燃的氣體泄漏造成的最壞情況的過壓，壓力釋放系統應適當設計並安裝至排氣系統，並考慮到氣體泄漏引起的爆炸。排氣上煙道內的壓力釋放系統應通往非危險位置，遠離人員。

16.8.2 *燃燒設備*

應設有自動系統在發動機功率波動最小的情況下方便快速地從氣體燃料作業轉換到油類燃料作業。

16.8.3 *安全*

16.8.3.1 應設有裝置監控和探測操作期間可能導致排氣系統中未燃氣體燃料的不良燃燒。如果探測到該情況，應關閉氣體燃料供應。

16.8.3.2 每個渦輪機應設有自動關閉設備以防止高排氣溫度。

16.9 替代燃料和技術

16.9.1 如果主管機關接受，其他貨物氣體可用作燃料，只要確保達到與本規則中天然氣相同的安全等級。

16.9.2 不應允許使用標識為有毒貨品的貨物。

16.9.3 對於除液化天然氣外的貨物，燃料供應系統應符合16.4.1、16.4.2、16.4.3和16.5的要求，並應包括防止系統中蒸氣凝聚的設施。

16.9.4 液化氣體燃料供應系統應符合16.4.5。

16.9.5 除16.4.3.2的要求外，通風進口和出口還應在機器處所外的非危險區域內。

第17章

特殊要求

目的

制定關於具體貨物的附加要求。

17.1 通則

本章的要求適用於本規則第19章表中的“i”欄引述到本章的貨物。這些規定是對本規則一般要求的補充。

17.2 結構材料

在正常操作期間，可能與貨物接觸的材料應能抵抗氣體的腐蝕作用。此外，用於液貨艙及其所屬管路、閥、附件和與貨物液體或蒸氣直接接觸的其他設備的下述結構材料不得用於在本規則第19章表中的“i”欄所引述的某些貨品：

.1 汞、銅和含銅合金及鋅；

.2 銅、銀、汞、鎂和其他乙炔化合物組成的金屬；

.3 鋁和含鋁合金；

.4 銅、銅合金、鋅和鍍鋅鋼；

.5 鋁、銅和兩者中任何一種合金；和

.6 銅和含銅量大於1%的銅合金。

17.3 獨立液貨艙

17.3.1 只能在獨立液貨艙內載運貨品。

17.3.2 應採用C型獨立液貨艙載運貨品，且應滿足7.1.2的規定。確定液貨艙的設計壓力時應考慮各種充填壓力或蒸氣卸載壓力。

17.4 製冷系統

17.4.1 只能採用7.3.1.2所述的間接系統。

17.4.2 對於載運易形成危險過氧化物的貨品的船舶，不允許使重新冷凝的貨物形成無法抑制的液體滯積囊，這可用下述任一方法予以實現：

.1 採用7.3.1.2所述的在液貨艙內裝設冷凝器的間接系統；或

.2 分別採用7.3.1.1和.3中所述的直接系統或混合系統，或採用7.3.1.2中所述的在液貨艙外設有冷凝器的間接系統。而冷凝系統的設計應避免在任何地方積聚和滯留液體。如不可能，則應在容易積聚和滯留液體的位置的上方添加抑制液體。

17.4.3 如果船舶在連續載運17.4.2所述貨品的航行期間進行次壓載航行，則在進行壓載航行前應除去所有非抑制液體。如果在連續載運這些貨物的航行之間需載運第2種貨物，則在裝載第2種貨物前對再液化系統應進行徹底排放和驅氣，驅氣時應使用惰性氣體或使用第2種貨物的蒸氣（如與原貨物相容時）。應採取切實的步驟確保貨物系統中不積聚聚合物或過氧化物。

17.5 要求1G型船舶的貨物

17.5.1 應對直徑超過75mm的貨物管路上的所有對接接頭進行100%的射線檢查。

17.5.2 不應將氣體取樣管路引至或通過非危險區域。當蒸氣濃度達到限制值時，應能觸發13.6.2所述的報警器。

17.5.3 不允許將13.6.5規定的可攜式設備作為替代裝置。

17.5.4 貨物控制室應位於非危險區域，此外，所有儀器應為間接型。

17.5.5 為防止人員受到主要貨物釋放的影響，應在居住區域內提供一個安全處所，對其設計和配備應使主管機關滿意。

17.5.6 儘管3.2.4.3有規定，不應允許通過面向貨物區域的門進入首樓處所，除非設有按3.6要求的空氣閘。

17.5.7 儘管3.2.7有規定，不應允許通過面向貨物區域的門進入轉塔系統的控制室和機器處所。

17.6 排除蒸氣處所中的空氣

裝載前應除去液貨艙及有關管系中的空氣，隨後依次應用下述方法驅除空氣：

.1 輸入惰性氣體以保持正壓力。惰性氣體的儲存或生產量應足以滿足正常操作的要求以及補償釋放閥的泄漏。惰性氣體中的含氧量在任何時候均不得超過0.2%（按容積計）；或

.2 控制貨物溫度，使其在任何時候保持正壓力。

17.7 濕度控制

對不易燃且可能具有腐蝕性或與水會起危險反應的氣體，應進行濕度控制，以確保液貨艙在裝載前乾燥，同時，在卸載期間，應輸入乾燥空氣或貨物蒸氣以防止出現負壓力。就本條而言，乾燥空氣係指在大氣壓力下具有-45℃或更低溫度的露點的空氣。

17.8 抑制

在整個航行期間，為了防止貨物發生自身反應（例如聚合或二聚），

應確保使貨物受到充分的抑制。船上應備有製造廠提供的證書，證書上應表明：

.1 所加入的抑制劑的名稱和數量；

.2 加入抑制劑的日期和在正常情況下預計的有效期；

.3 影響抑制劑的溫度限制；和

.4 當航行期超過抑制劑的有效期時應採取的措施。

17.9 透氣出口處的防火網

當載運本節所涉及的貨物時，應在液貨艙的透氣出口處配備易於更換的有效防火網或認可型的安全罩。設計防火網和安全罩時，應適當注意其在惡劣氣候條件下由於貨物蒸氣的凝聚或結冰而引起阻塞的可能性。當載運本節未涉及的貨物時，按8.2.15要求，防火網應取下並由保護網替代。

17.10 每個液貨艙的最大允許裝貨量

如載運本節所涉及的貨物時，任一液貨艙的裝貨量應不超過3000m^3。

17.11 貨泵和排放裝置

17.11.1 在裝載易燃液體之前以及在載運和卸載期間，應對設有深潛式電動泵的液貨艙的蒸氣處所進行惰化直至其達到正壓力。

17.11.2 二乙醚和乙烯基乙醚貨物只能採用深井泵或由液壓操縱的潛水泵卸貨。這些泵應設計成能避免液壓力作用於軸填料函上的型

式。

17.11.3 如貨物系統按規定壓力設計，則惰性氣體置換法可用於C型獨立液貨艙的卸貨。

17.12 氨

17.12.1 無水氨可能會使用碳錳鋼或鎳鋼製造的容器和處理系統產生應力腐蝕裂紋。為使產生這種危險的可能性降至最小，應採取17.12.2至17.12.8所述的適當措施。

17.12.2 當採用碳錳鋼時，對於液貨艙、處理用壓力容器和貨物管路，應用細晶粒鋼製造，其標定最低屈服強度應不超過355N/mm^2，而其實際屈服強度不超過440N/mm^2。還應採取下列之一的有關結構或操作方面的措施：

.1 應使用標定的最低抗拉強度不超過40N/mm2的較低強度材料；或

.2 應對液貨艙等進行焊後消除應力的熱處理；或

.3 運載溫度最好保持在接近貨物的沸點-33℃，但決不能高於-20℃；或

.4 氨中應含有不少於0.1%的水（按重量比），並應向船長提供文件證明。

17.12.3 如果使用17.12.2規定的那些鋼材以外的具有更高屈服性能的碳錳鋼，則應對已完工的液貨艙和管路等進行焊後消除應力的熱處理。

17.12.4 對於處理用壓力容器和冷卻泵系統中冷凝部分的管路，如是用17.12.1中所述的材料製造，則應對其進行焊後消除應力的熱處理。

17.12.5 焊接材料的抗拉和屈服性能應超過液貨艙或管路材料的抗拉和屈服性能中一個最小的實際數值。

17.12.6 含有高於5%鎳的鎳鋼和不符合17.12.2和17.12.3的要求的碳錳鋼，因為其特別容易受氨應力腐蝕裂紋的影響，故不應將其作為製造載運此種貨物的容器和管路系統的材料。

17.12.7 當載運溫度符合17.12.2.3中的規定時，可以使用含鎳不超過5%的鎳鋼。

17.12.8 為了使氨應力腐蝕裂紋的危險降至最小，最好能將溶解的氧含量保持在2.5ppm（按重量計）以下。達到這個目的的這個最好辦法是在液態氨被注入前，將液貨艙中的平均含氧量降至下表中根據載運溫度*T*所得到的函數值以下：

T（℃）	O_2（%，按容積計）
-30及以下	0.9
-20	0.5
-10	0.28
0	0.16
10	0.1
20	0.05
30	0.03

對於中間溫度的含氧量，可用內插法直接求得。

17.13 氯

17.13.1 *貨物圍護系統*

17.13.1.1 每一液貨艙的容積應不超過600m^3，而所有液貨艙的總容積應不超過1200m^3。

17.13.1.2 液貨艙的設計蒸氣壓力應不低於1.35MPa（參見7.1.2和17.3.2）。

17.13.1.3 應對在上甲板以上的液貨艙突出部分配備保護設施，以防在被火焰包圍時所產生的熱輻射。

17.13.1.4 每一液貨艙應配置2隻壓力釋放閥。在液貨艙和壓力釋放閥之間應安裝用合適材料制成的安全膜片。安全膜片的破裂壓力應比壓力釋放閥的開啟壓力低0.1MPa，應將釋放閥的開啟壓力定為液貨艙的設計蒸氣壓力，但不低於1.35MPa（表壓）。應通過超流量閥使安全膜片與釋放閥之間的空隙與壓力錶和氣體探測系統相連接。應採取措施以保持這一空隙的壓力在正常作業時保持或接近大氣壓力。

17.13.1.5 應將壓力釋放閥出口佈置成能使船上以及周圍環境的危險降至最低限度。釋放閥的滲漏應全部引至吸收裝置，以儘可能降低氣體的濃度。應將釋放閥的排放管佈置在船的前端，能在甲板平面上向舷外排放，並設有能選擇向左或右舷排放的裝置，同時還應有一個機械聯鎖裝置，以確保有一根排放管始終是開通的。

17.13.1.6 主管機關和港口主管當局可要求在規定的最大壓力下以冷凍狀態載運氯。

17.13.2 ***貨物管系***

17.13.2.1 進行貨物卸載時應採用岸上的壓縮氮蒸氣、乾燥空氣或其他可接受的氣體或全潛式泵。船上的貨物卸貨壓縮機不應用於此用途。在卸貨期間，液貨艙蒸氣處所內的壓力應不超過1.05MPa錶壓力。

17.13.2.2 貨物管系的設計壓力應不小於2.1MPa錶壓力。貨物管的內徑應不超過100mm。對於管系熱變形的補償只能採用彎管。應儘量限制使用法蘭接頭，如要使用法蘭，則應採用帶有槽和舌片的焊頸型法蘭。

17.13.2.3 應將貨物管系的釋放閥的排放管接至吸收裝置，設計釋放閥系統時，應考慮該裝置產生的流量限制（參見8.4.3和8.4.4）。

17.13.3 材料

17.13.3.1 對於液貨艙和貨物管系，應採用適合於貨物和溫度為-40℃的鋼材進行製造，即使擬採用較高的運輸溫度，也應如此。

17.13.3.2 應消除液貨艙的熱應力，不允許以消除機械應力作為其等效措施。

17.13.4 ***儀器：安全裝置***

17.13.4.1 船上應設有與貨物管系和液貨艙相連接的氣吸收裝置。吸收裝置應具有按合理的吸收率至少能中和貨艙總容量的2%的能力。

17.13.4.2 在對液貨艙進行除氣期間，不應將蒸氣排向大氣。

17.13.4.3 應配備能探測氣濃度至少為1ppm（按容積計）的氣體探測系統。吸氣點應位於：

.1 接近貨艙處所底部；

.2 從安全釋放閥引出的管子內；

.3 氣體吸收裝置的出口處；

.4 起居、服務和機器處所以及控制站的通風系統的進口處；和

.5 甲板上貨物區域的前端、船中和後端。僅要求在貨物操作和除氣作業期間使用。

氣體探測系統應配備聽覺和視覺報警器，其調定點為5ppm。

17.13.4.4 每一液貨艙應配備1個高壓報警器，在壓力達到1.05MPa錶壓力時發出聽覺報警。

17.13.5 ***人員保護***

17.5.5 要求的圍蔽處所應滿足下列要求：

.1 應能從開敞甲板和起居處所通過空氣閘方便而迅速地進入處所，並能快速關閉處所並保證其氣密性；

.2 在按14.4.3的要求設置的能消除污染的噴淋設備中應有1套位於該處所的空氣閘附近；

.3 該處所應設計成能容納船上的全部船員，並能提供維持不少於4h的未受污染的空氣源；和

.4 處所內應配備1套氧氣醫治療設備。

17.13.6 ***液貨艙充裝極限***

17.13.6.1 當擬載運氯氣時，15.1.3.2的要求不適用。

17.13.6.2 裝載後，液貨艙蒸氣處所內中的氯氣含量應大於80%（按容積計）。

17.14 環氧乙烷

17.14.1 載運環氧乙烷時，17.18的要求應適用，並應滿足本節附加和修改要求。

17.14.2 甲板液貨艙不應用於載運環氧乙烷。

17.14.3 環氧乙烷的貨物圍護系統和管系不能使用416型和442型的不鏽鋼及鑄鐵。

17.14.4 裝載前，應對液貨艙進行徹底有效地清洗，以除去液貨艙內及有關管路中前次所裝貨物的痕跡，但前次所裝貨物為環氧乙烷、環氧丙烷或是這些貨品的混合物除外。對非不鏽鋼液貨艙裝載氨的情況應予特別注意。

17.14.5 環氧乙烷只能採用深井泵或惰性氣體置換法卸貨。泵的佈置應符合17.18.15的規定。

17.14.6 環氧乙烷只能在冷卻狀態下載運，並應保持其溫度低於30℃。

17.14.7 壓力釋放閥的調定壓力應不低於0.55MPa錶壓力。最大調定壓力應經主管機關特別批准。

17.14.8 對於17.18.27所要求的氮氣保護氣墊，應能在任何時候使液貨艙蒸氣處所內的氮濃度不低於45%（按容積計）。

17.14.9 在裝載前及當液貨艙內含有環氧乙烷液體或蒸氣的任何時間，應用氮氣對液貨艙進行惰化。

17.14.10 在火焰包圍貨物圍護系統的情況下，17.18.29和11.3所要求的水霧系統應能自動噴灑。

17.14.11 應設有貨物投棄裝置，以便在發生不可控制的環氧乙烷自身反應時，緊急排放環氧乙烷。

17.15 獨立的管路系統

應設置1.2.47規定的獨立的管路系統。

17.16 甲基乙炔一丙二烯混合物

17.16.1 應對甲基乙炔一丙二烯混合物適當地進行穩定性處理以便於運輸。此外，對混合物進行製冷期間，應規定其溫度和壓力的上限。

17.16.2 可接受的具有穩定組合的貨物的舉例如下：

.1 組合1：

.1 甲基乙炔對丙二烯的最大摩爾比為3：1；

.2 甲基乙炔對丙二烯的最大組合濃度為65摩爾%；

.3 丙烷、丁烷和異丁烷的最小組合濃度為24摩爾%，其中，至少1/3（以摩爾為基準）應為丁烷以及1/3為丙烷；

.4 丙烯和丁二烯的最大組合濃度為10摩爾%。

.2 組合2：

.1 甲基乙炔和丙二烯的最大組合濃度為30摩爾%；

.2 甲基乙炔的最大濃度為20摩爾%；

.3 丙二烯的最大濃度為20摩爾%；

.4 丙烯的最大濃度為45摩爾%；

.5 丁二烯和丁烯的最大組合濃度為2摩爾%；

.6 飽和C4碳氫化合物的最小濃度為4摩爾%；和

.7 丙烷的最小濃度為25摩爾%。

17.16.3 只要所提供的混合物的穩定性經驗證能使主管機關滿意，也可接受其他的組合。

17.16.4 如果船舶具有直接蒸氣壓縮製冷系統，根據貨物組合成分確定的壓力和溫度的界限，該系統應滿足下列要求。對於17.16.2中所列貨物組合的舉例，應配備下列設備：

.1 1台蒸氣壓縮機，在其運行期間，溫度的升高不應超過60℃，壓力的增加不應大於1.75MPa錶壓力，且在連續運行期間，不允許蒸氣滯留在壓縮機內；

.2 壓縮機的每一級排放管路或往復式壓縮機同一級內的每隻氣缸均應具有：

.1 2隻被設定在60℃或60℃以下溫度時動作的溫度激勵關閉開關；

.2 1隻被設定在壓力為1.75MPa或以下錶壓力時動作的壓力激勵關閉開關；和

.3 1隻被調定在壓力為1.8MPa或以下錶壓力時釋放的安全釋放閥；

.3 應將.2.3所要求的釋放閥通向至符合8.2.10、8.2.11和8.2.15要求的桅杆處，且不應將氣體釋放至壓縮機的吸入管內；和

.4 1個報警器，當高壓開關或高溫開關動作時，應能在貨物控制處所和駕駛室發出聲響警報。

17.16.5 對於裝載甲基乙炔一丙二烯混合物的液貨艙，其管路系統包括貨物製冷系統應是獨立的（如1.2.28中的規定）或應與其他液貨艙的管系和製冷系統隔離（如1.2.47中的規定）。此種隔離適用於所有液體和蒸氣的透氣管路以及其他可能的連接管路，諸如公用的惰性氣體供應管路。

17.17 氮

結構材料和附屬設備（諸如絕熱材料）應能承受低溫時由於貨物系統各部分氧冷凝和濃縮而產生的高濃度氧的作用。應適當考慮對這些可能產生冷凝的區域進行通風，以避免形成富氧大氣層。

17.18 環氧丙烷和含有環氧乙烷不超過30%（按重量計）的環氧乙烷－環氧丙烷混合物

17.18.1 按本節規定運輸的貨物不應含有乙炔。

17.18.2 除非液貨艙已經適當清洗，否則不應用曾經儲存已知有催化聚合作用的下列3種貨物之一的液貨艙載運這些貨物：

.1 無水氨和氨溶液；

.2 胺和胺溶液；和

.3 氧化物質（例如氯）。

17.18.3 裝載前，應對液貨艙進行徹底有效的清洗，以除去艙內及有關管路中的前次所裝貨物的痕跡，但前次所裝的貨物為環氧丙烷或環氧乙烷－環氧丙烷的混合物除外。對於非不鏽鋼的鋼質液貨艙，在其裝有氨的情況下應予特別注意。

17.18.4 任何情況下，應通過適當的試驗或檢驗，對用於液貨艙及有關管路的清洗方法的有效性進行校核，以查明確無酸性或鹼性物質的痕跡，因由於這些物質的存在，可能會出現危險情況。

17.18.5 初次裝載這些貨物之前，應進入液貨艙進行檢查，以保證液貨艙內無污染物，無大量鐵鏽沉積以及無明顯的結構缺陷。如這些液貨艙連續裝運上述貨物，則此種檢查的間隔期應不超過2年。

17.18.6 載運這些貨物的液貨艙應為鋼質或不鏽鋼結構。

17.18.7 採用沖洗或驅氣方法對裝運過這些貨品的液貨艙及有關管路系統進行徹底的清洗後，該液貨艙仍可載運其他貨物。

17.18.8 所有的閥、法蘭、附件和輔助設備均應為適合於在載運這些貨品中使用的型式，且製造材料應為鋼質或不鏽鋼或符合公認標準。應採用含鉻量不低於11%的不鏽鋼製造閥盤或閥盤面。閥座和閥的其

他易磨損的部件。

17.18.9 對於在閥、法蘭、附件和輔助設備中所用的氣密襯墊，應由不與這些貨品起反應，不溶解於這些貨品，不會降低這些貨品的自燃溫度，且能耐火和具有合適的機械性能的材料予以製造。對於接觸貨物的氣密襯墊的表面，應為聚四氟乙烯（PTFE）或因其惰性而能達到同樣安全程度的其他材料。如經主管機關或代表主管機關的被認可組織批准，可以接受用聚四氟乙烯（PTFE）或類似氟化聚合物的墊料成螺旋形地纏繞的不鏽鋼。

17.18.10 如果使用絕熱材料和填料，則應採用不與這些貨物起反應、不溶解於這些貨品或不會降低這些貨品的自燃溫度的材料。

17.18.11 下列材料通常認為不適用於這些貨品的圍護系統中的氣密襯墊、填料和作類似用途的物件，因此，在取得認可前，要求對這些材料進行試驗：

.1 氯丁橡膠或天然橡膠（當與這些貨品接觸時）；

.2 石棉或石棉的黏合劑；和

.3 含有鎂氧化物的材料，例如礦棉。

17.18.12 裝卸管應延伸至至液貨艙底部或任何集液槽底100mm範圍內。

17.18.13 應以適當方式裝卸貨品，以不致使液貨艙中的氣體排到大氣中去。在液貨艙裝載期間，如由岸上回收貨物蒸氣，則與該貨品的圍護系統相連接的蒸氣回收系統應獨立於所有其他的圍護系統。

17.18.14 在卸貨作業期間，應將液貨艙內的壓力保持在0.007MPa錶壓力以上。

17.18.15 對這種貨物進行卸載時，只能採用深井泵，液壓操作的潛水泵或隋性氣體置換法。應將每台貨物泵佈置成能確保當泵的排放管路被截止或阻塞時，不會使該貨品明顯發熱。

17.18.16 載運這些貨物的液貨艙透氣系統應獨立於載運其他貨物液貨艙透氣系統。應配備能在液貨艙不與空氣相通的情況下對液貨艙內貨物進行取樣的設施。

17.18.17 應在用於駁運這些貨物的軟管上標明：“駁運環氧烷類專用”。

17.18.18 應對載運這些貨品的貨艙處所進行監測。對A型和B型獨立液貨艙周圍的貨艙處所也應進行惰化，並應監測氧的含量，這些處所的含氧量應低於2%。可以採用可攜式的取樣設備。

17.18.19 在拆卸通岸管路之前，應通過安裝在裝載集流管上的合適的閥釋放液體和蒸氣管路中的壓力，不應將這些管路中的液體和蒸氣排到大氣中去。

17.18.20 對於液貨艙，應按其在貨物的裝載、載運或卸載過程中可能遇到的最大壓力進行設計。

17.18.21 對於載運環氧丙烷且設計蒸氣壓力低於0.06MPa的液貨艙以及載運環氧乙烷－環氧丙烷混合物且設計蒸氣壓力低於0.12MPa的液貨艙，均應設有冷卻系統，以保持貨物的溫度能低於基準溫度。對於基準溫度，見15.1.3。

17.18.22 壓力釋放閥的調定值應不小於0.02MPa錶壓力，而對於C型獨立液貨艙，在載運環氧丙烷時，其壓力釋放閥的調定值應不大於0.7MPa錶壓力，在載運環氧乙烷－環氧丙烷混合物時，其壓力釋放閥的調定值應不大於0.53MPa錶壓力。

17.18.23 對裝有這些貨品的液貨艙，其管系應與所有其他液貨艙（包括空載液貨艙）的管系以及所有貨物壓縮機完全隔離。如果裝有這些貨品的液貨艙管系沒有被設計成1.2.28所定義的那種獨立，則應採用拆卸短管、閥或其他管段並在這些位置安裝盲板法蘭的方法，以達到所要求的管系分隔。上述所要求的分隔也適用於所有液體和蒸氣管路、液體和蒸氣的透氣管路以及任何其他可能的連接管路，諸如通用的惰性氣體供應管路。

17.18.24 對於這些貨品，只能按主管機關批准的貨物裝卸設計圖進行運輸。對於所擬定的每一種裝載方案，均應在單獨的裝卸圖中予以表明。在貨物裝卸圖中應標明全部貨物管路系統以及為滿足上述管路分隔要求所需盲板法蘭的安裝位置。經批准准的每份貨物裝卸圖的副本應被存放在船上。在對《國際散裝運輸液化氣體適裝證書》進行簽署時應包括查閱經批准的貨物裝卸圖。

17.18.25 在首次裝載這些貨物及以後每次重新裝載這些貨物之前，應從港口主管當局承認的負責人員處取得證明該船已達到所要求的管系分隔的證書，並應將證書放在船上。盲板法蘭和管路法蘭之間的每一連接處應由負責人員裝上金屬絲並給予鉛封，以保證不致於因疏忽拆卸盲板法蘭。

17.18.26 按照15.5，應註明在所採用的每一裝載溫度下每一液貨艙

的最大許可裝載極限。

17.18.27 載運這些貨物時，應在液貨艙內充以適當的氮氣作為保護氣墊。還應設有氮氣的自動補給系統，以防萬一由於環境條件變化或製冷系統失靈而造成貨物溫度下降致使液貨艙壓力下降至0.007MPa錶壓力以下。船上應配備足量的氮氣以滿足自動壓力控制的需要。應採用商業純度為99.9%（按容積計）的氮氣作為液貨艙的保護氣墊。一組氮氣瓶通過減壓閥與液貨艙連接可以達到有關“自動”的目的。

17.18.28 液貨艙的蒸氣空間在裝載前後應進行試驗，以保證含氧量為2%或以下（按容積計）。

17.18.29 應設置足夠容量的水霧系統，以能有效地覆蓋貨物集管及與裝卸貨物有關的露天甲板管系和液貨艙氣室等周圍的區域。管路和噴嘴應佈置成能使水霧的均勻分佈率達到每分鐘為$10l/m^2$。佈置應保證能使任何溢出的貨物被沖洗乾淨。

17.18.30 在發生涉及貨物圍護系統的火災時，水霧系統應既能就地人工操作又能遙控操作。遙控人工操作應佈置成能從貨物區域外鄰近居住處所的合適位置遙控啟動水霧系統的供水泵和遙控操作系統中任何通常關閉的閥，並在被保護區域發生火災時能易於進入和操作。

17.18.31 除上述水霧要求外，在裝卸作業期間，如環境溫度許可，應有隨時可用的加壓輸水軟管。

17.19 氯乙烯

在添加抑制劑能防止氯乙烯的聚合反應時，17.8的規定適用。在

未添加抑制劑或抑制劑的添加量不足時，按17.6規定使用的任何惰性氣體的含氧量應不超過0.1%（以體積計）。在開始裝載前，還應對液貨艙和管路的惰性氣體進行取樣分析。當載運氯乙烯時，液貨艙內應始終保持正壓，甚至在連續運載這些貨物之間的壓載航行時，也應如此。

17.20 混合C4貨物

17.20.1 按本規則要求單獨載運的貨物（主要是丁烷、丁烯和丁二烯）可按本節規定作為混合物載運。這些貨物可稱為“原C4”、“原丁二烯”、“原蒸汽開裂C4”、“用盡的蒸汽開裂C4”、“C4流”、“C4殘油”或在不同的說明下載運。在所有情況下，由於混合物的丁二烯含量很重要（其潛在有毒和有反應），應查閱材料安全數據單（MSDS）。如認識到丁二烯的蒸氣壓力相對較低，如果該混合物包含丁二烯，其應視作有毒並應採取適當的預防措施。

17.20.2 如按本節規定載運的混合C4貨物包含50%以上的丁二烯，應採用17.8中的抑制劑預防措施。

17.20.3 除非裝載的具體混合物給出液體膨脹係數的具體數據，否則應將貨物視為包含100%成分並具有最高膨脹率來計算第15章的充裝極限限制。

17.21 二氧化碳：高純度

17.21.1 貨物未受控的壓力喪失會造成“升華”且貨物會從液體變成固體狀態。裝載貨物前，應提供特定二氧化碳貨物的準確“3點”溫度，這取決於貨物純度，並應考慮到何時調節貨物儀器。對於載運

的具體貨物，本節中所述的報警和自動行動的設定壓力應設至至少3點以上0.05MPa。純二氧化碳的“3點”出現在0.5MPa（錶壓）和-54.4℃。

17.21.2 如果按照8.2設置的液貨艙釋放閥在打開位置失效，貨物可能固化。為避免這種情況，應設有隔離液貨艙安全閥的設施，當載運該二氧化碳時，8.2.9.2的要求不適用。自安全釋放閥的排放管道應設計成無導致堵塞的障礙物。防護屏不應設在釋放閥排放管道的出口，所以8.2.15的要求不適用。

17.21.3 自安全釋放閥的排放管道不要求符合8.2.10，但應設計成無導致堵塞的障礙物。防護屏不應設在釋放閥排放管道的出口，所以8.2.15的要求不適用。

17.21.4 載運二氧化碳貨物時，應連續監控液貨艙的低壓。貨物控制位置和駕駛室應發出聽覺和視覺報警。如果液貨艙壓力持續降至特定貨物“3點”的0.05MPa範圍內，監控系統應自動關閉所有貨物總管液體和蒸氣閥並停止所有貨物壓縮機和貨泵。18.10要求的應急關閉系統可用於此目的。

17.21.5 液貨艙和貨物管系使用的所有材料應適於營運期間可能出現的最低溫度，其定義為17.21.1中所述的自動安全系統設定壓力下二氧化碳貨物的飽和溫度。

17.21.6 貨艙處所、貨物壓縮機室和二氧化碳會積聚的其他圍蔽處所應連續監控二氧化碳的形成。該固定氣體探測系統替代13.6的要求，即使船舶有C型貨物圍護，應一直監測貨艙處所。

17.22 二氧化碳：回收的質量

17.22.1 17.21的要求也適用於本貨物。此外，如果回收質量二氧化碳貨物包含雜質（例如水、二氧化硫等），其會造成酸腐蝕或其他問題，貨物系統中使用的構造材料也應考慮到腐蝕的可能性。

第18章
操作要求

目的

確保所有涉及貨物作業的船上人員有足夠的關於貨物性質和操作貨物系統的資料，以使其能安全進行貨物操作。

18.1 通則

18.1.1 涉及液化氣體運輸船舶操作的人員應意識到與其安全操作相關的特殊要求和安全操作必需的預防措施。

18.1.2 適用本規則的每艘船上應備有本規則的副本或納入本規則規定的國家法規。

18.2 貨物操作手冊

18.2.1 船舶應配備經主管機關認可的詳細的貨物系統操作手冊副本，以使經培訓人員能安全操作船舶，並適當考慮到允許載運的貨物的危險和特性。

18.2.2 手冊內容應包括但不限於：

.1 貨物從乾塢至乾塢的整個操作，包括液貨艙冷卻和加熱、駁運（包括船至船駁運）、貨物取樣、除氣、壓載、清洗液貨艙和更換貨物的程序；

.2 貨物溫度和壓力控制系統；

.3 貨物系統限制，包括最低溫度（貨物系統和內殼）、最大壓力、駁運速度、充裝極限和晃蕩限制；

.4 氮和惰性氣體系統；

.5 滅火程序：滅火系統的操作和維護以及滅火劑的使用；

.6 用於特種貨物安全操作所需的特殊設備；

.7 固定和可攜式氣體探測；

.8 控制、報警和安全系統；

.9 緊急關閉系統；

.10 按照8.2.8和4.13.2.3變更液貨艙壓力釋放閥設定壓力的程序；和

.11 應急程序，包括液貨艙釋放閥隔離、單艙除氣、進入和應急船至船駁運操作。

18.3 貨物資料

18.3.1 船上應備有供所有有關方面使用並以貨物資料數據單形式的資料，這些資料能為安全載運貨物提供必要的數據。這些資料應

包括所載運的每一種貨品。其具體項目如下：

.1 一份關於貨物安全載運和圍護所必需的物理和化學性能的詳細說明；

.2 與能按照《國際散裝運輸液化氣體適裝證書》在船上載運的其他貨物的反應；

.3 當發生貨物溢出或泄漏時所需要採取的措施；

.4 防備人員意外與貨物接觸的防範措施；

.5 滅火程序和滅火劑；

.6 用於特種貨物安全操作所需的特殊設備；和

.7 應急程序。

18.3.2 按照18.3.1.1向船長提供的物理數據應包括關於不同溫度下相對貨物密度的信息以能按照第15章的要求計算液貨艙充裝極限。

18.3.3 按照18.3.1.3應對大氣溫度下載運貨物溢出的應急計劃應考慮潛在的局部溫度降低（例如當逃逸的貨物已降至大氣壓力）和船體鋼冷卻的潛在影響。

18.4 載運的適合性

18.4.1 船長應確認船上所裝載的每一貨品的數量和特性是在1.4規定的《國際散裝運輸液化氣體適裝證書》和2.2.5規定的《裝載和穩性資料手冊》所述的範圍內，且按《國際散裝運輸液化氣體適裝證書》

第4項的要求，這些貨品已列入其中。

18.4.2 當貨物被混合時應注意避免發生危險的化學反應，下列方面特別重要：

.1 在同一液貨艙內連續裝貨之間所需要的液貨艙清洗程序；和

.2 只有當整個貨物系統，包括（但並不限於）貨物管路、液貨艙、透氣系統和製冷系統，均按1.2.47規定予以隔離時，才能允許同時載運混合時會起化學反應的貨物。

18.4.3 如要求抑制貨物，在離開前應提供17.8要求的證書，否則不得載運貨物。

18.5 在低溫下載運貨物

在低溫下載運貨物時，應注意下列事項：

.1 應嚴格遵守為特定液貨艙、管系和附屬設備所規定的冷卻程序；

.2 所採用的裝載方式應能確保在任何液貨艙、管系或其他附屬設備中未超過設計溫度梯度；和

.3 如設有與貨物圍護系統相關的加熱裝置，對於加熱裝置的操作，應能確保船體結構的溫度不致下降到低於材料的設計溫度。

18.6 貨物駁運操作

18.6.1 船上人員和負責駁運設施的人員應召開貨物操作前的會議。交換的信息應包括擬定貨物駁運操作和應急程序的詳細情況。對於擬定的貨物駁運，應填寫公認的行業清單，並在整個操作期間保持有效的通信聯繫。

18.6.2 貨物駁運操作前，應對必要的貨物裝卸控制和報警裝置進行核查和試驗。

18.7 人員培訓

18.7.1 人員應進行經修正的1978年國際海員培訓、發證和值班標準公約、國際安全管理規則和醫療急救指南（MFAG）要求的液化氣船操作和安全的適當培訓。至少：

.1 應對所有人員在使用船上備有的保護設備方面進行適當培訓，同時還應對他們進行與其職務相適應的、在緊急情況下所必需的程序的基本培訓；和

.2 應對高級船員進行應急程序培訓，以處理貨物泄漏、溢出或火災事故，並應對其中足夠數量的人員進行適於所載貨物的主要急救措施的講授和訓練。

18.8 進入圍蔽處所

18.8.1 在正常操作情況下，人員不得進入可能有氣體聚集的液貨艙、貨艙處所、留空處所或其他圍蔽處所，除非用固定式或便攜式設備確定上述處所的空氣中具有足夠的氧氣且不存在有毒氣體。

18.8.2 如果在日常檢查中必須對A類液貨艙周圍的貨艙處所進

行除氣和通氣，且液貨艙載運易燃貨物，當液貨艙只包含最少數量的貨物“橫傾”以保持液貨艙冷卻時，應進行檢查。檢查結束後，貨艙應重新惰化。

18.8.3 人員在進入載有可燃貨物船舶的任何被設計成危險的處所時，均不得帶有任何潛在的着火源，除非經驗證，已對該處所進行除氣並仍保持這種狀態。

18.9 貨物取樣

18.9.1 任何貨物取樣應在高級船員的監督下進行，其應確保操作人員使用適合貨物危險的防護服。

18.9.2 對液體貨物取樣時，高級船員應確保取樣設備適合相關溫度和壓力，包括貨泵排放壓力。

18.9.3 高級船員應確保使用的任何貨物樣品設備適當連接以避免任何貨物泄漏。

18.9.4 如果取樣貨物為有毒貨品，高級船員應確保使用1.2.15中規定的“閉環”取樣系統以使至大氣的任何貨物釋放降至最少。

18.9.5 取樣操作完成後，高級船員應確保使用的任何樣品閥適當關閉，且使用的連接正確隔斷。

18.10 貨物應急關閉（ESD）系統

18.10.1 ***通則***

18.10.1.1 應設有貨物應急關閉系統以在緊急情況下（船舶內部或貨物駁運至船上或岸上時）停止貨物流。ESD系統的設計應避免可能產

生貨物駁運管工作內的壓力波動（見18.10.2.1.4）。

18.10.1.2 就ESD而言，使用有毒或易燃液體或蒸氣調節貨物的輔助系統應視作貨物系統。使用惰性介質（例如氮）的間接製冷系統無需納入ESD功能。

18.10.1.3 ESD系統應由表18.1中所列的手動和自動開始啟動。對於任何附加開始，如表明其納入不降低整個系統的完整性和可靠性，才可納入ESD系統。

18.10.1.4 船舶ESD系統應按照公認標準包含船岸連接。

18.10.1.5 貨物控制室和駕駛室中應有ESD系統和相關系統的功能流程圖。

18.10.2 ***ESD閥要求***

18.10.2.1 通則

18.10.2.1.1 ESD閥係指ESD系統操作的任何閥。

18.10.2.1.2 ESD閥應為遙控、故障關閉（動力消失關閉）型、能就地手動關閉並指示實際閥的位置。作為就地手動關閉ESD閥的替代，應允許一系列手動操作關閉閥與ESD閥一起使用。手動閥的位置應鄰近ESD閥。一旦ESD閥關閉，而手動閥也關閉，應能處理截留的液體。

18.10.2.1.3 液體管系中的ESD閥應在啟動30秒內平穩緊閉。船上應備有關於閥關閉時間及其操作特徵的資料，並且關閉時間應能予以驗證和可重複。

18.10.2.1.4 13.3.1至13.3.3中所述的閥的關閉時間（即從開始激發關閉

信號至閥完全關閉的時間）應不大於：

$$\frac{3600U}{LR} \quad （秒）$$

式中：

U＝發出操作信號時艙內液面以上的容積，（m^3）；

L_R＝船和岸上設備之間相互約定的最大裝載速率，（m^3/h）。

考慮到裝載軟管或吊臂以及船上和岸上的有關管路系統，應對裝載速率進行調整，以使閥關閉時的衝擊壓力被限制在一個可以承受的水平。

18.10.2.2 船岸和船船總管連接

每個總管連接處應設有1個ESD閥。不用於駁運作業的貨物總管連接應用管系設計壓力下的盲板法蘭隔斷。

18.10.2.3 貨物系統閥

如果5.5中規定的貨物系統閥也是18.10中規定的ESD閥，18.10的要求應適用。

18.10.3 ***ESD系統控制***

18.10.3.1 ESD系統至少應能通過駕駛室和13.1.2要求的控制位置或貨物控制室（如設有）的單獨控制進行手動操作，且貨物區域中不少於2個位置。

18.10.3.2 探測到貨物區域和/或貨物機器處所的露天甲板失火時，

ESD系統應自動啟動。露天甲板上使用的探測方法應至少覆蓋液貨艙的液體和蒸氣氣室、貨物總管和液體管路經常被拆開的區域。探測可通過設計成在溫度98℃和104℃之間熔化的易熔元件，或通過區域失火探測方法。

18.10.3.3 運作的貨物機器應按照表18.1中的原因和影響矩陣通過啟動ESD系統停止。

18.10.3.4 ESD控制系統應能以安全受控的方式進行13.3.5中要求的高位試驗。就試驗而言，當溢流控制系統越控時，可操作貨泵。液位報警試驗和高位報警試驗結束後ESD系統重新設定的程序應納入18.2.1要求的操作手冊。

表18.1－ESD功能佈置

	泵	**壓縮機系統**					**閥**	**連接**
關閉行動→ **開始↓**	貨泵/貨物增壓泵	噴淋/清艙泵	蒸氣返回壓縮機	燃氣壓縮機	再液化裝置***，包括冷凝返回泵（如有）	氣體燃燒裝置	ESD閥	至船/岸連接的信號連接****
應急按鈕（見18.10.3.1）	√	√	√	註2	√	√	√	√
甲板上或壓縮機室中的探火*（見18.10.3.2）	√	√	√	√	√	√	√	√
液貨艙高位（見13.3.2和13.3.3）	√	√	√	註1 註2	註1 註3	註1	註6	√

自船/岸連接的信號（見18.10.1.4）	√	√	√	註2	註3	n/a	√	n/a
喪失至ESD閥的動力**	√	√	√	註2	註3	n/a	√	√
主電力失效（“斷電”）	註7	註7	註7	註7	註7	註7	√	√
液位報警越控（見13.3.7）	註4	註4 註5	√	註1	註1	註1	√	√

註1：設備的這些項目能從這些具體的自動關閉引發器省略，只要設備進口無貨物液體進入。

註2：如果燃氣壓縮機用於將貨物蒸氣返回岸上，其應納入ESD系統（在該模式操作時）。

註3：如果再液化裝置壓縮機用於蒸氣返回/岸上管線清洗，其應納入ESD系統（在該模式操作時）。

註4：13.3.7允許的越控系統可在海上使用以防止錯誤報警或關閉。當液位報警越控，應禁止貨泵和總管ESD閥開口的操作，按照13.3.5進行高位報警試驗除外（見18.10.3.4）。

註5：只有當在該模式操作時，用於強制噴霧器的貨物噴淋或清艙泵可不包括在ESD系統中。

註6：作為關閉18.10.2.2中所述的ESD閥的替代，13.3.2中所述的傳感器可用於自動關閉安裝傳感器的單個液貨艙的液貨艙充裝閥。如採用該選項，當已啟動應裝載的所有液貨艙的高位傳感器時，應開始啟動整個ESD系統。

註7：設備的這些項目應設計成不在主電源恢復後重新啟動且無需確認安全條件。

* 可在甲板上使用易熔塞、電子點溫度監測或區域探火。

** 遙控操作的ESD閥傳動裝置的液壓、電動或氣壓動力失效。

*** 構成再液化裝置一部分的間接製冷系統無需納入ESD功能，如果其在製冷循環中使用惰性介質（例如氮）。

**** 信號無需指示啟動ESD的事項。

√ 功能要求。

N/A 不適用

18.10.4 *附加關閉*

18.10.4.1 8.3.11中使液貨艙免受外壓差的要求可通過使用啟動ESD系統或至少停止任何貨泵或壓縮機的獨立低壓跳脫來實現。

18.10.4.2 探測到高液位時，可提供自13.3要求的溢流控制系統至ESD的輸入停止任何貨泵或壓縮機運行，因為該報警可能是疏忽所致的艙至艙內部駁運。

18.10.5 *操作前試驗*

在貨物裝卸作業開始前，應對貨物駁運中涉及的貨物緊急關閉和報警系統進行檢查和試驗。

18.11 貨物圍護系統上或附近的熱工

18.11.1 在液貨艙附近應採取特殊的防火預防措施，特別是易燃或受碳氫化合物污染或由於燃燒可能發出有毒煙氣的絕熱系統。

18.12 附加操作要求

本規則下列段落為附加的操作要求：

2.2.2，2.2.5，2.2.8，3.8.4，3.8.5，5.3.2，5.3.3.3，5.7.3，7.1，8.2.7，8.2.8，8.2.9，9.2，9.3，9.4.4，12.1.1，13.1.3，13.3.6，13.6.18，14.3.3，15.3，15.6，16.6.3，17.4.2，17.6，17.7，17.9，17.10，17.11，17.12，17.13，17.14，17.16，17.18，17.19，17.21和17.22。

第19章

最低要求一覽表

對最低要求一覽表的註釋：

貨品名稱 *（a欄）*	任何散裝運輸貨物的裝船文件中應使用貨品名稱。任何附加的名稱可放在貨品名稱後的括號內。貨品名稱有時可能與以前頒發的本規則中所提供的名稱不一致
（b欄）	刪除
船型 *（c欄）*	1 1G型船舶（2.1.2.1） 2 2G型船舶（2.1.2.2） 3 2PG型船舶（2.1.2.3） 4 3G型船舶（2.1.2.4）
要求的C型獨立液貨艙 *（d欄）*	C型獨立液貨艙（4.23）
液貨艙環境控制 *（e欄）*	惰性：惰化（9.4） 乾：烘乾（17.7） -：本規則無特殊要求
蒸氣探測 *（f欄）*	F：易燃蒸氣的探測 T：有毒蒸氣的探測 F+T：易燃和有毒蒸氣的探測 A：窒息
測量 *（g欄）*	I：間接型或封閉型（13.2.3.1和.2） R：間接型、封閉型或限制型（13.2.3.1、.2、.3和.4） C：間接型或封閉型（13.2.3.1、.2和.3）
（h欄）	刪除
特殊要求 *（i欄）*	如具體參考第14章和/或第17章，這些要求應作為任何其他欄要求的附加要求
製冷氣體	無毒和不易燃氣體

除另有規定外，對於運輸含乙炔總量低於5%的氣體混合物，除滿足對氣體混合物中主要成分的要求外，無進一步要求。

a *貨品名稱*	*b*	*c* *船型*	*d* *要求的C型獨立液貨艙*	*e* *液貨艙內蒸氣空間的控制*	*f* *氣體探測*	*g* *測量*	*h*	*i* *特殊要求*
乙醛		2G/2PG	-	惰化	F+T	C		14.4.2，14.3.3.1，17.4.1，17.6.1
氨－無水的		2G/2PG	-	-	T	C		14.4，17.2.1，17.12
丁二烯（所有異構體）		2G/2PG	-	-	F+T	C		14.4，17.2.2，17.4.2，17.4.3，17.6，17.8
丁烷（所有異構體）		2G/2PG	-	-	F	R		
丁烷/丙烷混合物		2G/2PG	-	-	F	R		
丁烯（所有異構體）		2G/2PG	-	-	F	R		
二氧化碳（高純度）		3G	-	-	A	R		17.21
二氧化碳（再生質量）		3G	-	-	A	R		17.22
氯		1G	是	乾燥	T	I		14.4，17.3.2，17.4.1，17.5，17.7，17.9，17.13
二乙醚*		2G/2PG	-	惰化	F+T	C		14.4.1，14.4.2，17.2.6，17.3.1，17.6.1，17.9，17.10，17.11.2，17.11.3
二甲基胺		2G/2PG	-	-	F+T	C		14.4，17.2.1
二甲醚		2G/2PG			F+T	C		
乙烷		2G	-	-	F	R		
氯乙烷		2G/2PG	-	-	F+T	C		
乙烯		2G	-	-	F	R		
環氧乙烯		1G	是	惰化	F+T	C		14.4，17.2.2，17.3.2，

								17.4.1，17.5，17.6.1，17.14
a *貨品名稱*	*b*	*c* *船型*	*d* *要求的C型獨立液貨艙*	*e* *液貨艙內蒸氣空間的控制*	*f* *氣體探測*	*g* *測量*	*h*	*i* *特殊要求*
環氧乙烷/環氧丙烷混合物，但環氧乙烷含量按重量計不超過30%*		2G/2PG	-	惰化	F+T	C		14.4.2 ， 17.3.1 ， 17.4.1 ，17.6.1，17.9，17.10，17.18
異戊二烯*（所有異構體）		2G/2PG	-	-	F	R		14.4.2，17.8，17.9，17.11.1
異戊二烯（部分精煉*）		2G/2PG	-	-	F	R		14.4.2，17.8，17.9，17.11.1
異丙胺*		2G/2PG	-	-	F+T	C		14.4.1 ， 14.4.2 ， 17.2.4 ，17.9，17.10，17.11.1，17.15
甲烷（液化天然氣）		2G	-	-	F	C		
甲基乙炔丙二烯混合物		2G/2PG	-	-	F	R		17.16
溴甲烷		1G	是	-	F+T	C		14.4 ， 17.2.3 ， 17.3.2 ，17.4.1，17.5
氯甲烷		2G/2PG	-	-	F+T	C		17.2.3
混合C4貨物		2G/2PG	-	-	F+T	C		14.4 ， 17.2.2 ， 17.4.2 ，17.4.3，17.6，17.20
乙胺*		2G/2PG	-	-	F+T	C		14.4，17.2.1，17.3.1，17.9，17.10，17.11.1，17.15
氮		3G	-	-	A	C		17.17
戊烷（所有異構體）*		2G/2PG	-	-	F	R		17.9，17.11
戊烯（所有異構		2G/2PG	-	-	F	R		17.9，17.11

體）*								
丙烷		2G/2PG	-	-	F	R		
a *貨品名稱*	*b*	*c* *船型*	*d* *要求的C型獨立液貨艙*	*e* *液貨艙內蒸氣空間的控制*	*f* *氣體探測*	*g* *測量*	*h*	*i* *特殊要求*
丙烯		2G/2PG	-	-	F	R		
環氧丙烷*		2G/2PG	-	惰化	F+T	C		14.4.2，17.3.1，17.4.1，17.6.1，17.9，17.10，17.18
製冷氣體		3G	-	-	-	R		
二氧化硫		1G	是	乾燥	T	C		14.4，17.3.2，17.4.1，17.5，17.7
氯乙烯		2G/2PG	-	-	F+T	C		14.4.1，14.4.2，17.2.2，17.2.3，17.3.1，17.6，17.19
乙烯基乙基醚*		2G/2PG	-	惰化	F+T	C		17.3.1，17.6.1，17.8，17.9，17.10，17.11.2，17.11.3
二氯乙烯*		2G/2PG	-	惰化	F+T	C		14.4.1，14.4.2，17.2.5，17.6.1，17.8，17.9，17.10

* 此貨物也包括在IBC規則內。

附錄1

IGC規則貨品數據報告格式

建議在IGC規則船舶上載運的貨品的特徵

1 貨品標識

貨品名稱

任何散裝運輸貨物的裝船文件中應使用貨品名稱。任何附加的名稱可放在貨品名稱後的括號內。

1.1 其他名稱和標識號

主要商品名 : _____

主要化學名稱 : _____

化學公式 : _____

C.A.S號 : _____

EHS號 : _____

BMR號 : _____

RTECS號 : _____

1.2 相關同義詞

結構

同義詞名稱	類型

1.3 成分

成分名稱	%	類型

2 物理特性

參考/備註	單位	質量	低值	高值
分子重量				
20℃時的密度	(kg/m^3)			
閃點（c.c）	（℃）			
沸點（℃）				
20℃時的水溶性	（mg/l）			
20℃時的蒸氣壓力	（Pa）			
自燃溫度	（℃）			
爆炸極限	（% v/v）			
MESG	（mm）			

3 相關化學特性

水反應性 （0-2）

0＝無反應性
1＝有反應性
2＝高反應性

詳細情況

貨品是否與空氣反應造成潛在危險狀況（是/否）

如果是，提供詳細情況

參照

是否需要抑制劑或穩定劑防止危險反應？（是/否）

如果是，提供詳細情況

參照	

4 哺乳動物毒性

4.1 急性毒性		質量	低值	高值	種類	參考/備註
口腔（mg/kg）	LD_{50}					
皮膚（mg/kg）	LD_{50}					
吸入（mg/l/4h）	LD_{50}					

4.2 腐蝕和刺激

	單位	質量	低值	高值	參考/備註
皮膚腐蝕時間	（小時）				

	結果觀察	種類	參考/備註
皮膚刺激（4小時暴露）			
眼睛刺激			

無刺激、輕微刺激、適度刺激、中度刺激、嚴重刺激或腐蝕

4.3 過敏

			參考/備註
呼吸過敏源（人）	（是/否）		
皮膚過敏	（是/否）		

4.4 其他具體長期影響

			參考/備註
致癌物	（是/否）		
誘變因素	（是/否）		
對繁殖有毒	（是/否）		
其他長期	（是/否）		

4.5 其他相關哺乳動物毒性

5 建議的載運要求

《IGC規則》中的欄	特性	值
c	船型	
d	要求的C型獨立液貨艙	
e	液貨艙內蒸氣處所的控制	
f	蒸氣探測	
g	測量	
i	特殊要求	

附錄2

《國際散裝運輸液化氣體適裝證書》的格式樣本

國際散裝運輸液化氣體適裝證書

（公章）

本證書由.....

（國家全名）

政府授權.....

（主管機關認可的適任人員或組織的全名）

按國際散裝運輸液化氣體船舶構造和設備規則簽發。

船舶資料[1]

船名 .....

船舶編號或呼號 .....

IMO編號[2] .....

船籍港 .....

貨艙容量（m^3） .....

船型[3]（規則的2.1.2） .....

安放龍骨或船舶處於類似建造階段的日期，或對於改建船舶，改建成氣體運輸船開始的日期

.....

船舶也完全符合規則的下列修正案：.....

.....

.

.....

.

船舶免除符合規則的下列規定：.....
.....
.....

茲證明：

1 該船業已按規則1.4的規定進行了檢驗。

2 檢驗表明該船構造和設備及其狀況在各方面均屬合格，且該船符合規則的相關規定。

3 下列設計衡準已經使用：

.1 環境氣溫.....℃[4]

.2 環境水溫.....℃[4]

.3

液貨艙種類和編號	應力因素				材料[5]	MARVS[6]
	A	B	C	D		
貨物管道						

註：表中的液貨艙編號見附件2“經簽字和有日期的液貨艙圖”。

.4 液貨艙材料的力學性能在℃[7]確定。

4 該船適合散裝運輸下列貨品，只要遵守規則所有相關操作規定[8]。

貨品	載運狀況（液貨艙編號等）	最低溫度
在附件1“附加經簽字和有日期的表格”繼續。 本表中的液貨艙編號附件2經簽字和有日期的液貨艙圖”		

5 按照1.4/2.6.2*，有關該船的規則規定以下列方式予以修改：

.....

6 該船應：

.1* 僅根據使用按本規則2.2.6配備的認可的穩性儀進行完整和破損穩性要求符合性驗證的裝載工況進行裝載；

.2* 如給予本規則2.2.7允許的免除並且未配備本規則2.2.6要求的認可的穩性儀，應按以下一種或多種認可方法進行裝載：

.i* 根據經批准的裝載手冊所述的裝載工況，蓋章並註明日期.....並由主管機關的負責人或經主管機關認可的組織的負責人簽字；或

.ii* 根據使用認可的方法.....遠程驗證的裝載工況；或

.iii* 根據上述i所述的經批准的裝載手冊所定義的批准的工程範圍內的裝載工況；或

.iv* 根據使用上述i所述的經批准的裝載手冊所定義的批准的臨界KG/GM數據驗證的裝載工況；

.3* 根據本證書所附的裝載限制。

如要求不按上述指導裝載船舶，則應將能證明提議的裝載工況合理性的必要計算資料提交發證主管機關，主管機關可書面授權採

---

* 不適應者劃去。

* 不適用者劃去。

用所提議的裝載工況**。

本證書有效期限至.....止，在此期間應按規則1.4規定接受檢驗。

本證書基於的檢驗完成日期：.....

（年/月/日）

簽發於.....

（證書簽發地點）

....

（簽發日期） *（經授權發證的官員簽字）*

（主管當局蓋章或鋼印）

證書填寫註釋：

1 船舶資料也可在表格中橫向排列。

2 按照本組織A.600（15）決議通過的《IMO船舶編號體系》。

3 任何條目應與所有相關建議案有關，例如，條目“2G型”應係指規則規定的2G型。

4 插入4.19.1.1要求的環境溫度。

5 插入按規則的4.22.3.1和4.23.3.1可接受的應力因數和材料。

** 該文本如經正式簽字和蓋章，可附於本證書後，而不是填入本證書中。

6 插入按4.13.2指定的所有釋放閥設定值。

7 插入4.18.1.3要求的主管機關或代表主管機關的被認可組織接受的溫度。

8 應只列出規則第19章列出的貨品或已按照1.1.6.1經主管機關評估的貨品或其相容的物理比例在液貨艙設計限制內的混合物。對於“新貨品”，按三方協議臨時同意的任何特殊要求應在證書附錄中指出。

年度檢驗和中間檢驗的簽署

茲證明業已按規則1.4.2的要求進行了檢驗，查明該船符合規則的有關規定。

年度檢驗： 簽字：.....

（經正式授權的官員簽字）

地點：.....

日期（年/月/日）：.....

（主管當局蓋章或鋼印）

年度/中間*檢驗： 簽字：.....

（經正式授權的官員簽字）

地點：.....

日期（年/月/日）：.....

（主管當局蓋章或鋼印）

年度/中間*檢驗： 簽字：.....

（經正式授權的官員簽字）

地點：.....

日期（年/月/日）：.....

（主管當局蓋章或鋼印）

年度檢驗： 簽字：.....

（經正式授權的官員簽字）

地點：.....

---

* 不適用者劃去。

日期（年/月/日）：.....

（主管當局蓋章或鋼印）

按第 1.4.6.8.3 條進行的年度/中間檢驗

茲證明業已按規則第1.4.6.8.3條的要求進行了年度/中間*檢驗，查明該船符合規則的有關規定。

簽字：.....

（經正式授權的官員簽字）

地點：.....

日期（年/月/日）：.....

（主管當局蓋章或鋼印）

在適用第 1.4.6.3 條的情況下，有效期少於 5 年的證書展期簽署

該船符合規則的有關規定，本證書根據規則第1.4.6.3條應視為有效，有效期限至止。

簽字：.....

（經正式授權的官員簽字）

地點：.....

日期（年/月/日）：.....

（主管當局蓋章或鋼印）

在已完成換證檢驗並適用第 1.4.6.4 條情況下的簽署

該船符合規則的有關規定，本證書根據規則第1.4.6.4條應視為有效，有效期限至止。

年度檢驗

簽字：.....

（經正式授權的官員簽字）

地點：.....

---

* 不適應者劃去。

日期（年/月/日）：.....

（主管當局蓋章或鋼印）

在適用第1.4.6.5條或第1.4.6.6條的情況下，將證書有效期展期至駛抵進行檢驗的港口或給予寬限期的的簽署

本證書根據規則第1.4.6.5/1.4.6.6*條應視為有效，有效期限至.....止。

簽字：.....

（經正式授權的官員簽字）

地點：.....

日期（年/月/日）：.....

（主管當局蓋章或鋼印）

在適用第1.4.6.8條的情況下，周年日提前的簽署

根據規則第1.4.6.8條，新的周年日為.....。

簽字：.....

（經正式授權的官員簽字）

地點：.....

日期（年/月/日）：.....

（主管當局蓋章或鋼印）

根據第1.4.6.8條，新的周年日為.....。

---

* 不適應者劃去。

簽字：.....

（經正式授權的官員簽字）

地點：.....

日期（年/月/日）：.....

（主管當局蓋章或鋼印）

《國際散裝運輸液化氣體適裝證書》附件1

證書第4項中規定貨品的後續清單及其載運條件。

貨品	載運條件 （液貨艙編號等）	最低溫度

日期：..... .....

（簽發日期） （經授權發證的官員簽字）

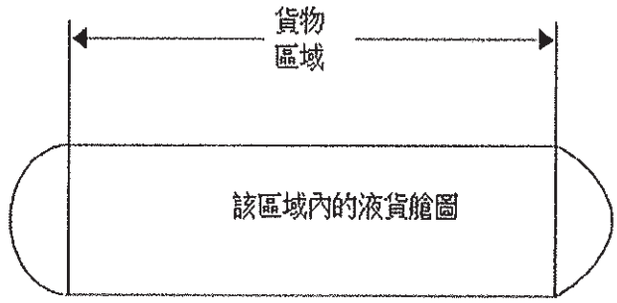
附件2

《國際散裝運輸液化氣體適裝證書》

液貨艙圖（試樣）

船名：

船舶編號或呼號：



日期：..... .....

（簽發日期） （經授權發證的官員簽字）

附錄3

《國際散裝運輸液化氣體適裝證書》附錄示例

證書附錄編號：			簽發日期：（年/月/日）		
由.....政府授權， 按照經修正的國際散裝運輸液化氣體船舶構造和設備規則簽發					
船名	**船舶編號或呼號**	**IMO編號**	**船籍港**	**貨艙容量（m^3）**	**船型**

茲證明：

船舶滿足散裝運輸下列貨品的要求，只要遵守規則的所有相關操作規定：

貨品	**載運條件（液貨艙編號等）**	**最低溫度**	**MARVS**

允許在下列國家之間載運該貨品：

本附錄的簽發基於文件：.....

該貨品的三方協議有效期至：（年/月/日）.....

本附錄有效期至：（年/月/日）.....

簽發地點和日期：（年/月/日）.....

簽字：.....

（經正式授權的官員簽字）

附錄4

非金屬材料

1 通則

1.1 本附錄中的指導作為 4.19 要求的補充，適用於非金屬材料。

1.2 非金屬材料的製造、試驗、檢查和文件記錄通常應符合公認標準和本規則的具體要求（如適用）。

1.3 選擇非金屬材料時，設計方應確保材料特性適合系統要求的分析和說明。可選擇材料滿足一個或多個要求。

1.4 可考慮大範圍的非金屬材料。因此，有關材料選擇衡準的下節不能包括每種可能性且應視作指導。

2 材料選擇衡準

2.1 考慮到下列基本特性，非金屬材料可用於液化氣體船舶貨物系統的不同部分：

.1 絕熱－限制熱流的能力；

.2 承載－維持圍護系統強度的能力；

.3 密性－提供液體和蒸氣密性屏壁的能力；

.4 連接－連接能力（例如通過黏接、焊接或緊固）。

2.2 根據具體系統設計，附加考慮可適用。

3 材料特性

3.1 絕熱材料的柔性係指絕熱材料易於彎曲或成形而無破損或斷裂的能力。

3.2 鬆散填充材料係指均質固體，通常以細顆粒的形式，例如粉或珠，一般用於填充不能接近處所中的空隙以提供有效絕熱。

3.3 納米材料係指特性源自其具體細微結構的材料。

3.4 微孔材料係指含有開式、閉式或兩者兼具的微孔並在其質量中散開的材料。

3.5 黏性材料係指通過黏合工藝連接或黏接兩個相鄰表面的產品。

3.6 其他材料係指本規則的本節中未描述並應標識和列出的材料。用於評估材料是否適於在貨物系統中使用的相關試驗應標識並用文件記錄。

4 材料選擇和試驗要求

4.1 *材料說明*

4.1.1 如已進行材料的初始選擇，應進行試驗以證明該材料適於擬定用途。

4.1.2 使用的材料清晰標識，相關試驗應用文件完整記錄。

4.1.3 應按照擬定用途選擇材料。材料應：

.1 與所載運的所有貨品相容；

.2 不被任何貨物污染也不與其反應；

.3 不具有受到貨物影響的特徵或特性；和

.4 能在操作溫度範圍內經受熱衝擊。

4.2 ***材料試驗***

特定材料要求的試驗取決於設計分析，說明和擬定功能。下列試驗清單用於說明。要求的任何附加試驗（例如關於滑動、制動和電絕熱）應清晰標識並用文件記錄。按本附錄的 4.1 選擇的材料應進一步按照下表進行試驗：

功能	絕熱	承載結構	密性	連接
力學試驗		×		×
密性試驗			×	
熱試驗	×			

熱衝擊試驗應提交材料和/或組件至操作期間會經歷的最極端熱梯度。

4.2.1 材料的固有特性

4.2.1.1 應進行試驗以確保所選材料的固有特性對擬定用途無任何負面影響。

4.2.1.2 對所有所選材料，應評估下列特性：

.1 密度；舉例標準 ISO845；和

.2 熱膨脹的線性係數（LCTE）：舉例標準 ISO11359，在規定的最廣泛操作溫度範圍內。但是，對於鬆散填充材料，應評估熱膨脹的體積係數（VCTE），因為這更恰當。

4.2.1.3 無論其固有特性和擬定功能，當設計服務溫度範圍降至最低設計溫度以下 5℃ 但不低於-196℃，所選的所有材料應進行試驗。

4.2.1.4 每個特性評估試驗應按照公認標準進行。如無這類標準，建議的試驗程序應詳述並提交主管機關認可。取樣應足以確保所選材料性能的真實體現。

4.2.2 力學試驗

4.2.2.1 力學試驗應按照下表進行：

力學試驗	承載結構
抗拉	ISO 527 ISO 1421 ISO 3346 ISO 1926
剪切	ISO 4587 ISO 3347 ISO 1922 ISO 6237
壓縮	ISO 604 ISO 844

	ISO 3132
彎曲	ISO 3133 ISO 14679
蠕變	ISO 7850

4.2.2.2 如果所選材料功能取決於特定性能，例如抗拉、壓縮和剪切強度、屈服應力、模量或延伸，這些特性應按照公認標準進行試驗。如果要求的性能按照高階行為定律通過數字模擬進行評估，試驗應使主管機關滿意。

4.2.2.3 蠕變可由持續載荷造成，例如貨物壓力或結構載荷。蠕變試驗應基於圍護系統設計壽命期間預期會遇到的載荷。

4.2.3 密性試驗

4.2.3.1 材料密性要求應與其操作功能有關。

4.2.3.2 應進行密性試驗以通過使用留存液體（例如貨物、水蒸氣或追蹤氣體）在對應於預計用途的佈置（例如厚度和應力條件）中測量的材料的滲透率

4.2.3.3 密性試驗應基於下表中所述的試驗：

密性試驗	**密性**
孔積率/滲透率	ISO 15106 ISO 2528 ISO 2782

4.2.4 熱傳導性試驗

4.2.4.1 熱傳導性試驗應代表絕熱材料的生命周期，以能評估貨物系統設計壽命期間的特性。如果這些特性可能隨時間退化，材料應儘可能在對應於其生命周期的環境下老化，例如操作溫度、光、蒸氣和安裝（例如包裝、袋、箱等）。

4.2.4.2 應選擇熱傳導性和熱容量的絕對值和可接受範圍的要求，並考慮到對貨物圍護系統操作效率的影響。還應特別注意相關貨物裝卸系統和部件（如安全釋放閥以及蒸氣回流和處理設備）的排量。

4.2.4.3 熱試驗應基於下表中所述的試驗或等效試驗：

熱試驗	絕熱
熱傳導性	ISO 8301 ISO 8302
熱容量	×

4.2.5 物理試驗

4.2.5.1 除 4.19.2.3 和 4.19.3.2 的要求外，下表還提供關於可考慮的一些附加物理試驗的指導和信息。

物理試驗	彈性絕熱	鬆散填充	納米材料	微孔	黏合劑
顆粒大小		×			
閉式微孔容量				ISO 4590	
吸收/解吸	ISO 12571	×	×	ISO 2896	
黏性					ISO 2555 ISO 2431
開放時間					ISO 10364
觸變性					×
硬度					ISO 868

4.2.5.2 應選擇鬆散填充材料分隔要求，並考慮到其在環境變化（例如熱循環和振動）時對材料性能（密度、熱傳導性）潛在的不利影響

4.2.5.3 對具有閉式微孔結構的材料的要求應基於其在瞬態熱相期間對氣流和緩衝量的最終影響。

4.2.5.4 同樣，吸附和吸收要求應考慮到不受控的液體或氣體緩衝可能對系統存在的潛在的不利影響。

5 質量保證和質量控制（QA/QC）

5.1 *通則*

5.1.1 一旦選擇材料，在進行本附錄 4 中所述的試驗後，應使用詳細的質量保證/質量控制（QA/QC）計劃以確保在安裝和服務期間材料持續符合要求。該計劃應從製造商的質量手冊（QM）開始考慮材料，然後在貨物系統建造期間遵循手冊

5.1.2 QA/QC 計劃應包括加工、貯存、處理和採取預防措施防止材料暴露於有害結果的程序。這可包括，例如，陽光對某些絕熱材料的影響或與個人產品（例如護手霜）接觸造成材料表面污染。應規定 QA/QC 計劃中的取樣方法和試驗頻率以確保所選材料在其生產和安裝期間持續符合要求。

5.1.3 當產生粉末或顆粒狀絕熱材料時，應將其佈置成能防止由於振動而使材料壓實。

5.2 部件製造期間的 QA/QC

關於部件製造的 QA/QC 計劃應至少包括但不限於下列各項。

5.2.1 部件標識

5.2.1.1 對於每種材料，製造商應實施標記系統以清晰標識生產批號。標記系統決不能妨礙產品的特性。

5.2.1.2 標記系統應確保部件的可追溯性並應包括：

.1 生產日期和可能的失效日期；

.2 製造商的說明；

.3 參考說明；

.4 參考指令；和

.5 如必需，運輸和儲存期間應保存的任何可能的環境參數。

5.2.2 生產取樣和審核方法

5.2.2.1 生產期間要求定期取樣以確保所選材料的質量水準和持續符合性。

5.2.2.2 在 QA/QC 計劃中應規定頻率、方法和應進行的試驗，例如，這些試驗通常包括原材料、過程參數和部件校核。

5.2.2.3 對於所選材料，生產 QC 試驗的過程參數和結果應嚴格按照 QM 中的具體要求。

5.2.2.4 QM 中所述的審核方法的目的是控制過程反覆性和 QA/QC 計劃的效力。

5.2.2.5 審核期間，審核員應能自由出入所有生產和 QC 區域。審核結果應按照相關 QM 中所述的值和公差。

6 黏接和連接過程要求的試驗

6.1 ***黏接程序資格***

6.1.1 黏接程序說明和資格試驗應按照公認標準規定。

6.1.2 工作開始前，應完整記錄黏接程序以確保黏接特性可接受。

6.1.3 制定黏接程序說明時，應考慮下列參數：

.1 表面處理；

.2 安裝前材料的儲存和處理；

.3 覆蓋時間；

.4 開放時間；

.5 混合率，熔敷量；

.6 環境參數（溫度、濕度）；和

.7 固化壓力、溫度和時間。

6.1.4 必要時可納入附加要求以確保可接受的結果。

6.1.5 黏接程序說明應通過適當程序資格試驗計劃驗證。

6.2 ***人員資格***

6.2.1 黏接過程涉及的人員應經培訓並符合公認標準的要求。

6.2.2 應定期進行試驗以確保進行黏接作業的人員連續工作以確保黏接質量一致。

7 生產黏接試驗和控制

7.1 *有損檢測*

生產期間，應選取有代表性的樣品並進行試驗以核查其符合設計要求的強度水平。

7.2 *無損檢測*

7.2.1 生產期間，應進行對黏接完整性無害的試驗，並使用適當的方法，例如：

.1 目視檢查；

.2 內部缺陷探測（例如聲音、超音波或剪切試驗）；和

.3 局部密性試驗。

7.2.2 如果黏接必須提供密性作為其設計功能的一部分，按照設計方計劃和 QA/QC 計劃，安裝結束後應完成貨物圍護系統整體密性試驗。

7.2.3 QA/QC 標準應包括建成並在圍護系統生命周期內的黏接部件的密性驗收標準。

附錄 5

新穎形狀的貨物圍護系統設計中極限狀態方法的使用標準

1. 通則

1.1 本標準的目的是按照本規則的4.27提供新穎形狀的貨物圍護系統的極限狀態設計的程序和相關設計參數。

1.2 極限狀態設計是一種系統方法，對每個結構件按與本規則4.3.4中標識的設計條件相關的可能失效模式進行評估。極限狀態可定義為超出後結構或部分結構不再滿足要求的狀態。

1.3 極限狀態分為以下3類：

.1 最終極限狀態（ULS），在完整（無破損）條件下，對應於最大承載能力，或在某些情況下，對應於最大適用應變、變形或屈曲和塑性破壞引起的結構不穩定；

.2 疲勞極限狀態（FLS），對應於由於循環裝載的影響造成的降級；和

.3 意外極限狀態（ALS），與結構的抗意外狀況能力有關。

1.4 根據貨物圍護系統概念，應符合本規則第4章A部分至D部分（如適用）。

2 設計格式

2.1 本標準中的設計格式基於載荷和阻力因數設計格式。載荷和阻力因數設計格式的基本原則是驗證在任何情景下，對於任何所考慮的失效模式，設計載荷作用L_d不超過設計阻力R_d：

$$L_d \leq R_d$$

設計載荷 F_{dk} 通過特徵載荷乘以與給出的載荷種類相關的載荷因數獲得：

$$F_{dk} = \gamma_f F_k$$

式中：

γ_f 是載荷因數；和

F_k 是本規則第 4 章的 B 部分和 C 部分中規定的特徵載荷。

設計載荷作用 L_d（例如應力、應變、位移和振動）是從設計載荷導出的最不利組合載荷作用，可從下列公式獲得：

$$L_d = q\ (F_{d1}\ ,\ F_{d2}\ ,\ \ldots\ ,\ F_{dN})$$

式中：q 表示結構分析確定的載荷和載荷作用之間的功能關係。

設計阻力 R_d 由下式獲得：

$$R_d = \frac{R_k}{\gamma_R \bullet \gamma_C}$$

式中：

R_k 是特性阻力。對於本規則第 6 章涉及的材料，其可為但不限於規定的最小屈服應力、規定的最小抗拉強度、橫截面的塑性阻力和極限屈曲強度；

γ_R 是阻力因數，$\gamma_R = \gamma_m \gamma_s$；

γ_m 是部分阻力因數，考慮到材料特性的概率分佈（材料因數）；

γ_s 是部分阻力因數，考慮到結構能力的不確定性，例如結構質量，確定性能的方法，包括分析的準確性；和

γ_C 是結果等級因數，說明故障可能造成的後果，包括貨物泄放和可能的人員受傷。

2.2 貨物圍護設計應考慮到可能的失效結果。結果等級見表 1，當失效模式與最終極限狀態、疲勞極限狀態或意外極限狀態有關時，規定失效結果。

表 1：結果等級

結果等級	定義
低	失效意味着較少貨物泄放。
中	失效意味着貨物泄放和人員受傷的可能性。
高	失效意味着大量貨物泄放和極有可能造成人員傷亡。

3 要求的分析

3.1 三維有限元分析應作為液貨艙和船體的組合模型進行，包括適用的支持件和鍵固系統。應確定所有失效模式以避免意想不到的失效。應進行水動力分析確定在不規則波中的特定船舶加速度和運動，以及船舶及其貨物圍護系統對這些力和運動的響應。

3.2 承受外部壓力和引起壓縮應力的其他載荷的液貨艙應按照公認標準進行屈曲強度分析。方法應充分考慮到理論和實際屈曲應力值之間的差別；此差別是由於板不平、板邊對中失誤、平直、橢圓度以及在規定弧長或弦長範圍內存在的失圓度而引起的。

3.3 疲勞和裂紋擴展分析應按照本標準的 5.1 進行。

4 最終極限狀態

4.1 結構阻力可通過試驗或完整的分析確定，並考慮到彈性和塑性材料特性。極限強度的安全裕量應根據部分安全因數，並考慮到載荷和阻力的隨機性（動載荷、壓力載荷、重力載荷、材料強度和屈曲能力）。

4.2 分析中應考慮永久載荷、功能載荷和環境載荷（包括晃蕩載荷）的適當組合。至少 2 個具有表 2 中給出的部分載荷因數的載荷組合應用於評估最終極限狀態。

表 2：部分載荷因數

載荷組合	永久載荷	功能載荷	環境載荷
'a'	1.1	1.1	0.7
'b'	1.0	1.0	1.3

載荷組合 *'a'* 中的永久和功能載荷的載荷因數與適用於貨物圍護系統的通常良好受控和/或規定的載荷有關，例如蒸氣壓力、貨物重量、系統自重等。如預測模型中固有可變性和/或不確定性更高，高載荷因數可能與永久和功能載荷有關。

4.3 對於晃蕩載荷、根據估算方法的可靠性，主管機關或代表主管機關的被認可組織可要求較大的載荷因數。

4.4 如果貨物圍護系統的結構失效視作極有可能造成人員受傷和大量貨物泄放，結果等級因數應取作 $\gamma_C = 1.2$。如果通過風險評估證明並經主管機關或代表主管機關的被認可組織認可，該值可降低。風險評估應考慮的因素包括但不限於設有完整或部分次屏壁以保護船體結構免於遭受與擬載運貨物相關的泄漏和較小的危險。相反，主管機關或代表主管機關的被認可組織可確定較高值，例如，對於載運更危險或更高壓力貨物的船舶。結果等級因數決不能小於 1.0。

4.5 使用的載荷因數和阻力因數應使安全等級等於本規則 4.21 至 4.26 中所述的貨物圍護系統的安全等級。這可通過按已知成功設計校準因數來進行。

4.6 材料因數 γ_m 一般應反映材料力學性能的統計分佈，並需要與規定的特有力學性能一起解釋。對於本規則第 6 章中規定的材料，材料因數 γ_m 可取作：

1.1 當被認可組織規定的特有力學性能在力學性能的統計分佈中代表較低的 2.5%分位數；或

1.0 當被認可組織規定的特有力學性能代表足夠小的分位數以使力學性能比規定值低的概率極低並可忽略不計。

4.7 部分阻力因數 γ_{si} 的確定一般應基於結構能力的不確定性，並考慮到建造公差、建造質量、使用的分析方法的準確性。

4.7.1 對於使用本標準 4.8 中給出的極限狀態衡準針對過度塑性變形的設計，部分阻力因數 γ_{si} 應取：

$$\gamma_{s1} = 0.76 \cdot \frac{B}{k_1}$$

$$\gamma_{s2} = 0.76 \cdot \frac{D}{k_2}$$

$$k_1 = Min\left(\frac{R_m}{R_e} \cdot \frac{B}{A}\ ;\ 1.0\right)$$

$$k_2 = Min\left(\frac{R_m}{R_e} \cdot \frac{D}{C}\ ;\ 1.0\right)$$

因數 A、B、C 和 D 的定義見本規則的 4.22.3.1。R_m 和 R_e 的定義見本規則的 4.18.1.3。

上述給出的部分阻力因數是校準至傳統 B 型獨立液貨艙的結果。

4.8 ***針對過度塑性變形的設計***

4.8.1 下列給出的應力驗收衡準參見彈性應力分析。

4.8.2 主要由結構中的薄膜響應承載的貨物圍護系統部分應滿足下列極限狀態衡準：

$$\sigma_m \leq f$$

$$\sigma_L \leq 1.5f$$

$$\sigma_b \leq 1.5F$$

$$\sigma_L + \sigma_b \leq 1.5F$$

$$\sigma_m + \sigma_b \leq 1.5F$$

$$\sigma_m + \sigma_b + \sigma_g \leq 3.0F$$

$$\sigma_L + \sigma_b + \sigma_g \leq 3.0F$$

式中：

σ_m＝ 等效總體主膜應力

σ_L＝ 等效局部主膜應力

σ_b＝ 等效主彎曲應力

σ_g＝ 等效二階應力

$$f = \frac{R_e}{\gamma_{s1} \cdot \gamma_m \cdot \gamma_c}$$

$$F = \frac{R_e}{\gamma_{s2} \cdot \gamma_m \cdot \gamma_c}$$

σ_m、σ_L、σ_b和σ_g參見本規則 4.28.3 中應力分類的定義。

指導性說明：

上述應力總和應通過將每個應力分量（σ_x、σ_y、τ_{xy}）相加，隨後應基於下列所示的合成應力分量計算等效應力。

$$\sigma_L + \sigma_b = \sqrt{(\sigma_L + \sigma_b)^2 + (\sigma_{Lx} + \sigma_{bx})(\sigma_{Ly} + \sigma_{by}) + (\sigma_{Ly} + \sigma_{by})^2 + 3(\tau_{Lxy} + \tau_{bxy})^2}$$

4.8.3 主要由縱桁、扶強材和板彎曲承載的貨物圍護系統部分應滿足下列極限狀態衡準：

$$\sigma_{ms} + \sigma_{bp} \leq 1.25F$$（見註 1 和 2）

$$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} \leq 1.25F$$（見註 2）

$$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} + \sigma_{bt} + \sigma_g \leq 3.0F$$

註 1：等效截面膜應力和主結構等效膜應力之和（$\sigma_{ms} + \sigma_{bp}$）通常可直接從三維有限元分析獲得。

註 2：考慮到設計概念、結構形狀和應力計算所使用的方法，主管機關或代表主管機關的被認可組織可修改係數 1.25。

式中：

σ_{ms} = 主結構的等效截面膜應力；

σ_{bp} = 主結構的等效膜應力以及主結構彎曲造成的次結構和第三級結構中的應力；

σ_{bs} = 次結構中的截面彎曲應力和次結構彎曲造成的第三級結構中的應力；

σ_{bt} = 第三級結構中的截面彎曲應力；

σ_g = 等效二階應力。

$$f = \frac{R_e}{\gamma_{s1} \cdot \gamma_m \cdot \gamma_c}$$

$$F = \frac{R_e}{\gamma_{s2} \cdot \gamma_m \cdot \gamma_c}$$

應力σ_{ms}、σ_{bp}、σ_{bs}和σ_{bt}的定義見4.8.4。σ_g的定義見本規則 4.28.3。

指導性說明：

上述應力總和應通過將每個應力分量（σ_x、σ_y、τ_{xy}）相加，隨後應基於合成應力分量計算等效應力。

殼板應按照主管機關或代表主管機關的被認可組織的要求進行設計。當膜應力較大，應另外適當考慮膜應力對板彎曲能力的影響。

4.8.4 截面應力種類

正應力是垂直於基準平面的應力分量。

等效截面膜應力是在考慮的結構橫截面範圍內，均勻分佈且等於應力平均值的正應力的分量。如果這是簡單的殼截面，該截面膜應力等於本標準 4.8.2 中規定的膜應力。

截面彎曲應力是線性分佈在暴露於彎曲作用的結構截面上的正應力分量，如圖 1 所示。

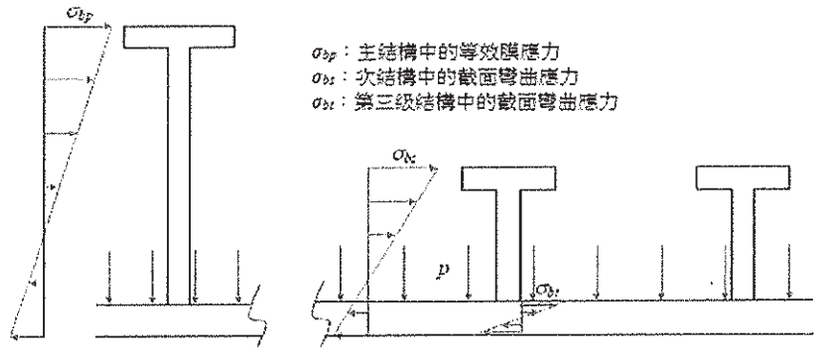


圖1：3種截面應力的定義

（應力σ_{bp}和σ_{bs}垂直於所示的橫截面）

4.9 除公認的屈曲標準中另有規定外，相同的因數γ_C、γ_m、γ_{si}應用於防屈曲設計。在任何情況下，整體安全等級應不小於這些因數給出的值。

5 疲勞極限狀態

5.1 按照貨物圍護系統概念，應符合本規則4.18.2中所述的疲勞設計條件（如適用）。對於按本規則4.27和本標準進行設計的貨物圍護系統，要求進行疲勞分析。

5.2 對於所有載荷種類，疲勞極限狀態的載荷因數應取1.0。

5.3 結果等級因數γ_C和阻力因數γ_R應取1.0。

5.4 疲勞破損應按本規則的4.18.2.2至4.18.2.5所述進行計算。計算的貨物圍護系統的累積疲勞破損率應小於或等於表3中給出的值。

表3：許用最大累積疲勞破損率

	結果等級		
Cw	低	中	高
	1.0	0.5	0.5*

註*：按照缺陷或裂紋的可探測性，應按照本規則的4.18.2.7至4.18.2.9使用低值。

5.5 主管機關或代表主管機關的被認可組織可確定低值，例如對於不能確保有效探測缺陷或裂紋的液貨艙結構或載運更危險貨物的船舶。

5.6 按照本規則的4.18.2.6至4.18.2.9，要求進行裂紋擴展分析。分析應按照經主管機關或代表主管機關的被認可組織認可的標準中規定的方法進行。

6 意外極限狀態

6.1 按照貨物圍護系統概念，應符合本規則的4.18.3中所述的意外設計條件（如適用）。

6.2 考慮到只要破損和變形不使意外情景升級，可接受破損和變形，與最終極限狀態相比，可放寬載荷和阻力因數。

6.3 對於永久載荷、功能載荷和環境載荷，意外極限狀態的載荷因數應取1.0。

6.4 本規則的4.13.9（靜橫傾載荷）和4.15（船舶浸水引起的碰撞和載荷）中所述的載荷無需進行相互間的合成，也無需與本規則

的4.14中規定的環境載荷進行合成。

6.5 阻力因數 γ_R 一般應取1.0。

6.6 結果等級因數 γ_C 一般應按本標準的4.4的規定選取，但考慮到意外情景的性質，可適當放寬。

6.7 阻力 R_k 一般按最終極限狀態選取，但考慮到意外情景的性質，可適當放寬。

6.8 附加相關的意外情景應基於風險評估確定。

7 試驗

7.1 根據貨物圍護系統的概念，按本標準設計的貨物圍護系統的試驗範圍應與本規則4.20.3所述相同。”

RESOLUTION MSC.370(93)
(adopted on 22 May 2014)

AMENDMENTS TO THE INTERNATIONAL CODE FOR THE CONSTRUCTION AND EQUIPMENT OF SHIPS CARRYING LIQUEFIED GASES IN BULK (IGC CODE)

THE MARITIME SAFETY COMMITTEE,

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

NOTING resolution MSC.5(48), by which it adopted the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (hereinafter referred to as "the IGC Code"), which has become mandatory under chapter VII of the International Convention for the Safety of Life at Sea (SOLAS), 1974 (hereinafter referred to as "the Convention"),

NOTING ALSO article VIII(b) and regulation VII/11.1 of the Convention concerning the procedure for amending the IGC Code,

HAVING CONSIDERED, at its ninety-third session, amendments to the IGC Code proposed and circulated in accordance with article VIII(b)(i) of the Convention,

1 ADOPTS, in accordance with article VIII(b)(iv) of the Convention, amendments to the IGC Code, the text of which is set out in the annex to the present resolution;

2 DETERMINES, in accordance with article VIII(b)(vi)(2)(bb) of the Convention, that the amendments shall be deemed to have been accepted on 1 July 2015 unless, prior to that date, more than one third of the Contracting Governments to the Convention or Contracting Governments the combined merchant fleets of which constitute not less than 50% of the gross tonnage of the world's merchant fleet, have notified their objections to the amendments;

3 INVITES Contracting Governments to note that, in accordance with article VIII(b)(vii)(2) of the Convention, the amendments shall enter into force on 1 January 2016 upon their acceptance in accordance with paragraph 2 above;

4 REQUESTS the Secretary-General, in conformity with article VIII(b)(v) of the Convention, to transmit certified copies of the present resolution and the text of the amendments contained in the annex to all Contracting Governments to the Convention;

5 ALSO REQUESTS the Secretary-General to transmit copies of this resolution and its annex to Members of the Organization, which are not Contracting Governments to the Convention.

ANNEX

AMENDMENTS TO THE INTERNATIONAL CODE FOR THE CONSTRUCTION AND EQUIPMENT OF SHIPS CARRYING LIQUEFIED GASES IN BULK (IGC CODE)

The complete text of the IGC Code is replaced by the following:

"Contents

Preamble	
Chapter 1	General
Chapter 2	Ship survival capability and location of cargo tanks
Chapter 3	Ship arrangements
Chapter 4	Cargo containment
Chapter 5	Process pressure vessels and liquids, vapour and pressure piping systems
Chapter 6	Materials of construction and quality control
Chapter 7	Cargo pressure/Temperature control
Chapter 8	Vent systems for cargo containment
Chapter 9	Cargo containment system atmosphere control
Chapter 10	Electrical installations
Chapter 11	Fire protection and extinction
Chapter 12	Artificial ventilation in the cargo area
Chapter 13	Instrumentation and automation systems
Chapter 14	Personnel protection
Chapter 15	Filling limits for cargo tanks
Chapter 16	Use of cargo as fuel
Chapter 17	Special requirements
Chapter 18	Operating requirements
Chapter 19	Summary of minimum requirements

Appendix 1	IGC Code product data reporting form
Appendix 2	Model form of International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk
Appendix 3	Example of an addendum to the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk
Appendix 4	Non-metallic materials
Appendix 5	Standard for the use of limit state methodologies in the design of cargo containment systems of novel configuration

Preamble

1 The purpose of this Code is to provide an international standard for the safe carriage, by sea in bulk, of liquefied gases and certain other substances that are listed in chapter 19. Through consideration of the products carried, it prescribes the design and construction standards of the ships involved and the equipment they should carry to minimize the risk to the ship, its crew and the environment.

2 The basic philosophy is one of ship types related to the hazards of the products covered by the Code. Each of the products may have one or more hazard properties, which include flammability, toxicity, corrosivity and reactivity. A further possible hazard may arise where products are transported under cryogenic or pressure conditions.

3 Severe collisions or strandings could lead to cargo tank damage and result in uncontrolled release of the product. Such a release could result in evaporation and dispersion of the product and, in some cases, could cause brittle fracture of the ship's hull. The requirements in the Code are intended to minimize this risk as far as is practicable, based upon present knowledge and technology.

4 Throughout the development of the Code, it was recognized that it must be based on sound naval architectural and engineering principles and the best understanding available as to the hazards of the various products covered. Gas carrier design technology is not only a complex technology but is rapidly evolving and the Code shall not remain static. The Organization will periodically review the Code, continually taking into account both experience and future development.

5 Requirements for new products and their conditions of carriage will be circulated as recommendations, on an interim basis, when adopted by the Maritime Safety Committee of the Organization, prior to the entry into force of the appropriate amendments, under the terms of article VIII of the International Convention for the Safety of Life at Sea, 1974.

6 The Code primarily deals with ship design and equipment. To ensure the safe transport of the products the total system must, however, be appraised. Other important facets of the safe transport of the products, such as training, operation, traffic control and handling in port, are being or will be examined further by the Organization.

7 The development of the Code has been greatly assisted by a number of organizations in consultative status, such as the Society of International Gas Tanker and Terminal Operators Limited (SIGTTO) and other organizations, such as members of the International Association of Classification Societies (IACS).

8 Chapter 18 of the Code dealing with operation of liquefied gas carriers highlights the regulations in other chapters that are operational in nature and mentions those other important safety features that are peculiar to gas carrier operations.

9 The layout of the Code is in line with the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code), adopted by the Maritime Safety Committee at its forty-eighth session. Gas carriers may also carry in bulk liquid chemicals covered by the IBC Code, as prescribed in the IGC Code.

10 Floating production, storage and offloading (FPSO) facilities, which are designed to handle liquefied gases in bulk, do not fall under the IGC Code. However, designers of such units may consider using the IGC Code to the extent that the Code provides the most appropriate risk mitigation measures for the operations the unit is to perform. Where other more appropriate risk mitigation measures are determined that are contrary to this Code, they shall take precedence over the Code.

CHAPTER 1

GENERAL

Goal

To provide an international standard for the safe carriage, by sea in bulk, of liquefied gases by laying down the design and construction standards of ships involved in such carriage and the equipment, they shall carry to minimize the risk to the ship, its crew and to the environment, having regard to the nature of the products including flammability, toxicity, asphyxiation, corrosivity, reactivity and low temperature and vapour pressure.

1.1 Application and implementation

1.1.1 The Code applies to ships regardless of their size, including those of less than 500 gross tonnage, engaged in the carriage of liquefied gases having a vapour pressure exceeding 0.28 MPa absolute at a temperature of 37.8°C and other products, as shown in chapter 19, when carried in bulk.

1.1.2.1 Unless expressly provided otherwise, the Code applies to ships whose keels are laid, or which are at a similar stage of construction where:

.1 construction identifiable with the ship begins; and

.2 assembly of that ship has commenced, comprising at least 50 tonnes or 1% of the estimated mass of all structural material, whichever is less,

on or after 1 July 2016.

1.1.2.2 For the purpose of the Code, the expression "ships constructed" means ships the keels of which are laid or which are at a similar stage of construction.

1.1.2.3 Unless expressly provided otherwise, for ships constructed on or after 1 July 1986 and before 1 July 2016, the Administration shall ensure that the requirements which are applicable under this Code, as adopted by resolution MSC.5(48) as amended by resolutions MSC.17(58), MSC.30(61), MSC.32(63), MSC.59(67), MSC.103(73), MSC.177(79) and MSC.220(82), are complied with.

1.1.3 A ship, irrespective of the date of construction, which is converted to a gas carrier on or after 1 July 2016, shall be treated as a gas carrier constructed on the date on which such conversion commences.

1.1.4.1 When cargo tanks contain products for which the Code requires a type 1G ship, neither flammable liquids having a flashpoint of 60°C (closed cup test) or less, nor flammable products listed in chapter 19, shall be carried in tanks located within the protective zones described in 2.4.1.1.

1.1.4.2 Similarly, when cargo tanks contain products for which the Code requires a type 2G/2PG ship, the flammable liquids as described in 1.1.4.1, shall not be carried in tanks located within the protective zones described in 2.4.1.2.

1.1.4.3 In each case, for cargo tanks loaded with products for which the Code requires a type 1G or 2G/2PG ship, the restriction applies to the protective zones within the longitudinal extent of the hold spaces for those tanks.

1.1.4.4 The flammable liquids and products described in 1.1.4.1 may be carried within these protective zones when the quantity of products retained in the cargo tanks, for which the Code requires a type 1G or 2G/2PG ship is solely used for cooling, circulation or fuelling purposes.

1.1.5 Except as provided in 1.1.7.1, when it is intended to carry products covered by this Code and products covered by the *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk* (IBC Code), adopted by resolution MSC.4(48), as may be amended by the Organization, the ship shall comply with the requirements of both Codes appropriate to the products carried.

1.1.6.1 Where it is proposed to carry products that may be considered to come within the scope of this Code that are not at present designated in chapter 19, the Administration and the port Administrations involved in such carriage shall establish a Tripartite Agreement based on a provisional assessment and lay down preliminary suitable conditions of carriage based on the principles of the Code.

1.1.6.2 For the evaluation of such products, the manufacturer of the product shall submit to the Administration a completed assessment form (see appendix 1), which includes the proposed ship type and carriage requirements.

1.1.6.3 When a provisional assessment for a pure or technically pure product has been completed and agreed with the other parties, the Administration shall submit the assessment form and a proposal for a new and complete entry in the IGC Code, to the relevant sub-committee of the Organization (see appendix 1).

1.1.6.4 After provisional assessment by Tripartite Agreement and express or tacit agreement has been established, an addendum to the relevant ship's certificate may be issued (see appendix 3).

1.1.7.1 The requirements of this Code shall take precedence when a ship is designed and constructed for the carriage of the following products:

.1 those listed exclusively in chapter 19 of the Code; and

.2 one or more of the products that are listed both in the Code and in the International Bulk Chemical Code. These products are marked with an asterisk in column "a" in the table contained within chapter 19.

1.1.7.2 When a ship is intended to exclusively carry one or more of the products referred to in 1.1.7.1.2, the requirements of the International Bulk Chemical Code, as amended, shall apply.

1.1.8 The ship's compliance with the requirements of the International Gas Carrier Code shall be shown by its International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk, as described in 1.4. Compliance with the amendments to the Code, as appropriate, shall also be indicated in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

1.1.9 Where reference is made in the Code to a paragraph, all the provisions of the subparagraph of that designation shall apply.

1.1.10 When a ship is intended to operate for periods at a fixed location in a re-gasification and gas discharge mode or a gas receiving, processing, liquefaction and storage mode, the Administration and port Administrations involved in the operation shall take appropriate steps to ensure implementation of the provisions of the Code as are applicable to the proposed arrangements. Furthermore, additional requirements shall be established based on the principles of the Code as well as recognized standards that address specific risks not envisaged by it. Such risks may include, but not be limited to:

.1 fire and explosion;

.2 evacuation;

.3 extension of hazardous areas;

.4 pressurized gas discharge to shore;

.5 high-pressure gas venting;

.6 process upset conditions;

.7 storage and handling of flammable refrigerants;

.8 continuous presence of liquid and vapour cargo outside the cargo containment system;

.9 tank over-pressure and under-pressure;

.10 ship-to-ship transfer of liquid cargo; and

.11 collision risk during berthing manoeuvres.

1.1.11 Where a risk assessment or study of similar intent is utilized within the Code, the results shall also include, but not be limited to, the following as evidence of effectiveness:

.1 description of methodology and standards applied;

.2 potential variation in scenario interpretation or sources of error in the study;

.3 validation of the risk assessment process by an independent and suitable third party;

.4 quality system under which the risk assessment was developed;

.5 the source, suitability and validity of data used within the assessment;

.6 the knowledge base of persons involved within the assessment;

.7 system of distribution of results to relevant parties; and

.8 validation of results by an independent and suitable third party.

1.1.12 Although the Code is legally treated as a mandatory instrument under the SOLAS Convention, the provisions of section 4.28 and appendices 1, 3 and 4 of the Code are recommendatory or informative.

1.2 Definitions

Except where expressly provided otherwise, the following definitions apply to the Code. Additional definitions are provided in chapters throughout the Code.

1.2.1 *Accommodation spaces* are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobby rooms, barber shops, pantries without cooking appliances and similar spaces.

1.2.2 "*A*" *class divisions* are divisions as defined in regulation II-2/3.2 of the SOLAS Convention.

1.2.3 *Administration* means the Government of the State whose flag the ship is entitled to fly. For *Administration (port)*, see *port Administration.*

1.2.4 *Anniversary date* means the day and the month of each year that will correspond to the date of expiry of the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

1.2.5 *Boiling point* is the temperature at which a product exhibits a vapour pressure equal to the atmospheric pressure.

1.2.6 *Breadth (B)* means the maximum breadth of the ship, measured amidships to the moulded line of the frame in a ship with a metal shell, and to the outer surface of the hull in a ship with a shell of any other material. The breadth *(B)* shall be measured in metres.

1.2.7 *Cargo area* is that part of the ship which contains the cargo containment system and cargo pump and compressor rooms and includes the deck areas over the full length and breadth of the part of the ship over these spaces. Where fitted, the cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the foremost hold space are excluded from the cargo area.

1.2.8 *Cargo containment system* is the arrangement for containment of cargo including, where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure, if necessary, for the support of these elements. If the secondary barrier is part of the hull structure, it may be a boundary of the hold space.

1.2.9 *Cargo control room* is a space used in the control of cargo handling operations.

1.2.10 *Cargo machinery spaces* are the spaces where cargo compressors or pumps, cargo processing units, are located, including those supplying gas fuel to the engine-room.

1.2.11 *Cargo pumps* are pumps used for the transfer of liquid cargo including main pumps, booster pumps, spray pumps, etc.

1.2.12 *Cargoes* are products listed in chapter 19, that are carried in bulk by ships subject to the Code.

1.2.13 *Cargo service spaces* are spaces within the cargo area, used for workshops, lockers and store-rooms that are of more than 2 m^2 in area.

1.2.14 *Cargo tank* is the liquid-tight shell designed to be the primary container of the cargo and includes all such containment systems whether or not they are associated with the insulation or/and the secondary barriers.

1.2.15 *Closed loop sampling* is a cargo sampling system that minimizes the escape of cargo vapour to the atmosphere by returning product to the cargo tank during sampling.

1.2.16 *Cofferdam* is the isolating space between two adjacent steel bulkheads or decks. This space may be a void space or a ballast space.

1.2.17 *Control stations* are those spaces in which ship's radio, main navigating equipment or the emergency source of power is located or where the fire-recording or fire control equipment is centralized. This does not include special fire control equipment, which can be most practically located in the cargo area.

1.2.18 *Flammable products* are those identified by an "F" in column "*f*" in the table of chapter 19.

1.2.19 *Flammability limits* are the conditions defining the state of fuel-oxidant mixture at which application of an adequately strong external ignition source is only just capable of producing flammability in a given test apparatus.

1.2.20 *FSS Code* is the Fire Safety Systems Code meaning the *International Code for Fire Safety Systems*, adopted by the Maritime Safety Committee of the Organization by resolution MSC.98(73), as amended.

1.2.21 *Gas carrier* is a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas or other products listed in the table of chapter 19.

1.2.22 *Gas combustion unit (GCU)* is a means of disposing excess cargo vapour by thermal oxidation.

1.2.23 *Gas consumer* is any unit within the ship using cargo vapour as a fuel.

1.2.24 *Hazardous area* is an area in which an explosive gas atmosphere is, or may be expected to be present, in quantities that require special precautions for the construction, installation and use of electrical equipment. When a gas atmosphere is present, the following hazards may also be present: toxicity, asphyxiation, corrosivity, reactivity and low temperature. These hazards shall also be taken into account and additional precautions for the ventilation of spaces and protection of the crew will need to be considered. Examples of hazardous areas include, but are not limited to, the following:

.1 the interiors of cargo containment systems and any pipework of pressure-relief or other venting systems for cargo tanks, pipes and equipment containing the cargo;

.2 interbarrier spaces;

.3 hold spaces where the cargo containment system requires a secondary barrier;

.4 hold spaces where the cargo containment system does not require a secondary barrier;

.5 a space separated from a hold space by a single gastight steel boundary where the cargo containment system requires a secondary barrier;

.6 cargo machinery spaces;

.7 areas on open deck, or semi-enclosed spaces on open deck, within 3 m of possible sources of gas release, such as cargo valve, cargo pipe flange, cargo machinery space ventilation outlet, etc.;

.8 areas on open deck, or semi-enclosed spaces on open deck within 1.5 m of cargo machinery space entrances, cargo machinery space ventilation inlets;

.9 areas on open deck over the cargo area and 3 m forward and aft of the cargo area on the open deck up to a height of 2.4 m above the weather deck;

.10 an area within 2.4 m of the outer surface of a cargo containment system where such surface is exposed to the weather;

.11 enclosed or semi-enclosed spaces in which pipes containing cargoes are located, except those where pipes containing cargo products for boil-off gas fuel burning systems are located;

.12 an enclosed or semi-enclosed space having a direct opening into any hazardous area;

.13 void spaces, cofferdams, trunks, passageways and enclosed or semi-enclosed spaces, adjacent to, or immediately above or below, the cargo containment system;

.14 areas on open deck or semi-enclosed spaces on open deck above and in the vicinity of any vent riser outlet, within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet and within a hemisphere of 6 m radius below the outlet; and

.15 areas on open deck within spillage containment surrounding cargo manifold valves and 3 m beyond these up to a height of 2.4 m above deck.

1.2.25 *Non-hazardous area* is an area other than a hazardous area.

1.2.26 *Hold space* is the space enclosed by the ship's structure in which a cargo containment system is situated.

1.2.27 *IBC Code* means the *International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk*, adopted by the Maritime Safety Committee of the Organization by resolution MSC.4(48), as amended.

1.2.28 *Independent* means that a piping or venting system, for example, is in no way connected to another system and that there are no provisions available for the potential connection to other systems.

1.2.29 *Insulation space* is the space, which may or may not be an interbarrier space, occupied wholly or in part by insulation.

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

1.2.31 *Length (L)* is the length as defined in the International Convention on Load Lines in force.

1.2.32 *Machinery spaces of category A* are those spaces, and trunks to those spaces, which contain either:

.1 internal combustion machinery used for main propulsion; or

.2 internal combustion machinery used for purposes other than main propulsion where such machinery has, in the aggregate, a total power output of not less than 375 kW; or

.3 any oil-fired boiler or oil fuel unit or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc.

1.2.33 *Machinery spaces* are machinery spaces of category A and other spaces containing propelling machinery, boilers, oil fuel units, steam and internal-combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces and the trunks to such spaces.

1.2.34 *MARVS* is the maximum allowable relief valve setting of a cargo tank (gauge pressure).

1.2.35 *Nominated surveyor* is a surveyor nominated/appointed by an Administration to enforce the provisions of the SOLAS Convention regulations with regard to inspections and surveys and the granting of exemptions therefrom.

1.2.36 *Oil fuel unit* is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0.18 MPa gauge.

1.2.37 *Organization* is the International Maritime Organization (IMO).

1.2.38 *Permeability* of a space means the ratio of the volume within that space which is assumed to be occupied by water to the total volume of that space.

1.2.39 *Port Administration* means the appropriate authority of the country for the port where the ship is loading or unloading.

1.2.40 *Primary barrier* is the inner element designed to contain the cargo when the cargo containment system includes two boundaries.

1.2.41 *Products* is the collective term used to cover the list of gases indicated in chapter 19 of this Code.

1.2.42 *Public spaces* are those portions of the accommodation that are used for halls, dining rooms, lounges and similar permanently enclosed spaces.

1.2.43 *Recognized organization* is an organization authorized by an Administration in accordance with SOLAS regulation XI-1/1.

1.2.44 *Recognized standards* are applicable international or national standards acceptable to the Administration, or standards laid down and maintained by the recognized organization.

1.2.45 *Relative density* is the ratio of the mass of a volume of a product to the mass of an equal volume of fresh water.

1.2.46 *Secondary barrier* is the liquid-resisting outer element of a cargo containment system, designed to afford temporary containment of any envisaged leakage of liquid cargo through the primary barrier and to prevent the lowering of the temperature of the ship's structure to an unsafe level. Types of secondary barrier are more fully defined in chapter 4.

1.2.47 *Separate systems* are those cargo piping and vent systems that are not permanently connected to each other.

1.2.48 *Service spaces* are those used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, store-rooms, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces.

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

1.2.50 *Tank cover* is the protective structure intended to either protect the cargo containment system against damage where it protrudes through the weather deck or to ensure the continuity and integrity of the deck structure.

1.2.51 *Tank dome* is the upward extension of a portion of a cargo tank. In the case of below-deck cargo containment systems, the tank dome protrudes through the weather deck or through a tank cover.

1.2.52 *Thermal oxidation method* means a system where the boil-off vapours are utilized as fuel for shipboard use or as a waste heat system subject to the provisions of chapter 16 or a system not using the gas as fuel complying with this Code.

1.2.53 *Toxic products* are those defined by a "T" in column "*f*" in the table of chapter 19.

1.2.54 *Turret compartments* are those spaces and trunks that contain equipment and machinery for retrieval and release of the disconnectable turret mooring system, high-pressure hydraulic operating systems, fire protection arrangements and cargo transfer valves.

1.2.55 *Vapour pressure* is the equilibrium pressure of the saturated vapour above the liquid, expressed in Pascals (Pa) absolute at a specified temperature.

1.2.56 *Void space* is an enclosed space in the cargo area external to a cargo containment system, other than a hold space, ballast space, oil fuel tank, cargo pumps or compressor room, or any space in normal use by personnel.

1.3 Equivalents

1.3.1 Where the Code requires that a particular fitting, material, appliance, apparatus, item of equipment or type thereof shall be fitted or carried in a ship, or that any particular provision shall be made, or any procedure or arrangement shall be complied with, the Administration may allow any other fitting, material, appliance, apparatus, item of equipment or type thereof to be fitted or carried, or any other provision, procedure or arrangement to be made in that ship, if it is satisfied by trial thereof or otherwise that such fitting, material, appliance, apparatus, item of equipment or type thereof, or that any particular provision, procedure or arrangement, is at least as effective as that required by the Code. However, the Administration may not allow operational methods or procedures to be made as an alternative to a particular fitting, material, appliance, apparatus, item of equipment, or type thereof that is prescribed by the Code, unless such a substitution is specifically allowed by the Code.

1.3.2 When the Administration so allows, any fitting, material, appliance, apparatus, item of equipment, or type thereof, or provision, procedure or arrangement or novel design or application to be substituted, it shall communicate to the Organization the particulars thereof, together with a report on the evidence submitted, so that the Organization may circulate the same to other Contracting Governments to the SOLAS Convention for the information of their officers.

1.4 Surveys and certification

1.4.1 *Survey procedure*

1.4.1.1 The survey of ships, so far as regards the enforcement of the provisions of the Code and granting of exemptions therefrom, shall be carried out by officers of the Administration. The Administration may, however, entrust the surveys either to surveyors nominated for the purpose or to organizations recognized by it.

1.4.1.2 The recognized organization, referred to in 1.2.43, shall comply with the provisions of the SOLAS Convention and with the Code for recognized organizations (RO Code).

1.4.1.3 The Administration nominating surveyors or recognizing organizations to conduct surveys shall, as a minimum, empower any nominated surveyor or recognized organization to:

.1 require repairs to a ship; and

.2 carry out surveys if requested by the appropriate authorities of a port State.

The Administration shall notify the Organization of the specific responsibilities and conditions of the authority delegated to nominated surveyors or recognized organizations, for circulation to the Contracting Governments.

1.4.1.4 When a nominated surveyor or recognized organization determines that the condition of a ship or its equipment does not correspond substantially with the particulars of the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk, or is such that the ship is not fit to proceed to sea without danger to the ship or persons on board, or without presenting unreasonable threat of harm to the marine environment, the surveyor or organization shall immediately ensure that corrective action is taken and shall, in due course, notify the Administration. If such corrective action is not taken, the certificate shall be withdrawn and the Administration shall be notified immediately. If the ship is in a port of another Contracting Government, the appropriate authorities of the port State shall be notified immediately. When an officer of the Administration, a nominated surveyor or a recognized organization has notified the appropriate authorities of the port State, the Government of the port State concerned shall give the officer, surveyor or organization any necessary assistance to carry out their obligations under this paragraph. When applicable, the Government of the port State concerned shall take such steps as will ensure that the ship does not sail until it can proceed to sea or leave the port for the purpose of proceeding to the nearest appropriate repair yard available without danger to the ship or persons on board or without presenting an unreasonable threat of harm to the marine environment.

1.4.1.5 In every case, the Administration shall guarantee the completeness and efficiency of the survey and shall undertake to ensure the necessary arrangements to satisfy this obligation.

1.4.2 *Survey requirements*

The structure, equipment, fittings, arrangements and material (other than items in respect of which a Cargo Ship Safety Construction Certificate, Cargo Ship Safety Equipment Certificate and Cargo Ship Safety Radio Certificate; or Cargo Ship Safety Certificate, required by the SOLAS Convention, are issued) of a gas carrier shall be subjected to the following surveys:

.1 An initial survey before the ship is put in service or before the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk is issued for the first time, which shall include a complete examination of its structure,

equipment, fittings, arrangements and materials in so far as the ship is covered by the Code. This survey shall be such as to ensure that the structure, equipment, fittings, arrangements and material fully comply with the applicable provisions of the Code.

.2 A renewal survey at intervals specified by the Administration, but not exceeding five years, except where regulation 1.4.6.2.1, 1.4.6.5, 1.4.6.6 or 1.4.6.7 is applicable. The renewal survey shall be such as to ensure that the structure, equipment, fittings, arrangements and material fully comply with the applicable provisions of the Code.

.3 An intermediate survey within three months before or after the second anniversary date, or within three months before or after the third anniversary date of the certificate, which shall take the place of one of the annual surveys specified in 1.4.2.4. The intermediate survey shall be such as to ensure that the safety equipment, and other equipment, and associated pump and piping systems fully comply with the applicable provisions of the Code and are in good working order. Such intermediate surveys shall be endorsed on the certificate issued under 1.4.4 or 1.4.5.

.4 An annual survey within three months before or after each anniversary date of the certificate, including a general inspection of the structure, equipment, fittings, arrangements and material referred to in 1.4.2.1 to ensure that they have been maintained in accordance with 1.4.3 and that they remain satisfactory for the service for which the ship is intended. Such annual surveys shall be endorsed on the certificate issued under 1.4.4 or 1.4.5.

.5 An additional survey, either general or partial according to the circumstances, shall be made when required after an investigation prescribed in 1.4.3.3, or whenever any important repairs or renewals are made. Such a survey shall ensure that the necessary repairs or renewals have been effectively made, that the materials and workmanship of such repairs or renewals are satisfactory, and that the ship is fit to proceed to sea without danger to the ship or persons on board or without presenting unreasonable threat of harm to the marine environment.

1.4.3 ***Maintenance of conditions after survey***

1.4.3.1 The condition of the ship and its equipment shall be maintained to conform with the provisions of the Code and to ensure that the ship will remain fit to proceed to sea without danger to the ship or persons on board or without presenting unreasonable threat of harm to the marine environment.

1.4.3.2 After any survey of the ship, as described in 1.4.2, has been completed, no change shall be made in the structure, equipment, fittings, arrangements and material covered by the survey without the sanction of the Administration, except by direct replacement.

1.4.3.3 Whenever an accident occurs to a ship or a defect is discovered, either of which affects the safety of the ship or the efficiency or completeness of its life-saving appliances or other equipment covered by the Code, the master or owner of the ship shall report at the earliest opportunity to the Administration, the nominated surveyor or recognized organization responsible for issuing the certificate, who shall cause investigations to be initiated to determine whether a survey, as required by 1.4.2.5, is necessary. If the ship is in a port of another Contracting Government, the master or owner shall also report immediately to the appropriate authorities of the port State and the nominated surveyor or recognized organization shall ascertain that such a report has been made.

1.4.4 ***Issue and endorsement of an International Certificate of Fitness of Liquefied Gases in Bulk***

1.4.4.1 An International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk shall be issued, after an initial or renewal survey, to a gas carrier engaged on international voyages that comply with the relevant provisions of the Code.

1.4.4.2 Such a certificate shall be drawn up in the form corresponding to the model given in appendix 2. If the language used is not English, French or Spanish, the text shall include a translation into one of these languages.

1.4.4.3 The certificate issued under the provisions of this section shall be available on board for examination at all times.

1.4.4.4 Notwithstanding any other provisions of the amendments to the Code, adopted by the Maritime Safety Committee by resolution MSC.17(58), any International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk that is current when these amendments enter into force shall remain valid until it expires under the terms of this Code prior to the amendments entering into force.

1.4.5 ***Issue or endorsement of an International Certificate of Fitness of Liquefied Gases in Bulk by another Government***

1.4.5.1 A Contracting Government to the SOLAS Convention may, at the request of another Contracting Government, cause a ship entitled to fly the flag of the other State to be surveyed and, if satisfied that the requirements of the Code are complied with, issue or authorize the issue of the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk to the ship and, where appropriate, endorse or authorize the endorsement of the certificate on board the ship in accordance with the Code. Any certificate so issued shall contain a statement to the effect that it has been issued at the request of the Government of the State whose flag the ship is entitled to fly.

1.4.6 ***Duration and validity of an International Certificate of Fitness of Liquefied Gases in Bulk***

1.4.6.1 An International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk shall be issued for a period specified by the Administration, which shall not exceed five years.

1.4.6.2.1 Notwithstanding the provisions of 1.4.6.1, when the renewal survey is completed within three months before the expiry date of the existing certificate, the new certificate shall be valid from the date of completion of the renewal survey to a date not exceeding five years from the date of expiry of the existing certificate.

1.4.6.2.2 When the renewal survey is completed after the expiry date of the existing certificate, the new certificate shall be valid from the date of completion of the renewal survey to a date not exceeding five years from the date of expiry of the existing certificate.

1.4.6.2.3 When the renewal survey is completed more than three months before the expiry date of the existing certificate, the new certificate shall be valid from the date of completion of the renewal survey to a date not exceeding five years from the date of completion of the renewal survey.

1.4.6.3 If a certificate is issued for a period of less than five years, the Administration may extend the validity of the certificate beyond the expiry date to the maximum period specified

in 1.4.6.1, provided that the surveys referred to in regulations 1.4.2.3 and 1.4.2.4, applicable when a certificate is issued for a period of five years, are carried out as appropriate.

1.4.6.4 If a renewal survey has been completed and a new certificate cannot be issued or placed on board the ship before the expiry date of the existing certificate, the person or organization authorized by the Administration may endorse the existing certificate. Such a certificate shall be accepted as valid for a further period which shall not exceed five months from the expiry date.

1.4.6.5 If a ship is not in a port in which it is to be surveyed at the time when a certificate expires, the Administration may extend the period of validity of the certificate. However, the extension shall be granted only for the purpose of allowing the ship to complete its voyage to the port in which it is to be surveyed, and then only in cases where it appears proper and reasonable to do so.

1.4.6.6 A certificate, issued to a ship engaged on short voyages, that has not been extended under the foregoing provisions of this section may be extended by the Administration for a period of grace of up to one month from the date of expiry stated on it. When the renewal survey is completed, the new certificate shall be valid to a date not exceeding five years from the date of expiry of the existing certificate before the extension was granted.

1.4.6.7 In special circumstances, as determined by the Administration, a new certificate need not be dated from the date of expiry of the existing certificate as required by 1.4.6.2.2, 1.4.6.5 or 1.4.6.6. In these special circumstances, the new certificate shall be valid to a date not exceeding five years from the date of completion of the renewal survey.

1.4.6.8 If an annual or intermediate survey is completed before the period specified in 1.4.2, then:

.1 the anniversary date shown on the certificate shall be amended by endorsement to a date that shall not be more than three months later than the date on which the survey was completed;

.2 the subsequent annual or intermediate survey required by 1.4.2 shall be completed, at the intervals prescribed by that section, using the new anniversary date; and

.3 the expiry date may remain unchanged, provided one or more annual or intermediate surveys, as appropriate, are carried out so that the maximum intervals between the surveys prescribed by 1.4.2 are not exceeded.

1.4.6.9 A certificate issued under 1.4.4 or 1.4.5 shall cease to be valid in any of the following cases:

.1 if the relevant surveys are not completed within the periods specified in 1.4.2;

.2 if the certificate is not endorsed in accordance with 1.4.2.3 or 1.4.2.4; and

.3 upon transfer of the ship to the flag of another State. A new certificate shall only be issued when the Government issuing the new certificate is fully satisfied that the ship is in compliance with the provisions of 1.4.3.1 and 1.4.3.2. In the case of a transfer between Contracting Governments to the SOLAS Convention, if requested within three months after the transfer has taken place, the Government of the State whose flag the ship was

formerly entitled to fly shall, as soon as possible, transmit to the Administration copies of the certificate carried by the ship before the transfer and, if available, copies of the relevant survey reports.

CHAPTER 2

SHIP SURVIVAL CAPABILITY AND LOCATION OF CARGO TANKS

Goal

To ensure that the cargo tanks are in a protective location in the event of minor hull damage, and that the ship can survive the assumed flooding conditions.

2.1 General

2.1.1 Ships subject to the Code shall survive the hydrostatic effects of flooding following assumed hull damage caused by some external force. In addition, to safeguard the ship and the environment, the cargo tanks shall be protected from penetration in the case of minor damage to the ship resulting, for example, from contact with a jetty or tug, and also given a measure of protection from damage in the case of collision or grounding, by locating them at specified minimum distances inboard from the ship's shell plating. Both the damage to be assumed and the proximity of the tanks to the ship's shell shall be dependent upon the degree of hazard presented by the product to be carried. In addition, the proximity of the cargo tanks to the ship's shell shall be dependent upon the volume of the cargo tank.

2.1.2 Ships subject to the Code shall be designed to one of the following standards:

.1 A *type 1G ship* is a gas carrier intended to transport the products indicated in chapter 19 that require maximum preventive measures to preclude their escape.

.2 A *type 2G ship* is a gas carrier intended to transport the products indicated in chapter 19, that require significant preventive measures to preclude their escape.

.3 A *type 2PG ship* is a gas carrier of 150 m in length or less intended to transport the products indicated in chapter 19 that require significant preventive measures to preclude their escape, and where the products are carried in type C independent tanks designed (see 4.23) for a MARVS of at least 0.7 MPa gauge and a cargo containment system design temperature of -55°C or above. A ship of this description that is over 150 m in length is to be considered a type 2G ship.

.4 A *type 3G ship* is a gas carrier intended to carry the products indicated in chapter 19 that require moderate preventive measures to preclude their escape.

Therefore, a type 1G ship is a gas carrier intended for the transportation of products considered to present the greatest overall hazard and types 2G/2PG and type 3G for products of progressively lesser hazards. Accordingly, a type 1G ship shall survive the most severe standard of damage and its cargo tanks shall be located at the maximum prescribed distance inboard from the shell plating.

2.1.3 The ship type required for individual products is indicated in column "*c*" in the table of chapter 19.

2.1.4 If a ship is intended to carry more than one of the products listed in chapter 19, the standard of damage shall correspond to the product having the most stringent ship type requirements. The requirements for the location of individual cargo tanks, however, are those for ship types related to the respective products intended to be carried.

2.1.5 For the purpose of this Code, the position of the moulded line for different containment systems is shown in figures 2.5 (a) to (e).

2.2 Freeboard and stability

2.2.1 Ships subject to the Code may be assigned the minimum freeboard permitted by the International Convention on Load Lines in force. However, the draught associated with the assignment shall not be greater than the maximum draught otherwise permitted by this Code.

2.2.2 The stability of the ship, in all seagoing conditions and during loading and unloading cargo, shall comply with the requirements of the International Code on Intact Stability. This includes partial filling and loading and unloading at sea, when applicable. Stability during ballast water operations shall fulfil stability criteria.

2.2.3 When calculating the effect of free surfaces of consumable liquids for loading conditions, it shall be assumed that, for each type of liquid, at least one transverse pair or a single centre tank has a free surface. The tank or combination of tanks to be taken into account shall be those where the effect of free surfaces is the greatest. The free surface effect in undamaged compartments shall be calculated by a method according to the International Code on Intact Stability.

2.2.4 Solid ballast shall not normally be used in double bottom spaces in the cargo area. Where, however, because of stability considerations, the fitting of solid ballast in such spaces becomes unavoidable, its disposition shall be governed by the need to enable access for inspection and to ensure that the impact loads resulting from bottom damage are not directly transmitted to the cargo tank structure.

2.2.5 The master of the ship shall be supplied with a loading and stability information booklet. This booklet shall contain details of typical service conditions, loading, unloading and ballasting operations, provisions for evaluating other conditions of loading and a summary of the ship's survival capabilities. The booklet shall also contain sufficient information to enable the master to load and operate the ship in a safe and seaworthy manner.

2.2.6 All ships, subject to the Code shall be fitted with a stability instrument, capable of verifying compliance with intact and damage stability requirements, approved by the Administration having regard to the performance standards recommended by the Organization.

.1 ships constructed before 1 July 2016 shall comply with this paragraph at the first scheduled renewal survey of the ship after 1 July 2016 but not later than 1 July 2021;

.2 notwithstanding the requirements of paragraph 2.2.6.1 a stability instrument installed on a ship constructed before 1 July 2016 need not be replaced provided it is capable of verifying compliance with intact and damage stability, to the satisfaction of the Administration; and

.3 for the purposes of control under SOLAS regulation XI-1/4, the Administration shall issue a document of approval for the stability instrument.

2.2.7 The Administration may waive the requirements of paragraph 2.2.6 for the following ships, provided the procedures employed for intact and damage stability verification maintain the same degree of safety, as being loaded in accordance with the approved conditions. Any such waiver shall be duly noted on the International Certificate of Fitness referred to in paragraph 1.4.4:

.1 ships which are on a dedicated service, with a limited number of permutations of loading such that all anticipated conditions have been approved in the stability information provided to the master in accordance with the requirements of paragraph 2.2.5;

.2 ships where stability verification is made remotely by a means approved by the Administration;

.3 ships which are loaded within an approved range of loading conditions; or

.4 ships constructed before 1 July 2016 provided with approved limiting KG/GM curves covering all applicable intact and damage stability requirements.

2.2.8 ***Conditions of loading***

Damage survival capability shall be investigated on the basis of loading information submitted to the Administration for all anticipated conditions of loading and variations in draught and trim. This shall include ballast and, where applicable, cargo heel.

2.3 Damage assumptions

2.3.1 The assumed maximum extent of damage shall be:

.1	Side damage		
.1.1	Longitudinal extent:	1/3 $L^{2/3}$ or 14.5 m, whichever is less	
.1.2	Transverse extent: measured inboard from the moulded line of the outer shell at right angles to the centreline at the level of the summer waterline	B/5 or 11.5 m, whichever is less	
.1.3	Vertical extent: from the moulded line of the outer shell	Upwards, without limit	
.2	Bottom damage:	For 0.3 L from the forward perpendicular of the ship	Any other part of the ship
.2.1	Longitudinal extent:	1/3$L^{2/3}$ or 14.5 m, whichever is less	1/3$L^{2/3}$ or 14.5 m, whichever is less
.2.2	Transverse extent:	B/6 or 10 m, whichever is less	B/6 or 5 m, whichever is less
.2.3	Vertical extent:	B/15 or 2 m, whichever is less, measured from the moulded line of the bottom shell plating at centreline (see 2.4.3)	B/15 or 2 m, whichever is less measured from the moulded line of the bottom shell plating at centreline (see 2.4.3)

2.3.2 ***Other damage***

2.3.2.1 If any damage of a lesser extent than the maximum damage specified in 2.3.1 would result in a more severe condition, such damage shall be assumed.

2.3.2.2 Local damage anywhere in the cargo area extending inboard distance "*d*" as defined in 2.4.1, measured normal to the moulded line of the outer shell shall be considered. Bulkheads shall be assumed damaged when the relevant subparagraphs of 2.6.1 apply. If a damage of a lesser extent than "*d*" would result in a more severe condition, such damage shall be assumed.

2.4 Location of cargo tanks

2.4.1 Cargo tanks shall be located at the following distances inboard:

.1 Type 1G ships: from the moulded line of the outer shell, not less than the transverse extent of damage specified in 2.3.1.1.2 and, from the moulded line of the bottom shell at centreline, not less than the vertical extent of damage specified in 2.3.1.2.3, and nowhere less than *"d"* where *"d"* is as follows:

.1 for Vc below or equal 1,000 m^3, d = 0.8 m;

.2 for 1,000 m^3 < Vc < 5,000 m^3, d = 0.75 + Vc x 0.2/4,000 m;

.3 for 5,000 m^3 ≤ Vc < 30,000 m^3, *d* = 0.8 + Vc/25,000 m; and

.4 for Vc ≥ 30,000 m^3, *d* = 2 m,

where:

- Vc corresponds to 100% of the gross design volume of the individual cargo tank at 20°C, including domes and appendages (see figures 2.1 and 2.2). For the purpose of cargo tank protective distances, the cargo tank volume is the aggregate volume of all the parts of tank that have a common bulkhead(s); and

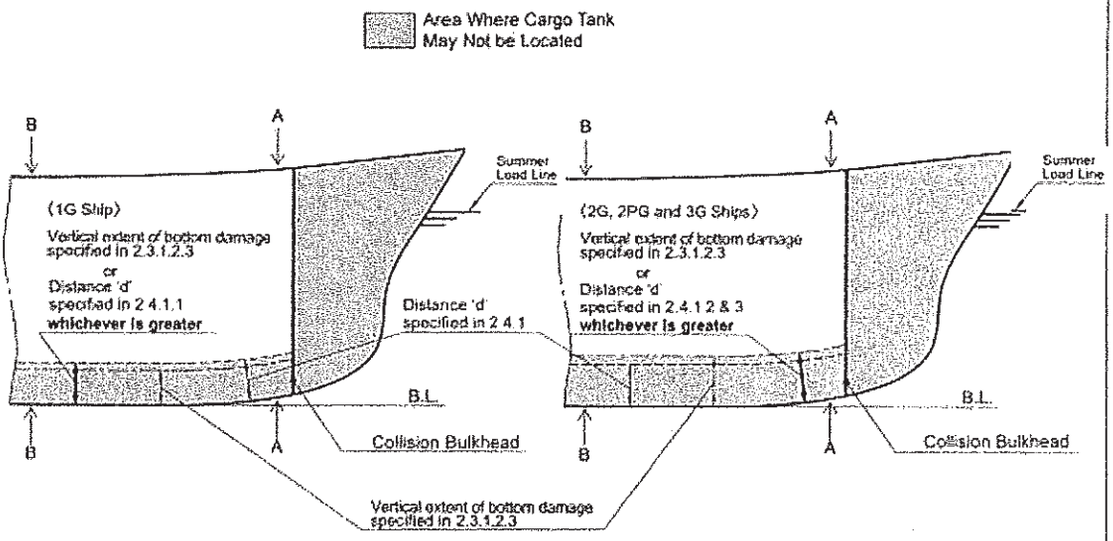
- "*d*" is measured at any cross section at a right angle from the moulded line of outer shell.

Tank size limitations may apply to type 1G ship cargoes in accordance with chapter 17.

.2 Types 2G/2PG: from the moulded line of the bottom shell at centreline not less than the vertical extent of damage specified in 2.3.1.2.3 and nowhere less than "*d*" as indicated in 2.4.1.1 (see figures 2.1 and 2.3).

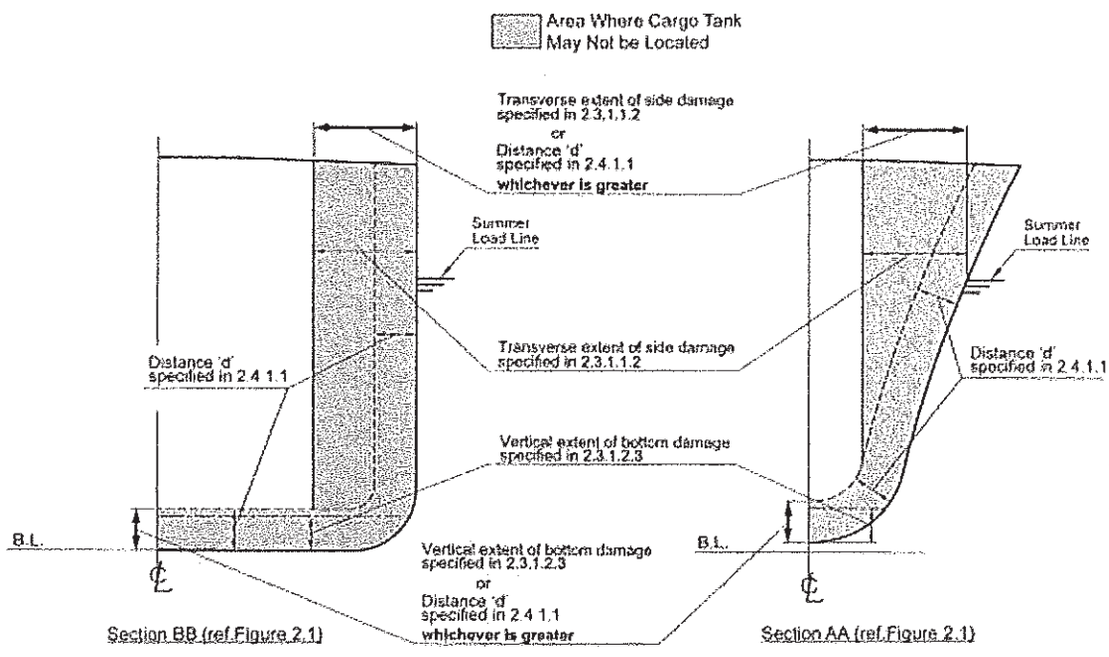
.3 Type 3G ships: from the moulded line of the bottom shell at centreline not less than the vertical extent of damage specified in 2.3.1.2.3 and nowhere less than "*d*", where "*d*" = 0.8 m from the moulded line of outer shell (see figures 2.1 and 2.4).

2.4.2 For the purpose of tank location, the vertical extent of bottom damage shall be measured to the inner bottom when membrane or semi-membrane tanks are used, otherwise to the bottom of the cargo tanks. The transverse extent of side damage shall be measured to the longitudinal bulkhead when membrane or semi-membrane tanks are used, otherwise to the side of the cargo tanks. The distances indicated in 2.3 and 2.4 shall be applied as in figures 2.5(a) to (e). These distances shall be measured plate to plate, from the moulded line to the moulded line, excluding insulation.



Centreline Profile - Type 1G, 2G, 2PG and 3G Ships

Figure 2.1 - *Cargo tank location requirements*



Transverse Sections - Type 1G Ship

Figure 2.2 - *Cargo tank location requirements*

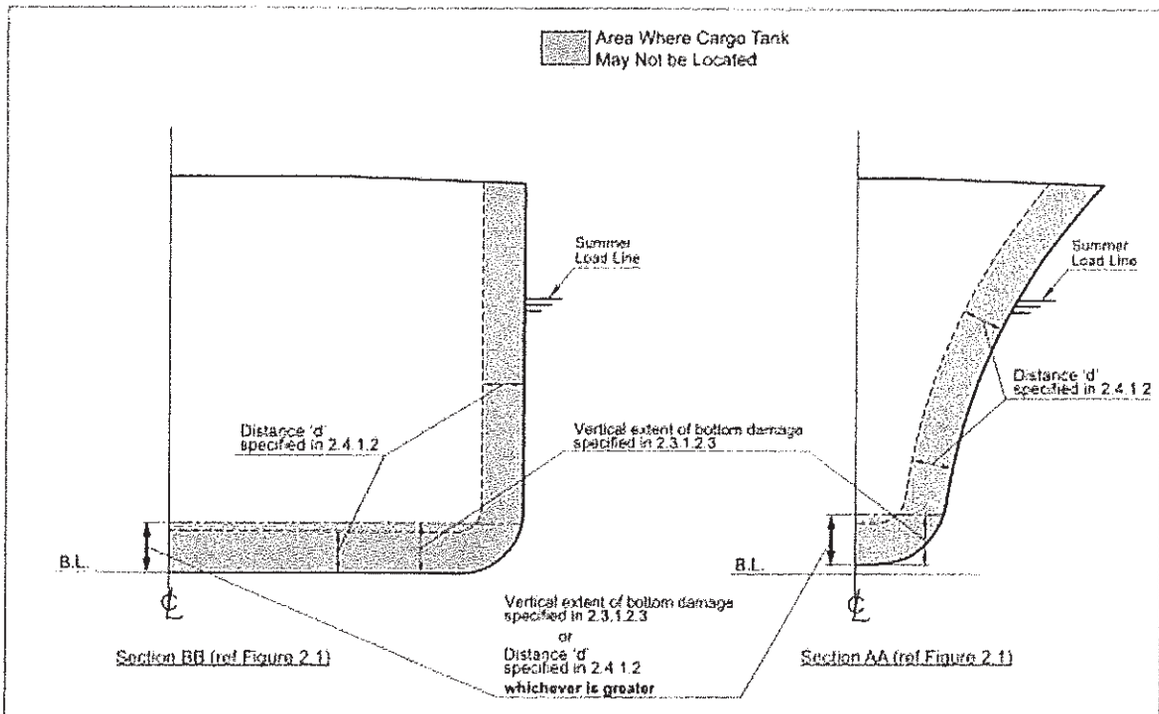


Figure 2.3 - *Cargo tank location requirements*

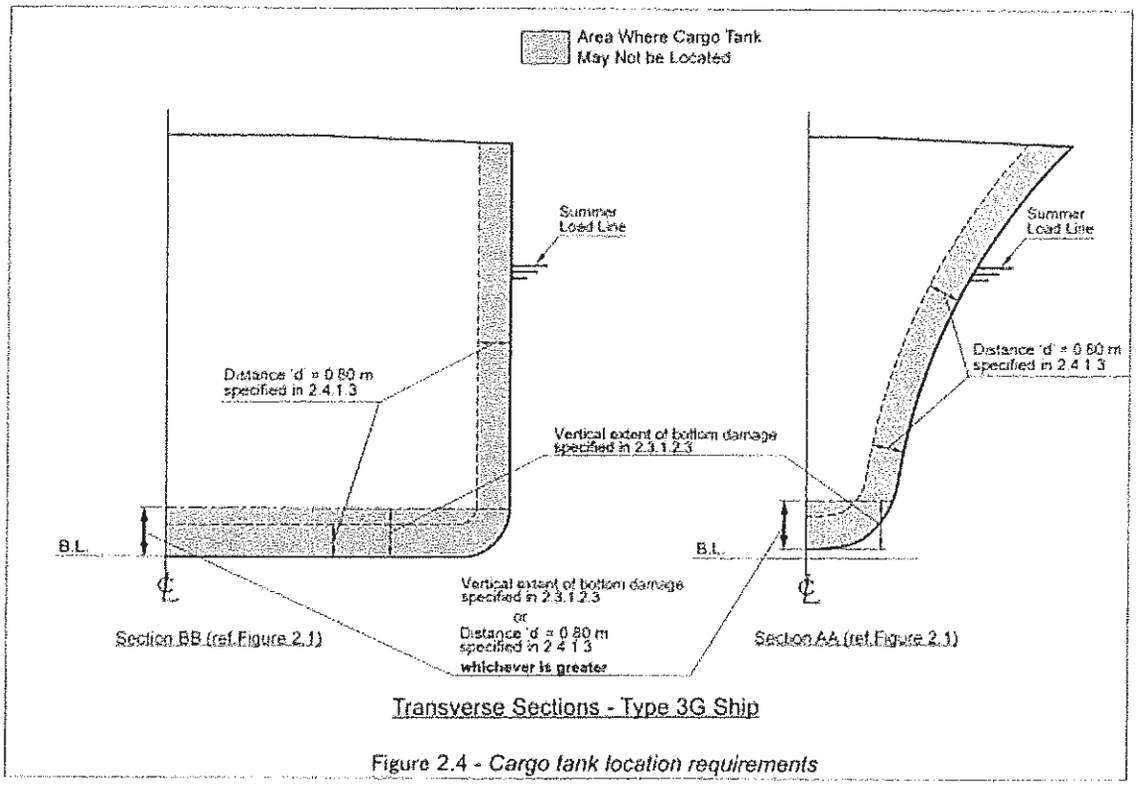
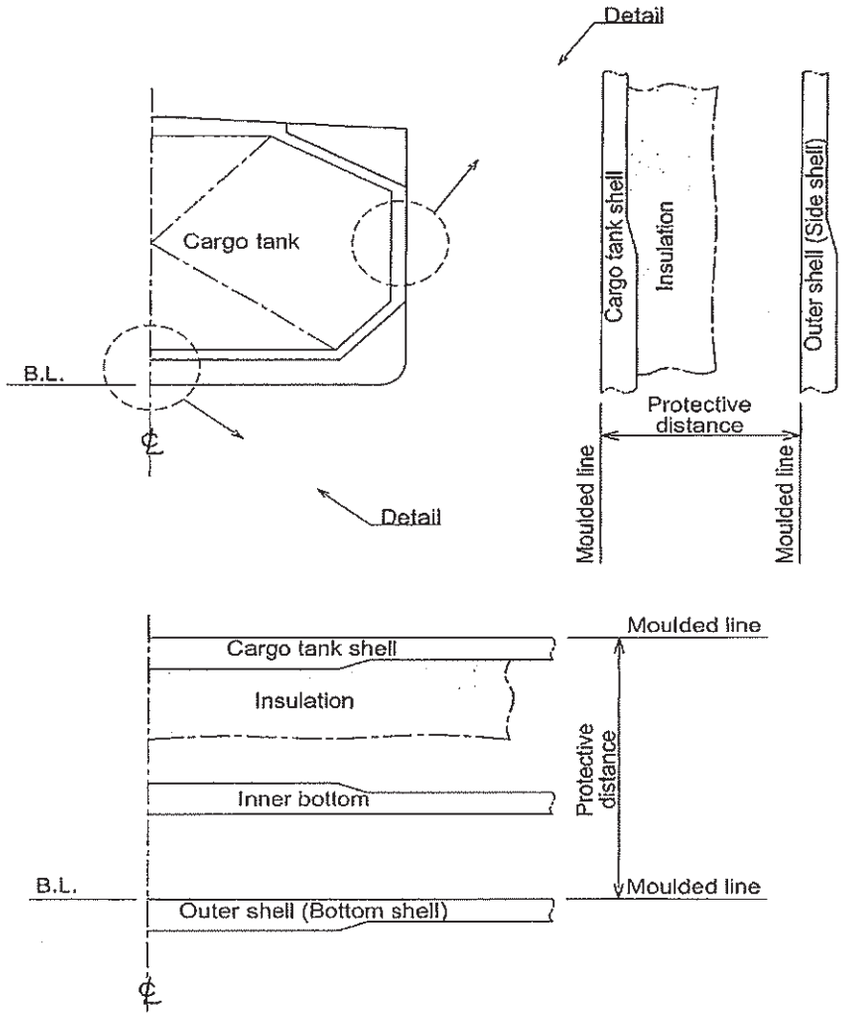
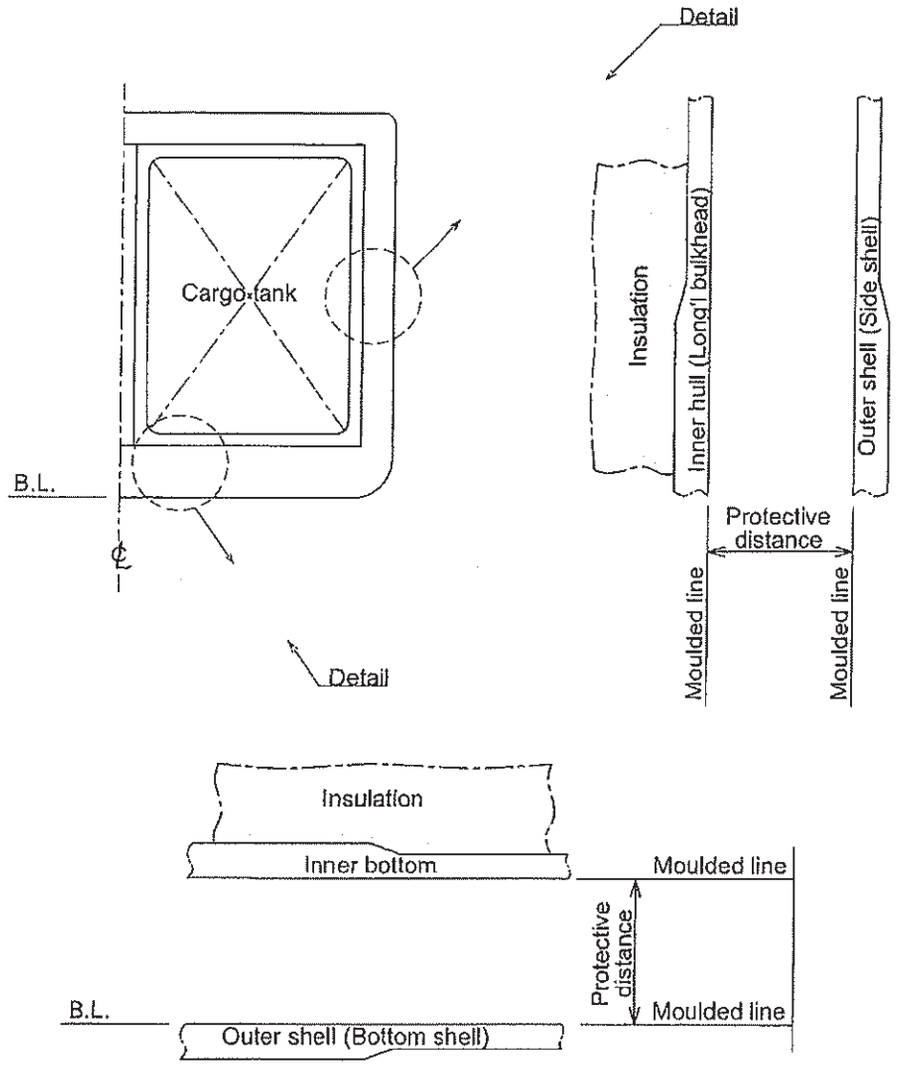


Figure 2.4 - *Cargo tank location requirements*



Independent prismatic tank

Figure 2.5(a) - *Protective distance*



Semi-membrane tank

Figure 2.5(b) - *Protective distance*

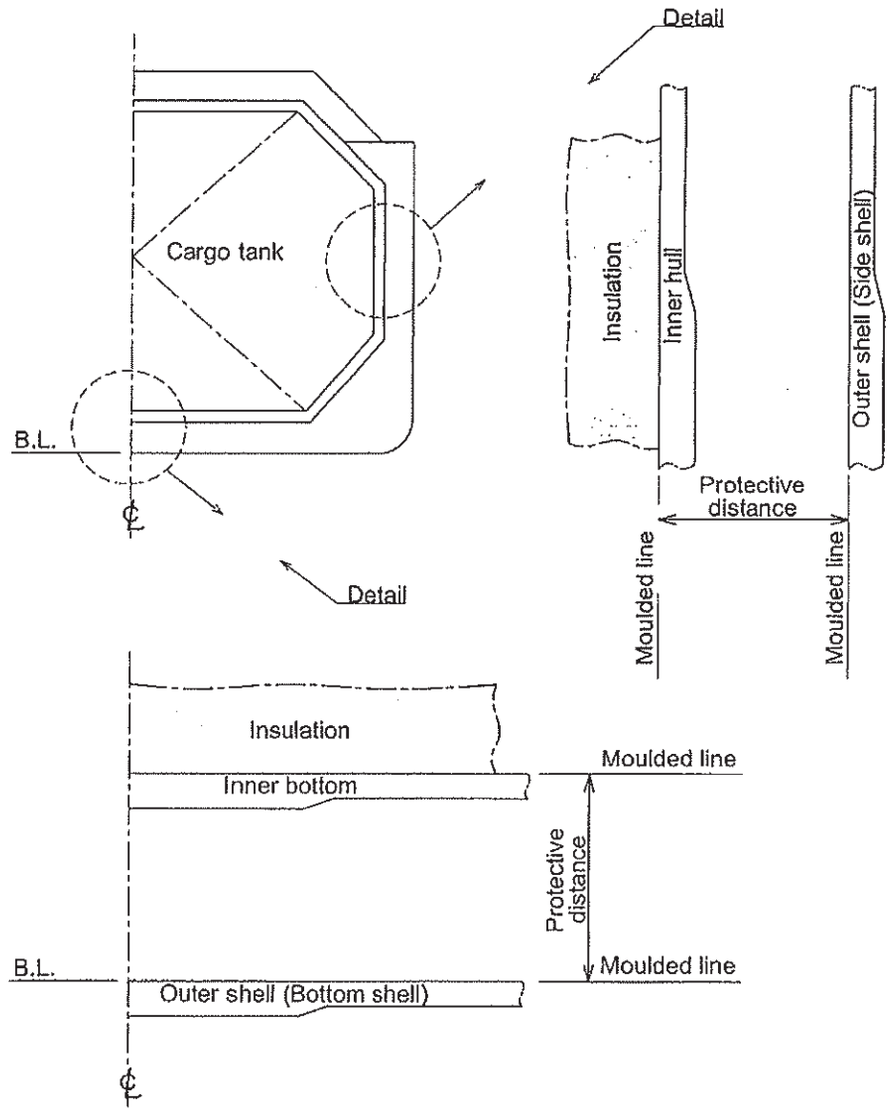


Figure 2.5(c) - *Protective distance*

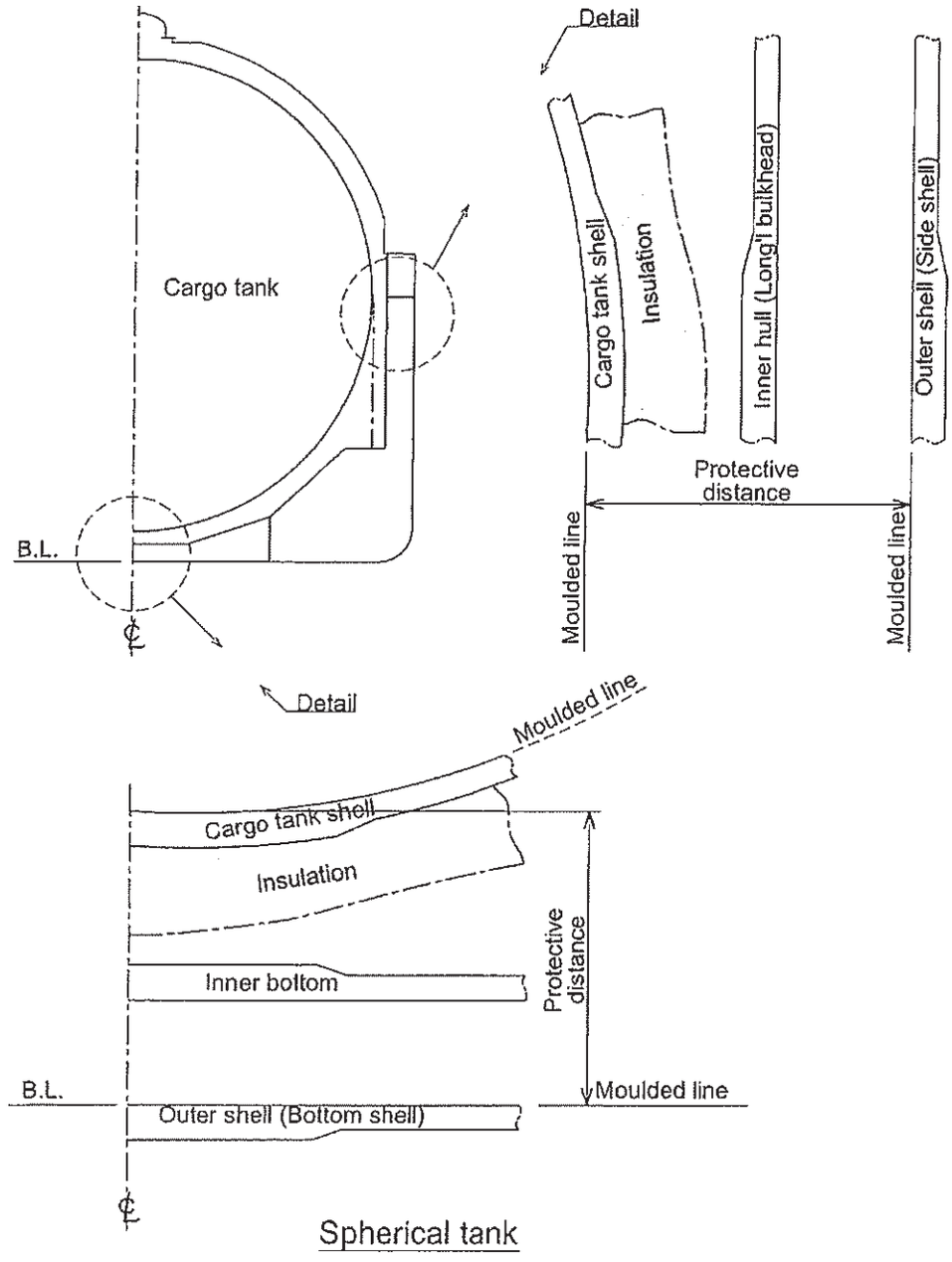
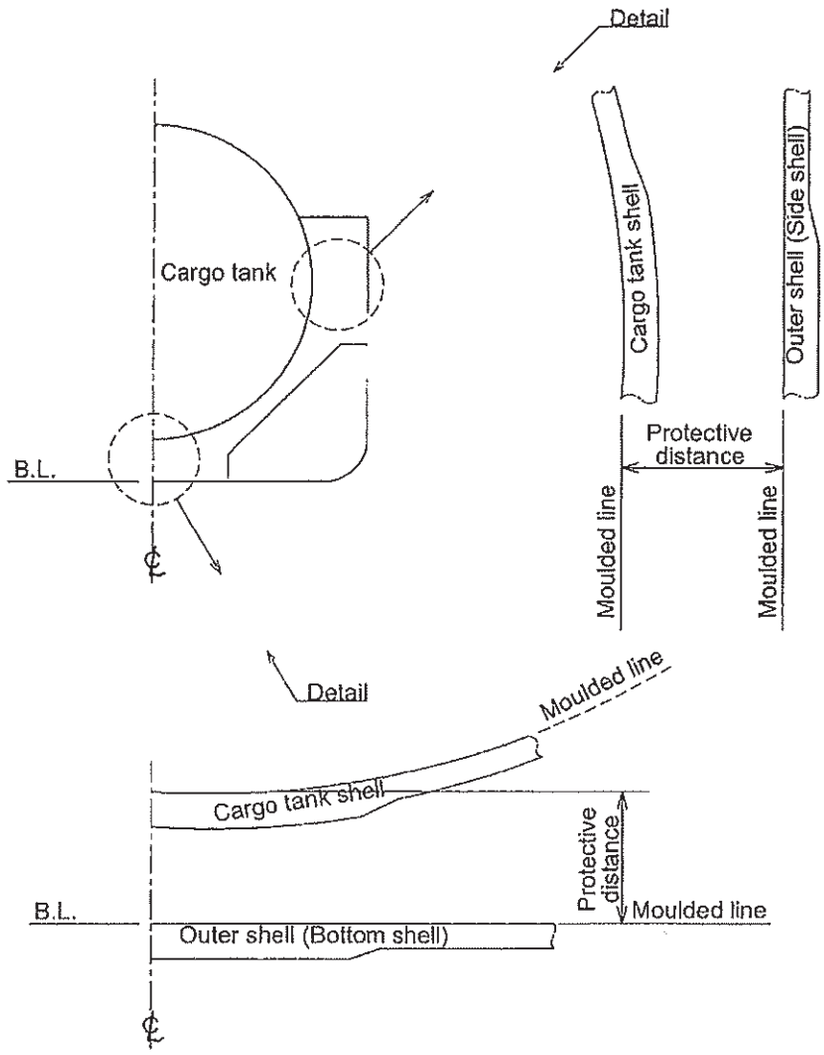


Figure 2.5(d) - *Protective distance*



Pressure type tank

Figure 2.5(e) - *Protective distance*

2.4.3 Except for type 1G ships, suction wells installed in cargo tanks may protrude into the vertical extent of bottom damage specified in 2.3.1.2.3 provided that such wells are as small as practicable and the protrusion below the inner bottom plating does not exceed 25% of the depth of the double bottom or 350 mm, whichever is less. Where there is no double bottom, the protrusion below the upper limit of bottom damage shall not exceed 350 mm. Suction wells installed in accordance with this paragraph may be ignored when determining the compartments affected by damage.

2.4.4 Cargo tanks shall not be located forward of the collision bulkhead.

2.5 Flood assumptions

2.5.1 The requirements of 2.7 shall be confirmed by calculations that take into consideration the design characteristics of the ship, the arrangements, configuration and contents of the damaged compartments, the distribution, relative densities and the free surface effects of liquids and the draught and trim for all conditions of loading.

2.5.2 The permeabilities of spaces assumed to be damaged shall be as follows:

Spaces	Permeabilities
Stores	0.6
Accommodation	0.95
Machinery	0.85
Voids	0.95
Hold spaces	0.95[1]
Consumable liquids	0 to 0.95[2]
Other liquids	0 to 0.95[2]

Note 1 Other values of permeability can be considered based on the detailed calculations. Interpretations of regulation of part B-1 of SOLAS chapter II-1 (MSC/Circ.651) are referred.

Note 2 The permeability of partially filled compartments shall be consistent with the amount of liquid carried in the compartment.

2.5.3 Wherever damage penetrates a tank containing liquids, it shall be assumed that the contents are completely lost from that compartment and replaced by salt water up to the level of the final plane of equilibrium.

2.5.4 Where the damage between transverse watertight bulkheads is envisaged, as specified in 2.6.1.4, 2.6.1.5, and 2.6.1.6, transverse bulkheads shall be spaced at least at a distance equal to the longitudinal extent of damage specified in 2.3.1.1.1 in order to be considered effective. Where transverse bulkheads are spaced at a lesser distance, one or more of these bulkheads within such extent of damage shall be assumed as non-existent for the purpose of determining flooded compartments. Further, any portion of a transverse bulkhead bounding side compartments or double bottom compartments shall be assumed damaged if the watertight bulkhead boundaries are within the extent of vertical or horizontal penetration required by 2.3. Also, any transverse bulkhead shall be assumed damaged if it contains a step or recess of more than 3 m in length located within the extent of penetration of assumed damage. The step formed by the after peak bulkhead and the after peak tank top shall not be regarded as a step for the purpose of this paragraph.

2.5.5 The ship shall be designed to keep unsymmetrical flooding to the minimum consistent with efficient arrangements.

2.5.6 Equalization arrangements requiring mechanical aids such as valves or cross-levelling pipes, if fitted, shall not be considered for the purpose of reducing an angle of heel or attaining the minimum range of residual stability to meet the requirements of 2.7.1, and sufficient residual stability shall be maintained during all stages where equalization is used. Spaces linked by ducts of large cross-sectional area may be considered to be common.

2.5.7 If pipes, ducts, trunks or tunnels are situated within the assumed extent of damage penetration, as defined in 2.3, arrangements shall be such that progressive flooding cannot thereby extend to compartments other than those assumed to be flooded for each case of damage.

2.5.8 The buoyancy of any superstructure directly above the side damage shall be disregarded. However, the unflooded parts of superstructures beyond the extent of damage may be taken into consideration, provided that:

.1 they are separated from the damaged space by watertight divisions and the requirements of 2.7.1.1 in respect of these intact spaces are complied with; and

.2 openings in such divisions are capable of being closed by remotely operated sliding watertight doors and unprotected openings are not immersed within the minimum range of residual stability required in 2.7.2.1. However, the immersion of any other openings capable of being closed weathertight may be permitted.

2.6 Standard of damage

2.6.1 Ships shall be capable of surviving the damage indicated in 2.3 with the flood assumptions in 2.5, to the extent determined by the ship's type, according to the following standards:

.1 a type 1G ship shall be assumed to sustain damage anywhere in its length;

.2 a type 2G ship of more than 150 m in length shall be assumed to sustain damage anywhere in its length;

.3 a type 2G ship of 150 m in length or less shall be assumed to sustain damage anywhere in its length, except involving either of the bulkheads bounding a machinery space located aft;

.4 a type 2PG ship shall be assumed to sustain damage anywhere in its length except involving transverse bulkheads spaced further apart than the longitudinal extent of damage as specified in 2.3.1.1.1;

.5 a type 3G ship of 80 m in length or more shall be assumed to sustain damage anywhere in its length, except involving transverse bulkheads spaced further apart than the longitudinal extent of damage specified in 2.3.1.1.1; and

.6 a type 3G ship less than 80 m in length shall be assumed to sustain damage anywhere in its length, except involving transverse bulkheads spaced further apart than the longitudinal extent of damage specified in 2.3.1.1.1 and except damage involving the machinery space when located after.

2.6.2 In the case of small type 2G/2PG and 3G ships that do not comply in all respects with the appropriate requirements of 2.6.1.3, 2.6.1.4 and 2.6.1.6, special dispensations may only be considered by the Administration provided that alternative measures can be taken which maintain the same degree of safety. The nature of the alternative measures shall be approved and clearly stated and be available to the port Administration. Any such dispensation shall be duly noted on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk referred to in 1.4.4.

2.7 Survival requirements

Ships subject to the Code shall be capable of surviving the assumed damage specified in 2.3, to the standard provided in 2.6, in a condition of stable equilibrium and shall satisfy the following criteria.

2.7.1 In any stage of flooding:

.1 the waterline, taking into account sinkage, heel and trim, shall be below the lower edge of any opening through which progressive flooding or downflooding may take place. Such openings shall include air pipes and openings that are closed by means of weathertight doors or hatch covers and may exclude those openings closed by means of watertight manhole covers and watertight flush scuttles, small watertight cargo tank hatch covers that maintain the high integrity of the deck, remotely operated watertight sliding doors and sidescuttles of the non-opening type;

.2 the maximum angle of heel due to unsymmetrical flooding shall not exceed 30°; and

.3 the residual stability during intermediate stages of flooding shall not be less than that required by 2.7.2.1.

2.7.2 At final equilibrium after flooding:

.1 the righting lever curve shall have a minimum range of 20° beyond the position of equilibrium in association with a maximum residual righting lever of at least 0.1 m within the 20° range; the area under the curve within this range shall not be less than 0.0175 m-radians. The 20° range may be measured from any angle commencing between the position of equilibrium and the angle of 25° (or 30° if no deck immersion occurs). Unprotected openings shall not be immersed within this range unless the space concerned is assumed to be flooded. Within this range, the immersion of any of the openings listed in 2.7.1.1 and other openings capable of being closed weathertight may be permitted; and

.2 the emergency source of power shall be capable of operating.

CHAPTER 3

SHIP ARRANGEMENTS

Goal

To ensure that the cargo containment and handling system are located such that the consequences of any release of cargo will be minimized, and to provide safe access for operation and inspection.

3.1 Segregation of the cargo area

3.1.1 Hold spaces shall be segregated from machinery and boiler spaces, accommodation spaces, service spaces, control stations, chain lockers, domestic water tanks and from stores. Hold spaces shall be located forward of machinery spaces of category A. Alternative arrangements, including locating machinery spaces of category A forward, may be accepted, based on SOLAS regulation II-2/17, after further consideration of involved risks, including that of cargo release and the means of mitigation.

3.1.2 Where cargo is carried in a cargo containment system not requiring a complete or partial secondary barrier, segregation of hold spaces from spaces referred to in 3.1.1 or spaces either below or outboard of the hold spaces may be effected by cofferdams, oil fuel tanks or a single gastight bulkhead of all-welded construction forming an "A-60" class division. A gastight "A-0" class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

3.1.3 Where cargo is carried in a cargo containment system requiring a complete or partial secondary barrier, segregation of hold spaces from spaces referred to in 3.1.1, or spaces either below or outboard of the hold spaces that contain a source of ignition or fire hazard, shall be effected by cofferdams or oil fuel tanks. A gastight "A-0" class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

3.1.4 Turret compartments segregation from spaces referred to in 3.1.1, or spaces either below or outboard of the turret compartment that contain a source of ignition or fire hazard, shall be effected by cofferdams or an A-60 class division. A gastight "A-0" class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

3.1.5 In addition, the risk of fire propagation from turret compartments to adjacent spaces shall be evaluated by a risk analysis (see 1.1.11) and further preventive measures, such as the arrangement of a cofferdam around the turret compartment, shall be provided if needed.

3.1.6 When cargo is carried in a cargo containment system requiring a complete or partial secondary barrier:

.1 at temperatures below -10ºC, hold spaces shall be segregated from the sea by a double bottom; and

.2 at temperatures below -55ºC, the ship shall also have a longitudinal bulkhead forming side tanks.

3.1.7 Arrangements shall be made for sealing the weather decks in way of openings for cargo containment systems.

3.2 Accommodation, service and machinery spaces and control stations

3.2.1 No accommodation space, service space or control station shall be located within the cargo area. The bulkhead of accommodation spaces, service spaces or control stations that face the cargo area shall be so located as to avoid the entry of gas from the hold space to such spaces through a single failure of a deck or bulkhead on a ship having a containment system requiring a secondary barrier.

3.2.2 To guard against the danger of hazardous vapours, due consideration shall be given to the location of air intakes/outlets and openings into accommodation, service and machinery spaces and control stations in relation to cargo piping, cargo vent systems and machinery space exhausts from gas burning arrangements.

3.2.3 Access through doors, gastight or otherwise, shall not be permitted from a non-hazardous area to a hazardous area except for access to service spaces forward of the cargo area through airlocks, as permitted by 3.6.1, when accommodation spaces are aft.

3.2.4.1 Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and control stations shall not face the cargo area. They shall be located on the end bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse or on both at a distance of at least 4% of the length (*L*) of the ship but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance, however, need not exceed 5 m.

3.2.4.2 Windows and sidescuttles facing the cargo area and on the sides of the superstructures or deckhouses within the distance mentioned above shall be of the fixed (non-opening) type. Wheelhouse windows may be non-fixed and wheelhouse doors may be located within the above limits so long as they are designed in a manner that a rapid and efficient gas and vapour tightening of the wheelhouse can be ensured.

3.2.4.3 For ships dedicated to the carriage of cargoes that have neither flammable nor toxic hazards, the Administration may approve relaxations from the above requirements.

3.2.4.4 Accesses to forecastle spaces containing sources of ignition may be permitted through a single door facing the cargo area, provided the doors are located outside hazardous areas as defined in chapter 10.

3.2.5 Windows and sidescuttles facing the cargo area and on the sides of the superstructures and deckhouses within the limits specified in 3.2.4, except wheelhouse windows, shall be constructed to "A-60" class. Wheelhouse windows shall be constructed to not less than "A-0" class (for external fire load). Sidescuttles in the shell below the uppermost continuous deck and in the first tier of the superstructure or deckhouse shall be of fixed (non-opening) type.

3.2.6 All air intakes, outlets and other openings into the accommodation spaces, service spaces and control stations shall be fitted with closing devices. When carrying toxic products, they shall be capable of being operated from inside the space. The requirement for fitting air intakes and openings with closing devices operated from inside the space for toxic products need not apply to spaces not normally manned, such as deck stores, forecastle stores, workshops. In addition, the requirement does not apply to cargo control rooms located within the cargo area.

3.2.7 Control rooms and machinery spaces of turret systems may be located in the cargo area forward or aft of cargo tanks in ships with such installations. Access to such spaces containing sources of ignition may be permitted through doors facing the cargo area, provided the doors are located outside hazardous areas or access is through airlocks.

3.3 Cargo machinery spaces and turret compartments

3.3.1 Cargo machinery spaces shall be situated above the weather deck and located within the cargo area. Cargo machinery spaces and turret compartments shall be treated as cargo pump-rooms for the purpose of fire protection according to SOLAS regulation II-2/9.2.4, and for the purpose of prevention of potential explosion according to SOLAS regulation II-2/4.5.10.

3.3.2 When cargo machinery spaces are located at the after end of the aftermost hold space or at the forward end of the foremost hold space, the limits of the cargo area, as defined in 1.2.7, shall be extended to include the cargo machinery spaces for the full breadth and depth of the ship and the deck areas above those spaces.

3.3.3 Where the limits of the cargo area are extended by 3.3.2, the bulkhead that separates the cargo machinery spaces from accommodation and service spaces, control stations and machinery spaces of category A shall be located so as to avoid the entry of gas to these spaces through a single failure of a deck or bulkhead.

3.3.4 Cargo compressors and cargo pumps may be driven by electric motors in an adjacent non-hazardous space separated by a bulkhead or deck, if the seal around the bulkhead penetration ensures effective gastight segregation of the two spaces. Alternatively, such equipment may be driven by certified safe electric motors adjacent to them if the electrical installation complies with the requirements of chapter 10.

3.3.5 Arrangements of cargo machinery spaces and turret compartments shall ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. At least two widely separated escape routes and doors shall be provided in cargo machinery spaces, except that a single escape route may be accepted where the maximum travel distance to the door is 5 m or less.

3.3.6 All valves necessary for cargo handling shall be readily accessible to personnel wearing protective clothing. Suitable arrangements shall be made to deal with drainage of pump and compressor rooms.

3.3.7 Turret compartments shall be designed to retain their structural integrity in case of explosion or uncontrolled high-pressure gas release (overpressure and/or brittle fracture), the characteristics of which shall be substantiated on the basis of a risk analysis with due consideration of the capabilities of the pressure relieving devices.

3.4 Cargo control rooms

3.4.1 Any cargo control room shall be above the weather deck and may be located in the cargo area. The cargo control room may be located within the accommodation spaces, service spaces or control stations, provided the following conditions are complied with:

.1 the cargo control room is a non-hazardous area;

.2 if the entrance complies with 3.2.4.1, the control room may have access to the spaces described above; and

.3 if the entrance does not comply with 3.2.4.1, the cargo control room shall have no access to the spaces described above and the boundaries for such spaces shall be insulated to "A-60" class.

3.4.2 If the cargo control room is designed to be a non-hazardous area, instrumentation shall, as far as possible, be by indirect reading systems and shall, in any case, be designed to prevent any escape of gas into the atmosphere of that space. Location of the gas detection system within the cargo control room will not cause the room to be classified as a hazardous area, if installed in accordance with 13.6.11.

3.4.3 If the cargo control room for ships carrying flammable cargoes is classified as a hazardous area, sources of ignition shall be excluded and any electrical equipment shall be installed in accordance with chapter 10.

3.5 Access to spaces in the cargo area

3.5.1 Visual inspection of at least one side of the inner hull structure shall be possible without the removal of any fixed structure or fitting. If such a visual inspection, whether combined with those inspections required in 3.5.2, 4.6.2.4 or 4.20.3.7 or not, is only possible at the outer face of the inner hull, the inner hull shall not be a fuel-oil tank boundary wall.

3.5.2 Inspection of one side of any insulation in hold spaces shall be possible. If the integrity of the insulation system can be verified by inspection of the outside of the hold space boundary when tanks are at service temperature, inspection of one side of the insulation in the hold space need not be required.

3.5.3 Arrangements for hold spaces, void spaces, cargo tanks and other spaces classified as hazardous areas, shall be such as to allow entry and inspection of any such space by personnel wearing protective clothing and breathing apparatus and shall also allow for the evacuation of injured and/or unconscious personnel. Such arrangements shall comply with the following:

.1 Access shall be provided as follows:

.1 access to all cargo tanks. Access shall be direct from the weather deck;

.2 access through horizontal openings, hatches or manholes. The dimensions shall be sufficient to allow a person wearing a breathing apparatus to ascend or descend any ladder without obstruction, and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening shall be not less than 600 mm x 600 mm;

.3 access through vertical openings or manholes providing passage through the length and breadth of the space. The minimum clear opening shall be not less than 600 mm x 800 mm at a height of not more than 600 mm from the bottom plating unless gratings or other footholds are provided; and

.4 circular access openings to type C tanks shall have a diameter of not less than 600 mm.

.2 The dimensions referred to in 3.5.3.1.2 and 3.5.3.1.3 may be decreased, if the requirements of 3.5.3 can be met to the satisfaction of the Administration.

.3 Where cargo is carried in a containment system requiring a secondary barrier, the requirements of 3.5.3.1.2 and 3.5.3.1.3 do not apply to spaces separated from a hold space by a single gastight steel boundary. Such spaces shall be provided only with direct or indirect access from the weather deck, not including any enclosed non-hazardous area.

.4 Access required for inspection shall be a designated access through structures below and above cargo tanks, which shall have at least the cross-sections as required by 3.5.3.1.3.

.5 For the purpose of 3.5.1 or 3.5.2, the following shall apply:

.1 where it is required to pass between the surface to be inspected, flat or curved, and structures such as deck beams, stiffeners, frames, girders, etc., the distance between that surface and the free edge of the structural elements shall be at least 380 mm. The distance between the surface to be inspected and the surface to which the above structural elements are fitted, e.g. deck, bulkhead or shell, shall be at least 450 mm for a curved tank surface (e.g. for a type C tank), or 600 mm for a flat tank surface (e.g. for a type A tank) (see figure 3.1);

.2 where it is not required to pass between the surface to be inspected and any part of the structure, for visibility reasons the distance between the free edge of that structural element and the surface to be inspected shall be at least 50 mm or half the breadth of the structure's face plate, whichever is the larger (see figure 3.2);

.3 if for inspection of a curved surface where it is required to pass between that surface and another surface, flat or curved, to which no structural elements are fitted, the distance between both surfaces shall be at least 380 mm (see figure 3.3). Where it is not required to pass between that curved surface and another surface, a smaller distance than 380 mm may be accepted taking into account the shape of the curved surface;

.4 if for inspection of an approximately flat surface where it is required to pass between two approximately flat and approximately parallel surfaces, to which no structural elements are fitted, the distance between those surfaces shall be at least 600 mm. Where fixed access ladders are fitted, a clearance of at least 450 mm shall be provided for access (see figure 3.4);

.5 the minimum distances between a cargo tank sump and adjacent double bottom structure in way of a suction well shall not be less than those shown in figure 3.5 (figure 3.5 shows that the distance between the plane surfaces of the sump and the well is a minimum of 150 mm and that the clearance between the edge between the inner bottom plate, and the vertical side of the well and the knuckle point between the spherical or circular surface and sump of the tank is at least 380 mm). If there is no suction well, the distance between the cargo tank sump and the inner bottom shall not be less than 50 mm;

.6 the distance between a cargo tank dome and deck structures shall not be less than 150 mm (see figure 3.6);

.7 fixed or portable staging shall be installed as necessary for inspection of cargo tanks, cargo tank supports and restraints (e.g. anti-pitching, anti-rolling and anti-flotation chocks), cargo tank insulation etc. This staging shall not impair the clearances specified in 3.5.3.5.1 to 3.5.3.5.4; and

.8 if fixed or portable ventilation ducting shall be fitted in compliance with 12.1.2, such ducting shall not impair the distances required under 3.5.3.5.1 to 3.5.3.5.4.

3.5.4 Access from the open weather deck to non-hazardous areas shall be located outside the hazardous areas as defined in chapter 10, unless the access is by means of an airlock in accordance with 3.6.

3.5.5 Turret compartments shall be arranged with two independent means of access/egress.

3.5.6 Access from a hazardous area below the weather deck to a non-hazardous area is not permitted.

3.6 Airlocks

3.6.1 Access between hazardous area on the open weather deck and non-hazardous spaces shall be by means of an airlock. This shall consist of two self-closing, substantially gastight, steel doors without any holding back arrangements, capable of maintaining the overpressure, at least 1.5 m but no more than 2.5 m apart. The airlock space shall be artificially ventilated from a non-hazardous area and maintained at an overpressure to the hazardous area on the weather deck.

3.6.2 Where spaces are protected by pressurization, the ventilation shall be designed and installed in accordance with recognized standards.

3.6.3 An audible and visible alarm system to give a warning on both sides of the airlock shall be provided. The visible alarm shall indicate if one door is open. The audible alarm shall sound if doors on both sides of the air lock are moved from the closed positions.

3.6.4 In ships carrying flammable products, electrical equipment that is located in spaces protected by airlocks and not of the certified safe type, shall be de-energized in case of loss of overpressure in the space.

3.6.5 Electrical equipment for manoeuvring, anchoring and mooring, as well as emergency fire pumps that are located in spaces protected by airlocks, shall be of a certified safe type.

3.6.6 The airlock space shall be monitored for cargo vapours (see 13.6.2).

3.6.7 Subject to the requirements of the International Convention on Load Lines in force, the door sill shall not be less than 300 mm in height.

3.7 Bilge, ballast and oil fuel arrangements

3.7.1 Where cargo is carried in a cargo containment system not requiring a secondary barrier, suitable drainage arrangements for the hold spaces that are not connected with the machinery space shall be provided. Means of detecting any leakage shall be provided.

3.7.2 Where there is a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through the adjacent ship structure shall be provided. The suction shall not lead to pumps inside the machinery space. Means of detecting such leakage shall be provided.

3.7.3 The hold or interbarrier spaces of type A independent tank ships shall be provided with a drainage system suitable for handling liquid cargo in the event of cargo tank leakage or rupture. Such arrangements shall provide for the return of any cargo leakage to the liquid cargo piping.

3.7.4 Arrangements referred to in 3.7.3 shall be provided with a removable spool piece.

3.7.5 Ballast spaces, including wet duct keels used as ballast piping, oil fuel tanks and non-hazardous spaces, may be connected to pumps in the machinery spaces. Dry duct keels with ballast piping passing through may be connected to pumps in the machinery spaces, provided the connections are led directly to the pumps, and the discharge from the pumps is led directly overboard with no valves or manifolds in either line that could connect the line from the duct keel to lines serving non-hazardous spaces. Pump vents shall not be open to machinery spaces.

3.8 Bow and stern loading and unloading arrangements

3.8.1 Subject to the requirements of this section and chapter 5, cargo piping may be arranged to permit bow or stern loading and unloading.

3.8.2 Bow or stern loading and unloading lines that are led past accommodation spaces, service spaces or control stations shall not be used for the transfer of products requiring a type 1G ship. Bow or stern loading and unloading lines shall not be used for the transfer of toxic products as specified in 1.2.53, where the design pressure is above 2.5 MPa.

3.8.3 Portable arrangements shall not be permitted.

3.8.4.1 Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and controls stations, shall not face the cargo shore connection location of bow or stern loading and unloading arrangements. They shall be located on the outboard side of the superstructure or deckhouse at a distance of at least 4% of the length of the ship, but not less than 3 m from the end of the superstructure or deckhouse facing the cargo shore connection location of the bow or stern loading and unloading arrangements. This distance need not exceed 5 m.

3.8.4.2 Windows and sidescuttles facing the shore connection location and on the sides of the superstructure or deckhouse within the distance mentioned above shall be of the fixed (non-opening) type.

3.8.4.3 In addition, during the use of the bow or stern loading and unloading arrangements, all doors, ports and other openings on the corresponding superstructure or deckhouse side shall be kept closed.

3.8.4.4 Where, in the case of small ships, compliance with 3.2.4.1 to 3.2.4.4 and 3.8.4.1 to 3.8.4.3 is not possible, the Administration may approve relaxations from the above requirements.

3.8.5 Deck openings and air inlets and outlets to spaces within distances of 10 m from the cargo shore connection location shall be kept closed during the use of bow or stern loading or unloading arrangements.

3.8.6 Firefighting arrangements for the bow or stern loading and unloading areas shall be in accordance with 11.3.1.4 and 11.4.6.

3.8.7 Means of communication between the cargo control station and the shore connection location shall be provided and, where applicable, certified for use in hazardous areas.

Figure 3.1

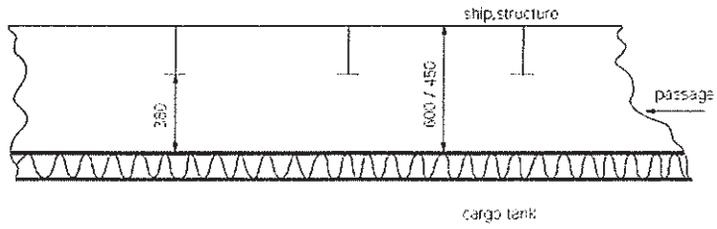


Figure 3.2

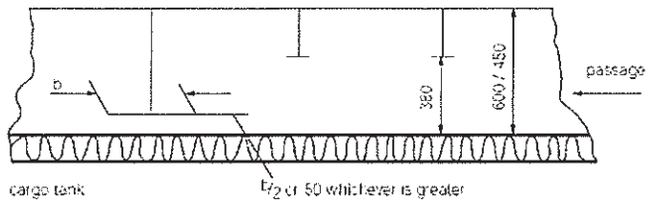


Figure 3.3

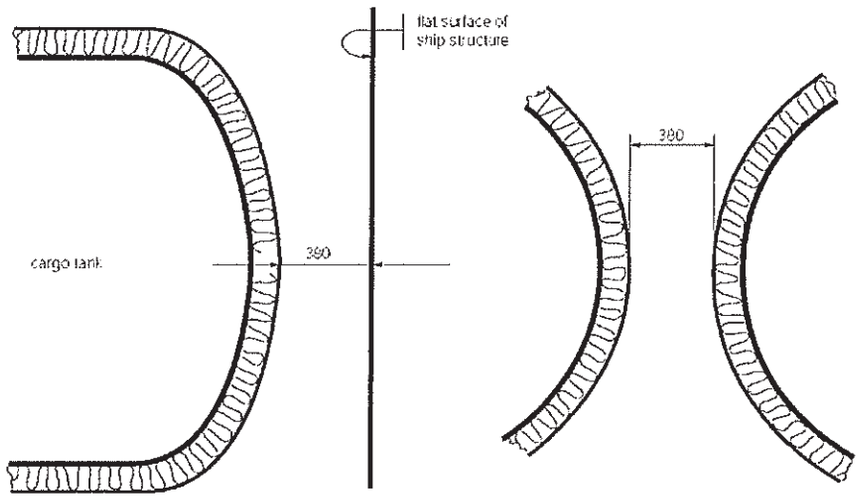


Figure 3.4

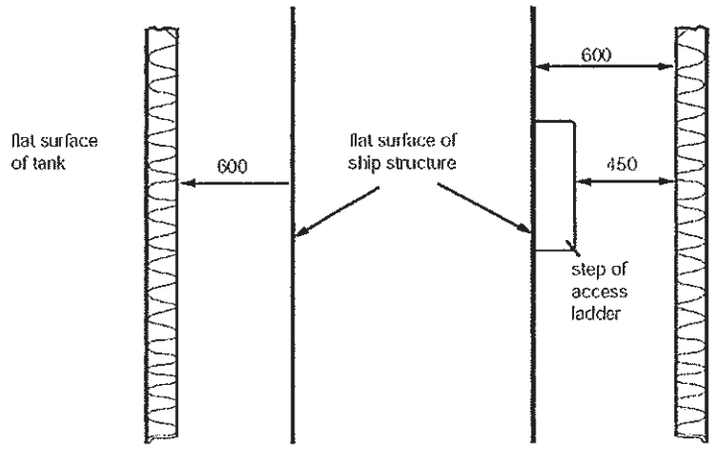


Figure 3.5

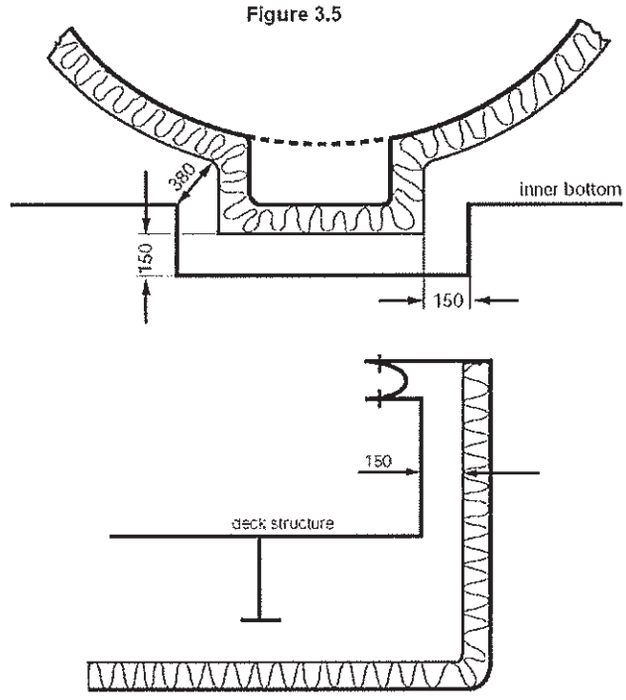


Figure 3.6

CHAPTER 4

CARGO CONTAINMENT

Goal

To ensure the safe containment of cargo under all design and operating conditions having regard to the nature of the cargo carried. This will include measures to:

.1 provide strength to withstand defined loads;

.2 maintain the cargo in a liquid state;

.3 design for or protect the hull structure from low temperature exposure; and

.4 prevent the ingress of water or air into the cargo containment system.

4.1 Definitions

4.1.1 *A cold spot* is a part of the hull or thermal insulation surface where a localized temperature decrease occurs with respect to the allowable minimum temperature of the hull or of its adjacent hull structure, or to design capabilities of cargo pressure/temperature control systems required in chapter 7.

4.1.2 *Design vapour pressure* "P_0" is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank.

4.1.3 *Design temperature* for selection of materials is the minimum temperature at which cargo may be loaded or transported in the cargo tanks.

4.1.4 *Independent tanks* are self-supporting tanks. They do not form part of the ship's hull and are not essential to the hull strength. There are three categories of independent tank, which are referred to in 4.21, 4.22 and 4.23.

4.1.5 *Membrane tanks* are non-self-supporting tanks that consist of a thin liquid and gastight layer (membrane) supported through insulation by the adjacent hull structure. Membrane tanks are covered in 4.24.

4.1.6 *Integral tanks* are tanks that form a structural part of the hull and are influenced in the same manner by the loads that stress the adjacent hull structure. Integral tanks are covered in 4.25.

4.1.7 *Semi-membrane tanks* are non-self-supporting tanks in the loaded condition and consist of a layer, parts of which are supported through insulation by the adjacent hull structure. Semi-membrane tanks are covered in 4.26.

4.1.8 In addition to the definitions in 1.2, the definitions given in this chapter shall apply throughout the Code.

4.2 Application

Unless otherwise specified in part E, the requirements of parts A to D shall apply to all types of tanks, including those covered in part F.

PART A
CARGO CONTAINMENT

4.3 Functional requirements

4.3.1 The design life of the cargo containment system shall not be less than the design life of the ship.

4.3.2 Cargo containment systems shall be designed for North Atlantic environmental conditions and relevant long-term sea state scatter diagrams for unrestricted navigation. Lesser environmental conditions, consistent with the expected usage, may be accepted by the Administration for cargo containment systems used exclusively for restricted navigation. Greater environmental conditions may be required for cargo containment systems operated in conditions more severe than the North Atlantic environment.

4.3.3 Cargo containment systems shall be designed with suitable safety margins:

.1 to withstand, in the intact condition, the environmental conditions anticipated for the cargo containment system's design life and the loading conditions appropriate for them, which include full homogeneous and partial load conditions, partial filling within defined limits and ballast voyage loads; and

.2 being appropriate for uncertainties in loads, structural modelling, fatigue, corrosion, thermal effects, material variability, ageing and construction tolerances.

4.3.4 The cargo containment system structural strength shall be assessed against failure modes, including but not limited to plastic deformation, buckling and fatigue. The specific design conditions which shall be considered for the design of each cargo containment system are given in 4.21 to 4.26. There are three main categories of design conditions:

.1 Ultimate design conditions – the cargo containment system structure and its structural components shall withstand loads liable to occur during its construction, testing and anticipated use in service, without loss of structural integrity. The design shall take into account proper combinations of the following loads:

.1 internal pressure;

.2 external pressure;

.3 dynamic loads due to the motion of the ship;

.4 thermal loads;

.5 sloshing loads;

.6 loads corresponding to ship deflections;

.7 tank and cargo weight with the corresponding reaction in way of supports;

.8 insulation weight;

.9 loads in way of towers and other attachments; and

.10 test loads.

.2 Fatigue design conditions – the cargo containment system structure and its structural components shall not fail under accumulated cyclic loading.

.3 The cargo containment system shall meet the following criteria:

.1 Collision – the cargo containment system shall be protectively located in accordance with 2.4.1 and withstand the collision loads specified in 4.15.1 without deformation of the supports, or the tank structure in way of the supports, likely to endanger the tank structure.

.2 Fire – the cargo containment systems shall sustain, without rupture, the rise in internal pressure specified in 8.4.1 under the fire scenarios envisaged therein.

.3 Flooded compartment causing buoyancy on tank – the anti-flotation arrangements shall sustain the upward force, specified in 4.15.2, and there shall be no endangering plastic deformation to the hull.

4.3.5 Measures shall be applied to ensure that scantlings required meet the structural strength provisions and be maintained throughout the design life. Measures may include, but are not limited to, material selection, coatings, corrosion additions, cathodic protection and inerting. Corrosion allowance need not be required in addition to the thickness resulting from the structural analysis. However, where there is no environmental control, such as inerting around the cargo tank, or where the cargo is of a corrosive nature, the Administration or recognized organization acting on its behalf may require a suitable corrosion allowance.

4.3.6 An inspection/survey plan for the cargo containment system shall be developed and approved by the Administration or recognized organization acting on its behalf. The inspection/survey plan shall identify areas that need inspection during surveys throughout the cargo containment system's life and, in particular, all necessary in-service survey and maintenance that was assumed when selecting cargo containment system design parameters. Cargo containment systems shall be designed, constructed and equipped to provide adequate means of access to areas that need inspection as specified in the inspection/survey plan. Cargo containment systems, including all associated internal equipment, shall be designed and built to ensure safety during operations, inspection and maintenance (see 3.5).

4.4 Cargo containment safety principles

4.4.1 The containment systems shall be provided with a full secondary liquid-tight barrier capable of safely containing all potential leakages through the primary barrier and, in conjunction with the thermal insulation system, of preventing lowering of the temperature of the ship structure to an unsafe level.

4.4.2 However, the size and configuration or arrangement of the secondary barrier may be reduced where an equivalent level of safety is demonstrated in accordance with the requirements of 4.4.3 to 4.4.5, as applicable.

4.4.3 Cargo containment systems for which the probability for structural failures to develop into a critical state has been determined to be extremely low, but where the possibility of leakages through the primary barrier cannot be excluded, shall be equipped with a partial secondary barrier and small leak protection system capable of safely handling and disposing of the leakages. The arrangements shall comply with the following requirements:

.1 failure developments that can be reliably detected before reaching a critical state (e.g. by gas detection or inspection) shall have a sufficiently long development time for remedial actions to be taken; and

.2 failure developments that cannot be safely detected before reaching a critical state shall have a predicted development time that is much longer than the expected lifetime of the tank.

4.4.4 No secondary barrier is required for cargo containment systems, e.g. type C independent tanks, where the probability for structural failures and leakages through the primary barrier is extremely low and can be neglected.

4.4.5 No secondary barrier is required where the cargo temperature at atmospheric pressure is at or above -10°C.

4.5 Secondary barriers in relation to tank types

Secondary barriers in relation to the tank types defined in 4.21 to 4.26 shall be provided in accordance with the following table.

Cargo temperature at atmospheric pressure	**-10°C and above**	**Below -10°C down to -55°C**	**Below -55°C**
Basic tank type	No secondary barrier required	Hull may act as secondary barrier	Separate secondary barrier where required
Integral		Tank type not normally allowed[1]	
Membrane		Complete secondary barrier	
Semi-membrane		Complete secondary barrier[2]	
Independent:			
-type A		Complete secondary barrier	
-type B		Partial secondary barrier	
-type C		No secondary barrier required	

Note 1: A complete secondary barrier shall normally be required if cargoes with a temperature at atmospheric pressure below -10°C are permitted in accordance with 4.25.1.

Note 2: In the case of semi-membrane tanks that comply in all respects with the requirements applicable to type B independent tanks, except for the manner of support, the Administration may, after special consideration, accept a partial secondary barrier.

4.6 Design of secondary barriers

4.6.1 Where the cargo temperature at atmospheric pressure is not below -55°C, the hull structure may act as a secondary barrier based on the following:

.1 the hull material shall be suitable for the cargo temperature at atmospheric pressure as required by 4.19.1.4; and

.2 the design shall be such that this temperature will not result in unacceptable hull stresses.

4.6.2 The design of the secondary barrier shall be such that:

.1 it is capable of containing any envisaged leakage of liquid cargo for a period of 15 days, unless different criteria apply for particular voyages, taking into account the load spectrum referred to in 4.18.2.6;

.2 physical, mechanical, or operational events within the cargo tank that could cause failure of the primary barrier shall not impair the due function of the secondary barrier, or vice versa;

.3 failure of a support or an attachment to the hull structure will not lead to loss of liquid tightness of both the primary and secondary barriers;

.4 it is capable of being periodically checked for its effectiveness by means acceptable to the Administration or recognized organization acting on its behalf. This may be by means of a visual inspection or a pressure/vacuum test or other suitable means carried out according to a documented procedure agreed with the Administration or the recognized organization acting on its behalf;

.5 the methods required in .4 above shall be approved by the Administration or recognized organization acting on its behalf and shall include, where applicable to the test procedure:

.1 details on the size of defect acceptable and the location within the secondary barrier, before its liquid-tight effectiveness is compromised;

.2 accuracy and range of values of the proposed method for detecting defects in .1 above;

.3 scaling factors to be used in determining the acceptance criteria, if full scale model testing is not undertaken; and

.4 effects of thermal and mechanical cyclic loading on the effectiveness of the proposed test; and

.6 the secondary barrier shall fulfil its functional requirements at a static angle of heel of 30°.

4.7 Partial secondary barriers and primary barrier small leak protection system

4.7.1 Partial secondary barriers as permitted in 4.4.3 shall be used with a small leak protection system and meet all the requirements in 4.6.2. The small leak protection system shall include means to detect a leak in the primary barrier, provision such as a spray shield to deflect any liquid cargo down into the partial secondary barrier, and means to dispose of the liquid, which may be by natural evaporation.

4.7.2 The capacity of the partial secondary barrier shall be determined, based on the cargo leakage corresponding to the extent of failure resulting from the load spectrum referred to in 4.18.2.6, after the initial detection of a primary leak. Due account may be taken of liquid evaporation, rate of leakage, pumping capacity and other relevant factors.

4.7.3 The required liquid leakage detection may be by means of liquid sensors, or by an effective use of pressure, temperature or gas detection systems, or any combination thereof.

4.8 Supporting arrangements

4.8.1 The cargo tanks shall be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in 4.12 to 4.15, where applicable, while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and the hull.

4.8.2 Anti-flotation arrangements shall be provided for independent tanks and capable of withstanding the loads defined in 4.15.2 without plastic deformation likely to endanger the hull structure.

4.8.3 Supports and supporting arrangements shall withstand the loads defined in 4.13.9 and 4.15, but these loads need not be combined with each other or with wave-induced loads.

4.9 Associated structure and equipment

4.9.1 Cargo containment systems shall be designed for the loads imposed by associated structure and equipment. This includes pump towers, cargo domes, cargo pumps and piping, stripping pumps and piping, nitrogen piping, access hatches, ladders, piping penetrations, liquid level gauges, independent level alarm gauges, spray nozzles, and instrumentation systems (such as pressure, temperature and strain gauges).

4.10 Thermal insulation

4.10.1 Thermal insulation shall be provided, as required, to protect the hull from temperatures below those allowable (see 4.19.1) and limit the heat flux into the tank to the levels that can be maintained by the pressure and temperature control system applied in chapter 7.

4.10.2 In determining the insulation performance, due regard shall be given to the amount of the acceptable boil-off in association with the reliquefaction plant on board, main propulsion machinery or other temperature control system.

PART B
DESIGN LOADS

4.11 General

This section defines the design loads to be considered with regard to the requirements in 4.16, 4.17 and 4.18. This includes:

.1 load categories (permanent, functional, environmental and accidental) and the description of the loads;

.2 the extent to which these loads shall be considered depending on the type of tank, and is more fully detailed in the following paragraphs; and

.3 tanks, together with their supporting structure and other fixtures, that shall be designed taking into account relevant combinations of the loads described below.

4.12 Permanent loads

4.12.1 *Gravity loads*

The weight of tank, thermal insulation, loads caused by towers and other attachments shall be considered.

4.12.2 *Permanent external loads*

Gravity loads of structures and equipment acting externally on the tank shall be considered.

4.13 Functional loads

4.13.1 Loads arising from the operational use of the tank system shall be classified as functional loads. All functional loads that are essential for ensuring the integrity of the tank system, during all design conditions, shall be considered. As a minimum, the effects from the following criteria, as applicable, shall be considered when establishing functional loads:

.1 internal pressure;

.2 external pressure;

.3 thermally induced loads;

.4 vibration;

.5 interaction loads;

.6 loads associated with construction and installation;

.7 test loads;

.8 static heel loads; and

.9 weight of cargo.

4.13.2 ***Internal pressure***

.1 In all cases, including 4.13.2.2, P_o shall not be less than MARVS.

.2 For cargo tanks, where there is no temperature control and where the pressure of the cargo is dictated only by the ambient temperature, P_o shall not be less than the gauge vapour pressure of the cargo at a temperature of 45°C except as follows:

.1 lower values of ambient temperature may be accepted by the Administration or recognized organization acting on its behalf for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required; and

.2 for ships on voyages of restricted duration, P_o may be calculated based on the actual pressure rise during the voyage, and account may be taken of any thermal insulation of the tank.

.3 Subject to special consideration by the Administration and to the limitations given in 4.21 to 4.26, for the various tank types, a vapour pressure P_h higher than P_o may be accepted for site specific conditions (harbour or other locations), where dynamic loads are reduced. Any relief valve setting resulting from this paragraph shall be recorded in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

.4 The internal pressure P_{eq} results from the vapour pressure P_o or P_h plus the maximum associated dynamic liquid pressure P_{gd}, but not including the effects of liquid sloshing loads. Guidance formulae for associated dynamic liquid pressure P_{gd} are given in 4.28.1.

4.13.3 ***External pressure***

External design pressure loads shall be based on the difference between the minimum internal pressure and the maximum external pressure to which any portion of the tank may be simultaneously subjected.

4.13.4 ***Thermally induced loads***

4.13.4.1 Transient thermally induced loads during cooling down periods shall be considered for tanks intended for cargo temperatures below -55°C.

4.13.4.2 Stationary thermally induced loads shall be considered for cargo containment systems where the design supporting arrangements or attachments and operating temperature may give rise to significant thermal stresses (see 7.2).

4.13.5 ***Vibration***

The potentially damaging effects of vibration on the cargo containment system shall be considered.

4.13.6 ***Interaction loads***

The static component of loads resulting from interaction between cargo containment system and the hull structure, as well as loads from associated structure and equipment, shall be considered.

4.13.7 ***Loads associated with construction and installation***

Loads or conditions associated with construction and installation, e.g. lifting, shall be considered.

4.13.8 ***Test loads***

Account shall be taken of the loads corresponding to the testing of the cargo containment system referred to in 4.21 to 4.26.

4.13.9 ***Static heel loads***

Loads corresponding to the most unfavourable static heel angle within the range 0° to 30° shall be considered.

4.13.10 ***Other loads***

Any other loads not specifically addressed, which could have an effect on the cargo containment system, shall be taken into account.

4.14 Environmental loads

Environmental loads are defined as those loads on the cargo containment system that are caused by the surrounding environment and that are not otherwise classified as a permanent, functional or accidental load.

4.14.1 ***Loads due to ship motion***

4.14.1.1 The determination of dynamic loads shall take into account the long-term distribution of ship motion in irregular seas, which the ship will experience during its operating life. Account may be taken of the reduction in dynamic loads due to necessary speed reduction and variation of heading.

4.14.1.2 The ship's motion shall include surge, sway, heave, roll, pitch and yaw. The accelerations acting on tanks shall be estimated at their centre of gravity and include the following components:

.1 vertical acceleration: motion accelerations of heave, pitch and, possibly, roll (normal to the ship base);

.2 transverse acceleration: motion accelerations of sway, yaw and roll and gravity component of roll; and

.3 longitudinal acceleration: motion accelerations of surge and pitch and gravity component of pitch.

4.14.1.3 Methods to predict accelerations due to ship motion shall be proposed and approved by the Administration or recognized organization acting on its behalf.

4.14.1.4 Guidance formulae for acceleration components are given in 4.28.2.

4.14.1.5 Ships for restricted service may be given special consideration.

4.14.2 ***Dynamic interaction loads***

Account shall be taken of the dynamic component of loads resulting from interaction between cargo containment systems and the hull structure, including loads from associated structures and equipment.

4.14.3 ***Sloshing loads***

4.14.3.1 The sloshing loads on a cargo containment system and internal components shall be evaluated based on allowable filling levels.

4.14.3.2 When significant sloshing-induced loads are expected to be present, special tests and calculations shall be required covering the full range of intended filling levels.

4.14.4 ***Snow and ice loads***

Snow and icing shall be considered, if relevant.

4.14.5 ***Loads due to navigation in ice***

Loads due to navigation in ice shall be considered for vessels intended for such service.

4.15 Accidental loads

Accidental loads are defined as loads that are imposed on a cargo containment system and its supporting arrangements under abnormal and unplanned conditions.

4.15.1 ***Collision loads***

The collision load shall be determined based on the cargo containment system under fully loaded condition with an inertial force corresponding to 0.5 g in the forward direction and 0.25 g in the aft direction, where "g" is gravitational acceleration.

4.15.2 ***Loads due to flooding on ship***

For independent tanks, loads caused by the buoyancy of an empty tank in a hold space flooded to the summer load draught shall be considered in the design of the anti-flotation chocks and the supporting hull structure.

PART C
STRUCTURAL INTEGRITY

4.16 General

4.16.1 The structural design shall ensure that tanks have an adequate capacity to sustain all relevant loads with an adequate margin of safety. This shall take into account the possibility of plastic deformation, buckling, fatigue and loss of liquid and gas tightness.

4.16.2 The structural integrity of cargo containment systems shall be demonstrated by compliance with 4.21 to 4.26, as appropriate, for the cargo containment system type.

4.16.3 The structural integrity of cargo containment system types that are of novel design and differ significantly from those covered by 4.21 to 4.26 shall be demonstrated by compliance with 4.27 to ensure that the overall level of safety provided in this chapter is maintained.

4.17 Structural analyses

4.17.1 ***Analysis***

4.17.1.1 The design analyses shall be based on accepted principles of statics, dynamics and strength of materials.

4.17.1.2 Simplified methods or simplified analyses may be used to calculate the load effects, provided that they are conservative. Model tests may be used in combination with, or instead of, theoretical calculations. In cases where theoretical methods are inadequate, model or full-scale tests may be required.

4.17.1.3 When determining responses to dynamic loads, the dynamic effect shall be taken into account where it may affect structural integrity.

4.17.2 ***Load scenarios***

4.17.2.1 For each location or part of the cargo containment system to be considered and for each possible mode of failure to be analysed, all relevant combinations of loads that may act simultaneously shall be considered.

4.17.2.2 The most unfavourable scenarios for all relevant phases during construction, handling, testing and in service, and conditions shall be considered.

4.17.3 When the static and dynamic stresses are calculated separately, and unless other methods of calculation are justified, the total stresses shall be calculated according to:

$$\sigma_x = \sigma_{x.st} \pm \sqrt{\sum \left(\sigma_{x.dyn}\right)^2}$$

$$\sigma_y = \sigma_{y.st} \pm \sqrt{\sum \left(\sigma_{y.dyn}\right)^2}$$

$$\sigma_z = \sigma_{z.st} \pm \sqrt{\sum \left(\sigma_{z.dyn}\right)^2}$$

$$\tau_{xy} = \tau_{xy.st} \pm \sqrt{\sum \left(\tau_{xy.dyn}\right)^2}$$

$$\tau_{xz} = \tau_{xz.st} \pm \sqrt{\sum \left(\tau_{xz.dyn}\right)^2}$$

$$\tau_{yz} = \tau_{yz.st} \pm \sqrt{\sum \left(\tau_{yz.dyn}\right)^2}$$

where:

$\sigma_{x.st}$, $\sigma_{y.st}$, $\sigma_{z.st}$, $\tau_{xy.st}$, $\tau_{xz.st}$ and $\tau_{yz.st}$ are static stresses; and
$\sigma_{x.dyn}$, $\sigma_{y.dyn}$, $\sigma_{z.dyn}$, $\tau_{xy.dyn}$, $\tau_{xz.dyn}$ and $\tau_{yz.dyn}$ are dynamic stresses,

each shall be determined separately from acceleration components and hull strain components due to deflection and torsion.

4.18 Design conditions

All relevant failure modes shall be considered in the design for all relevant load scenarios and design conditions. The design conditions are given in the earlier part of this chapter, and the load scenarios are covered by 4.17.2.

4.18.1 *Ultimate design condition*

Structural capacity may be determined by testing, or by analysis, taking into account both the elastic and plastic material properties, by simplified linear elastic analysis or by the Code provisions.

4.18.1.1 Plastic deformation and buckling shall be considered.

4.18.1.2 Analysis shall be based on characteristic load values as follows:

Permanent loads:	Expected values
Functional loads:	Specified values
Environmental loads:	For wave loads: most probable largest load encountered during 10^8 wave encounters.

4.18.1.3 For the purpose of ultimate strength assessment, the following material parameters apply:

.1.1 R_e = specified minimum yield stress at room temperature (N/mm^2). If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress applies.

.1.2 R_m = specified minimum tensile strength at room temperature (N/mm^2).

For welded connections where under-matched welds, i.e. where the weld metal has lower tensile strength than the parent metal, are unavoidable, such as in some aluminium alloys, the respective R_e and R_m of the welds, after any applied heat treatment, shall be used. In such cases, the transverse weld tensile strength shall not be less than the actual yield strength of the parent metal. If this cannot be achieved, welded structures made from such materials shall not be incorporated in cargo containment systems.

.2 The above properties shall correspond to the minimum specified mechanical properties of the material, including the weld metal in the as-fabricated condition. Subject to special consideration by the Administration or recognized organization acting on its behalf, account may be taken of the enhanced yield stress and tensile strength at low temperature. The temperature on which the material properties are

based shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk required in 1.4.

4.18.1.4 The equivalent stress σ_C (von Mises, Huber) shall be determined by:

$$\sigma_c = \sqrt{\sigma_x^{\ 2} + \sigma_y^{\ 2} + \sigma_z^{\ 2} - \sigma_x\sigma_y - \sigma_x\sigma_z - \sigma_y\sigma_z + 3(\tau_{xy}^{\ 2} + \tau_{xz}^{\ 2} + \tau_{yz}^{\ 2})}$$

where:

σ_x = total normal stress in x-direction;
σ_y = total normal stress in y-direction;
σ_z = total normal stress in z-direction;
τ_{xy} = total shear stress in x-y plane;
τ_{xz} = total shear stress in x-z plane; and
τ_{yz} = total shear stress in y-z plane.

The above values shall be calculated as described in 4.17.3.

4.18.1.5 Allowable stresses for materials other than those covered by chapter 6 shall be subject to approval by the Administration or recognized organization acting on its behalf in each case.

4.18.1.6 Stresses may be further limited by fatigue analysis, crack propagation analysis and buckling criteria.

4.18.2 ***Fatigue design condition***

4.18.2.1 The fatigue design condition is the design condition with respect to accumulated cyclic loading.

4.18.2.2 Where a fatigue analysis is required, the cumulative effect of the fatigue load shall comply with:

$$\sum \frac{n_i}{N_i} + \frac{n_{Loading}}{N_{Loading}} \leq C_w$$

where:

n_I = number of stress cycles at each stress level during the life of the tank;
N_i = number of cycles to fracture for the respective stress level according to the Wohler (S-N) curve;
$n_{Loading}$ = number of loading and unloading cycles during the life of the tank, not to be less than 1000. Loading and unloading cycles include a complete pressure and thermal cycle;
$N_{Loading}$ = number of cycles to fracture for the fatigue loads due to loading and unloading; and
C_w = maximum allowable cumulative fatigue damage ratio.

The fatigue damage shall be based on the design life of the tank but not less than 10^8 wave encounters.

4.18.2.3 Where required, the cargo containment system shall be subject to fatigue analysis, considering all fatigue loads and their appropriate combinations for the expected life of the cargo containment system. Consideration shall be given to various filling conditions.

4.18.2.4.1 Design S-N curves used in the analysis shall be applicable to the materials and weldments, construction details, fabrication procedures and applicable state of the stress envisioned.

4.18.2.4.2 The S-N curves shall be based on a 97.6% probability of survival corresponding to the mean-minus-two-standard-deviation curves of relevant experimental data up to final failure. Use of S-N curves derived in a different way requires adjustments to the acceptable C_w values specified in 4.18.2.7 to 4.18.2.9.

4.18.2.5 Analysis shall be based on characteristic load values as follows:

Permanent loads:	Expected values
Functional loads:	Specified values or specified history
Environmental loads:	Expected load history, but not less than 10^8 cycles

If simplified dynamic loading spectra are used for the estimation of the fatigue life, they shall be specially considered by the Administration or recognized organization acting on its behalf.

4.18.2.6.1 Where the size of the secondary barrier is reduced, as is provided for in 4.4.3, fracture mechanics analyses of fatigue crack growth shall be carried out to determine:

.1 crack propagation paths in the structure;

.2 crack growth rate;

.3 the time required for a crack to propagate to cause a leakage from the tank;

.4 the size and shape of through thickness cracks; and

.5 the time required for detectable cracks to reach a critical state.

The fracture mechanics are, in general, based on crack growth data taken as a mean value plus two standard deviations of the test data.

4.18.2.6.2 In analysing crack propagation, the largest initial crack not detectable by the inspection method applied shall be assumed, taking into account the allowable non-destructive testing and visual inspection criterion, as applicable.

4.18.2.6.3 Crack propagation analysis under the condition specified in 4.18.2.7: the simplified load distribution and sequence over a period of 15 days may be used. Such distributions may be obtained as indicated in figure 4.4. Load distribution and sequence for longer periods, such as in 4.18.2.8 and 4.18.2.9 shall be approved by the Administration or recognized organization acting on its behalf.

4.18.2.6.4 The arrangements shall comply with 4.18.2.7 to 4.18.2.9, as applicable.

4.18.2.7 For failures that can be reliably detected by means of leakage detection:

C_w shall be less than or equal to 0.5.

Predicted remaining failure development time, from the point of detection of leakage till reaching a critical state, shall not be less than 15 days, unless different requirements apply for ships engaged in particular voyages.

4.18.2.8 For failures that cannot be detected by leakage but that can be reliably detected at the time of in-service inspections:

C_w shall be less than or equal to 0.5.

Predicted remaining failure development time, from the largest crack not detectable by in-service inspection methods until reaching a critical state, shall not be less than three times the inspection interval.

4.18.2.9 In particular locations of the tank, where effective defect or crack development detection cannot be assured, the following, more stringent, fatigue acceptance criteria shall be applied as a minimum:

C_w shall be less than or equal to 0.1.

Predicted failure development time, from the assumed initial defect until reaching a critical state, shall not be less than three times the lifetime of the tank.

4.18.3 ***Accident design condition***

4.18.3.1 The accident design condition is a design condition for accidental loads with extremely low probability of occurrence.

4.18.3.2 Analysis shall be based on the characteristic values as follows:

Permanent loads:	Expected values
Functional loads:	Specified values
Environmental loads:	Specified values
Accidental loads:	Specified values or expected values

4.18.3.3 Loads mentioned in 4.13.9 and 4.15 need not be combined with each other or with wave-induced loads.

PART D
MATERIALS AND CONSTRUCTION

4.19 Materials

Goal

To ensure that the cargo containment system, primary and secondary barriers, the thermal insulation, adjacent ship structure and other materials in the cargo containment system are constructed from materials of suitable properties for the conditions they will experience, both in normal service and in the event of failure of the primary barrier, where applicable.

4.19.1 ***Materials forming ship structure***

4.19.1.1 To determine the grade of plate and sections used in the hull structure, a temperature calculation shall be performed for all tank types when the cargo temperature is below -10°C. The following assumptions shall be made in this calculation:

.1 the primary barrier of all tanks shall be assumed to be at the cargo temperature;

.2 in addition to .1, where a complete or partial secondary barrier is required, it shall be assumed to be at the cargo temperature at atmospheric pressure for any one tank only;

.3 for worldwide service, ambient temperatures shall be taken as 5°C for air and 0°C for seawater. Higher values may be accepted for ships operating in restricted areas and, conversely, lower values may be fixed by the Administration for ships trading to areas where lower temperatures are expected during the winter months;

.4 still air and seawater conditions shall be assumed, i.e. no adjustment for forced convection;

.5 degradation of the thermal insulation properties over the life of the ship due to factors such as thermal and mechanical ageing, compaction, ship motions and tank vibrations, as defined in 4.19.3.6 and 4.19.3.7, shall be assumed;

.6 the cooling effect of the rising boil-off vapour from the leaked cargo shall be taken into account, where applicable;

.7 credit for hull heating may be taken in accordance with 4.19.1.5, provided the heating arrangements are in compliance with 4.19.1.6;

.8 no credit shall be given for any means of heating, except as described in 4.19.1.5; and

.9 for members connecting inner and outer hulls, the mean temperature may be taken for determining the steel grade.

The ambient temperatures used in the design, described in this paragraph, shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk required in 1.4.4.

4.19.1.2 The shell and deck plating of the ship and all stiffeners attached thereto shall be in accordance with recognized standards. If the calculated temperature of the material in the design condition is below -5°C due to the influence of the cargo temperature, the material shall be in accordance with table 6.5.

4.19.1.3 The materials of all other hull structures for which the calculated temperature in the design condition is below 0°C, due to the influence of cargo temperature and that do not form the secondary barrier, shall also be in accordance with table 6.5. This includes hull structure supporting the cargo tanks, inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.

4.19.1.4 The hull material forming the secondary barrier shall be in accordance with table 6.2. Where the secondary barrier is formed by the deck or side shell plating, the material grade required by table 6.2 shall be carried into the adjacent deck or side shell plating, where applicable, to a suitable extent.

4.19.1.5 Means of heating structural materials may be used to ensure that the material temperature does not fall below the minimum allowed for the grade of material specified in table 6.5. In the calculations required in 4.19.1.1, credit for such heating may be taken in accordance with the following:

.1 for any transverse hull structure;

.2 for longitudinal hull structure referred to in 4.19.1.2 and 4.19.1.3 where colder ambient temperatures are specified, provided the material remains suitable for the ambient temperature conditions of +5°C for air

and 0°C for seawater with no credit taken in the calculations for heating; and

.3 as an alternative to .2, for longitudinal bulkhead between cargo tanks, credit may be taken for heating, provided the material remain suitable for a minimum design temperature of -30°C, or a temperature 30°C lower than that determined by 4.19.1.1 with the heating considered, whichever is less. In this case, the ship's longitudinal strength shall comply with SOLAS regulation II-1/3-1 for both when those bulkhead(s) are considered effective and not.

4.19.1.6 The means of heating referred to in 4.19.1.5 shall comply with the following requirements:

.1 the heating system shall be arranged so that, in the event of failure in any part of the system, standby heating can be maintained equal to not less than 100% of the theoretical heat requirement;

.2 the heating system shall be considered as an essential auxiliary. All electrical components of at least one of the systems provided in accordance with 4.19.1.5.1 shall be supplied from the emergency source of electrical power; and

.3 the design and construction of the heating system shall be included in the approval of the containment system by the Administration or recognized organization acting on its behalf.

4.19.2 ***Materials of primary and secondary barriers***

4.19.2.1 Metallic materials used in the construction of primary and secondary barriers not forming the hull, shall be suitable for the design loads that they may be subjected to, and be in accordance with, table 6.1, 6.2 or 6.3.

4.19.2.2 Materials, either non-metallic or metallic but not covered by tables 6.1, 6.2 and 6.3, used in the primary and secondary barriers may be approved by the Administration or recognized organization acting on its behalf, considering the design loads that they may be subjected to, their properties and their intended use.

4.19.2.3 Where non-metallic materials, including composites, are used for, or incorporated in the primary or secondary barriers, they shall be tested for the following properties, as applicable, to ensure that they are adequate for the intended service:

.1 compatibility with the cargoes;

.2 ageing;

.3 mechanical properties;

.4 thermal expansion and contraction;

.5 abrasion;

.6 cohesion;

.7 resistance to vibrations;

.8 resistance to fire and flame spread; and

.9 resistance to fatigue failure and crack propagation.

4.19.2.4 The above properties, where applicable, shall be tested for the range between the expected maximum temperature in service and +5°C below the minimum design temperature, but not lower than -196°C.

4.19.2.5.1 Where non-metallic materials, including composites, are used for the primary and secondary barriers, the joining processes shall also be tested as described above.

4.19.2.5.2 Guidance on the use of non-metallic materials in the construction of primary and secondary barriers is provided in appendix 4.

4.19.2.6 Consideration may be given to the use of materials in the primary and secondary barrier, which are not resistant to fire and flame spread, provided they are protected by a suitable system such as a permanent inert gas environment, or are provided with a fire-retardant barrier.

4.19.3 ***Thermal insulation and other materials used in cargo containment systems***

4.19.3.1 Load-bearing thermal insulation and other materials used in cargo containment systems shall be suitable for the design loads.

4.19.3.2 Thermal insulation and other materials used in cargo containment systems shall have the following properties, as applicable, to ensure that they are adequate for the intended service:

.1 compatibility with the cargoes;

.2 solubility in the cargo;

.3 absorption of the cargo;

.4 shrinkage;

.5 ageing;

.6 closed cell content;

.7 density;

.8 mechanical properties, to the extent that they are subjected to cargo and other loading effects, thermal expansion and contraction;

.9 abrasion;

.10 cohesion;

.11 thermal conductivity;

.12 resistance to vibrations;

.13 resistance to fire and flame spread; and

.14 resistance to fatigue failure and crack propagation.

4.19.3.3 The above properties, where applicable, shall be tested for the range between the expected maximum temperature in service and 5°C below the minimum design temperature, but not lower than -196°C.

4.19.3.4 Due to location or environmental conditions, thermal insulation materials shall have suitable properties of resistance to fire and flame spread and shall be adequately protected against penetration of water vapour and mechanical damage. Where the thermal insulation is located on or above the exposed deck, and in way of tank cover penetrations, it shall have suitable fire resistance properties in accordance with recognized standards or be covered with a material having low flame-spread characteristics and forming an efficient approved vapour seal.

4.19.3.5 Thermal insulation that does not meet recognized standards for fire resistance may be used in hold spaces that are not kept permanently inerted, provided its surfaces are covered with material with low flame-spread characteristics and that forms an efficient approved vapour seal.

4.19.3.6 Testing for thermal conductivity of thermal insulation shall be carried out on suitably aged samples.

4.19.3.7 Where powder or granulated thermal insulation is used, measures shall be taken to reduce compaction in service and to maintain the required thermal conductivity and also prevent any undue increase of pressure on the cargo containment system.

4.20 Construction processes

Goal

To define suitable construction processes and test procedures in order to ensure, as far as reasonably practical, that the cargo containment system will perform satisfactorily in service in accordance with the assumptions made at the design stage.

4.20.1 *Weld joint design*

4.20.1.1 All welded joints of the shells of independent tanks shall be of the in-plane butt weld full penetration type. For dome-to-shell connections only, tee welds of the full penetration type may be used depending on the results of the tests carried out at the approval of the welding procedure. Except for small penetrations on domes, nozzle welds shall also be designed with full penetration.

4.20.1.2 Welding joint details for type C independent tanks, and for the liquid-tight primary barriers of type B independent tanks primarily constructed of curved surfaces, shall be as follows:

.1 all longitudinal and circumferential joints shall be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds shall be obtained by double welding or by the use of backing rings. If used, backing rings shall be removed except from very small process pressure vessels. Other edge preparations may be permitted, depending on the results of the tests carried out at the approval of the welding procedure; and

.2 the bevel preparation of the joints between the tank body and domes and between domes and relevant fittings shall be designed according to a standard acceptable to the Administration or recognized organization acting on its behalf. All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles shall be full penetration welds.

4.20.1.3 Where applicable, all the construction processes and testing, except that specified in 4.20.3, shall be done in accordance with the applicable provisions of chapter 6.

4.20.2 ***Design for gluing and other joining processes***

The design of the joint to be glued (or joined by some other process except welding) shall take account of the strength characteristics of the joining process.

4.20.3 ***Testing***

4.20.3.1 All cargo tanks and process pressure vessels shall be subjected to hydrostatic or hydropneumatic pressure testing in accordance with 4.21 to 4.26, as applicable for the tank type.

4.20.3.2 All tanks shall be subject to a tightness test which may be performed in combination with the pressure test referred to in 4.20.3.1.

4.20.3.3 Requirements with respect to inspection of secondary barriers shall be decided by the Administration or recognized organization acting on its behalf in each case, taking into account the accessibility of the barrier (see 4.6.2).

4.20.3.4 The Administration may require that for ships fitted with novel type B independent tanks, or tanks designed according to 4.27 at least one prototype tank and its supporting structures shall be instrumented with strain gauges or other suitable equipment to confirm stress levels. Similar instrumentation may be required for type C independent tanks, depending on their configuration and on the arrangement of their supports and attachments.

4.20.3.5 The overall performance of the cargo containment system shall be verified for compliance with the design parameters during the first full loading and discharging of the cargo, in accordance with the survey procedure and requirements in 1.4 and the requirements of the Administration or recognized organization acting on its behalf. Records of the performance of the components and equipment essential to verify the design parameters, shall be maintained and be available to the Administration.

4.20.3.6 Heating arrangements, if fitted in accordance with 4.19.1.5 and 4.19.1.6, shall be tested for required heat output and heat distribution.

4.20.3.7 The cargo containment system shall be inspected for cold spots during, or immediately following, the first loaded voyage. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked shall be carried out in accordance with recognized standards.

PART E
TANK TYPES

4.21 Type A independent tanks

4.21.1 ***Design basis***

4.21.1.1 Type A independent tanks are tanks primarily designed using classical ship-structural analysis procedures in accordance with recognized standards. Where such tanks are primarily constructed of plane surfaces, the design vapour pressure P_o shall be less than 0.07 MPa.

4.21.1.2 If the cargo temperature at atmospheric pressure is below -10°C, a complete secondary barrier shall be provided as required in 4.5. The secondary barrier shall be designed in accordance with 4.6.

4.21.2 ***Structural analysis***

4.21.2.1 A structural analysis shall be performed taking into account the internal pressure as indicated in 4.13.2, and the interaction loads with the supporting and keying system as well as a reasonable part of the ship's hull.

4.21.2.2 For parts, such as supporting structures, not otherwise covered by the requirements of the Code, stresses shall be determined by direct calculations, taking into account the loads referred to in 4.12 to 4.15 as far as applicable, and the ship deflection in way of supporting structures.

4.21.2.3 The tanks with supports shall be designed for the accidental loads specified in 4.15. These loads need not be combined with each other or with environmental loads.

4.21.3 ***Ultimate design condition***

4.21.3.1 For tanks primarily constructed of plane surfaces, the nominal membrane stresses for primary and secondary members (stiffeners, web frames, stringers, girders), when calculated by classical analysis procedures, shall not exceed the lower of $R_m/2.66$ or $R_e/1.33$ for nickel steels, carbon-manganese steels, austenitic steels and aluminium alloys, where R_m and R_e are defined in 4.18.1.3. However, if detailed calculations are carried out for the primary members, the equivalent stress σ_c, as defined in 4.18.1.4, may be increased over that indicated above to a stress acceptable to the Administration or recognized organization acting on its behalf. Calculations shall take into account the effects of bending, shear, axial and torsional deformation as well as the hull/cargo tank interaction forces due to the deflection of the double bottom and cargo tank bottoms.

4.21.3.2 Tank boundary scantlings shall meet at least the requirements of the Administration or recognized organization acting on its behalf for deep tanks taking into account the internal pressure as indicated in 4.13.2 and any corrosion allowance required by 4.3.5.

4.21.3.3 The cargo tank structure shall be reviewed against potential buckling.

4.21.4 ***Accident design condition***

4.21.4.1 The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in 4.3.4.3 and 4.15, as relevant.

4.21.4.2 When subjected to the accidental loads specified in 4.15, the stress shall comply with the acceptance criteria specified in 4.21.3, modified as appropriate, taking into account their lower probability of occurrence.

4.21.5 ***Testing***

All type A independent tanks shall be subjected to a hydrostatic or hydropneumatic test. This test shall be performed such that the stresses approximate, as far as practicable, the design stresses, and that the pressure at the top of the tank corresponds at least to the MARVS. When a hydropneumatic test is performed, the conditions shall simulate, as far as practicable, the design loading of the tank and of its support structure, including dynamic components, while avoiding stress levels that could cause permanent deformation.

4.22 Type B independent tanks

4.22.1 *Design basis*

4.22.1.1 Type B independent tanks are tanks designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarily constructed of plane surfaces (prismatic tanks), the design vapour pressure P_o shall be less than 0.07 MPa.

4.22.1.2 If the cargo temperature at atmospheric pressure is below -10°C, a partial secondary barrier with a small leak protection system shall be provided as required in 4.5. The small leak protection system shall be designed according to 4.7.

4.22.2 *Structural analysis*

4.22.2.1 The effects of all dynamic and static loads shall be used to determine the suitability of the structure with respect to:

.1 plastic deformation;

.2 buckling;

.3 fatigue failure; and

.4 crack propagation.

Finite element analysis or similar methods and fracture mechanics analysis, or an equivalent approach, shall be carried out.

4.22.2.2 A three-dimensional analysis shall be carried out to evaluate the stress levels, including interaction with the ship's hull. The model for this analysis shall include the cargo tank with its supporting and keying system, as well as a reasonable part of the hull.

4.22.2.3 A complete analysis of the particular ship accelerations and motions in irregular waves, and of the response of the ship and its cargo tanks to these forces and motions shall be performed, unless the data is available from similar ships.

4.22.3 *Ultimate design condition*

4.22.3.1 Plastic deformation

4.22.3.1.1 For type B independent tanks, primarily constructed of bodies of revolution, 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;

f = the lesser of (R_m / A) or (R_e / B); and

F = the lesser of (R_m / C) or (R_e / D),

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	2	1.6	1.5
C	3	3	3
D	1.5	1.5	1.5

The above figures may be altered, taking into account the design condition considered in acceptance with the Administration.

4.22.3.1.2 For type B independent tanks, primarily constructed of plane surfaces, the allowable membrane equivalent stresses applied for finite element analysis shall not exceed:

.1 for nickel steels and carbon-manganese steels, the lesser of R_m/2 or R_e/1.2;

.2 for austenitic steels, the lesser of R_m/2.5 or R_e/1.2; and

.3 for aluminium alloys, the lesser of R_m/2.5 or R_e/1.2.

The above figures may be amended, taking into account the locality of the stress, stress analysis methods and design condition considered in acceptance with the Administration.

4.22.3.1.3 The thickness of the skin plate and the size of the stiffener shall not be less than those required for type A independent tanks.

4.22.3.2 ***Buckling***

Buckling strength analyses of cargo tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with recognized standards. The method shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, lack of straightness or flatness, ovality and deviation from true circular form over a specified arc or chord length, as applicable.

4.22.4 ***Fatigue design condition***

4.22.4.1 Fatigue and crack propagation assessment shall be performed in accordance with 4.18.2. The acceptance criteria shall comply with 4.18.2.7, 4.18.2.8 or 4.18.2.9, depending on the detectability of the defect.

4.22.4.2 Fatigue analysis shall consider construction tolerances.

4.22.4.3 Where deemed necessary by the Administration, model tests may be required to determine stress concentration factors and fatigue life of structural elements.

4.22.5 ***Accident design condition***

4.22.5.1 The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in 4.3.4.3 and 4.15, as applicable.

4.22.5.2 When subjected to the accidental loads specified in 4.15, the stress shall comply with the acceptance criteria specified in 4.22.3, modified as appropriate, taking into account their lower probability of occurrence.

4.22.6 ***Testing***

Type B independent tanks shall be subjected to a hydrostatic or hydropneumatic test as follows:

.1 the test shall be performed as required in 4.21.5 for type A independent tanks; and

.2 in addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions shall not exceed 90% of the yield strength of the material (as fabricated) at the test temperature. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 75% of the yield strength, the prototype test shall be monitored by the use of strain gauges or other suitable equipment.

4.22.7 ***Marking***

Any marking of the pressure vessel shall be achieved by a method that does not cause unacceptable local stress raisers.

4.23 Type C independent tanks

4.23.1 ***Design basis***

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 the thickness of the shell during the lifetime of the tank.

4.23.1.2 The design vapour pressure shall not be less than:

$P_o = 0.2 + AC(\rho_r)^{1.5}$ (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);

ρ_r = the relative density of the cargo (ρ_r = 1 for fresh water) at the design temperature.

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

4.23.1.3 The Administration may allocate a tank complying with the criteria of type C tank minimum design pressure as in 4.23.1.2, to a type A or type B, dependent on the configuration of the tank and the arrangement of its supports and attachments.

4.23.2 ***Shell thickness***

4.23.2.1 The shell thickness shall be as follows:

.1 For pressure vessels, the thickness calculated according to 4.23.2.4 shall be considered as a minimum thickness after forming, without any negative tolerance.

.2 For pressure vessels, the minimum thickness of shell and heads including corrosion allowance, after forming, shall not be less than 5 mm for carbon-manganese steels and nickel steels, 3 mm for austenitic steels or 7 mm for aluminium alloys.

.3 The welded joint efficiency factor to be used in the calculation according to 4.23.2.4 shall be 0.95 when the inspection and the non-destructive testing referred to in 6.5.6.5 are carried out. This figure may be increased up to 1 when account is taken of other considerations, such as the material used, type of joints, welding procedure and type of loading. For process pressure vessels, the Administration or recognized organization acting on its behalf may accept partial non-destructive examinations, but not less than those of 6.5.6.5, depending on such factors as the material used, the design temperature, the nil-ductility transition temperature of the material, as fabricated, and the type of joint and welding procedure, but in this case an efficiency factor of not more than 0.85 shall be adopted. For special materials, the above-mentioned factors shall be reduced, depending on the specified mechanical properties of the welded joint.

4.23.2.2 The design liquid pressure defined in 4.13.2 shall be taken into account in the internal pressure calculations.

4.23.2.3 The design external pressure P_e, used for verifying the buckling of the pressure vessels, shall not be less than that given by:

$$P_e = P_1+P_2+P_3+P_4 \quad \text{(MPa)},$$

where:

P_1 = setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves, P_1 shall be specially considered, but shall not, in general, be taken as less than 0.025 MPa;

P_2 = the set pressure of the pressure relief valves (PRVs) for completely closed spaces containing pressure vessels or parts of pressure vessels; elsewhere P_2=0;

P_3 = compressive actions in or on the shell due to the weight and contraction of thermal insulation, weight of shell including corrosion allowance and other miscellaneous external pressure loads to which the pressure vessel may be subjected. These include, but are not limited to, weight of domes, weight of towers and piping, effect of product in the partially filled condition, accelerations and hull deflection. In addition, the local effect of external or internal pressures or both shall be taken into account; and

P_4 = external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks; elsewhere P_4 = 0.

4.23.2.4 Scantlings based on internal pressure shall be calculated as follows: the thickness and form of pressure-containing parts of pressure vessels, under internal pressure, as defined in 4.13.2, including flanges, shall be determined. These calculations shall in all cases be based on accepted pressure vessel design theory. Openings in pressure-containing parts of pressure vessels shall be reinforced in accordance with recognized standards.

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.

4.23.3 ***Ultimate design condition***

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.

4.23.4 ***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.

4.23.5 ***Accident design condition***

4.23.5.1 The tanks and the tank supporting structures shall be designed for the accidental loads and design conditions specified in 4.3.4.3 and 4.15, as applicable.

4.23.5.2 When subjected to the accidental loads specified in 4.15, the stress shall comply with the acceptance criteria specified in 4.23.3.1, modified as appropriate taking into account their lower probability of occurrence.

4.23.6 ***Testing***

4.23.6.1 Each pressure vessel shall be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than 1.5 P_o. In no case during the pressure test shall the calculated primary membrane stress at any point exceed 90% of the yield stress of the material. To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0.75 times the yield strength, the prototype test shall be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.

4.23.6.2 The temperature of the water used for the test shall be at least 30°C above the nil-ductility transition temperature of the material, as fabricated.

4.23.6.3 The pressure shall be held for 2 h per 25 mm of thickness, but in no case less than 2 h.

4.23.6.4 Where necessary for cargo pressure vessels, a hydropneumatic test may be carried out under the conditions prescribed in 4.23.6.1 to 4.23.6.3.

4.23.6.5 Special consideration may be given to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, the requirements of 4.23.6.1 shall be fully complied with.

4.23.6.6 After completion and assembly, each pressure vessel and its related fittings shall be subjected to an adequate tightness test which may be performed in combination with the pressure testing referred to in 4.23.6.1.

4.23.6.7 Pneumatic testing of pressure vessels other than cargo tanks shall only be considered on an individual case basis. Such testing shall only be permitted for those vessels designed or supported such that they cannot be safely filled with water, or for those vessels that cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated.

4.23.7 ***Marking***

The required marking of the pressure vessel shall be achieved by a method that does not cause unacceptable local stress raisers.

4.24 Membrane tanks

4.24.1 ***Design basis***

4.24.1.1 The design basis for membrane containment systems is that thermal and other expansion or contraction is compensated for without undue risk of losing the tightness of the membrane.

4.24.1.2 A systematic approach based on analysis and testing shall be used to demonstrate that the system will provide its intended function in consideration of the events identified in service as specified in 4.24.2.1.

4.24.1.3 If the cargo temperature at atmospheric pressure is below -10°C, a complete secondary barrier shall be provided as required in 4.5. The secondary barrier shall be designed according to 4.6.

4.24.1.4 The design vapour pressure P_o shall not normally exceed 0.025 MPa. If the hull scantlings are increased accordingly and consideration is given, where appropriate, to the strength of the supporting thermal insulation, P_o may be increased to a higher value, but less than 0.07 MPa.

4.24.1.5 The definition of membrane tanks does not exclude designs such as those in which non-metallic membranes are used or where membranes are included or incorporated into the thermal insulation.

4.24.1.6 The thickness of the membranes shall not normally exceed 10 mm.

4.24.1.7 The circulation of inert gas throughout the primary insulation space and the secondary insulation space, in accordance with 9.2.1, shall be sufficient to allow for effective means of gas detection.

4.24.2 ***Design considerations***

4.24.2.1 Potential incidents that could lead to loss of fluid tightness over the life of the membranes shall be evaluated. These include, but are not limited to:

.1 Ultimate design events:

.1 tensile failure of membranes;

.2 compressive collapse of thermal insulation;

.3 thermal ageing;

.4 loss of attachment between thermal insulation and hull structure;

.5 loss of attachment of membranes to thermal insulation system;

.6 structural integrity of internal structures and their supporting structures; and

.7 failure of the supporting hull structure.

.2 Fatigue design events:

.1 fatigue of membranes including joints and attachments to hull structure;

.2 fatigue cracking of thermal insulation;

.3 fatigue of internal structures and their supporting structures; and

.4 fatigue cracking of inner hull leading to ballast water ingress.

.3 Accident design events:

.1 accidental mechanical damage (such as dropped objects inside the tank while in service);

.2 accidental overpressurization of thermal insulation spaces;
.3 accidental vacuum in the tank; and

.4 water ingress through the inner hull structure.

Designs where a single internal event could cause simultaneous or cascading failure of both membranes are unacceptable.

4.24.2.2 The necessary physical properties (mechanical, thermal, chemical, etc.) of the materials used in the construction of the cargo containment system shall be established during the design development in accordance with 4.24.1.2.

4.24.3 ***Loads and load combinations***

Particular consideration shall be given to the possible loss of tank integrity due to either an overpressure in the interbarrier space, a possible vacuum in the cargo tank, the sloshing effects, hull vibration effects, or any combination of these events.

4.24.4 ***Structural analyses***

4.24.4.1 Structural analyses and/or testing for the purpose of determining the ultimate strength and fatigue assessments of the cargo containment and associated structures, e.g. structures as defined in 4.9, shall be performed. The structural analysis shall provide the data required to assess each failure mode that has been identified as critical for the cargo containment system.

4.24.4.2 Structural analyses of the hull shall take into account the internal pressure as indicated in 4.13.2. Special attention shall be paid to deflections of the hull and their compatibility with the membrane and associated thermal insulation.

4.24.4.3 The analyses referred to in 4.24.4.1 and 4.24.4.2 shall be based on the particular motions, accelerations and response of ships and cargo containment systems.

4.24.5 ***Ultimate design condition***

4.24.5.1 The structural resistance of every critical component, subsystem or assembly shall be established, in accordance with 4.24.1.2, for in-service conditions.

4.24.5.2 The choice of strength acceptance criteria for the failure modes of the cargo containment system, its attachments to the hull structure and internal tank structures, shall reflect the consequences associated with the considered mode of failure.

4.24.5.3 The inner hull scantlings shall meet the requirements for deep tanks, taking into account the internal pressure as indicated in 4.13.2 and the specified appropriate requirements for sloshing load as defined in 4.14.3.

4.24.6 ***Fatigue design condition***

4.24.6.1 Fatigue analysis shall be carried out for structures inside the tank, i.e. pump towers, and for parts of membrane and pump tower attachments, where failure development cannot be reliably detected by continuous monitoring.

4.24.6.2 The fatigue calculations shall be carried out in accordance with 4.18.2, with relevant requirements depending on:

.1 the significance of the structural components with respect to structural integrity; and

.2 availability for inspection.

4.24.6.3 For structural elements for which it can be demonstrated by tests and/or analyses that a crack will not develop to cause simultaneous or cascading failure of both membranes, C_w shall be less than or equal to 0.5.

4.24.6.4 Structural elements subject to periodic inspection, and where an unattended fatigue crack can develop to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in 4.18.2.8.

4.24.6.5 Structural element not accessible for in-service inspection, and where a fatigue crack can develop without warning to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in 4.18.2.9.

4.24.7 ***Accident design condition***

4.24.7.1 The containment system and the supporting hull structure shall be designed for the accidental loads specified in 4.15. These loads need not be combined with each other or with environmental loads.

4.24.7.2 Additional relevant accident scenarios shall be determined based on a risk analysis. Particular attention shall be paid to securing devices inside tanks.

4.24.8 ***Design development testing***

4.24.8.1 The design development testing required in 4.24.1.2 shall include a series of analytical and physical models of both the primary and secondary barriers, including corners and joints, tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads. This will culminate in the construction of a prototype-scaled model of the complete cargo containment system. Testing conditions considered in the analytical and physical models shall represent the most extreme service conditions the cargo containment system will be likely to encounter over its life. Proposed acceptance criteria for periodic testing of secondary barriers required in 4.6.2 may be based on the results of testing carried out on the prototype-scaled model.

4.24.8.2 The fatigue performance of the membrane materials and representative welded or bonded joints in the membranes shall be determined by tests. The ultimate strength and fatigue performance of arrangements for securing the thermal insulation system to the hull structure shall be determined by analyses or tests.

4.24.9 ***Testing***

4.24.9.1 In ships fitted with membrane cargo containment systems, all tanks and other spaces that may normally contain liquid and are adjacent to the hull structure supporting the membrane, shall be hydrostatically tested.

4.24.9.2 All hold structures supporting the membrane shall be tested for tightness before installation of the cargo containment system.

4.24.9.3 Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested.

4.25 Integral tanks

4.25.1 ***Design basis***

Integral tanks that form a structural part of the hull and are affected by the loads that stress the adjacent hull structure shall comply with the following:

.1 the design vapour pressure P_o as defined in 4.1.2 shall not normally exceed 0.025 MPa. If the hull scantlings are increased accordingly, P_o may be increased to a higher value, but less than 0.07 MPa;

.2 integral tanks may be used for products, provided the boiling point of the cargo is not below -10°C. A lower temperature may be accepted by the Administration or recognized organization acting on its behalf subject to special consideration, but in such cases a complete secondary barrier shall be provided; and

.3 products required by chapter 19 to be carried in type 1G ships shall not be carried in integral tanks.

4.25.2 ***Structural analysis***

The structural analysis of integral tanks shall be in accordance with recognized standards.

4.25.3 ***Ultimate design condition***

4.25.3.1 The tank boundary scantlings shall meet the requirements for deep tanks, taking into account the internal pressure as indicated in 4.13.2.

4.25.3.2 For integral tanks, allowable stresses shall normally be those given for hull structure in the requirements of the Administration or recognized organization acting on its behalf.

4.25.4 ***Accident design condition***

4.25.4.1 The tanks and the tank supports shall be designed for the accidental loads specified in 4.3.4.3 and 4.15, as relevant.

4.25.4.2 When subjected to the accidental loads specified in 4.15, the stress shall comply with the acceptance criteria specified in 4.25.3, modified as appropriate, taking into account their lower probability of occurrence.

4.25.5 ***Testing***

All integral tanks shall be hydrostatically or hydropneumatically tested. The test shall be performed so that the stresses approximate, as far as practicable, to the design stresses and that the pressure at the top of the tank corresponds at least to the MARVS.

4.26 Semi-membrane tanks

4.26.1 ***Design basis***

4.26.1.1 Semi-membrane tanks are non-self-supporting tanks when in the loaded condition and consist of a layer, parts of which are supported through thermal insulation by the adjacent hull structure, whereas the rounded parts of this layer connecting the above-mentioned supported parts are designed also to accommodate the thermal and other expansion or contraction.

4.26.1.2 The design vapour pressure P_o shall not normally exceed 0.025 MPa. If the hull scantlings are increased accordingly, and consideration is given, where appropriate, to the strength of the supporting thermal insulation, P_o may be increased to a higher value, but less than 0.07 MPa.

4.26.1.3 For semi-membrane tanks the relevant requirements in this section for independent tanks or for membrane tanks shall be applied as appropriate.

4.26.1.4 In the case of semi-membrane tanks that comply in all respects with the requirements applicable to type B independent tanks, except for the manner of support, the Administration may, after special consideration, accept a partial secondary barrier.

PART F
CARGO CONTAINMENT SYSTEMS OF NOVEL CONFIGURATION

4.27 Limit state design for novel concepts

4.27.1 Cargo containment systems that are of a novel configuration that cannot be designed using sections 4.21 to 4.26 shall be designed using this section and parts A and B of this chapter, and also parts C and D, as applicable. Cargo containment system design according to this section shall be based on the principles of limit state design which is an approach to structural design that can be applied to established design solutions as well as novel designs. This more generic approach maintains a level of safety similar to that achieved for known containment systems as designed using 4.21 to 4.26.

4.27.2.1 The limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design conditions identified in 4.3.4. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the requirements.

4.27.2.2 For each failure mode, one or more limit states may be relevant. By consideration of all relevant limit states, the limit load for the structural element is found as the minimum limit load resulting from all the relevant limit states. The limit states are divided into the three following categories:

.1 Ultimate limit states (ULS), which correspond to the maximum load-carrying capacity or, in some cases, to the maximum applicable strain or deformation; under intact (undamaged) conditions.

.2 Fatigue limit states (FLS), which correspond to degradation due to the effect of time varying (cyclic) loading.

.3 Accident limit states (ALS), which concern the ability of the structure to resist accidental situations.

4.27.3 The procedure and relevant design parameters of the limit state design shall comply with the Standards for the Use of limit state methodologies in the design of cargo containment systems of novel configuration (LSD Standard), as set out in appendix 5.

PART G
GUIDANCE

4.28 Guidance notes for chapter 4

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

4.28.1.1 This section provides guidance for the calculation of the associated dynamic liquid pressure for the purpose of static design calculations. This pressure may be used for determining the internal pressure referred to in 4.13.2.4, where:

.1 (P_{gd})max is the associated liquid pressure determined using the maximum design accelerations.

.2 $(P_{gd}$ site)max is the associated liquid pressure determined using site specific accelerations.

.3 P_{eq} should be the greater of P_{eq1} and P_{eq2} calculated as follows:

$$P_{eq1} = P_o + (P_{gd})\max \quad \text{(MPa)},$$

$$P_{eq2} = P_h + (P_{gd}\ \text{site})\max \quad \text{(MPa)}.$$

4.28.1.2 The internal liquid pressures are those created by the resulting acceleration of the centre of gravity of the cargo due to the motions of the ship referred to in 4.14.1. The value of internal liquid pressure P_{gd} resulting from combined effects of gravity and dynamic accelerations should be calculated as follows:

$$P_{gd} = \alpha_\beta Z_\beta \frac{\rho}{1.02 \times 10^{-2}} \quad \text{(MPa)},$$

where:

a_β = dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction β (see figure 4.1).

For large tanks, an acceleration ellipsoid taking account of transverse vertical and longitudinal accelerations, should be used.

Z_β = largest liquid height (m) above the point where the pressure is to be determined measured from the tank shell in the β direction (see figure 4.2).

Tank domes considered to be part of the accepted total tank volume shall be taken into account when determining Z_β, unless the total volume of tank domes V_d does not exceed the following value:

$$V_d = V_t\left(\frac{100 - FL}{FL}\right)$$

with:

V_t = tank volume without any domes; and
FL = filling limit according to chapter 15.

ρ = maximum cargo density (kg/m^3) at the design temperature.

The direction that gives the maximum value $(P_{gd})\max$ or $(P_{gd}\text{site})\max$ should be considered. The above formula applies only to full tanks.

4.28.1.3 Equivalent calculation procedures may be applied.

4.28.2 ***Guidance formulae for acceleration components***

4.28.2.1 The following formulae are given as guidance for the components of acceleration due to ship's motions corresponding to a probability level of 10^{-8} in the North Atlantic and apply to ships with a length exceeding 50 m and at or near their service speed:

- vertical acceleration, as defined in 4.14.1:

$$a_z = \pm a_0 \sqrt{1 + \left(5.3 - \frac{45}{L_0}\right)^2 \left(\frac{x}{L_0} + 0.05\right)^2 \left(\frac{0.6}{C_B}\right)^{1.5} + \left(\frac{0.6yK^{1.5}}{B}\right)^2}$$

- transverse acceleration, as defined in 4.14.1:

$$a_y = \pm a_0 \sqrt{0.6 + 2.5\left(\frac{x}{L_0} + 0.05\right)^2 + K\left(1 + 0.6K\frac{z}{B}\right)^2}$$

- longitudinal acceleration, as defined in 4.14.1:

$$a_x = \pm a_0 \sqrt{0.06 + A^2 - 0.25A}$$

where:

$$a_0 = 0.2\frac{V}{\sqrt{L_0}} + \frac{34 - \left(\frac{600}{L_0}\right)}{L_0}$$

L_0 = length of the ship for determination of scantlings as defined in recognized standards (m);

C_B = block coefficient;

B = greatest moulded breadth of the ship (m);

x = longitudinal distance (m) from amidships to the centre of gravity of the tank with contents; x is positive forward of amidships, negative aft of amidships;

y = transverse distance (m) from centreline to the centre of gravity of the tank with contents;

z = vertical distance (m) from the ship's actual waterline to the centre of gravity of tank with contents; z is positive above and negative below the waterline;

K = 1 in general. For particular loading conditions and hull forms, determination of K according to the following formula may be necessary:

$K = 13GM/B$, where $K \geq 1$ and GM = metacentric height (m);

$$A = \left(0.7 - \frac{L_0}{1200} + 5\frac{z}{L_0}\right)\left(\frac{0.6}{C_B}\right)$$; and

V = service speed (knots);

a_x, a_y, a_z = maximum dimensionless accelerations (i.e. relative to the acceleration of gravity) in the respective directions. They are considered as acting separately for calculation purposes, and a_z does not include the component due to the static weight, a_y includes the component due to the static weight in the transverse direction due to rolling and a_x includes the component due to the static weight in the longitudinal direction due to pitching. The accelerations derived from the above formulae are applicable

only to ships at or near their service speed, not while at anchor or otherwise near stationary in exposed locations.

4.28.3 ***Stress categories***

4.28.3.1 For the purpose of stress evaluation, stress categories are defined in this section as follows.

4.28.3.2 *Normal stress* is the component of stress normal to the plane of reference.

4.28.3.3 *Membrane stress* is the component of normal stress that is uniformly distributed and equal to the average value of the stress across the thickness of the section under consideration.

4.28.3.4 *Bending stress* is the variable stress across the thickness of the section under consideration, after the subtraction of the membrane stress.

4.28.3.5 *Shear stress* is the component of the stress acting in the plane of reference.

4.28.3.6 *Primary stress* is a stress produced by the imposed loading, which is necessary to balance the external forces and moments. The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses that considerably exceed the yield strength will result in failure or at least in gross deformations.

4.28.3.7 *Primary general membrane stress* is a primary membrane stress that is so distributed in the structure that no redistribution of load occurs as a result of yielding.

4.28.3.8 *Primary local membrane stress* arises where a membrane stress produced by pressure or other mechanical loading and associated with a primary or a discontinuity effect produces excessive distortion in the transfer of loads for other portions of the structure. Such a stress is classified as a primary local membrane stress, although it has some characteristics of a secondary stress. A stress region may be considered as local, if:

$S_1 \leq 0.5\sqrt{Rt}$ and

$S_2 \geq 2.5\sqrt{Rt}$,

where:

S_1 = distance in the meridional direction over which the equivalent stress exceeds 1.1*f*;

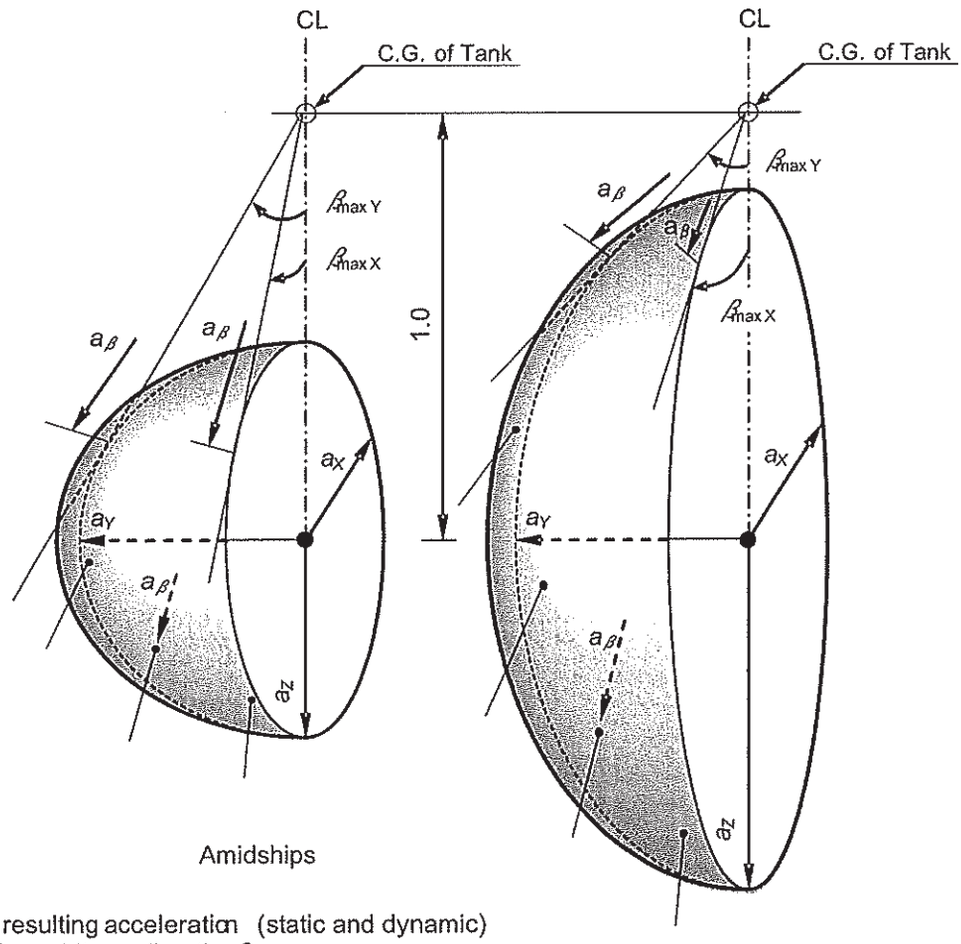
S_2 = distance in the meridional direction to another region where the limits for primary general membrane stress are exceeded;

R = mean radius of the vessel;

t = wall thickness of the vessel at the location where the primary general membrane stress limit is exceeded; and

f = allowable primary general membrane stress.

4.28.3.9 *Secondary stress* is a normal stress or shear stress developed by constraints of adjacent parts or by self-constraint of a structure. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can satisfy the conditions that cause the stress to occur.



a_β = resulting acceleration (static and dynamic) in arbitrary direction β
a_X = longitudinal component of acceleration
a_Y = transverse component of acceleration
a_Z = vertical component of acceleration

Figure 4.1 – Acceleration ellipsoid

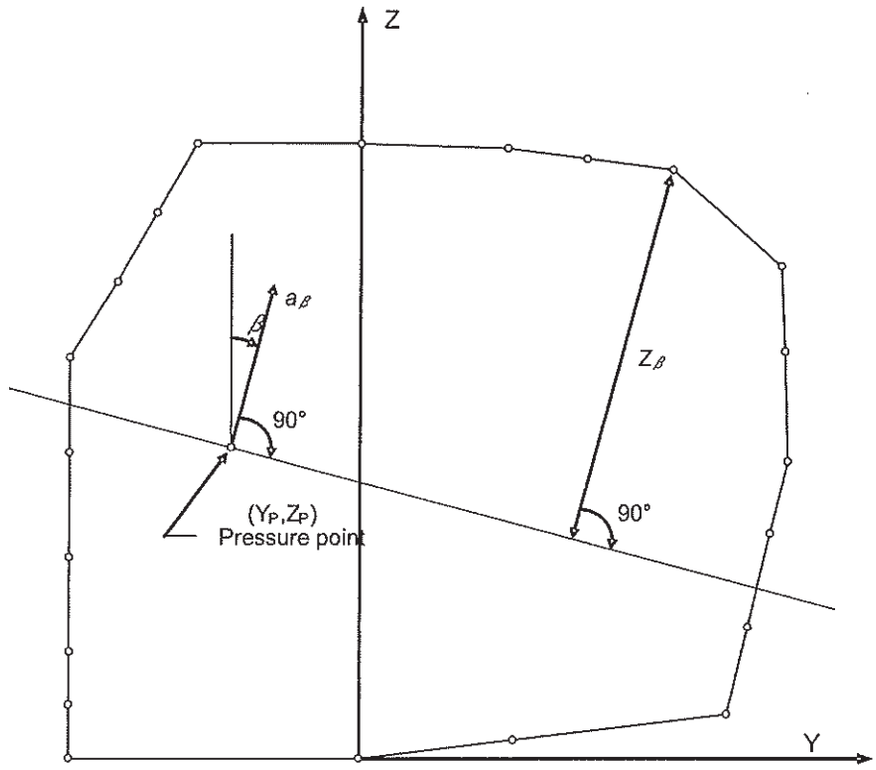


Figure 4.2 – Determination of internal pressure heads

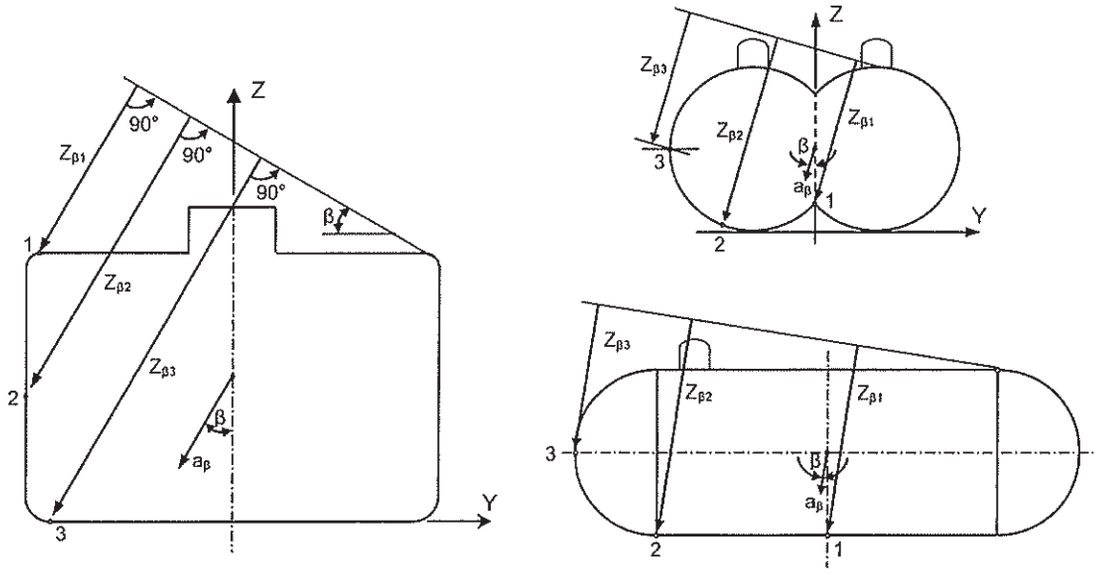
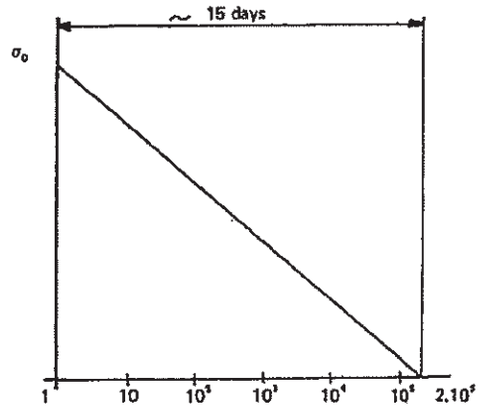


Figure 4.3 – Determination of liquid height Z_β for points 1, 2 and 3



σ_0 = most probable maximum stress over the life of the ship

Response cycle scale is logarithmic; the value of 2.10^5 is given as an example of estimate.

Figure 4.4 – Simplified load distribution

CHAPTER 5

PROCESS PRESSURE VESSELS AND LIQUIDS, VAPOUR AND PRESSURE PIPING SYSTEMS

Goal

To ensure the safe handling of all cargo and process liquid and vapour, under all operating conditions, to minimize the risk to the ship, crew and to the environment, having regard to the nature of the products involved. This will:

.1 *ensure the integrity of process pressure vessels, piping systems and cargo hoses;*

.2 *prevent the uncontrolled transfer of cargo;*

.3 *ensure reliable means to fill and empty the containment systems; and*

.4 *prevent pressure or vacuum excursions of cargo containment systems, beyond design parameters, during cargo transfer operations.*

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.

5.1.2 The requirements for type C independent tanks provided in chapter 4 may also apply to process pressure vessels. If so required, the term "pressure vessels" as used in chapter 4, covers both type C independent tanks and process pressure vessels.

5.1.3 Process pressure vessels include surge tanks, heat exchangers and accumulators that store or treat liquid or vapour cargo.

5.2 System requirements

5.2.1 The cargo handling and cargo control systems shall be designed taking into account the following:

.1 prevention of an abnormal condition escalating to a release of liquid or vapour cargo;

.2 the safe collection and disposal of cargo fluids released;

.3 prevention of the formation of flammable mixtures;

.4 prevention of ignition of flammable liquids or gases and vapours released; and

.5 limiting the exposure of personnel to fire and other hazards.

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;

.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 trunkway 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.

5.2.2.2 Suitable means shall be provided to relieve the pressure and remove liquid cargo from loading and discharging crossover headers; likewise, any piping between the outermost manifold valves and loading arms or cargo hoses to the cargo tanks, or other suitable location, prior to disconnection.

5.2.2.3 Piping systems carrying fluids for direct heating or cooling of cargo shall not be led outside the cargo area unless a suitable means is provided to prevent or detect the migration of cargo vapour outside the cargo area (see 13.6.2.6).

5.2.2.4 Relief valves discharging liquid cargo from the piping system shall discharge into the cargo tanks. Alternatively, they may discharge to the cargo vent mast, if means are provided to detect and dispose of any liquid cargo that may flow into the vent system. Where required to prevent overpressure in downstream piping, relief valves on cargo pumps shall discharge to the pump suction.

5.3 Arrangements for cargo piping outside the cargo area

5.3.1 *Emergency cargo jettisoning*

If fitted, an emergency cargo jettisoning piping system shall comply with 5.2.2, as appropriate, and may be led aft, external to accommodation spaces, service spaces or control stations or machinery spaces, but shall not pass through them. If an emergency cargo jettisoning piping system is permanently installed, a suitable means of isolating the piping system from the cargo piping shall be provided within the cargo area.

5.3.2 *Bow and stern loading arrangements*

5.3.2.1 Subject to the requirements of 3.8, this section and 5.10.1, cargo piping may be arranged to permit bow or stern loading and unloading.

5.3.2.2 Arrangements shall be made to allow such piping to be purged and gas-freed after use. When not in use, the spool pieces shall be removed and the pipe ends blank-flanged. The vent pipes connected with the purge shall be located in the cargo area.

5.3.3 *Turret compartment transfer systems*

For the transfer of liquid or vapour cargo through an internal turret arrangement located outside the cargo area, the piping serving this purpose shall comply with 5.2.2, as applicable, 5.10.2 and the following:

.1 piping shall be located above the weather deck, except for the connection to the turret;

.2 portable arrangements shall not be permitted; and

.3 arrangements shall be made to allow such piping to be purged and gas-freed after use. When not in use, the spool pieces for isolation from the cargo piping shall be removed and the pipe ends blank-flanged. The vent pipes connected with the purge shall be located in the cargo area.

5.3.4 *Gas fuel piping systems*

Gas fuel piping in machinery spaces shall comply with all applicable sections of this chapter in addition to the requirements of chapter 16.

5.4 Design pressure

5.4.1 The design pressure P_o, used to determine minimum scantlings of piping and piping system components, shall be not less than the maximum gauge pressure to which the system may be subjected in service. The minimum design pressure used shall not be less than 1 MPa gauge, except for open-ended lines or pressure relief valve discharge lines, where it shall be not less than the lower of 0.5 MPa gauge, or 10 times the relief valve set pressure.

5.4.2 The greater of the following design conditions shall be used for piping, piping systems and components, based on the cargoes being carried:

.1 for vapour piping systems or components that may be separated from their relief valves and which may contain some liquid, the saturated vapour pressure at a design temperature of 45°C. Higher or lower values may be used (see 4.13.2.2); or

.2 for systems or components that may be separated from their relief valves and which contain only vapour at all times, the superheated vapour pressure at 45°C. Higher or lower values may be used (see 4.13.2.2), assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or

.3 the MARVS of the cargo tanks and cargo processing systems; or

.4 the pressure setting of the associated pump or compressor discharge relief valve; or

.5 the maximum total discharge or loading head of the cargo piping system considering all possible pumping arrangements or the relief valve setting on a pipeline system.

5.4.3 Those parts of the liquid piping systems that may be subjected to surge pressures shall be designed to withstand this 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.

5.5 Cargo system valve requirements

5.5.1.1 Every cargo tank and piping system shall be fitted with manually operated valves for isolation purposes as specified in this section.

5.5.1.2 In addition, remotely operated valves shall also be fitted, as appropriate, as part of the emergency shutdown (ESD) system the purpose of which is to stop cargo flow or leakage in the event of an emergency when cargo liquid or vapour transfer is in progress. The ESD system is intended to return the cargo system to a safe static condition so that any remedial action can be taken. Due regard shall be given in the design of the ESD system to avoid the generation of surge pressures within the cargo transfer pipework. The equipment to be shut down on ESD activation includes manifold valves during loading or discharge, any pump or compressor, etc., transferring cargo internally or externally (e.g. to shore or another ship/barge) and cargo tank valves, if the MARVS exceeds 0.07 MPa.

5.5.2 ***Cargo tank connections***

5.5.2.1 All liquid and vapour connections, except for safety relief valves and liquid level gauging devices, shall have shutoff valves located as close to the tank as practicable. These valves shall provide full closure and shall be capable of local manual operation. They may also be capable of remote operation.

5.5.2.2 For cargo tanks with a MARVS exceeding 0.07 MPa gauge, the above connections shall also be equipped with remotely controlled ESD valves. These valves shall be located as close to the tank as practicable. A single valve may be substituted for the two separate valves, provided the valve complies with the requirements of 18.10.2 and provides full closure of the line.

5.5.3 ***Cargo manifold connections***

5.5.3.1 One remotely controlled ESD valve shall be provided at each cargo transfer connection in use to stop liquid and vapour transfer to or from the ship. Transfer connections not in use shall be isolated with suitable blank flanges.

5.5.3.2 If the cargo tank MARVS exceeds 0.07 MPa, an additional manual valve shall be provided for each transfer connection in use, and may be inboard or outboard of the ESD valve to suit the ship's design.

5.5.4 Excess flow valves may be used in lieu of ESD valves, if the diameter of the protected pipe does not exceed 50 mm. Excess flow valves shall close automatically at the rated closing flow of vapour or liquid as specified by the manufacturer. The piping including fittings, valves and appurtenances protected by an excess flow valve shall have a capacity greater than the rated closing flow of the excess flow valve. Excess flow valves may be designed with a bypass not exceeding the area of a 1 mm diameter circular opening to allow equalization of pressure after a shutdown activation.

5.5.5 Cargo tank connections for gauging or measuring devices need not be equipped with excess flow valves or ESD valves, provided that the devices are constructed so that the outward flow of tank contents cannot exceed that passed by a 1.5 mm diameter circular hole.

5.5.6 All pipelines or components which may be isolated in a liquid full condition shall be protected with relief valves for thermal expansion and evaporation.

5.5.7 All pipelines or components which may be isolated automatically due to a fire with a liquid volume of more than 0.05 m^3 entrapped shall be provided with PRVs sized for a fire condition.

5.6 Cargo transfer arrangements

5.6.1 Where cargo transfer is by means of cargo pumps that are not accessible for repair with the tanks in service, at least two separate means shall be provided to transfer cargo from each cargo tank, and the design shall be such that failure of one cargo pump or means of transfer will not prevent the cargo transfer by another pump or pumps, or other cargo transfer means.

5.6.2 The procedure for transfer of cargo by gas pressurization shall preclude lifting of the relief valves during such transfer. Gas pressurization may be accepted as a means of transfer of cargo for those tanks where the design factor of safety is not reduced under the conditions prevailing during the cargo transfer operation. If the cargo tank relief valves or set pressure are changed for this purpose, as it is permitted in accordance with 8.2.7 and 8.2.8, the new set pressure shall not exceed P_h as is defined in 4.13.2.

5.6.3 ***Vapour return connections***

Connections for vapour return to the shore installations shall be provided.

5.6.4 ***Cargo tank vent piping systems***

The pressure relief system shall be connected to a vent piping system designed to minimize the possibility of cargo vapour accumulating on the decks, or entering accommodation spaces, service spaces, control stations and machinery spaces, or other spaces where it may create a dangerous condition.

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.

5.6.5.2 Liquid sampling systems shall be provided with two valves on the sample inlet. One of these valves shall be of the multi-turn type to avoid accidental opening, and shall be spaced far enough apart to ensure that they can isolate the line if there is blockage, by ice or hydrates for example.

5.6.5.3 On closed loop systems, the valves on the return pipe shall also comply with 5.6.5.2.

5.6.5.4 The connection to the sample container shall comply with recognized standards and be supported so as to be able to support the weight of a sample container. Threaded connections shall be tack-welded, or otherwise locked, to prevent them being unscrewed during the normal connection and disconnection of sample containers. The sample connection shall be fitted with a closure plug or flange to prevent any leakage when the connection is not in use.

5.6.5.5 Sample connections used only for vapour samples may be fitted with a single valve in accordance with 5.5, 5.8 and 5.13, and shall also be fitted with a closure plug or flange.

5.6.5.6 Sampling operations shall be undertaken as prescribed in 18.9.

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.

5.7 Installation requirements

5.7.1 ***Design for expansion and contraction***

Provision shall be made to protect the piping, piping system and components and cargo tanks from excessive stresses due to thermal movement and from movements of the tank and hull structure. The preferred method outside the cargo tanks is by means of offsets, bends or loops, but multi-layer bellows may be used if offsets, bends or loops are not practicable.

5.7.2 ***Precautions against low temperature***

Low temperature piping shall be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material. Where liquid piping is dismantled regularly, or where liquid leakage may be anticipated, such as at shore connections and at pump seals, protection for the hull beneath shall be provided.

5.7.3 ***Water curtain***

For cargo temperatures below -110°C, a water distribution system shall be fitted in way of the hull under the shore connections to provide a low-pressure water curtain for additional protection of the hull steel and the ship's side structure. This system is in addition to the requirements of 11.3.1.4, and shall be operated when cargo transfer is in progress.

5.7.4 ***Bonding***

Where tanks or cargo piping and piping equipment are separated from the ship's structure by thermal isolation, provision shall be made for electrically bonding both the piping and the tanks. All gasketed pipe joints and hose connections shall be electrically bonded. Except where bonding straps are used, it shall be demonstrated that the electrical resistance of each joint or connection is less than 1MΩ.

5.8 Piping fabrication and joining details

5.8.1 ***General***

The requirements of this section apply to piping inside and outside the cargo tanks. Relaxation from these requirements may be accepted, in accordance with recognized standards for piping inside cargo tanks and open-ended piping.

5.8.2 ***Direct connections***

The following direct connection of pipe lengths, without flanges, may be considered:

.1 butt-welded joints with complete penetration at the root may be used in all applications. For design temperatures colder than -10°C, butt welds shall be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas backup on the first pass. For design pressures in excess of 1 MPa and design temperatures of -10°C or colder, backing rings shall be removed;

.2 slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognized standards, shall only be used for instrument lines and open-ended lines with an external diameter of 50 mm or less and design temperatures not colder than -55°C; and

.3 screwed couplings complying with recognized standards shall only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

5.8.3 ***Flanged connections***

5.8.3.1 Flanges in flanged connections shall be of the welded neck, slip-on or socket welded type.

5.8.3.2 Flanges shall comply with recognized standards for their type, manufacture and test. For all piping, except open ended, the following restrictions apply:

.1 for design temperatures colder than -55°C, only welded-neck flanges shall be used; and

.2 for design temperatures colder than -10°C, slip-on flanges shall not be used in nominal sizes above 100 mm and socket welded flanges shall not be used in nominal sizes above 50 mm.

5.8.4 ***Expansion joints***

Where bellows and expansion joints are provided in accordance with 5.7.1, the following requirements apply:

.1 if necessary, bellows shall be protected against icing; and

.2 slip joints shall not be used except within the cargo tanks.

5.8.5 ***Other connections***

Piping connections shall be joined in accordance with 5.8.2 to 5.8.4, but for other exceptional cases the Administration may consider alternative arrangements.

5.9 Welding, post-weld heat treatment and non-destructive testing

5.9.1 ***General***

Welding shall be carried out in accordance with 6.5.

5.9.2 ***Post-weld heat treatment***

Post-weld heat treatment shall be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steels. The Administration or recognized organization acting on its behalf may waive the requirements for thermal stress relieving of pipes with wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.

5.9.3 ***Non-destructive testing***

In addition to normal controls before and during the welding, and to the visual inspection of the finished welds, as necessary for proving that the welding has been carried out correctly and according to the requirements of this paragraph, the following tests shall be required:

.1 100% radiographic or ultrasonic inspection of butt-welded joints for piping systems with design temperatures colder than -10°C, or with inside diameters of more than 75 mm, or wall thicknesses greater than 10 mm;

.2 when such butt-welded joints of piping sections are made by automatic welding procedures approved by the Administration or recognized organization acting on its behalf, then a progressive reduction in the extent of radiographic or ultrasonic inspection can be agreed, but in no case to less than 10% of each joint. If defects are revealed, the extent of examination shall be increased to 100% and shall include inspection of previously accepted welds. This approval can only be granted if well-documented quality assurance procedures and records are available to assess the ability of the manufacturer to produce satisfactory welds consistently; and

.3 for other butt-welded joints of pipes not covered by 5.9.3.1 and 5.9.3.2, spot radiographic or ultrasonic inspection or other non-destructive tests shall be carried out depending upon service, position and materials. In general, at least 10% of butt-welded joints of pipes shall be subjected to radiographic or ultrasonic inspection.

5.10 Installation requirements for cargo piping outside the cargo area

5.10.1 *Bow and stern loading arrangements*

The following requirements shall apply to cargo piping and related piping equipment located outside the cargo area:

.1 cargo piping and related piping equipment outside the cargo area shall have only welded connections. The piping outside the cargo area shall run on the weather decks and shall be at least 0.8 m inboard, except for athwartships shore connection piping. Such piping shall be clearly identified and fitted with a shutoff valve at its connection to the cargo piping system within the cargo area. At this location, it shall also be capable of being separated by means of a removable spool piece and blank flanges, when not in use; and

.2 the piping shall be full penetration butt-welded and subjected to full radiographic or ultrasonic inspection, regardless of pipe diameter and design temperature. Flange connections in the piping shall only be permitted within the cargo area and at the shore connection.

5.10.2 *Turret compartment transfer systems*

The following requirements shall apply to liquid and vapour cargo piping where it is run outside the cargo area:

.1 cargo piping and related piping equipment outside the cargo area shall have only welded connections; and

.2 the piping shall be full penetration butt-welded, and subjected to full radiographic or ultrasonic inspection, regardless of pipe diameter and design temperature. Flange connections in the piping shall only be permitted within the cargo area and at connections to cargo hoses and the turret connection.

5.10.3 *Gas fuel piping*

Gas fuel piping, as far as practicable, shall have welded joints. Those parts of the gas fuel piping that are not enclosed in a ventilated pipe or duct according to 16.4.3, and are on the weather decks outside the cargo area, shall have full penetration butt-welded joints and shall be subjected to full radiographic or ultrasonic inspection.

5.11 Piping system component requirements

5.11.1 Piping scantlings. Piping systems shall be designed in accordance with recognized standards.

5.11.2.1 The following criteria shall be used for determining pipe wall thickness.

5.11.2.2 The wall thickness of pipes shall not be less than:

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

where:

t_o = theoretical thickness, determined by the following formula:

$$t_0 = \frac{P \cdot D}{2K \cdot e + P} \quad \text{(mm)}$$

with:

P = design pressure (MPa) referred to in 5.4;
D = outside diameter (mm);

K = allowable stress (N/mm²) referred to in 5.11.3;

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

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

$$b = \frac{D \cdot t_0}{2.5r} \quad \text{(mm)},$$

with:

r = mean radius of the bend (mm);

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

a = negative manufacturing tolerance for thickness (%).

5.11.2.3 The minimum wall thickness shall be in accordance with recognized standards.

5.11.2.4 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads, the wall thickness shall be increased over that required by 5.11.2.2 or, if this is impracticable or would cause excessive local stresses, these loads may be reduced, protected against or eliminated by other design methods. Such superimposed loads may be due to: supporting structures, ship deflections, liquid pressure surge during transfer operations, the weight of suspended valves, reaction to loading arm connections, or otherwise.

5.11.3 ***Allowable stress***

5.11.3.1 For pipes, the allowable stress K referred to in the formula in 5.11.2 is the lower of the following values:

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

where:

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

R_e = specified minimum yield stress at room temperature (N/mm²). If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress applies.

The values of A and B shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk required in 1.4.4, and have values of at least A = 2.7 and B = 1.8.

5.11.4 ***High-pressure gas fuel outer pipes or ducting scantlings***

In fuel gas piping systems of design pressure greater than the critical pressure, the tangential membrane stress of a straight section of pipe or ducting shall not exceed the tensile strength divided by 1.5 (R_m /1.5) when subjected to the design pressure specified in 5.4. The pressure ratings of all other piping components shall reflect the same level of strength as straight pipes.

5.11.5 ***Stress analysis***

When the design temperature is -110°C or lower, a complete stress analysis, taking into account all the stresses due to the weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship for each branch of the piping system shall be submitted to the Administration. For temperatures above -110°C, a stress analysis may be required by the Administration in relation to such matters as the design or stiffness of the piping system and the choice of materials. In any case, consideration shall be given to thermal stresses even though calculations are not submitted. The analysis may be carried out according to a code of practice acceptable to the Administration.

5.11.6 ***Flanges, valves and fittings***

5.11.6.1 Flanges, valves and other fittings shall comply with recognized standards, taking into account the material selected and the design pressure defined in 5.4. For bellows expansion joints used in vapour service, a lower minimum design pressure may be accepted.

5.11.6.2 For flanges not complying with a recognized standard, the dimensions of flanges and related bolts shall be to the satisfaction of the Administration or recognized organization acting on its behalf.

5.11.6.3 All emergency shutdown valves shall be of the "fire closed" type (see 5.13.1.1 and 18.10.2).

5.11.6.4 The design and installation of expansion bellows shall be in accordance with recognized standards and be fitted with means to prevent damage due to over-extension or compression.

5.11.7 ***Ship's cargo hoses***

5.11.7.1 Liquid and vapour hoses used for cargo transfer shall be compatible with the cargo and suitable for the cargo temperature.

5.11.7.2 Hoses subject to tank pressure, or the discharge pressure of pumps or vapour compressors, shall be designed for a bursting pressure not less than five times the maximum pressure the hose will be subjected to during cargo transfer.

5.11.7.3 Each new type of cargo hose, complete with end-fittings, shall be prototype-tested at a normal ambient temperature, with 200 pressure cycles from zero to at least twice the specified maximum working pressure. After this cycle pressure test has been carried out, the prototype test shall demonstrate a bursting pressure of at least 5 times its specified maximum working pressure at the upper and lower extreme service temperature. Hoses used for prototype testing shall not be used for cargo service. Thereafter, before being placed in service, each new length of cargo hose produced shall be hydrostatically tested at ambient temperature to a pressure not less than 1.5 times its specified maximum working pressure, but not more than two fifths of its bursting pressure. The hose shall be stencilled, or otherwise marked, with the date of testing, its specified maximum working pressure and, if used in services other than ambient temperature services, its maximum and minimum service temperature, as applicable. The specified maximum working pressure shall not be less than 1 MPa gauge.

5.12 Materials

5.12.1 The choice and testing of materials used in piping systems shall comply with the requirements of chapter 6, taking into account the minimum design temperature. However, some relaxation may be permitted in the quality of material of open-ended vent piping, provided that the temperature of the cargo at the pressure relief valve setting is not lower than 55°C, and that no liquid discharge to the vent piping can occur. Similar relaxations may be permitted under the same temperature conditions to open-ended piping inside cargo tanks, excluding discharge piping and all piping inside membrane and semi-membrane tanks.

5.12.2 Materials having a melting point below 925°C shall not be used for piping outside the cargo tanks except for short lengths of pipes attached to the cargo tanks, in which case fire-resisting insulation shall be provided.

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.

5.12.3.2 Where applicable, due to location or environmental conditions, insulation materials shall have suitable properties of resistance to fire and flame spread and shall be adequately protected against penetration of water vapour and mechanical damage.

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.

5.13 Testing requirements

5.13.1 *Type testing of piping components*

5.13.1.1 Valves

Each type of valve intended to be used at a working temperature below -55°C shall be subject to the following type tests:

.1 each size and type of valve shall be subjected to seat tightness testing over the full range of operating pressures for bi-directional flow and temperatures, at intervals, up to the rated design pressure of the valve. Allowable leakage rates shall be to the requirements of the Administration or recognized organization acting on its behalf. During the testing, satisfactory operation of the valve shall be verified;

.2 the flow or capacity shall be certified to a recognized standard for each size and type of valve;

.3 pressurized components shall be pressure tested to at least 1.5 times the rated pressure; and

.4 for emergency shutdown valves, with materials having melting temperatures lower than 925°C, the type testing shall include a fire test to a standard acceptable to the Administration.

5.13.1.2 Expansion bellows

The following type tests shall be performed on each type of expansion bellows intended for use on cargo piping outside the cargo tank and where required by the Administration or recognized organization acting on its behalf, on those installed within the cargo tanks:

.1 elements of the bellows, not pre-compressed, shall be pressure tested at not less than five times the design pressure without bursting. The duration of the test shall not be less than 5 min;

2 a pressure test shall be performed on a type expansion joint, complete with all the accessories such as flanges, stays and articulations, at the minimum design temperature and twice the design pressure at the extreme displacement conditions recommended by the manufacturer, without permanent deformation;

.3 a cyclic test (thermal movements) shall be performed on a complete expansion joint, which shall withstand at least as many cycles under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement as it will encounter in actual service. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature; and

.4 a cyclic fatigue test (ship deformation) shall be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2,000,000 cycles at a frequency not higher than 5 Hz. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.

5.13.2 ***System testing requirements***

5.13.2.1 The requirements of this section shall apply to piping inside and outside the cargo tanks.

5.13.2.2 After assembly, all cargo and process piping shall be subjected to a strength test with a suitable fluid. The test pressure shall be at least 1.5 times the design pressure (1.25 times the design pressure where the test fluid is compressible) for liquid lines and 1.5 times the maximum system working pressure (1.25 times the maximum system working pressure where the test fluid is compressible) for vapour lines. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation on board the ship. Joints welded on board shall be tested to at least 1.5 times the design pressure.

5.13.2.3 After assembly on board, each cargo and process piping system shall be subjected to a leak test using air, or other suitable medium, to a pressure depending on the leak detection method applied.

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.

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.

5.13.3 ***Emergency shutdown valves***

The closing characteristics of emergency shutdown valves used in liquid cargo piping systems shall be tested to demonstrate compliance with 18.10.2.1.3. This testing may be carried out on board after installation.

CHAPTER 6

MATERIALS OF CONSTRUCTION AND QUALITY CONTROL

Goal

To identify the required properties, testing standards and stability of metallic and non-metallic materials and fabrication processes used in the construction of cargo containment and piping systems to ensure they serve the functions for which they have been selected, as required in chapters 4 and 5.

6.1 Definitions

6.1.1 Where reference is made in this chapter to A, B, D, E, AH, DH, EH and FH hull structural steels, these steel grades are hull structural steels according to recognized standards.

6.1.2 *A piece* is the rolled product from a single slab or billet or from a single ingot, if this is rolled directly into plates, strips, sections or bars.

6.1.3 *A batch* is the number of items or pieces to be accepted or rejected together, on the basis of the tests to be carried out on a sampling basis. The size of a batch is given in the recognized standards.

6.1.4 *Controlled rolling (CR)* is a rolling procedure in which the final deformation is carried out in the normalizing temperature range, resulting in a material condition generally equivalent to that obtained by normalizing.

6.1.5 *Thermo-mechanical controlled processing (TMCP)* is a procedure that involves strict control of both the steel temperature and the rolling reduction. Unlike CR, the properties conferred by TMCP cannot be reproduced by subsequent normalizing or other heat treatment. The use of accelerated cooling on completion of TMCP may also be accepted, subject to approval by the Administration. The same applies for the use of tempering after completion of TMCP.

6.1.6 *Accelerated cooling (AcC)* is a process that aims to improve mechanical properties by controlled cooling with rates higher than air cooling, immediately after the final TMCP operation. Direct quenching is excluded from accelerated cooling. The material properties conferred by TMCP and AcC cannot be reproduced by subsequent normalizing or other heat treatment.

6.2 Scope and general requirements

6.2.1 This chapter gives the requirements for metallic and non-metallic materials used in the construction of the cargo system. This includes requirements for joining processes, production process, personnel qualification, NDT and inspection and testing including production testing. The requirements for rolled materials, forgings and castings are given in 6.4 and tables 6.1, to 6.5. The requirements for weldments are given in 6.5, and the guidance for non-metallic materials is given in appendix 4. A quality assurance/quality control programme shall be implemented to ensure that the requirements of 6.2 are complied with.

6.2.2 The manufacture, testing, inspection and documentation shall be in accordance with recognized standards and the specific requirements given in the Code.

6.2.3 Where post-weld heat treatment is specified or required, the properties of the base material shall be determined in the heat-treated condition, in accordance with the applicable table of this chapter, and the weld properties shall be determined in the heat treated condition in accordance with 6.5. In cases where a post-weld heat treatment is applied, the test requirements may be modified at the discretion of the Administration.

6.3 General test requirements and specifications

6.3.1 *Tensile test*

6.3.1.1 Tensile testing shall be carried out in accordance with recognized standards.

6.3.1.2 Tensile strength, yield stress and elongation shall be to the satisfaction of the Administration. For carbon-manganese steel and other materials with definitive yield points, consideration shall be given to the limitation of the yield to tensile ratio.

6.3.2 *Toughness test*

6.3.2.1 Acceptance tests for metallic materials shall include Charpy V-notch toughness tests, unless otherwise specified by the Administration. The specified Charpy V-notch requirements are minimum average energy values for three full size (10 mm × 10 mm) specimens and minimum single energy values for individual specimens. Dimensions and tolerances of Charpy V-notch specimens shall be in accordance with recognized standards. The testing and requirements for specimens smaller than 5 mm in size shall be in accordance with recognized standards. Minimum average values for subsized specimens shall be:

Charpy V-notch specimen size (mm)	Minimum average energy of three specimens
10 x 10	KV
10 x 7.5	5/6 KV
10 x 5	2/3 KV

where:

KV = the energy values (J) specified in tables 6.1 to 6.4.

Only one individual value may be below the specified average value, provided it is not less than 70% of that value.

6.3.2.2 For base metal, the largest size Charpy V-notch specimens possible for the material thickness shall be machined with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness and the length of the notch perpendicular to the surface as shown in figure 6.1.

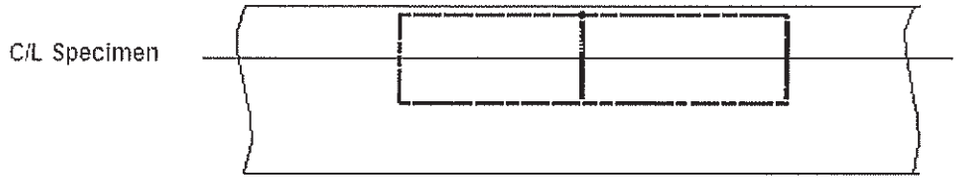


Figure 6.1 – Orientation of base metal test specimen

6.3.2.3 For a weld test specimen, the largest size Charpy V-notch specimens possible for the material thickness shall be machined, with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness. In all cases, the distance from the surface of the material to the edge of the specimen shall be approximately 1 mm or greater. In addition, for double-V butt welds, specimens shall be machined closer to the surface of the second welded section. The specimens shall be taken generally at each of the following locations, as shown in figure 6.2, on the centreline of the welds, the fusion line and 1 mm, 3 mm and 5 mm from the fusion line.

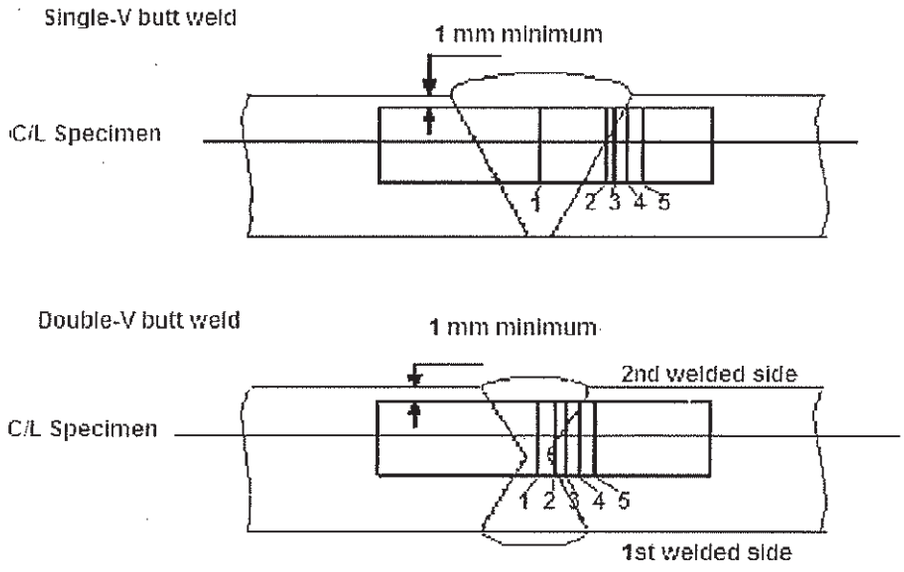


Figure 6.2 – Orientation of weld test specimen

Notch locations in figure 6.2:

.1 Centreline of the weld.

.2 Fusion line.

.3 In heat-affected zone (HAZ), 1 mm from the fusion line.

.4 In HAZ, 3 mm from the fusion line.

.5 In HAZ, 5 mm from the fusion line.

6.3.2.4 If the average value of the three initial Charpy V-notch specimens fails to meet the stated requirements, or the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, three additional specimens from the same material may be tested and the results be combined with those previously obtained to form a new average. If this new average complies with the requirements and if no more than two individual results are lower than the required average and no more than one result is lower than the required value for a single specimen, the piece or batch may be accepted.

6.3.3 ***Bend test***

6.3.3.1 The bend test may be omitted as a material acceptance test, but is required for weld tests. Where a bend test is performed, this shall be done in accordance with recognized standards.
6.3.3.2 The bend tests shall be transverse bend tests, which may be face, root or side bends at the discretion of the Administration. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels.

6.3.4 ***Section observation and other testing***

Macrosection, microsection observations and hardness tests may also be required by the Administration, and they shall be carried out in accordance with recognized standards, where required.

6.4 Requirements for metallic materials

6.4.1 ***General requirements for metallic materials***

6.4.1.1 The requirements for materials of construction are shown in the tables as follows:

.1 Table 6.1: Plates, pipes (seamless and welded), sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0°C.

.2 Table 6.2: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to -55°C.

.3 Table 6.3: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below -55°C and down to -165°C.

.4 Table 6.4: Pipes (seamless and welded), forgings and castings for cargo and process piping for design temperatures below 0°C and down to -165°C.

.5 Table 6.5: Plates and sections for hull structures required by 4.19.1.2 and 4.19.1.3.

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≤20	0
	20<t≤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 recognized organization acting on its behalf.

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 recognized organization acting on its behalf.

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 recognized organization acting on its behalf. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

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 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 Charpy V-notch and chemistry requirements 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°C, whichever is lower
30 < t ≤ 35	15°C below design temperature or -20°C, whichever is lower
35 < t ≤ 40	20°C below design temperature
40 < t	Temperature approved by the Administration or recognized organization acting on its behalf

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.

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
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 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 may be necessary.

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

Notes

1 The 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 specially agreed 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 impact tests shall be conducted as follows:

Material thickness (mm)	Test temperature (°C)
$25 < t \leq 30$	10°C below design temperature
$30 < t \leq 35$	15°C below design temperature
$35 < t \leq 40$	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.

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	
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, provided that the impact tests are carried out at -196°C.
9	The impact test may be omitted, subject to agreement with the Administration.

Table 6.4

PIPES (SEAMLESS AND WELDED) See note 1, FORGINGS See note 2 AND CASTINGS See note 2 FOR CARGO AND PROCESS PIPING FOR DESIGN TEMPERATURES BELOW 0°C AND DOWN TO -165°C See note 3 Maximum thickness 25 mm			
Minimum design temperature (°C)	Chemical composition See note 5 and heat treatment	Impact test	
		Test temp. (°C)	Minimum average energy (KV)
-55	Carbon-manganese steel. Fully killed fine grain. Normalized or as agreed See note 6	See note 4	27
-65	2.25% nickel steel. Normalized, normalized and tempered or quenched and tempered See note 6	-70	34
-90	3.5% nickel steel. Normalized, normalized and tempered or quenched and tempered See note 6	-95	34
-165	9% nickel steel See note 7. Double normalized and tempered or quenched and tempered	-196	41
	Austenitic steels, such as types 304. 304L, 316, 316L, 321 and 347. Solution treated See note 8	-196	41
	Aluminium alloys; such as type 5083 annealed		Not required
TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS			
Sampling frequency			
◆ Each "batch" to be tested.			
Toughness (Charpy V-notch test)			
◆ Impact test: Longitudinal test pieces			

Notes

1 The use of longitudinally or spirally welded pipes shall be specially approved by the Administration.

2 The requirements for forgings and castings may be subject to special consideration by the Administration.

3 The requirements for design temperatures below -165°C shall be specially agreed with the Administration.

4 The test temperature shall be 5°C below the design temperature or -20°C, whichever is lower.

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

6 A lower design temperature may be specially agreed with the Administration for quenched and tempered materials.

7 This chemical composition is not suitable for castings.

8 Impact tests may be omitted, subject to agreement with the Administration.

Table 6.5

PLATES AND SECTIONS FOR HULL STRUCTURES REQUIRED BY 4.19.1.2 AND 4.19.1.3								
Minimum design temperature of hull structure (°C)	Maximum thickness (mm) for steel grades							
	A	B	D	E	AH	DH	EH	FH
0 and above[See note 1] -5 and above[See note 2]	Recognized standards							
down to -5	15	25	30	50	25	45	50	50
down to -10	x	20	25	50	20	40	50	50
down to -20	x	x	20	50	x	30	50	50
down to -30	x	x	x	40	x	20	40	50
Below -30	In accordance with table 6.2, except that the thickness limitation given in table 6.2 and in note 2 of that table does not apply.							

Notes

"x" means steel grade not to be used.

1 For the purpose of 4.19.1.3.

2 For the purpose of 4.19.1.2.

6.5 Welding of metallic materials and non-destructive testing

6.5.1 *General*

6.5.1.1 This section shall apply to primary and secondary barriers only, including the inner hull where this forms the secondary barrier. Acceptance testing is specified for carbon, carbon-manganese, nickel alloy and stainless steels, but these tests may be adapted for other materials. At the discretion of the Administration, impact testing of stainless steel and aluminium alloy weldments may be omitted and other tests may be specially required for any material.

6.5.2 *Welding consumables*

6.5.2.1 Consumables intended for welding of cargo tanks shall be in accordance with recognized standards. Deposited weld metal tests and butt weld tests shall be required for all consumables. The results obtained from tensile and Charpy V-notch impact tests shall be in accordance with recognized standards. The chemical composition of the deposited weld metal shall be recorded for information.

6.5.3 *Welding procedure tests for cargo tanks and process pressure vessels*

6.5.3.1 Welding procedure tests for cargo tanks and process pressure vessels are required for all butt welds.

6.5.3.2 The test assemblies shall be representative of:

.1 each base material;

.2 each type of consumable and welding process; and

.3 each welding position.

6.5.3.3 For butt welds in plates, the test assemblies shall be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test shall be in accordance with recognized standards. Radiographic or ultrasonic testing may be performed at the option of the fabricator.

6.5.3.4 The following welding procedure tests for cargo tanks and process pressure vessels shall be carried out in accordance with 6.3, with specimens made from each test assembly:

.1 cross-weld tensile tests;

.2 longitudinal all-weld testing, where required by the recognized standards;

.3 transverse bend tests, which may be face, root or side bends. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels;

.4 one set of three Charpy V-notch impacts, generally at each of the following locations, as shown in figure 6.2:

.1 centreline of the weld;

.2 fusion line;

.3 1 mm from the fusion line;

.4 3 mm from the fusion line; and

.5 5 mm from the fusion line; and

.5 macrosection, microsection and hardness survey may also be required.

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 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;

.2 bend tests: no fracture is acceptable after a 180° bend over a former of a diameter four times the thickness of the test pieces; and

.3 Charpy V-notch impact tests: Charpy V-notch tests shall be conducted at the temperature prescribed for the base material being joined. The results of weld metal impact tests, minimum average energy (KV), shall be no less than 27 J. The weld metal requirements for subsize specimens and single energy values shall be in accordance with 6.3.2. The results of fusion line and heat-affected zone impact tests shall show a minimum average energy (KV) in accordance with the transverse or longitudinal requirements of the base material, whichever is applicable, and for subsize specimens, the minimum average energy (KV) shall be in accordance with 6.3.2. If the material thickness does not permit machining either full-size or standard subsize specimens, the testing procedure and acceptance standards shall be in accordance with recognized standards.

6.5.3.6 Procedure tests for fillet welding shall be in accordance with recognized standards. In such cases, consumables shall be so selected that exhibit satisfactory impact properties.

6.5.4 ***Welding procedure tests for piping***

Welding procedure tests for piping shall be carried out and shall be similar to those detailed for cargo tanks in 6.5.3.

6.5.5 ***Production weld tests***

6.5.5.1 For all cargo tanks and process pressure vessels, except integral and membrane tanks, production weld tests shall generally be performed for approximately each 50 m of butt-weld joints and shall be representative of each welding position. For secondary barriers, the same type production tests as required for primary tanks shall be performed, except that the number of tests may be reduced subject to agreement with the Administration. Tests, other than those specified in 6.5.5.2 to 6.5.5.5 may be required for cargo tanks or secondary barriers.

6.5.5.2 The production tests for type A and type B independent tanks and semi-membrane tanks shall include bend tests and, where required for procedure tests, one set of three Charpy V-notch tests. The tests shall be made for each 50 m of weld. The Charpy V-notch tests shall be made with specimens having the notch alternately located in the centre of the weld and in the heat-affected zone (most critical location based on procedure qualification results). For austenitic stainless steel, all notches shall be in the centre of the weld.

6.5.5.3 For type C independent tanks and process pressure vessels, transverse weld tensile tests are required in addition to the tests listed in 6.5.5.2. Tensile tests shall meet the requirements of 6.5.3.5.

6.5.5.4 The quality assurance/quality control programme shall ensure the continued conformity of the production welds as defined in the material manufacturers quality manual.

6.5.5.5 The test requirements for integral and membrane tanks are the same as the applicable test requirements listed in 6.5.3.

6.5.6 ***Non-destructive testing***

6.5.6.1 All test procedures and acceptance standards shall be in accordance with recognized standards, unless the designer specifies a higher standard in order to meet design assumptions. Radiographic testing shall be used, in principle, to detect internal defects. However, an approved ultrasonic test procedure in lieu of radiographic testing may be conducted, but, in addition, supplementary radiographic testing at selected locations shall be carried out to verify the results. Radiographic and ultrasonic testing records shall be retained.

6.5.6.2 For type A independent tanks and semi-membrane tanks, where the design temperature is below -20°C, and for type B independent tanks, regardless of temperature, all full penetration butt welds of the shell plating of cargo tanks shall be subjected to non-destructive testing suitable to detect internal defects over their full length. Ultrasonic testing in lieu of radiographic testing may be carried out under the same conditions as described in 6.5.6.1.

6.5.6.3 Where the design temperature is higher than -20°C, all full penetration butt welds in way of intersections and at least 10% of the remaining full penetration welds of tank structures shall be subjected to radiographic testing or ultrasonic testing under the same conditions as described in 6.5.6.1.

6.5.6.4 In each case, the remaining tank structure, including the welding of stiffeners and other fittings and attachments, shall be examined by magnetic particle or dye penetrant methods, as considered necessary.

6.5.6.5 For type C independent tanks, the extent of non-destructive testing shall be total or partial according to recognized standards, but the controls to be carried out shall not be less than the following:

.1 Total non-destructive testing referred to in 4.23.2.1.3:

Radiographic testing:

.1 all butt welds over their full length;

Non-destructive testing for surface crack detection:

.2 all welds over 10% of their length;

.3 reinforcement rings around holes, nozzles, etc., over their full length.

As an alternative, ultrasonic testing as described in 6.5.6.1 may be accepted as a partial substitute for the radiographic testing. In addition, the Administration may require total ultrasonic testing on welding of reinforcement rings around holes, nozzles, etc.

.2 Partial non-destructive testing referred to in 4.23.2.1.3:

Radiographic testing:

.1 all butt-welded crossing joints and at least 10% of the full length of butt welds at selected positions uniformly distributed;

Non-destructive testing for surface crack detection:

.2 reinforcement rings around holes, nozzles, etc., over their full length;

Ultrasonic testing:

.3 as may be required by the Administration or recognized organization acting on its behalf in each instance.

6.5.6.6 The quality assurance/quality control programme shall ensure the continued conformity of the non-destructive testing of welds, as defined in the material manufacturer's quality manual.

6.5.6.7 Inspection of piping shall be carried out in accordance with the requirements of chapter 5.

6.5.6.8 The secondary barrier shall be non-destructive tested for internal defects as considered necessary. Where the outer shell of the hull is part of the secondary barrier, all sheer strake butts and the intersections of all butts and seams in the side shell shall be tested by radiographic testing.

6.6 Other requirements for construction in metallic materials

6.6.1 *General*

6.6.1.1 Inspection and non-destructive testing of welds shall be in accordance with the requirements of 6.5.5 and 6.5.6. Where higher standards or tolerances are assumed in the design, they shall also be satisfied.

6.6.2 *Independent tank*

6.6.2.1 For type C tanks and type B tanks primarily constructed of bodies of revolution, the tolerances relating to manufacture, such as out-of-roundness, local deviations from the true form, welded joints alignment and tapering of plates having different thicknesses, shall comply with recognized standards. The tolerances shall also be related to the buckling analysis referred to in 4.22.3.2 and 4.23.3.2.

6.6.2.2 For type C tanks of carbon and carbon-manganese steel, post-weld heat treatment shall be performed after welding, if the design temperature is below -10°C. Post-weld heat treatment in all other cases and for materials other than those mentioned above shall be to recognized standards. The soaking temperature and holding time shall be to the recognized standards.

6.6.2.3 In the case of type C tanks and large cargo pressure vessels of carbon or carbon-manganese steel, for which it is difficult to perform the heat treatment, mechanical stress relieving by pressurizing may be carried out as an alternative to the heat treatment and subject to the following conditions:

.1 complicated welded pressure vessel parts such as sumps or domes with nozzles, with adjacent shell plates shall be heat treated before they are welded to larger parts of the pressure vessel;

.2 the mechanical stress relieving process shall preferably be carried out during the hydrostatic pressure test required by 4.23.6, by applying a higher pressure than the test pressure required by 4.23.6.1. The pressurizing medium shall be water;

.3 for the water temperature, 4.23.6.2 applies;

.4 stress relieving shall be performed while the tank is supported by its regular saddles or supporting structure or, when stress relieving cannot be carried out on board, in a manner which will give the same stresses and stress distribution as when supported by its regular saddles or supporting structure;

.5 the maximum stress relieving pressure shall be held for 2 h per 25 mm of thickness, but in no case less than 2 h;

.6 the upper limits placed on the calculated stress levels during stress relieving shall be the following:

.1 equivalent general primary membrane stress: 0.9 R_e;

.2 equivalent stress composed of primary bending stress plus membrane stress: 1.35 R_e, where R_e is the specific lower minimum yield stress or 0.2% proof stress at test temperature of the steel used for the tank;

.7 strain measurements will normally be required to prove these limits for at least the first tank of a series of identical tanks built consecutively. The location of strain gauges shall be included in the mechanical stress relieving procedure to be submitted in accordance with 6.6.2.3;

.8 the test procedure shall demonstrate that a linear relationship between pressure and strain is achieved at the end of the stress relieving process when the pressure is raised again up to the design pressure;

.9 high-stress areas in way of geometrical discontinuities such as nozzles and other openings shall be checked for cracks by dye penetrant or magnetic particle inspection after mechanical stress relieving. Particular attention in this respect shall be paid to plates exceeding 30 mm in thickness;

.10 steels which have a ratio of yield stress to ultimate tensile strength greater than 0.8 shall generally not be mechanically stress relieved. If, however, the yield stress is raised by a method giving high ductility of the steel, slightly higher rates may be accepted upon consideration in each case;

.11 mechanical stress relieving cannot be substituted for heat treatment of cold formed parts of tanks, if the degree of cold forming exceeds the limit above which heat treatment is required;

.12 the thickness of the shell and heads of the tank shall not exceed 40 mm. Higher thicknesses may be accepted for parts which are thermally stress relieved;

.13 local buckling shall be guarded against, particularly when tori-spherical heads are used for tanks and domes; and

.14 the procedure for mechanical stress relieving shall be to a recognized standard.

6.6.3 ***Secondary barriers***

During construction, the requirements for testing and inspection of secondary barriers shall be approved or accepted by the Administration or recognized organization acting on its behalf (see 4.6.2.5 and 4.6.2.6).

6.6.4 ***Semi-membrane tanks***

For semi-membrane tanks, the relevant requirements in section 6.6 for independent tanks or for membrane tanks shall be applied as appropriate.

6.6.5 ***Membrane tanks***

The quality assurance/quality control programme shall ensure the continued conformity of the weld procedure qualification, design details, materials, construction, inspection and production testing of components. These standards and procedures shall be developed during the prototype testing programme.

6.7 Non-metallic materials

6.7.1 ***General***

The information in the attached appendix 4 is given for guidance in the selection and use of these materials, based on the experience to date.

CHAPTER 7

CARGO PRESSURE/TEMPERATURE CONTROL

Goal

To maintain the cargo tank pressure and temperature within design limits of the containment system and/or carriage requirements of the cargo.

7.1 Methods of control

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.

7.1.2 For certain cargoes, where required by chapter 17, the cargo containment system shall be capable of withstanding the full vapour pressure of the cargo under conditions of the upper ambient design temperatures, irrespective of any system provided for dealing with boil-off gas.

7.1.3 Venting of the cargo to maintain cargo tank pressure and temperature shall not be acceptable except in emergency situations. The Administration may permit certain cargoes to be controlled by venting cargo vapours to the atmosphere at sea. This may also be permitted in port with the authorization of the port Administration.

7.2 Design of systems

For normal service, the upper ambient design temperature shall be:

- sea: 32°C
- air: 45°C

For service in particularly hot or cold zones, these design temperatures shall be increased or decreased, to the satisfaction of the Administration. The overall capacity of the system shall be such that it can control the pressure within the design conditions without venting to atmosphere.

7.3 Reliquefaction of cargo vapours

7.3.1 ***General***

The reliquefaction system may be arranged in one of the following ways:

.1 a direct system, where evaporated cargo is compressed, condensed and returned to the cargo tanks;

.2 an indirect system, where cargo or evaporated cargo is cooled or condensed by refrigerant without being compressed;

.3 a combined system, where evaporated cargo is compressed and condensed in a cargo/refrigerant heat exchanger and returned to the cargo tanks; and

.4 if the reliquefaction system produces a waste stream containing methane during pressure control operations within the design conditions, these waste gases, as far as reasonably practicable, are disposed of without venting to atmosphere.

Note:

The requirements of chapters 17 and 19 may preclude the use of one or more of these systems or may specify the use of a particular system.

7.3.2 ***Compatibility***

Refrigerants used for reliquefaction shall be compatible with the cargo they may come into contact with. In addition, when several refrigerants are used and may come into contact, they shall be compatible with each other.

7.4 Thermal oxidation of vapours

7.4.1 ***General***

Maintaining the cargo tank pressure and temperature by means of thermal oxidation of cargo vapours, as defined in 1.2.52 and 16.2 shall be permitted only for LNG cargoes. In general:

.1 thermal oxidation systems shall exhibit no externally visible flame and shall maintain the uptake exhaust temperature below 535°C;

.2 arrangement of spaces where oxidation systems are located shall comply with 16.3 and supply systems shall comply with 16.4; and

.3 if waste gases coming from any other system are to be burnt, the oxidation system shall be designed to accommodate all anticipated feed gas compositions.

7.4.2 ***Thermal oxidation systems***

Thermal oxidation systems shall comply with the following:

.1 each thermal oxidation system shall have a separate uptake;

.2 each thermal oxidation system shall have a dedicated forced draught system; and

.3 combustion chambers and uptakes of thermal oxidation systems shall be designed to prevent any accumulation of gas.

7.4.3 ***Burners***

Burners shall be designed to maintain stable combustion under all design firing conditions.

7.4.4 ***Safety***

7.4.4.1 Suitable devices shall be installed and arranged to ensure that gas flow to the burner is cut off unless satisfactory ignition has been established and maintained.

7.4.4.2 Each oxidation system shall have provision to manually isolate its gas fuel supply from a safely accessible position.

7.4.4.3 Provision shall be made for automatic purging the gas supply piping to the burners by means of an inert gas, after the extinguishing of these burners.

7.4.4.4 In case of flame failure of all operating burners for gas or oil or for a combination thereof, the combustion chambers of the oxidation system shall be automatically purged before relighting.

7.4.4.5 Arrangements shall be made to enable the combustion chamber to be manually purged.

7.5 Pressure accumulation systems

The containment system insulation, design pressure or both shall be adequate to provide for a suitable margin for the operating time and temperatures involved. No additional pressure and temperature control system is required. Conditions for acceptance shall be recorded in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk required in 1.4.4.

7.6 Liquid cargo cooling

The bulk cargo liquid may be refrigerated by coolant circulated through coils fitted either inside the cargo tank or onto the external surface of the cargo tank.

7.7 Segregation

Where two or more cargoes that may react chemically in a dangerous manner are carried simultaneously, separate systems as defined in 1.2.47, each complying with availability criteria as specified in 7.8, shall be provided for each cargo. For simultaneous carriage of two or more cargoes that are not reactive to each other but where, due to properties of their vapour, separate systems are necessary, separation may be by means of isolation valves.

7.8 Availability

The availability of the system and its supporting auxiliary services shall be such that:

.1 in case of a single failure of a mechanical non-static component or a component of the control systems, the cargo tanks' pressure and temperature can be maintained within their design range without affecting other essential services;

.2 redundant piping systems are not required;

.3 heat exchangers that are solely necessary for maintaining the pressure and temperature of the cargo tanks within their design ranges shall have a standby heat exchanger, unless they have a capacity in excess of 25% of the largest required capacity for pressure control and they can be repaired on board without external resources. Where an additional and separate method of cargo tank pressure and temperature control is fitted that is not reliant on the sole heat exchanger, then a standby heat exchanger is not required; and

.4 for any cargo heating or cooling medium, provisions shall be made to detect the leakage of toxic or flammable vapours into an otherwise non-hazardous area or overboard in accordance with 13.6. Any vent outlet from this leak detection arrangement shall be to a non-hazardous area and be fitted with a flame screen.

CHAPTER 8

VENT SYSTEMS FOR CARGO CONTAINMENT

Goal

To protect cargo containment systems from harmful overpressure or underpressure at all times.

8.1 General

All cargo tanks shall be provided with a pressure relief system appropriate to the design of the cargo containment system and the cargo being carried. Hold spaces and interbarrier spaces, which may be subject to pressures beyond their design capabilities, shall also be provided with a suitable pressure relief system. Pressure control systems specified in chapter 7 shall be independent of the pressure relief systems.

8.2 Pressure relief systems

8.2.1 Cargo tanks, including deck tanks, shall be fitted with a minimum of two pressure relief valves (PRVs), each being of equal size within manufacturer's tolerances and suitably designed and constructed for the prescribed service.

8.2.2 Interbarrier spaces shall be provided with pressure relief devices. For membrane systems, the designer shall demonstrate adequate sizing of interbarrier space PRVs.

8.2.3 The setting of the PRVs shall not be higher than the vapour pressure that has been used in the design of the tank. Where two or more PRVs are fitted, valves comprising not more than 50% of the total relieving capacity may be set at a pressure up to 5% above MARVS to allow sequential lifting, minimizing unnecessary release of vapour.

8.2.4 The following temperature requirements apply to PRVs fitted to pressure relief systems:

.1 PRVs on cargo tanks with a design temperature below 0ºC shall be designed and arranged to prevent their becoming inoperative due to ice formation;

.2 the effects of ice formation due to ambient temperatures shall be considered in the construction and arrangement of PRVs;

.3 PRVs shall be constructed of materials with a melting point above 925°C. Lower melting point materials for internal parts and seals may be accepted, provided that fail-safe operation of the PRV is not compromised; and

.4 sensing and exhaust lines on pilot operated relief valves shall be of suitably robust construction to prevent damage.

8.2.5 ***Valve testing***

8.2.5.1 PRVs shall be type-tested. Type tests shall include:

.1 verification of relieving capacity;

.2 cryogenic testing when operating at design temperatures colder than -55°C;

.3 seat tightness testing; and

.4 pressure containing parts are pressure tested to at least 1.5 times the design pressure.

PRVs shall be tested in accordance with recognized standards.

8.2.5.2 Each PRV shall be tested to ensure that:

.1 it opens at the prescribed pressure setting, with an allowance not exceeding ± 10% for 0 to 0.15 MPa, ± 6% for 0.15 to 0.3 MPa, ± 3% for 0.3 MPa and above;

.2 seat tightness is acceptable; and

.3 pressure containing parts will withstand at least 1.5 times the design pressure.

8.2.6 PRVs shall be set and sealed by the Administration or recognized organization acting on its behalf, and a record of this action, including the valves' set pressure, shall be retained on board the ship.

8.2.7 Cargo tanks may be permitted to have more than one relief valve set pressure in the following cases:

.1 installing two or more properly set and sealed PRVs and providing means, as necessary, for isolating the valves not in use from the cargo tank; or

.2 installing relief valves whose settings may be changed by the use of a previously approved device not requiring pressure testing to verify the new set pressure. All other valve adjustments shall be sealed.

8.2.8 Changing the set pressure under the provisions of 8.2.7 and the corresponding resetting of the alarms referred to in 13.4.2 shall be carried out under the supervision of the master in accordance with approved procedures and as specified in the ship's operating manual. Changes in set pressure shall be recorded in the ship's log and a sign shall be posted in the cargo control room, if provided, and at each relief valve, stating the set pressure.

8.2.9 In the event of a failure of a cargo tank-installed PRV, a safe means of emergency isolation shall be available:

.1 Procedures shall be provided and included in the cargo operations manual (see 18.2).

.2 The procedures shall allow only one of the cargo tank installed PRVs to be isolated.

.3 Isolation of the PRV shall be carried out under the supervision of the master. This action shall be recorded in the ship's log and a sign posted in the cargo control room, if provided, and at the PRV.

.4 The tank shall not be loaded until the full relieving capacity is restored.

8.2.10 Each PRV installed on a cargo tank shall be connected to a venting system, which shall be:

.1 so constructed that the discharge will be unimpeded and directed vertically upwards at the exit;

.2 arranged to minimize the possibility of water or snow entering the vent system;

.3 arranged such that the height of vent exits shall not be less than B/3 or 6 m, whichever is the greater, above the weather deck; and

.4 6 m above working areas and walkways.

8.2.11.1 Cargo PRV vent exits shall be arranged at a distance at least equal to B or 25 m, whichever is less, from the nearest air intake, outlet or opening to accommodation spaces, service spaces and control stations, or other non-hazardous areas. For ships less than 90 m in length, smaller distances may be permitted.

8.2.11.2 All other vent outlets connected to the cargo containment system shall be arranged at a distance of at least 10 m from the nearest air intake, outlet or opening to accommodation spaces, service spaces and control stations, or other non-hazardous areas.

8.2.12 All other cargo vent outlets not dealt with in other chapters shall be arranged in accordance with 8.2.10, 8.2.11.1 and 8.2.11.2. Means shall be provided to prevent liquid overflow from vent mast outlets, due to hydrostatic pressure from spaces to which they are connected.

8.2.13 If cargoes that react in a dangerous manner with each other are carried simultaneously, a separate pressure relief system shall be fitted for each one.

8.2.14 In the vent piping system, means for draining liquid from places where it may accumulate shall be provided. The PRVs and piping shall be arranged so that liquid can, under no circumstances, accumulate in or near the PRVs.

8.2.15 Suitable protection screens of not more than 13 mm square mesh shall be fitted on vent outlets to prevent the ingress of extraneous objects without adversely affecting the flow. Other requirements for protection screens apply when carrying specific cargoes (see 17.9 and 17.21).

8.2.16 All vent piping shall be designed and arranged not to be damaged by the temperature variations to which it may be exposed, forces due to flow or the ship's motions.

8.2.17 PRVs shall be connected to the highest part of the cargo tank above deck level. PRVs shall be positioned on the cargo tank so that they will remain in the vapour phase at the filling limit (*FL*) as defined in chapter 15, under conditions of 15° list and 0.015L trim, where L is defined in 1.2.31.

8.2.18 The adequacy of the vent system fitted on tanks loaded in accordance with 15.5.2 shall be demonstrated by the Administration, taking into account the recommendations developed by the Organization. A relevant certificate shall be permanently kept on board the ship. For the purposes of this paragraph, vent system means:

.1 the tank outlet and the piping to the PRV;

.2 the PRV; and

.3 the piping from the PRVs to the location of discharge to the atmosphere, including any interconnections and piping that joins other tanks.

8.3 Vacuum protection systems

8.3.1 Cargo tanks not designed to withstand a maximum external pressure differential 0.025 MPa, or tanks that cannot withstand the maximum external pressure differential that can be attained at maximum discharge rates with no vapour return into the cargo tanks, or by operation of a cargo refrigeration system, or by thermal oxidation, shall be fitted with:

.1 two independent pressure switches to sequentially alarm and subsequently stop all suction of cargo liquid or vapour from the cargo tank and refrigeration equipment, if fitted, by suitable means at a pressure sufficiently below the maximum external designed pressure differential of the cargo tank; or

.2 vacuum relief valves with a gas flow capacity at least equal to the maximum cargo discharge rate per cargo tank, set to open at a pressure sufficiently below the external design differential pressure of the cargo tank.

8.3.2 Subject to the requirements of chapter 17, the vacuum relief valves shall admit an inert gas, cargo vapour or air to the cargo tank and shall be arranged to minimize the possibility of the entrance of water or snow. If cargo vapour is admitted, it shall be from a source other than the cargo vapour lines.

8.3.3 The vacuum protection system shall be capable of being tested to ensure that it operates at the prescribed pressure.

8.4 Sizing of pressure relieving system

8.4.1 ***Sizing of pressure relief valves***

PRVs shall have a combined relieving capacity for each cargo tank to discharge the greater of the following, with not more than a 20% rise in cargo tank pressure above the MARVS:

8.4.1.1 The maximum capacity of the cargo tank inerting system, if the maximum attainable working pressure of the cargo tank inerting system exceeds the MARVS of the cargo tanks; or

8.4.1.2 Vapours generated under fire exposure computed using the following formula:

$$Q = FGA^{0.82} \quad (m^3/s),$$

where:

Q = minimum required rate of discharge of air at standard conditions of 273.15 Kelvin (K) and 0.1013 MPa;

F = fire exposure factor for different cargo types as follows:

- 1 for tanks without insulation located on deck;
- 0.5 for tanks above the deck, when insulation is approved by the Administration. Approval will be based on the use of a fireproofing material, the thermal conductance of insulation and its stability under fire exposure;
- 0.5 for uninsulated independent tanks installed in holds;
- 0.2 for insulated independent tanks in holds (or uninsulated independent tanks in insulated holds);

- 0.1 for insulated independent tanks in inerted holds (or uninsulated independent tanks in inerted, insulated holds);

- 0.1 for membrane and semi-membrane tanks. For independent tanks partly protruding through the weather decks, the fire exposure factor shall be determined on the basis of the surface areas above and below deck.

G = gas factor according to formula:

$$G = \frac{12.4}{LD}\sqrt{\frac{ZT}{M}}$$

with:

T = temperature in degrees Kelvin at relieving conditions, i.e. 120% of the pressure at which the pressure relief valve is set;

L = latent heat of the material being vaporized at relieving conditions, in kJ/kg;

D = a constant based on relation of specific heats k and is calculated as follows:

$$D = \sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

where:

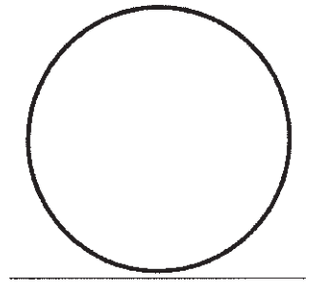
k = ratio of specific heats at relieving conditions, and the value of which is between 1 and 2.2. If k is not known, D = 0.606 shall be used;

Z = compressibility factor of the gas at relieving conditions. If not known, Z = 1 shall be used; and

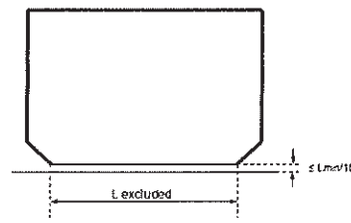
M = molecular mass of the product.

The gas factor of each cargo to be carried shall be determined and the highest value shall be used for PRV sizing.

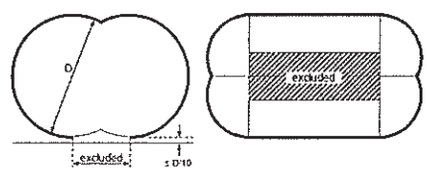
A = external surface area of the tank (m^2), as defined in 1.2.14, for different tank types, as shown in figure 8.1.



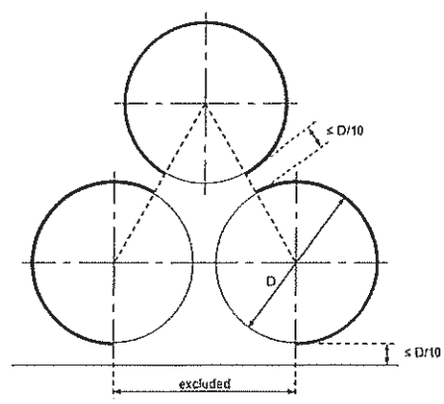
Cylindrical tanks with spherically dished, hemispherical or semi-ellipsoidal heads or spherical tanks



Prismatic tanks



Bilobe tanks



Horizontal cylindrical tanks arrangement

Figure 8.1

8.4.1.3 The required mass flow of air at relieving conditions is given by the formula:

$M_{air} = Q\ \rho_{air}$ (kg/s),

where:

density of air (ρ_{air}) = 1.293 kg/m^3 (air at 273.15 K, 0.1013 MPa).

8.4.2 ***Sizing of vent pipe system***

Pressure losses upstream and downstream of the PRVs shall be taken into account when determining their size to ensure the flow capacity required by 8.4.1.

8.4.3 ***Upstream pressure losses***

8.4.3.1 The pressure drop in the vent line from the tank to the PRV inlet shall not exceed 3% of the valve set pressure at the calculated flow rate, in accordance with 8.4.1.

8.4.3.2 Pilot-operated PRVs shall be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome.

8.4.3.3 Pressure losses in remotely sensed pilot lines shall be considered for flowing type pilots.

8.4.4 ***Downstream pressure losses***

8.4.4.1 Where common vent headers and vent masts are fitted, calculations shall include flow from all attached PRVs.

8.4.4.2 The built-up back pressure in the vent piping from the PRV outlet to the location of discharge to the atmosphere, and including any vent pipe interconnections that join other tanks, shall not exceed the following values:

.1	for unbalanced PRVs:	10% of MARVS;
.2	for balanced PRVs:	30% of MARVS; and
.3	for pilot operated PRVs:	50% of MARVS.

Alternative values provided by the PRV manufacturer may be accepted.

8.4.5 To ensure stable PRV operation, the blow-down shall not be less than the sum of the inlet pressure loss and 0.02 MARVS at the rated capacity.

CHAPTER 9

CARGO CONTAINMENT SYSTEM ATMOSPHERE CONTROL

Goal

To enable monitoring of the integrity of the containment system and to ensure that the atmosphere within the system and hold spaces is maintained in a safe condition at all times that the ship is in service.

9.1 Atmosphere control within the cargo containment system

9.1.1 A piping system shall be arranged to enable each cargo tank to be safely gas-freed, and to be safely filled with cargo vapour from a gas-free condition. The system shall be arranged to minimize the possibility of pockets of gas or air remaining after changing the atmosphere.

9.1.2 For flammable cargoes, the system shall be designed to eliminate the possibility of a flammable mixture existing in the cargo tank during any part of the atmosphere change operation by utilizing an inerting medium as an intermediate step.

9.1.3 Piping systems that may contain flammable cargoes shall comply with 9.1.1 and 9.1.2.

9.1.4 A sufficient number of gas sampling points shall be provided for each cargo tank and cargo piping system to adequately monitor the progress of atmosphere change. Gas sampling connections shall be fitted with a single valve above the main deck, sealed with a suitable cap or blank (see 5.6.5.5).

9.1.5 Inert gas utilized in these procedures may be provided from the shore or from the ship.

9.2 Atmosphere control within the hold spaces (cargo containment systems other than type C independent tanks)

9.2.1 Interbarrier and hold spaces associated with cargo containment systems for flammable gases requiring full or partial secondary barriers shall be inerted with a suitable dry inert gas and kept inerted with make-up gas provided by a shipboard inert gas generation system, or by shipboard storage, which shall be sufficient for normal consumption for at least 30 days.

9.2.2 Alternatively, subject to the restrictions specified in chapter 17, the spaces referred to in 9.2.1 requiring only a partial secondary barrier may be filled with dry air provided that the ship maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces, and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensures that any leakage from the cargo tanks will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand shall be provided.

9.2.3 For non-flammable gases, the spaces referred to in 9.2.1 and 9.2.2 may be maintained with a suitable dry air or inert atmosphere.

9.3 Environmental control of spaces surrounding type C independent tanks

Spaces surrounding cargo tanks that do not have secondary barriers shall be filled with suitable dry inert gas or dry air and be maintained in this condition with make-up inert gas provided by a shipboard inert gas generation system, shipboard storage of inert gas, or with

dry air provided by suitable air drying equipment. If the cargo is carried at ambient temperature, the requirement for dry air or inert gas is not applicable.

9.4 Inerting

9.4.1 Inerting refers to the process of providing a non-combustible environment. Inert gases shall be compatible chemically and operationally at all temperatures likely to occur within the spaces and the cargo. The dew points of the gases shall be taken into consideration.

9.4.2 Where inert gas is also stored for firefighting purposes, it shall be carried in separate containers and shall not be used for cargo services.

9.4.3 Where inert gas is stored at temperatures below 0°C, either as a liquid or as a vapour, the storage and supply system shall be designed so that the temperature of the ship's structure is not reduced below the limiting values imposed on it.

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 interbarrier spaces.

9.4.5 The arrangements shall be such that each space being inerted can be isolated and the necessary controls and relief valves, etc., shall be provided for controlling pressure in these spaces.

9.4.6 Where insulation spaces are continually supplied with an inert gas as part of a leak detection system, means shall be provided to monitor the quantity of gas being supplied to individual spaces.

9.5 Inert gas production on board

9.5.1 The equipment shall be capable of producing inert gas with an oxygen content at no time greater than 5% by volume, subject to the special requirements of chapter 17. A continuous-reading oxygen content meter shall be fitted to the inert gas supply from the equipment and shall be fitted with an alarm set at a maximum of 5% oxygen content by volume, subject to the requirements of chapter 17.

9.5.2 An inert gas system shall have pressure controls and monitoring arrangements appropriate to the cargo containment system.

9.5.3 Spaces containing inert gas generation plants shall have no direct access to accommodation spaces, service spaces or control stations, but may be located in machinery spaces. Inert gas piping shall not pass through accommodation spaces, service spaces or control stations.

9.5.4 Combustion equipment for generating inert gas shall not be located within the cargo area. Special consideration may be given to the location of inert gas generating equipment using a catalytic combustion process.

CHAPTER 10

ELECTRICAL INSTALLATIONS

Goal

To ensure that electrical installations are designed such as to minimize the risk of fire and explosion from flammable products, and that electrical generation and distribution systems relating to the safe carriage, handling and conditioning of cargo liquid and vapour are available.

10.1 Definitions

For the purpose of this chapter, unless expressly provided otherwise, the definitions below shall apply.

10.1.1 *Hazardous area* is an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

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

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

10.1.1.3 *Zone 2 hazardous area* is an area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so infrequently and for a short period only.

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

10.2 General requirements

10.2.1 Electrical installations shall be such as to minimize the risk of fire and explosion from flammable products.

10.2.2 Electrical installations shall be in accordance with recognized standards.

10.2.3 Electrical equipment or wiring shall not be installed in hazardous areas, unless essential for operational purposes or safety enhancement.

10.2.4 Where electrical equipment is installed in hazardous areas as provided in 10.2.3, it shall be selected, installed and maintained in accordance with standards not inferior to those acceptable to the Organization. Equipment for hazardous areas shall be evaluated and certified or listed by an accredited testing authority or notified body recognized by the Administration. Automatic isolation of non-certified equipment on detection of a flammable gas shall not be accepted as an alternative to the use of certified equipment.

10.2.5 To facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones in accordance with recognized standards.

10.2.6 Electrical generation and distribution systems, and associated control systems shall be designed such that a single fault will not result in the loss of ability to maintain cargo tank pressures, as required by 7.8.1, and hull structure temperature, as required by 4.19.1.6, within normal operating limits. Failure modes and effects shall be analysed and documented to a standard not inferior to those acceptable to the Administration.

10.2.7 The lighting system in hazardous areas shall be divided between at least two branch circuits. All switches and protective devices shall interrupt all poles or phases and shall be located in a non-hazardous area.

10.2.8 Electrical depth sounding or log devices and impressed current cathodic protection system anodes or electrodes shall be housed in gastight enclosures.

10.2.9 Submerged cargo pump motors and their supply cables may be fitted in cargo containment systems. Arrangements shall be made to automatically shut down the motors in the event of low-liquid level. This may be accomplished by sensing low pump discharge pressure, low motor current or low liquid level. This shutdown shall be alarmed at the cargo control station. Cargo pump motors shall be capable of being isolated from their electrical supply during gas-freeing operations.

CHAPTER 11

FIRE PROTECTION AND EXTINCTION

Goal

To ensure that suitable systems are provided to protect the ship and crew from fire in the cargo area.

11.1 Fire safety requirements

11.1.1 The requirements for tankers in SOLAS chapter II-2 shall apply to ships covered by the Code, irrespective of tonnage including ships of less than 500 gross tonnage, except that:

.1 regulations 4.5.1.6 and 4.5.10 do not apply;

.2 regulations 10.4 and 10.5 shall apply as they would apply to tankers of 2,000 gross tonnage and over;

.3 regulation 10.5.6 shall apply to ships of 2,000 gross tonnage and over;

.4 the following regulations of SOLAS chapter II-2 related to tankers do not apply and are replaced by chapters and sections of the Code as detailed below:

Regulation:	Replaced by:
10.10	11.6
4.5.1.1 and 4.5.1.2	Chapter 3
4.5.5	Relevant sections in the Code

10.8	11.3 and 11.4
10.9	11.5
10.2	11.2.1 to 11.2.4;

.5 regulations 13.3.4 and 13.4.3 shall apply to ships of 500 gross tonnage and over.

11.1.2 All sources of ignition shall be excluded from spaces where flammable vapour may be present, except as otherwise provided in chapters 10 and 16.

11.1.3 The provisions of this section shall apply in conjunction with chapter 3.

11.1.4 For the purposes of firefighting, any weather deck areas above cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forwardmost hold space shall be included in the cargo area.

11.2 Fire mains and hydrants

11.2.1 Irrespective of size, ships carrying products that are subject to the Code shall comply with the requirements of regulation II-2/10.2 of the SOLAS Convention, as applicable to cargo ships, except that the required fire pump capacity and fire main and water service pipe diameter shall not be limited by the provisions of regulations II-2/10.2.2.4.1 and II-2/10.2.1.3, when a fire pump is used to supply the water-spray system, as permitted by 11.3.3 of the Code. The capacity of this fire pump shall be such that these areas can be protected when simultaneously supplying two jets of water from fire hoses with 19 mm nozzles at a pressure of at least 0.5 MPa.

11.2.2 The arrangements shall be such that at least two jets of water can reach any part of the deck in the cargo area and those portions of the cargo containment system and tank covers that are above the deck. The necessary number of fire hydrants shall be located to satisfy the above arrangements and to comply with the requirements of regulations II-2/10.2.1.5.1 and II-2/10.2.3.3 of the SOLAS Convention, with hose lengths as specified in regulation II-2/10.2.3.1.1. In addition, the requirements of regulation II-2/10.2.1.6 shall be met at a pressure of at least 0.5 MPa gauge.

11.2.3 Stop valves shall be fitted in any crossover provided and in the fire main or mains in a protected location, before entering the cargo area and at intervals ensuring isolation of any damaged single section of the fire main, so that 11.2.2 can be complied with using not more than two lengths of hoses from the nearest fire hydrant. The water supply to the fire main serving the cargo area shall be a ring main supplied by the main fire pumps or a single main supplied by fire pumps positioned fore and aft of the cargo area, one of which shall be independently driven.

11.2.4 Nozzles shall be of an approved dual-purpose type (i.e. spray/jet type) incorporating a shutoff.

11.2.5 After installation, the pipes, valves, fittings and assembled system shall be subject to a tightness and function test.

11.3 Water-spray system

11.3.1 On ships carrying flammable and/or toxic products, a water-spray system, for cooling, fire prevention and crew protection shall be installed to cover:

.1 exposed cargo tank domes, any exposed parts of cargo tanks and any part of cargo tank covers that may be exposed to heat from fires in adjacent equipment containing cargo such as exposed booster pumps/heaters/re-gasification or re-liquefaction plants, hereafter addressed as gas process units, positioned on weather decks;

.2 exposed on-deck storage vessels for flammable or toxic products;

.3 gas process units positioned on deck;

.4 cargo liquid and vapour discharge and loading connections, including the presentation flange and the area where their control valves are situated, which shall be at least equal to the area of the drip trays provided;

.5 all exposed emergency shut-down (ESD) valves in the cargo liquid and vapour pipes, including the master valve for supply to gas consumers;

.6 exposed boundaries facing the cargo area, such as bulkheads of superstructures and deckhouses normally manned, cargo machinery spaces, store-rooms containing high fire-risk items and cargo control rooms. Exposed horizontal boundaries of these areas do not require protection unless detachable cargo piping connections are arranged above or below. Boundaries of unmanned forecastle structures not containing high fire-risk items or equipment do not require water-spray protection;

.7 exposed lifeboats, liferafts and muster stations facing the cargo area, regardless of distance to cargo area; and

.8 any semi-enclosed cargo machinery spaces and semi-enclosed cargo motor room.

Ships intended for operation as listed in 1.1.10 shall be subject to special consideration (see 11.3.3.2).

11.3.2.1 The system shall be capable of covering all areas mentioned in 11.3.1.1 to 11.3.1.8, with a uniformly distributed water application rate of at least 10 $\ell/m^2/min$ for the largest projected horizontal surfaces and 4 $\ell/m^2/min$ for vertical surfaces. For structures having no clearly defined horizontal or vertical surface, the capacity of the water-spray system shall not be less than the projected horizontal surface multiplied by 10 $\ell/m^2/min$.

11.3.2.2 On vertical surfaces, spacing of nozzles protecting lower areas may take account of anticipated rundown from higher areas. Stop valves shall be fitted in the main supply line(s) in the water-spray system, at intervals not exceeding 40 m, for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections that may be operated independently, provided the necessary controls are located together in a readily accessible position outside the cargo area. A section protecting any area included in 11.3.1.1 and .2 shall cover at least the entire athwartship tank grouping in that area. Any gas process unit(s) included in 11.3.1.3 may be served by an independent section.

11.3.3 The capacity of the water-spray pumps shall be capable of simultaneous protection of the greater of the following:

.1 any two complete athwartship tank groupings, including any gas process units within these areas; or

.2 for ships intended for operation as listed in 1.1.10, necessary protection subject to special consideration under 11.3.1 of any added fire hazard and the adjacent athwartship tank grouping,

in addition to surfaces specified in 11.3.1.4 to 11.3.1.8. Alternatively, the main fire pumps may be used for this service, provided that their total capacity is increased by the amount needed for the water-spray system. In either case, a connection, through a stop valve, shall be made between the fire main and water-spray system main supply line outside the cargo area.

11.3.4 The boundaries of superstructures and deckhouses normally manned, and lifeboats, liferafts and muster areas facing the cargo area, shall also be capable of being served by one of the fire pumps or the emergency fire pump, if a fire in one compartment could disable both fire pumps.

11.3.5 Water pumps normally used for other services may be arranged to supply the water-spray system main supply line.

11.3.6 All pipes, valves, nozzles and other fittings in the water-spray system shall be resistant to corrosion by seawater. Piping, fittings and related components within the cargo area (except gaskets) shall be designed to withstand 925°C. The water-spray system shall be arranged with in-line filters to prevent blockage of pipes and nozzles. In addition, means shall be provided to back-flush the system with fresh water.

11.3.7 Remote starting of pumps supplying the water-spray system and remote operation of any normally closed valves in the system shall be arranged in suitable locations outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the protected areas.

11.3.8 After installation, the pipes, valves, fittings and assembled system shall be subject to a tightness and function test.

11.4 Dry chemical powder fire-extinguishing systems

11.4.1 Ships in which the carriage of flammable products is intended shall be fitted with fixed dry chemical powder fire-extinguishing systems, approved by the Administration based on the guidelines developed by the Organization, for the purpose of firefighting on the deck in the cargo area, including any cargo liquid and vapour discharge and loading connections on deck and bow or stern cargo handling areas, as applicable.

11.4.2 The system shall be capable of delivering powder from at least two hand hose lines, or a combination of monitor/hand hose lines, to any part of the exposed cargo liquid and vapour piping, load/unload connection and exposed gas process units.

11.4.3 The dry chemical powder fire-extinguishing system shall be designed with not less than two independent units. Any part required to be protected by 11.4.2 shall be capable of being reached from not less than two independent units with associated controls, pressurizing medium fixed piping, monitors or hand hose lines. For ships with a cargo capacity of less than 1,000 m^3, only one such unit need be fitted. A monitor shall be arranged to protect any load/unload connection area and be capable of actuation and discharge both locally and remotely. The monitor is not required to be remotely aimed, if it can deliver the necessary powder to all required areas of coverage from a single position. One hose line

shall be provided at both port- and starboard side at the end of the cargo area facing the accommodation and readily available from the accommodation.

11.4.4 The capacity of a monitor shall be not less than 10 kg/s. Hand hose lines shall be non-kinkable and be fitted with a nozzle capable of on/off operation and discharge at a rate not less than 3.5 kg/s. The maximum discharge rate shall allow operation by one man. The length of a hand hose line shall not exceed 33 m. Where fixed piping is provided between the powder container and a hand hose line or monitor, the length of piping shall not exceed that length which is capable of maintaining the powder in a fluidized state during sustained or intermittent use, and which can be purged of powder when the system is shut down. Hand hose lines and nozzles shall be of weather-resistant construction or stored in weather resistant housing or covers and be readily accessible.

11.4.5 Hand hose lines shall be considered to have a maximum effective distance of coverage equal to the length of hose. Special consideration shall be given where areas to be protected are substantially higher than the monitor or hand hose reel locations.

11.4.6 Ships fitted with bow/stern load/unload connections shall be provided with independent dry powder unit protecting the cargo liquid and vapour piping, aft or forward of the cargo area, by hose lines and a monitor covering the bow/stern load/unload complying with the requirements of 11.4.1 to 11.4.5.

11.4.7 Ships intended for operation as listed in 1.1.10 shall be subject to special consideration.

11.4.8 After installation, the pipes, valves, fittings and assembled systems shall be subjected to a tightness test and functional testing of the remote and local release stations. The initial testing shall also include a discharge of sufficient amounts of dry chemical powder to verify that the system is in proper working order. All distribution piping shall be blown through with dry air to ensure that the piping is free of obstructions.

11.5 Enclosed spaces containing cargo handling equipment

11.5.1 Enclosed spaces meeting the criteria of cargo machinery spaces in 1.2.10, and the cargo motor room within the cargo area of any ship, shall be provided with a fixed fire-extinguishing system complying with the provisions of the FSS Code and taking into account the necessary concentrations/application rate required for extinguishing gas fires.

11.5.2 Enclosed spaces meeting the criteria of cargo machinery spaces in chapter 3.3, within the cargo area of ships that are dedicated to the carriage of a restricted number of cargoes, shall be protected by an appropriate fire-extinguishing system for the cargo carried.

11.5.3 Turret compartments of any ship shall be protected by internal water spray, with an application rate of not less than 10 $\ell/m^2/min$ of the largest projected horizontal surface. If the pressure of the gas flow through the turret exceeds 4 MPa, the application rate shall be increased to 20 $\ell/m^2/min$. The system shall be designed to protect all internal surfaces.

11.6 Firefighter's outfits

11.6.1 Every ship carrying flammable products shall carry firefighter's outfits complying with the requirements of regulation II-2/10.10 of the SOLAS Convention, as follows:

Total cargo capacity	Number of outfits
5,000 m^3 and below	4
Above 5,000 m^3	5

11.6.2 Additional requirements for safety equipment are given in chapter 14.

11.6.3 Any breathing apparatus required as part of a firefighter's outfit shall be a self-contained compressed air-operated breathing apparatus having a capacity of at least 1,200 ℓ of free air.

CHAPTER 12

ARTIFICIAL VENTILATION IN THE CARGO AREA

Goal

To ensure that arrangements are provided for enclosed spaces in the cargo area to control the accumulation of flammable and/or toxic vapours.

Scope

The requirements of this chapter replace the requirements of SOLAS regulations II-2/4.5.2.6 and 4.5.4.1, as amended.

12.1 Spaces required to be entered during normal cargo handling operations

12.1.1 Electric motor rooms, cargo compressor and pump-rooms, spaces containing cargo handling equipment and other enclosed spaces where cargo vapours may accumulate shall be fitted with fixed artificial ventilation systems capable of being controlled from outside such spaces. The ventilation shall be run continuously to prevent the accumulation of toxic and/or flammable vapours, with a means of monitoring acceptable to the Administration to be provided. A warning notice requiring the use of such ventilation prior to entering shall be placed outside the compartment.

12.1.2 Artificial ventilation inlets and outlets shall be arranged to ensure sufficient air movement through the space to avoid accumulation of flammable, toxic or asphyxiant vapours, and to ensure a safe working environment.

12.1.3 The ventilation system shall have a capacity of not less than 30 changes of air per hour, based upon the total volume of the space. As an exception, non-hazardous cargo control rooms may have eight changes of air per hour.

12.1.4 Where a space has an opening into an adjacent more hazardous space or area, it shall be maintained at an overpressure. It may be made into a less hazardous space or non-hazardous space by overpressure protection in accordance with recognized standards.

12.1.5 Ventilation ducts, air intakes and exhaust outlets serving artificial ventilation systems shall be positioned in accordance with recognized standards.

12.1.6 Ventilation ducts serving hazardous areas shall not be led through accommodation, service and machinery spaces or control stations, except as allowed in chapter 16.

12.1.7 Electric motors' driving fans shall be placed outside the ventilation ducts that may contain flammable vapours. Ventilation fans shall not produce a source of ignition in either the ventilated space or the ventilation system associated with the space. For hazardous areas, ventilation fans and ducts, adjacent to the fans, shall be of non-sparking construction, as defined below:

.1 impellers or housing of non-metallic construction, with due regard being paid to the elimination of static electricity;

.2 impellers and housing of non-ferrous materials;

.3 impellers and housing of austenitic stainless steel; and

.4 ferrous impellers and housing with design tip clearance of not less than 13 mm.

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

12.1.8 Where fans are required by this chapter, full required ventilation capacity for each space shall be available after failure of any single fan, or spare parts shall be provided comprising a motor, starter spares and complete rotating element, including bearings of each type.

12.1.9 Protection screens of not more than 13 mm square mesh shall be fitted to outside openings of ventilation ducts.

12.1.10 Where spaces are protected by pressurization, the ventilation shall be designed and installed in accordance with recognized standards.

12.2 Spaces not normally entered

12.2.1 Enclosed spaces where cargo vapours may accumulate shall be capable of being ventilated to ensure a safe environment when entry into them is necessary. This shall be capable of being achieved without the need for prior entry.

12.2.2 For permanent installations, the capacity of 8 air changes per hour shall be provided and for portable systems, the capacity of 16 air changes per hour.

12.2.3 Fans or blowers shall be clear of personnel access openings, and shall comply with 12.1.7.

CHAPTER 13

INSTRUMENTATION AND AUTOMATION SYSTEMS

Goal

To ensure that the instrumentation and automation systems provides for the safe carriage, handling and conditioning of cargo liquid and vapour.

13.1 General

13.1.1 Each cargo tank shall be provided with a means for indicating level, pressure and temperature of the cargo. Pressure gauges and temperature indicating devices shall be installed in the liquid and vapour piping systems, in cargo refrigeration installations.

13.1.2 If loading and unloading of the ship is performed by means of remotely controlled valves and pumps, all controls and indicators associated with a given cargo tank shall be concentrated in one control position.

13.1.3 Instruments shall be tested to ensure reliability under the working conditions, and recalibrated at regular intervals. Test procedures for instruments and the intervals between recalibration shall be in accordance with manufacturer's recommendations.

13.2 Level indicators for cargo tanks

13.2.1 Each cargo tank shall be fitted with liquid level gauging device(s), arranged to ensure that a level reading is always obtainable whenever the cargo tank is operational. The device(s) shall be designed to operate throughout the design pressure range of the cargo tank and at temperatures within the cargo operating temperature range.

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.

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.

13.3 Overflow control

13.3.1 Except as provided in 13.3.4, each cargo tank shall be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated.

13.3.2 An additional sensor operating independently of the high liquid level alarm shall automatically actuate a shutoff valve in a manner that will both avoid excessive liquid pressure in the loading line and prevent the tank from becoming liquid full.

13.3.3 The emergency shutdown valve referred to in 5.5 and 18.10 may be used for this purpose. If another valve is used for this purpose, the same information as referred to in 18.10.2.1.3 shall be available on board. During loading, whenever the use of these valves may possibly create a potential excess pressure surge in the loading system, alternative arrangements such as limiting the loading rate shall be used.

13.3.4 A high liquid level alarm and automatic shut-off of cargo tank filling need not be required, when the cargo tank:

.1 is a pressure tank with a volume not more than 200 m^3; or

.2 is designed to withstand the maximum possible pressure during the loading operation, and such pressure is below that of the set pressure of the cargo tank relief valve.

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.

13.3.6 All elements of the level alarms, including the electrical circuit and the sensor(s), of the high, and overfill alarms, shall be capable of being functionally tested. Systems shall be tested prior to cargo operation in accordance with 18.6.2.

13.3.7 Where arrangements are provided for overriding the overflow control system, they shall be such that inadvertent operation is prevented. When this override is operated, continuous visual indication shall be given at the relevant control station(s) and the navigation bridge.

13.4 Pressure monitoring

13.4.1 The vapour space of each cargo tank shall be provided with a direct reading gauge. Additionally, an indirect indication shall be provided at the control position required by 13.1.2. Maximum and minimum allowable pressures shall be clearly indicated.

13.4.2 A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm shall be provided on the navigation bridge and at the control position required by 13.1.2. Alarms shall be activated before the set pressures are reached.

13.4.3 For cargo tanks fitted with PRVs which can be set at more than one set pressure in accordance with 8.2.7, high-pressure alarms shall be provided for each set pressure.

13.4.4 Each cargo-pump discharge line and each liquid and vapour cargo manifold shall be provided with at least one pressure indicator.

13.4.5 Local-reading manifold pressure indication shall be provided to indicate the pressure between ship's manifold valves and hose connections to the shore.

13.4.6 Hold spaces and interbarrier spaces without open connection to the atmosphere shall be provided with pressure indication.

13.4.7 All pressure indications provided shall be capable of indicating throughout the operating pressure range.

13.5 Temperature indicating devices

13.5.1 Each cargo tank shall be provided with at least two devices for indicating cargo temperatures, one placed at the bottom of the cargo tank and the second near the top of the tank, below the highest allowable liquid level. The lowest temperature for which the cargo tank has been designed, as shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk required by 1.4.4, shall be clearly indicated by means of a sign on or near the temperature indicating devices.

13.5.2 The temperature indicating devices shall be capable of providing temperature indication across the expected cargo operating temperature range of the cargo tanks.

13.5.3 Where thermowells are fitted, they shall be designed to minimize failure due to fatigue in normal service.

13.6 Gas detection

13.6.1 Gas detection equipment shall be installed to monitor the integrity of the cargo containment, cargo handling and ancillary systems, in accordance with this section.

13.6.2 A permanently installed system of gas detection and audible and visual alarms shall be fitted in:

.1 all enclosed cargo and cargo machinery spaces (including turrets compartments) containing gas piping, gas equipment or gas consumers;

.2 other enclosed or semi-enclosed spaces where cargo vapours may accumulate, including interbarrier spaces and hold spaces for independent tanks other than type C tanks;

.3 airlocks;

.4 spaces in gas-fired internal combustion engines, referred to in 16.7.3.3;

.5 ventilation hoods and gas ducts required by chapter 16;

.6 cooling/heating circuits, as required by 7.8.4;

.7 inert gas generator supply headers; and

.8 motor rooms for cargo handling machinery.

13.6.3 Gas detection equipment shall be designed, installed and tested in accordance with recognized standards and shall be suitable for the cargoes to be carried in accordance with column "*f*" in table of chapter 19.

13.6.4 Where indicated 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 cargo tank hold spaces. 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.

13.6.5 In the case of toxic products or both toxic and flammable products, except when column "*i*" in the table of chapter 19 refers to 17.5.3, portable equipment can be used for the detection of toxic products as an alternative to a permanently installed system. This equipment shall be used prior to personnel entering the spaces listed in 13.6.2 and at 30-minute intervals while they remain in the space.

13.6.6 In the case of gases classified as toxic products, hold spaces and interbarrier spaces shall be provided with a permanently installed piping system for obtaining gas samples from the spaces. Gas from these spaces shall be sampled and analysed from each sampling head location.

13.6.7 Permanently installed gas detection shall be of the continuous detection type, capable of immediate response. Where not used to activate safety shutdown functions required by 13.6.9 and chapter 16, sampling type detection may be accepted.

13.6.8 When sampling type gas detection equipment is used, the following requirements shall be met:

.1 the gas detection equipment shall be capable of sampling and analysing for each sampling head location sequentially at intervals not exceeding 30 min;

.2 individual sampling lines from sampling heads to the detection equipment shall be fitted; and

.3 pipe runs from sampling heads shall not be led through non-hazardous spaces except as permitted by 13.6.9.

13.6.9 The gas detection equipment may be located in a non-hazardous space, provided that the detection equipment such as sample piping, sample pumps, solenoids and analysing units are located in a fully enclosed steel cabinet with the door sealed by a gasket. The atmosphere within the enclosure shall be continuously monitored. At gas concentrations above 30% lower flammable limit (LFL) inside the enclosure, the gas detection equipment shall be automatically shut down.

13.6.10 Where the enclosure cannot be arranged directly on the forward bulkhead, sample pipes shall be of steel or equivalent material and be routed on their shortest way. Detachable connections, except for the connection points for isolating valves required in 13.6.11 and analysing units, are not permitted.

13.6.11 When gas sampling equipment is located in a non-hazardous space, a flame arrester and a manual isolating valve shall be fitted in each of the gas sampling lines. The isolating valve shall be fitted on the non-hazardous side. Bulkhead penetrations of sample pipes between hazardous and non-hazardous areas shall maintain the integrity of the division penetrated. The exhaust gas shall be discharged to the open air in a non-hazardous area.

13.6.12 In every installation, the number and the positions of detection heads shall be determined with due regard to the size and layout of the compartment, the compositions and densities of the products intended to be carried and the dilution from compartment purging or ventilation and stagnant areas.

13.6.13 Any alarms status within a gas detection system required by this section shall initiate an audible and visible alarm:

.1 on the navigation bridge;

.2 at the relevant control station(s) where continuous monitoring of the gas levels is recorded; and

.3 at the gas detector readout location.

13.6.14 In the case of flammable products, the gas detection equipment provided for hold spaces and interbarrier spaces that are required to be inerted shall be capable of measuring gas concentrations of 0% to 100% by volume.

13.6.15 Alarms shall be activated when the vapour concentration by volume reaches the equivalent of 30% LFL in air.

13.6.16 For membrane containment systems, the primary and secondary insulation spaces shall be able to be inerted and their gas content analysed individually. The alarm in the secondary insulation space shall be set in accordance with 13.6.15, that in the primary space is set at a value approved by the Administration or recognized organization acting on its behalf.

13.6.17 For other spaces described by 13.6.2, alarms shall be activated when the vapour concentration reaches 30% LFL and safety functions required by chapter 16 shall be activated before the vapour concentration reaches 60% LFL. The crankcases of internal combustion engines that can run on gas shall be arranged to alarm before 100% LFL.

13.6.18 Gas detection equipment shall be so designed that it may readily be tested. Testing and calibration shall be carried out at regular intervals. Suitable equipment for this purpose shall be carried on board and be used in accordance with the manufacturer's recommendations. Permanent connections for such test equipment shall be fitted.

13.6.19 Every ship shall be provided with at least two sets of portable gas detection equipment that meet the requirement of 13.6.3 or an acceptable national or international standard.

13.6.20 A suitable instrument for the measurement of oxygen levels in inert atmospheres shall be provided.

13.7 Additional requirements for containment systems requiring a secondary barrier

13.7.1 *Integrity of barriers*

Where a secondary barrier is required, permanently installed instrumentation shall be provided to detect when the primary barrier fails to be liquid-tight at any location or when liquid cargo is in contact with the secondary barrier at any location. This instrumentation shall consist of appropriate gas detecting devices according to 13.6. However, the instrumentation need not be capable of locating the area where liquid cargo leaks through the primary barrier or where liquid cargo is in contact with the secondary barrier.

13.7.2 *Temperature indication devices*

13.7.2.1 The number and position of temperature-indicating devices shall be appropriate to the design of the containment system and cargo operation requirements.

13.7.2.2 When cargo is carried in a cargo containment system with a secondary barrier, at a temperature lower than -55°C, temperature-indicating devices shall be provided within the insulation or on the hull structure adjacent to cargo containment systems. The devices shall give readings at regular intervals and, where applicable, alarm of temperatures approaching the lowest for which the hull steel is suitable.

13.7.2.3 If cargo is to be carried at temperatures lower than -55°C, the cargo tank boundaries, if appropriate for the design of the cargo containment system, shall be fitted with a sufficient number of temperature-indicating devices to verify that unsatisfactory temperature gradients do not occur.

13.7.2.4 For the purposes of design verification and determining the effectiveness of the initial cooldown procedure on a single or series of similar ships, one tank shall be fitted with devices in excess of those required in 13.7.2.1. These devices may be temporary or permanent and only need to be fitted to the first ship, when a series of similar ships is built.

13.8 Automation systems

13.8.1 The requirements of this section shall apply where automation systems are used to provide instrumented control, monitoring/alarm or safety functions required by this Code.

13.8.2 Automation systems shall be designed, installed and tested in accordance with recognized standards.

13.8.3 Hardware shall be capable of being demonstrated to be suitable for use in the marine environment by type approval or other means.

13.8.4 Software shall be designed and documented for ease of use, including testing, operation and maintenance.

13.8.5 The user interface shall be designed such that the equipment under control can be operated in a safe and effective manner at all times.

13.8.6 Automation systems shall be arranged such that a hardware failure or an error by the operator does not lead to an unsafe condition. Adequate safeguards against incorrect operation shall be provided.

13.8.7 Appropriate segregation shall be maintained between control, monitoring/alarm and safety functions to limit the effect of single failures. This shall be taken to include all parts of the automation systems that are required to provide specified functions, including connected devices and power supplies.

13.8.8 Automation systems shall be arranged such that the software configuration and parameters are protected against unauthorized or unintended change.

13.8.9 A management of change process shall be applied to safeguard against unexpected consequences of modification. Records of configuration changes and approvals shall be maintained on board.

13.8.10 Processes for the development and maintenance of integrated systems shall be in accordance with recognized standards. These processes shall include appropriate risk identification and management.

13.9 System integration

13.9.1 Essential safety functions shall be designed such that risks of harm to personnel or damage to the installation or the environment are reduced to a level acceptable to the Administration, both in normal operation and under fault conditions. Functions shall be designed to fail-safe. Roles and responsibilities for integration of systems shall be clearly defined and agreed by relevant parties.

13.9.2 Functional requirements of each component subsystem shall be clearly defined to ensure that the integrated system meets the functional and specified safety requirements and takes account of any limitations of the equipment under control.

13.9.3 Key hazards of the integrated system shall be identified using appropriate risk-based techniques.

13.9.4 The integrated system shall have a suitable means of reversionary control.

13.9.5 Failure of one part of the integrated system shall not affect the functionality of other parts, except for those functions directly dependent on the defective part.

13.9.6 Operation with an integrated system shall be at least as effective as it would be with individual stand-alone equipment or systems.

13.9.7 The integrity of essential machinery or systems, during normal operation and fault conditions, shall be demonstrated.

CHAPTER 14

PERSONNEL PROTECTION

Goal

To ensure that protective equipment is provided for ship staff, considering both routine operations or emergency situations and possible short- or long-term effects of the product being handled.

14.1 Protective equipment

14.1.1 Suitable protective equipment, including eye protection to a recognized national or international standard, shall be provided for protection of crew members engaged in normal cargo operations, taking into account the characteristics of the products being carried.

14.1.2 Personal protective and safety equipment required in this chapter shall be kept in suitable, clearly marked lockers located in readily accessible places.

14.1.3 The compressed air equipment shall be inspected at least once a month by a responsible officer and the inspection logged in the ship's records. This equipment shall also be inspected and tested by a competent person at least once a year.

14.2 First-aid equipment

14.2.1 A stretcher that is suitable for hoisting an injured person from spaces below deck shall be kept in a readily accessible location.

14.2.2 The ship shall have onboard medical first-aid equipment, including oxygen resuscitation equipment, based on the requirements of the Medical First Aid Guide (MFAG) for the cargoes listed on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk shown in appendix 2.

14.3 Safety equipment

14.3.1 Sufficient, but not less than three complete sets of safety equipment shall be provided in addition to the firefighter's outfits required by 11.6.1. Each set shall provide adequate personal protection to permit entry and work in a gas-filled space. This equipment shall take into account the nature of the cargoes, listed on the International Certificate of Fitness for the Carriage of Liquified Gases in Bulk shown in appendix 2.

14.3.2 Each complete set of safety equipment shall consist of:

.1 one self-contained positive pressure air-breathing apparatus incorporating full face mask, not using stored oxygen and having a capacity of at least 1,200 ℓ of free air. Each set shall be compatible with that required by 11.6.1;

.2 protective clothing, boots and gloves to a recognized standard;

.3 steel-cored rescue line with belt; and

.4 explosion-proof lamp.

14.3.3 An adequate supply of compressed air shall be provided and shall consist of:

.1 at least one fully charged spare air bottle for each breathing apparatus required by 14.3.1;

.2 an air compressor of adequate capacity capable of continuous operation, suitable for the supply of high-pressure air of breathable quality; and

.3 a charging manifold capable of dealing with sufficient spare breathing apparatus air bottles for the breathing apparatus required by 14.3.1.

14.4 Personal protection requirements for individual products

14.4.1 Requirements of this section shall apply to ships carrying products for which those paragraphs are listed in column "*i*" in the table of chapter 19.

14.4.2 Suitable respiratory and eye protection for emergency escape purposes shall be provided for every person on board, subject to the following:

.1 filter-type respiratory protection is unacceptable;

.2 self-contained breathing apparatus shall have at least a duration of service of 15 min; and

.3 emergency escape respiratory protection shall not be used for firefighting or cargo-handling purposes and shall be marked to that effect.

14.4.3 One or more suitably marked decontamination showers and eyewash stations shall be available on deck, taking into account the size and layout of the ship. The showers and eyewashes shall be operable in all ambient conditions.

14.4.4 The protective clothing required under 14.3.2.2 shall be gastight.

CHAPTER 15

FILLING LIMITS FOR CARGO TANKS

Goal

To determine the maximum quantity of cargo that can be loaded.

15.1 Definitions

15.1.1 *Filling limit (FL)* means the maximum liquid volume in a cargo tank relative to the total tank volume when the liquid cargo has reached the reference temperature.

15.1.2 *Loading limit (LL)* means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded.

15.1.3 *Reference temperature* means (for the purposes of this chapter only):

.1 when no cargo vapour pressure/temperature control, as referred to in chapter 7, is provided, the temperature corresponding to the vapour pressure of the cargo at the set pressure of the PRVs; and

.2 when a cargo vapour pressure/temperature control, as referred to in chapter 7, is provided, the temperature of the cargo upon termination of loading, during transport or at unloading, whichever is the greatest.

15.1.4 *Ambient design temperature for unrestricted service* means sea temperature of 32°C and air temperature of 45°C. However, lesser values of these temperatures may be accepted by the Administration for ships operating in restricted areas or on voyages of restricted duration, and account may be taken in such cases of any insulation of the tanks. Conversely, higher values of these temperatures may be required for ships permanently operating in areas of high-ambient temperature.

15.2 General requirements

The maximum filling limit of cargo tanks shall be so determined that the vapour space has a minimum volume at reference temperature allowing for:

.1 tolerance of instrumentation such as level and temperature gauges;

.2 volumetric expansion of the cargo between the PRV set pressure and the maximum allowable rise stated in 8.4; and

.3 an operational margin to account for liquid drained back to cargo tanks after completion of loading, operator reaction time and closing time of valves, see 5.5 and 18.10.2.1.4.

15.3 Default filling limit

The default value for the filling limit (*FL*) of cargo tanks is 98% at the reference temperature. Exceptions to this value shall meet the requirements of 15.4.

15.4 Determination of increased filling limit

15.4.1 A filling limit greater than the limit of 98% specified in 15.3 may be permitted under the trim and list conditions specified in 8.2.17, providing:

.1 no isolated vapour pockets are created within the cargo tank;

.2 the PRV inlet arrangement shall remain in the vapour space; and

.3 allowances need to be provided for:

.1 volumetric expansion of the liquid cargo due to the pressure increase from the MARVS to full flow relieving pressure in accordance with 8.4.1;

.2 an operational margin of minimum 0.1% of tank volume; and

.3 tolerances of instrumentation such as level and temperature gauges.

15.4.2 In no case shall a filling limit exceeding 99.5% at reference temperature be permitted.

15.5 Maximum loading limit

15.5.1 The maximum loading limit (*LL*) to which a cargo tank may be loaded shall be determined by the following formula:

$$LL = FL\frac{\rho_R}{\rho_L}$$

where:

LL = loading limit as defined in 15.1.2, expressed in percentage;

FL = filling limit as specified in 15.3 or 15.4 expressed in percentage;

ρ_R = relative density of cargo at the reference temperature; and

ρ_L = relative density of cargo at the loading temperature.

15.5.2 The Administration may allow type C tanks to be loaded according to the formula in 15.5.1 with the relative density ρ_R as defined below, provided that the tank vent system has been approved in accordance with 8.2.18:

ρ_R = relative density of cargo at the highest temperature that the cargo may reach upon termination of loading, during transport, or at unloading, under the ambient design temperature conditions described in 15.1.4.

This paragraph does not apply to products requiring a type 1G ship.

15.6 Information to be provided to the master

15.6.1 A document shall be provided to the ship, specifying the maximum allowable loading limits for each cargo tank and product, at each applicable loading temperature and maximum reference temperature. The information in this document shall be approved by the Administration or recognized organization acting on its behalf.

15.6.2 Pressures at which the PRVs have been set shall also be stated in the document.

15.6.3 A copy of the above document shall be permanently kept on board by the master.

CHAPTER 16

USE OF CARGO AS FUEL

Goal

To ensure the safe use of cargo as fuel.

16.1 General

Except as provided for in 16.9, methane (LNG) is the only cargo whose vapour or boil-off gas may be utilized in machinery spaces of category A, and, in these spaces, it may be utilized only in systems such as boilers, inert gas generators, internal combustion engines, gas combustion unit and gas turbines.

16.2 Use of cargo vapour as fuel

This section addresses the use of cargo vapour as fuel in systems such as boilers, inert gas generators, internal combustion engines, gas combustion units and gas turbines.

16.2.1 For vaporized LNG, the fuel supply system shall comply with the requirements of 16.4.1, 16.4.2 and 16.4.3.

16.2.2 For vaporized LNG, gas consumers shall exhibit no visible flame and shall maintain the uptake exhaust temperature below 535°C.

16.3 Arrangement of spaces containing gas consumers

16.3.1 Spaces in which gas consumers are located shall be fitted with a mechanical ventilation system that is arranged to avoid areas where gas may accumulate, taking into account the density of the vapour and potential ignition sources. The ventilation system shall be separated from those serving other spaces.

16.3.2 Gas detectors shall be fitted in these spaces, particularly where air circulation is reduced. The gas detection system shall comply with the requirements of chapter 13.

16.3.3 Electrical equipment located in the double wall pipe or duct specified in 16.4.3 shall comply with the requirements of chapter 10.

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.

16.4 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.

16.4.2 ***Leak detection***

Continuous monitoring and alarms shall be provided to indicate a leak in the piping system in enclosed spaces and shut down the relevant gas fuel supply.

16.4.3 ***Routeing of fuel supply pipes***

Fuel piping may pass through or extend into enclosed spaces other than those mentioned in 16.4.1, provided it fulfils one of the following conditions:

.1 it is of a double-wall design with the space between the concentric pipes pressurized with inert gas at a pressure greater than the gas fuel pressure. The master gas fuel valve, as required by 16.4.6, closes automatically upon loss of inert gas pressure; or

.2 it is installed in a pipe or duct equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour and is arranged to maintain a pressure less than the atmospheric pressure. The mechanical ventilation is in accordance with chapter 12, as applicable. The ventilation is always in operation when there is fuel in the piping and the master gas fuel valve, as required by 16.4.6, closes automatically if the required air flow is not established and maintained by the exhaust ventilation system. The inlet or the duct may be from a non-hazardous machinery space, and the ventilation outlet is in a safe location.

16.4.4 ***Requirements for gas fuel with pressure greater than 1 MPa***

16.4.4.1 Fuel delivery lines between the high-pressure fuel pumps/compressors and consumers shall be protected with a double-walled piping system capable of containing a high pressure line failure, taking into account the effects of both pressure and low temperature. A single-walled pipe in the cargo area up to the isolating valve(s) required by 16.4.6 is acceptable.

16.4.4.2 The arrangement in 16.4.3.2 may also be acceptable providing the pipe or trunk is capable of containing a high pressure line failure, according to the requirements of 16.4.7 and taking into account the effects of both pressure and possible low temperature and providing both inlet and exhaust of the outer pipe or trunk are in the cargo area.

16.4.5 ***Gas consumer isolation***

The supply piping of each gas consumer unit shall be provided with gas fuel isolation by automatic double block and bleed, vented to a safe location, under both normal and emergency operation. The automatic valves shall be arranged to fail to the closed position on loss of actuating power. In a space containing multiple consumers, the shutdown of one shall not affect the gas supply to the others.

16.4.6 ***Spaces containing gas consumers***

16.4.6.1 It shall be possible to isolate the gas fuel supply to each individual space containing a gas consumer(s) or through which fuel gas supply piping is run, with an individual master valve, which is located within the cargo area. The isolation of gas fuel supply to a space shall not affect the gas supply to other spaces containing gas consumers if they are located in two or more spaces, and it shall not cause loss of propulsion or electrical power.

16.4.6.2 If the double barrier around the gas supply system is not continuous due to air inlets or other openings, or if there is any point where single failure will cause leakage into the space, the individual master valve for the space shall operate under the following circumstances:

.1 automatically by:

.1 gas detection within the space;

.2 leak detection in the annular space of a double-walled pipe;

.3 leak detection in other compartments inside the space, containing single-walled gas piping;

.4 loss of ventilation in the annular space of a double-walled pipe; and

.5 loss of ventilation in other compartments inside the space, containing single-walled gas piping; and

.2 manually from within the space, and at least one remote location.

16.4.6.3 If the double barrier around the gas supply system is continuous, an individual master valve located in the cargo area may be provided for each gas consumer inside the space. The individual master valve shall operate under the following circumstances:

.1 automatically by:

.1 leak detection in the annular space of a double-walled pipe served by that individual master valve;

.2 leak detection in other compartments containing single-walled gas piping that is part of the supply system served by the individual master valve; and

.3 loss of ventilation or loss of pressure in the annular space of a double-walled pipe; and

.2 manually from within the space, and at least one remote location.

16.4.7 ***Piping and ducting construction***

Gas fuel piping in machinery spaces shall comply with 5.1 to 5.9, as applicable. The piping shall, as far as practicable, have welded joints. Those parts of the gas fuel piping that are not enclosed in a ventilated pipe or duct according to 16.4.3, and are on the weather decks outside the cargo area, shall have full penetration butt-welded joints and shall be fully radiographed.

16.4.8 ***Gas detection***

Gas detection systems provided in accordance with the requirements of this chapter shall activate the alarm at 30% LFL and shut down the master gas fuel valve required by 16.4.6 at not more than 60% LFL (see 13.6.17).

16.5 Gas fuel plant and related storage tanks

16.5.1 ***Provision of gas fuel***

All equipment (heaters, compressors, vaporizers, filters, etc.) for conditioning the cargo and/or cargo boil off vapour for its use as fuel, and any related storage tanks, shall be located in the cargo area. If the equipment is in an enclosed space, the space shall be ventilated according to 12.1 and be equipped with a fixed fire-extinguishing system, according to 11.5, and with a gas detection system according to 13.6, as applicable.

16.5.2 ***Remote stops***

16.5.2.1 All rotating equipment utilized for conditioning the cargo for its use as fuel shall be arranged for manual remote stop from the engine-room. Additional remote stops shall be located in areas that are always easily accessible, typically cargo control room, navigation bridge and fire control station.

16.5.2.2 The fuel supply equipment shall be automatically stopped in the case of low suction pressure or fire detection. Unless expressly provided otherwise, the requirements of 18.10 need not apply to gas fuel compressors or pumps when used to supply gas consumers.

16.5.3 ***Heating and cooling mediums***

If the heating or cooling medium for the gas fuel conditioning system is returned to spaces outside the cargo area, provisions shall be made to detect and alarm the presence of cargo/cargo vapour in the medium. Any vent outlet shall be in a safe position and fitted with an effective flame screen of an approved type.

16.5.4 ***Piping and pressure vessels***

Piping or pressure vessels fitted in the gas fuel supply system shall comply with chapter 5.

16.6 Special requirements for main boilers

16.6.1 ***Arrangements***

16.6.1.1 Each boiler shall have a separate exhaust uptake.

16.6.1.2 Each boiler shall have a dedicated forced draught system. A crossover between boiler force draught systems may be fitted for emergency use providing that any relevant safety functions are maintained.

16.6.1.3 Combustion chambers and uptakes of boilers shall be designed to prevent any accumulation of gaseous fuel.

16.6.2 ***Combustion equipment***

16.6.2.1 The burner systems shall be of dual type, suitable to burn either: oil fuel or gas fuel alone, or oil and gas fuel simultaneously.

16.6.2.2 Burners shall be designed to maintain stable combustion under all firing conditions.

16.6.2.3 An automatic system shall be fitted to change over from gas fuel operation to oil fuel operation without interruption of the boiler firing, in the event of loss of gas fuel supply.

16.6.2.4 Gas nozzles and the burner control system shall be configured such that gas fuel can only be ignited by an established oil fuel flame, unless the boiler and combustion equipment is designed and approved by recognized organization to light on gas fuel.

16.6.3 ***Safety***

16.6.3.1 There shall be arrangements to ensure that gas fuel flow to the burner is automatically cut-off, unless satisfactory ignition has been established and maintained.

16.6.3.2 On the pipe of each gas-burner, a manually operated shut-off valve shall be fitted.

16.6.3.3 Provisions shall be made for automatically purging the gas supply piping to the burners, by means of an inert gas, after the extinguishing of these burners.

16.6.3.4 The automatic fuel changeover system required by 16.6.2.3 shall be monitored with alarms to ensure continuous availability.

16.6.3.5 Arrangements shall be made that, in case of flame failure of all operating burners, the combustion chambers of the boilers are automatically purged before relighting.

16.6.3.6 Arrangements shall be made to enable the boilers to be manually purged.

16.7 Special requirements for gas-fired internal combustion engines

Dual fuel engines are those that employ gas fuel (with pilot oil) and oil fuel. Oil fuels may include distillate and residual fuels. Gas only engines are those that employ gas fuel only.

16.7.1 ***Arrangements***

16.7.1.1 When gas is supplied in a mixture with air through a common manifold, flame arrestors shall be installed before each cylinder head.

16.7.1.2 Each engine shall have its own separate exhaust.

16.7.1.3 The exhausts shall be configured to prevent any accumulation of unburnt gaseous fuel.

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.

16.7.1.5 Each engine shall be fitted with vent systems independent of other engines for crankcases, sumps and cooling systems.

16.7.2 ***Combustion equipment***

16.7.2.1 Prior to admission of gas fuel, correct operation of the pilot oil injection system on each unit shall be verified.

16.7.2.2 For a spark ignition engine, if ignition has not been detected by the engine monitoring system within an engine specific time after opening of the gas supply valve, this shall be automatically shut off and the starting sequence terminated. It shall be ensured that any unburnt gas mixture is purged from the exhaust system.

16.7.2.3 For dual-fuel engines fitted with a pilot oil injection system, an automatic system shall be fitted to change over from gas fuel operation to oil fuel operation with minimum fluctuation of the engine power.

16.7.2.4 In the case of unstable operation on engines with the arrangement in 16.7.2.3 when gas firing, the engine shall automatically change to oil fuel mode.

16.7.3 ***Safety***

16.7.3.1 During stopping of the engine, the gas fuel shall be automatically shut off before the ignition source.

16.7.3.2 Arrangements shall be provided to ensure that there is no unburnt gas fuel in the exhaust gas system prior to ignition.

16.7.3.3 Crankcases, sumps, scavenge spaces and cooling system vents shall be provided with gas detection (see 13.6.17).

16.7.3.4 Provision shall be made within the design of the engine to permit continuous monitoring of possible sources of ignition within the crank case. Instrumentation fitted inside the crankcase shall be in accordance with the requirements of chapter 10.

16.7.3.5 A means shall be provided to monitor and detect poor combustion or misfiring that may lead to unburnt gas fuel in the exhaust system during operation. In the event that it is detected, the gas fuel supply shall be shut down. Instrumentation fitted inside the exhaust system shall be in accordance with the requirements of chapter 10.

16.8 Special requirements for gas turbine

16.8.1 ***Arrangements***

16.8.1.1 Each turbine shall have its own separate exhaust.

16.8.1.2 The exhausts shall be appropriately configured to prevent any accumulation of unburnt gas fuel.

16.8.1.3 Unless designed with the strength to withstand the worst case overpressure due to ignited gas leaks, pressure relief systems shall be suitably designed and fitted to the exhaust system, taking into consideration explosions due to gas leaks. Pressure relief systems within the exhaust uptakes shall be lead to a non-hazardous location, away from personnel.

16.8.2 ***Combustion equipment***

An automatic system shall be fitted to change over easily and quickly from gas fuel operation to oil fuel operation with minimum fluctuation of the engine power.

16.8.3 ***Safety***

16.8.3.1 Means shall be provided to monitor and detect poor combustion that may lead to unburnt gas fuel in the exhaust system during operation. In the event that it is detected, the gas fuel supply shall be shut down.

16.8.3.2 Each turbine shall be fitted with an automatic shutdown device for high exhaust temperatures.

16.9 Alternative fuels and technologies

16.9.1 If acceptable to the Administration, other cargo gases may be used as fuel, providing that the same level of safety as natural gas in this Code is ensured.

16.9.2 The use of cargoes identified as toxic products shall not be permitted.

16.9.3 For cargoes other than LNG, the fuel supply system shall comply with the requirements of 16.4.1, 16.4.2, 16.4.3 and 16.5, as applicable, and shall include means for preventing condensation of vapour in the system.

16.9.4 Liquefied gas fuel supply systems shall comply with 16.4.5.

16.9.5 In addition to the requirements of 16.4.3.2, both ventilation inlet and outlet shall be in a non-hazardous area external to the machinery space.

CHAPTER 17

SPECIAL REQUIREMENTS

Goal

To set out the additional requirements in respect of specific cargoes.

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.

17.2 Materials of construction

Materials that may be exposed to cargo during normal operations shall be resistant to the corrosive action of the gases. In addition, the following materials of construction for cargo tanks and associated pipelines, valves, fittings and other items of equipment normally in direct contact with the cargo liquid or vapour shall not be used for certain products as specified in column "*i*" in the table of chapter 19:

.1 mercury, copper and copper-bearing alloys, and zinc;

.2 copper, silver, mercury, magnesium and other acetylide-forming metals;

.3 aluminium and aluminium-bearing alloys;

.4 copper, copper alloys, zinc and galvanized steel;

.5 aluminium, copper and alloys of either; and

.6 copper and copper-bearing alloys with greater than 1% copper.

17.3 Independent tanks

17.3.1 Products shall be carried in independent tanks only.

17.3.2 Products shall be carried in type C independent tanks, and the requirements of 7.1.2 shall apply. The design pressure of the cargo tank shall take into account any padding pressure or vapour discharge unloading pressure.

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 reliquefaction 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.

17.5 Cargoes requiring type 1G ship

17.5.1 All butt-welded joints in cargo piping exceeding 75 mm in diameter shall be subject to 100% radiography.

17.5.2 Gas sampling lines shall not be led into or through non-hazardous areas. Alarms referred to in 13.6.2 shall be activated when the vapour concentration reaches the threshold limiting value.

17.5.3 The alternative of using portable gas detection equipment in accordance with 13.6.5 shall not be permitted.

17.5.4 Cargo control rooms shall be located in a non-hazardous area and, additionally, all instrumentation shall be of the indirect type.

17.5.5 Personnel shall be protected against the effects of a major cargo release by the provision of a space within the accommodation area that is designed and equipped to the satisfaction of the Administration.

17.5.6 Notwithstanding the requirements in 3.2.4.3, access to forecastle spaces shall not be permitted through a door facing the cargo area, unless airlock in accordance with 3.6 is provided.

17.5.7 Notwithstanding the requirements in 3.2.7, access to control rooms and machinery spaces of turret systems shall not be permitted through doors facing the cargo area.

17.6 Exclusion of air from vapour spaces

Air shall be removed from cargo tanks and associated piping before loading and, then, subsequently excluded by:

.1 introducing inert gas to maintain a positive pressure. Storage or production capacity of the inert gas shall be sufficient to meet normal operating requirements and relief valve leakage. The oxygen content of inert gas shall, at no time, be greater than 0.2% by volume; or

.2 control of cargo temperatures such that a positive pressure is maintained at all times.

17.7 Moisture control

For gases that are non-flammable and may become corrosive or react dangerously with water, moisture control shall be provided to ensure that cargo tanks are dry before loading and that, during discharge, dry air or cargo vapour is introduced to prevent negative pressures. For the purposes of this paragraph, dry air is air that has a dew point of -45°C or below at atmospheric pressure.

17.8 Inhibition

Care shall be taken to ensure that the cargo is sufficiently inhibited to prevent self-reaction (e.g. polymerization or dimerization) at all times during the voyage. Ships shall be provided with a certificate from the manufacturer stating:

.1 name and amount of inhibitor added;

.2 date inhibitor was added and the normally expected duration of its effectiveness;

.3 any temperature limitations affecting the inhibitor; and

.4 the action to be taken should the length of the voyage exceed the effective lifetime of the inhibitors.

17.9 Flame screens on vent outlets

When carrying a cargo referenced to this section, cargo tank vent outlets shall be provided with readily renewable and effective flame screens or safety heads of an approved type. Due attention shall be paid in the design of flame screens and vent heads, to the possibility of the blockage of these devices by the freezing of cargo vapour or by icing up in adverse weather conditions. Flame screens shall be removed and replaced by protection screens, in accordance with 8.2.15, when carrying cargoes not referenced to this section.

17.10 Maximum allowable quantity of cargo per tank

When carrying a cargo referenced to this section, the quantity of the cargo shall not exceed 3,000 m^3 in any one tank.

17.11 Cargo pumps and discharge arrangements

17.11.1 The vapour space of cargo tanks equipped with submerged electric motor pumps shall be inerted to a positive pressure prior to loading, during carriage and during unloading of flammable liquids.

17.11.2 The cargo shall be discharged only by deepwell pumps or by hydraulically operated submerged pumps. These pumps shall be of a type designed to avoid liquid pressure against the shaft gland.

17.11.3 Inert gas displacement may be used for discharging cargo from type C independent tanks, provided the cargo system is designed for the expected pressure.

17.12 Ammonia

17.12.1 Anhydrous ammonia may cause stress corrosion cracking in containment and process systems made of carbon-manganese steel or nickel steel. To minimize the risk of this occurring, measures detailed in 17.12.2 to 17.12.8 shall be taken, as appropriate.

17.12.2 Where carbon-manganese steel is used, cargo tanks, process pressure vessels and cargo piping shall be made of fine-grained steel with a specified minimum yield strength not exceeding 355 N/mm^2, and with an actual yield strength not exceeding 440 N/mm^2. One of the following constructional or operational measures shall also be taken:

.1 lower strength material with a specified minimum tensile strength not exceeding 410 N/mm^2 shall be used; or

.2 cargo tanks, etc., shall be post-weld stress relief heat treated; or

.3 carriage temperature shall be maintained, preferably at a temperature close to the product's boiling point of -33°C, but in no case at a temperature above -20°C; or

.4 the ammonia shall contain not less than 0.1% w/w water, and the master shall be provided with documentation confirming this.

17.12.3 If carbon-manganese steels with higher yield properties are used other than those specified in 17.12.2, the completed cargo tanks, piping, etc., shall be given a post-weld stress relief heat treatment.

17.12.4 Process pressure vessels and piping of the condensate part of the refrigeration system shall be given a post-weld stress relief heat treatment when made of materials mentioned in 17.12.1.

17.12.5 The tensile and yield properties of the welding consumables shall exceed those of the tank or piping material by the smallest practical amount.

17.12.6 Nickel steel containing more than 5% nickel and carbon-manganese steel, not complying with the requirements of 17.12.2 and 17.12.3, are particularly susceptible to ammonia stress corrosion cracking and shall not be used in containment and piping systems for the carriage of this product.

17.12.7 Nickel steel containing not more than 5% nickel may be used, provided the carriage temperature complies with the requirements specified in 17.12.2.3.

17.12.8 To minimize the risk of ammonia stress corrosion cracking, it is advisable to keep the dissolved oxygen content below 2.5 ppm w/w. This can best be achieved by reducing the average oxygen content in the tanks prior to the introduction of liquid ammonia to less than the values given as a function of the carriage temperature *T* in the table below:

T (°C)	O_2 (% v/v)
-30 and below	0.9
-20	0.5
-10	0.28
0	0.16
10	0.1
20	0.05
30	0.03

Oxygen percentages for intermediate temperatures may be obtained by direct interpolation.

17.13 Chlorine

17.13.1 ***Cargo containment system***

17.13.1.1 The capacity of each tank shall not exceed 600 m^3 and the total capacity of all cargo tanks shall not exceed 1,200 m^3.

17.13.1.2 The tank design vapour pressure shall not be less than 1.35 MPa (see 7.1.2 and 17.3.2).

17.13.1.3 Parts of tanks protruding above the upper deck shall be provided with protection against thermal radiation, taking into account total engulfment by fire.

17.13.1.4 Each tank shall be provided with two PRVs. A bursting disc of appropriate material shall be installed between the tank and the PRVs. The rupture pressure of the bursting disc shall be 0.1 MPa lower than the opening pressure of the pressure relief valve, which shall be set at the design vapour pressure of the tank but not less than 1.35 MPa gauge. The space between the bursting disc and the relief valve shall be connected through an excess flow valve to a pressure gauge and a gas detection system. Provisions shall be made to keep this space at or near the atmospheric pressure during normal operation.

17.13.1.5 Outlets from PRVs shall be arranged in such a way as to minimize the hazards on board the ship as well as to the environment. Leakage from the relief valves shall be led through the absorption plant to reduce the gas concentration as far as possible. The relief valve exhaust line shall be arranged at the forward end of the ship to discharge outboard at deck level with an arrangement to select either port or starboard side, with a mechanical interlock to ensure that one line is always open.

17.13.1.6 The Administration and the port Administration may require that chlorine is carried in a refrigerated state at a specified maximum pressure.

17.13.2 ***Cargo piping systems***

17.13.2.1 Cargo discharge shall be performed by means of compressed chlorine vapour from shore, dry air or another acceptable gas, or fully submerged pumps. Cargo discharge compressors on board ships shall not be used for this. The pressure in the vapour space of the tank during discharging shall not exceed 1.05 MPa gauge.

17.13.2.2 The design pressure of the cargo piping system shall be not less than 2.1 MPa gauge. The internal diameter of the cargo pipes shall not exceed 100 mm. Only pipe bends shall be accepted for compensation of pipeline thermal movement. The use of flanged joints shall be restricted to a minimum and, when used, the flanges shall be of the welding neck type with tongue and groove.

17.13.2.3 Relief valves of the cargo piping system shall discharge to the absorption plant, and the flow restriction created by this unit shall be taken into account when designing the relief valve system (see 8.4.3 and 8.4.4).

17.13.3 ***Materials***

17.13.3.1 The cargo tanks and cargo piping systems shall be made of steel suitable for the cargo and for a temperature of -40°C, even if a higher transport temperature is intended to be used.

17.13.3.2 The tanks shall be thermally stress relieved. Mechanical stress relief shall not be accepted as an equivalent.

17.13.4 ***Instrumentation: safety devices***

17.13.4.1 The ship shall be provided with a chlorine absorbing plant with a connection to the cargo piping system and the cargo tanks. The absorbing plant shall be capable of neutralizing at least 2% of the total cargo capacity at a reasonable absorption rate.

17.13.4.2 During the gas-freeing of cargo tanks, vapours shall not be discharged to the atmosphere.

17.13.4.3 A gas detecting system shall be provided that is capable of monitoring chlorine concentrations of at least 1 ppm by volume. Sample points shall be located:

.1 near the bottom of the hold spaces;

.2 in the pipes from the safety relief valves;

.3 at the outlet from the gas absorbing plant;

.4 at the inlet to the ventilation systems for the accommodation, service and machinery spaces and control stations; and

.5 on deck – at the forward end, midships and the after end of the cargo area. This is only required to be used during cargo handling and gas-freeing operations.

The gas detection system shall be provided with an audible and visual alarm with a set point of 5 ppm.

17.13.4.4 Each cargo tank shall be fitted with a high-pressure alarm giving an audible alarm at a pressure equal to 1.05 MPa gauge.

17.13.5 ***Personnel protection***

The enclosed space required by 17.5.5 shall meet the following requirements:

.1 the space shall be easily and quickly accessible from the weather decks and from accommodation spaces by means of air locks, and shall be capable of being rapidly closed gastight;

.2 one of the decontamination showers required by 14.4.3 shall be located near the weather deck airlock to the space;

.3 the space shall be designed to accommodate the entire crew of the ship and be provided with a source of uncontaminated air for a period of not less than 4 h; and

.4 one set of oxygen therapy equipment shall be carried in the space.

17.13.6 ***Filling limits for cargo tanks***

17.13.6.1 The requirements of 15.1.3.2 do not apply when it is intended to carry chlorine.

17.13.6.2 The chlorine content of the gas in the vapour space of the cargo tank after loading shall be greater than 80% by volume.

17.14 Ethylene oxide

17.14.1 For the carriage of ethylene oxide, the requirements of 17.18 shall apply, with the additions and modifications as given in this section.

17.14.2 Deck tanks shall not be used for the carriage of ethylene oxide.

17.14.3 Stainless steels types 416 and 442, as well as cast iron, shall not be used in ethylene oxide cargo containment and piping systems.

17.14.4 Before loading, tanks shall be thoroughly and effectively cleaned to remove all traces of previous cargoes from tanks and associated pipework, except where the immediate prior cargo has been ethylene oxide, propylene oxide or mixtures of these products. Particular care shall be taken in the case of ammonia in tanks made of steel other than stainless steel.

17.14.5 Ethylene oxide shall be discharged only by deepwell pumps or inert gas displacement. The arrangement of pumps shall comply with 17.18.15.

17.14.6 Ethylene oxide shall be carried refrigerated only and maintained at temperatures of less than 30°C.

17.14.7 PRVs shall be set at a pressure of not less than 0.55 MPa gauge. The maximum set pressure shall be specially approved by the Administration.

17.14.8 The protective padding of nitrogen gas, as required by 17.18.27, shall be such that the nitrogen concentration in the vapour space of the cargo tank will, at no time, be less than 45% by volume.

17.14.9 Before loading, and at all times when the cargo tank contains ethylene oxide liquid or vapour, the cargo tank shall be inerted with nitrogen.

17.14.10 The water-spray system required by 17.18.29 and that required by 11.3 shall operate automatically in a fire involving the cargo containment system.

17.14.11 A jettisoning arrangement shall be provided to allow the emergency discharge of ethylene oxide in the event of uncontrollable self-reaction.

17.15 Separate piping systems

Separate piping systems, as defined in 1.2.47, shall be provided.

17.16 Methyl acetylene-propadiene mixtures

17.16.1 Methyl acetylene-propadiene mixtures shall be suitably stabilized for transport. Additionally, upper limits of temperatures and pressure during the refrigeration shall be specified for the mixtures.

17.16.2 Examples of acceptable stabilized compositions are:

.1 Composition 1:

.1 maximum methyl acetylene to propadiene molar ratio of 3 to 1;

.2 maximum combined concentration of methyl acetylene and propadiene of 65 mol%;

.3 minimum combined concentration of propane, butane, and isobutane of 24 mol%, of which at least one third (on a molar basis) shall be butanes and one third propane;

.4 maximum combined concentration of propylene and butadiene of 10 mol%;

.2 Composition 2:

.1 maximum methyl acetylene and propadiene combined concentration of 30 mol%;

.2 maximum methyl acetylene concentration of 20 mol%;

.3 maximum propadiene concentration of 20 mol%;

.4 maximum propylene concentration of 45 mol%;

.5 maximum butadiene and butylenes combined concentration of 2 mol%;

.6 minimum saturated C4 hydrocarbon concentration of 4 mol%; and

.7 minimum propane concentration of 25 mol%.

17.16.3 Other compositions may be accepted, provided the stability of the mixture is demonstrated to the satisfaction of the Administration.

17.16.4 If a ship has a direct vapour compression refrigeration system, this shall comply with the following requirements, subject to pressure and temperature limitations depending on the composition. For the example compositions given in 17.16.2, the following features shall be provided:

.1 a vapour compressor that does not raise the temperature and pressure of the vapour above 60ºC and 1.75 MPa gauge during its operation, and that does not allow vapour to stagnate in the compressor while it continues to run;

.2 discharge piping from each compressor stage or each cylinder in the same stage of a reciprocating compressor shall have:

.1 two temperature-actuated shutdown switches set to operate at 60ºC or less;

.2 a pressure-actuated shutdown switch set to operate at 1.75 MPa gauge or less; and

.3 a safety relief valve set to relieve at 1.8 MPa gauge or less;

.3 the relief valve required by .2.3 shall vent to a mast meeting the requirements of 8.2.10, 8.2.11 and 8.2.15 and shall not relieve into the compressor suction line; and

.4 an alarm that sounds in the cargo control position and in the navigation bridge when a high-pressure switch, or a high-temperature switch, operates.

17.16.5 The piping system, including the cargo refrigeration system, for tanks to be loaded with methyl acetylene-propadiene mixtures shall be either independent (as defined in 1.2.28) or separate (as defined in 1.2.47) from piping and refrigeration systems for other tanks. This segregation shall apply to all liquid and vapour vent lines and any other possible connections, such as common inert gas supply lines.

17.17 Nitrogen

Materials of construction and ancillary equipment such as insulation shall be resistant to the effects of high oxygen concentrations caused by condensation and enrichment at the low temperatures attained in parts of the cargo system. Due consideration shall be given to ventilation in areas where condensation might occur, to avoid the stratification of oxygen-enriched atmosphere.

17.18 Propylene oxide and mixtures of ethylene oxide-propylene oxide with ethylene oxide content of not more than 30% by weight

17.18.1 Products transported under the provisions of this section shall be acetylene-free.

17.18.2 Unless cargo tanks are properly cleaned, these products shall not be carried in tanks that have contained as one of the three previous cargoes any product known to catalyse polymerization, such as:

.1 anhydrous ammonia and ammonia solutions;

.2 amines and amine solutions; and

.3 oxidizing substances (e.g. chlorine).

17.18.3 Before loading, tanks shall be thoroughly and effectively cleaned to remove all traces of previous cargoes from tanks and associated pipework, except where the immediate prior cargo has been propylene oxide or ethylene oxide-propylene oxide mixtures. Particular care shall be taken in the case of ammonia in tanks made of steel other than stainless steel.

17.18.4 In all cases, the effectiveness of cleaning procedures for tanks and associated pipework shall be checked, by suitable testing or inspection, to ascertain that no traces of acidic or alkaline materials remain that might create a hazardous situation in the presence of these products.

17.18.5 Tanks shall be entered and inspected prior to each initial loading of these products to ensure freedom from contamination, heavy rust deposits and any visible structural defects. When cargo tanks are in continuous service for these products, such inspections shall be performed at intervals of not more than two years.

17.18.6 Tanks for the carriage of these products shall be of steel or stainless steel construction.

17.18.7 Tanks that have contained these products may be used for other cargoes after thorough cleaning of tanks and associated pipework systems by washing or purging.

17.18.8 All valves, flanges, fittings and accessory equipment shall be of a type suitable for use with these products and shall be constructed of steel or stainless steel in accordance with recognized standards. Disc or disc faces, seats and other wearing parts of valves shall be made of stainless steel containing not less than 11% chromium.

17.18.9 Gaskets shall be constructed of materials which do not react with, dissolve in, or lower the auto-ignition temperature of, these products and which are fire-resistant and possess adequate mechanical behaviour. The surface presented to the cargo shall be polytetrafluoroethylene (PTFE) or materials giving a similar degree of safety by their inertness. Spirally-wound stainless steel with a filler of PTFE or similar fluorinated polymer may be accepted, if approved by the Administration or recognized organization acting on its behalf.

17.18.10 Insulation and packing, if used, shall be of a material which does not react with, dissolve in, or lower the auto-ignition temperature of, these products.

17.18.11 The following materials are generally found unsatisfactory for use in gaskets, packing and similar uses in containment systems for these products and would require testing before being approved:

.1 neoprene or natural rubber, if it comes into contact with the products;

.2 asbestos or binders used with asbestos; and

.3 materials containing oxides of magnesium, such as mineral wools.

17.18.12 Filling and discharge piping shall extend to within 100 mm of the bottom of the tank or any sump.

17.18.13 The products shall be loaded and discharged in such a manner that venting of the tanks to atmosphere does not occur. If vapour return to shore is used during tank loading, the vapour return system connected to a containment system for the product shall be independent of all other containment systems.

17.18.14 During discharging operations, the pressure in the cargo tank shall be maintained above 0.007 MPa gauge.

17.18.15 The cargo shall be discharged only by deepwell pumps, hydraulically operated submerged pumps or inert gas displacement. Each cargo pump shall be arranged to ensure that the product does not heat significantly if the discharge line from the pump is shut off or otherwise blocked.

17.18.16 Tanks carrying these products shall be vented independently of tanks carrying other products. Facilities shall be provided for sampling the tank contents without opening the tank to atmosphere.

17.18.17 Cargo hoses used for transfer of these products shall be marked "FOR ALKYLENE OXIDE TRANSFER ONLY".

17.18.18 Hold spaces shall be monitored for these products. Hold spaces surrounding type A and type B independent tanks shall also be inerted and monitored for oxygen. The oxygen content of these spaces shall be maintained below 2% by volume. Portable sampling equipment is satisfactory.

17.18.19 Prior to disconnecting shore lines, the pressure in liquid and vapour lines shall be relieved through suitable valves installed at the loading header. Liquid and vapour from these lines shall not be discharged to atmosphere.

17.18.20 Tanks shall be designed for the maximum pressure expected to be encountered during loading, carriage or unloading of cargo.

17.18.21 Tanks for the carriage of propylene oxide with a design vapour pressure of less than 0.06 MPa, and tanks for the carriage of ethylene oxide-propylene oxide mixtures with a design vapour pressure of less than 0.12 MPa, shall have a cooling system to maintain the cargo below the reference temperature. The reference temperatures are referred to in 15.1.3.

17.18.22 Pressure relief valve settings shall not be less than 0.02 MPa gauge; and for type C independent tanks not greater than 0.7 MPa gauge for the carriage of propylene oxide and not greater than 0.53 MPa gauge for the carriage of ethylene oxide-propylene oxide mixtures.

17.18.23 The piping system for tanks to be loaded with these products shall be completely separate from piping systems for all other tanks, including empty tanks, and from all cargo compressors. If the piping system for the tanks to be loaded with these products is not independent, as defined in 1.2.28, the required piping separation shall be accomplished by the removal of spool pieces, valves, or other pipe sections and the installation of blank flanges at these locations. The required separation applies to all liquid and vapour piping, liquid and vapour vent lines and any other possible connections such as common inert gas supply lines.

17.18.24 The products shall be transported only in accordance with cargo handling plans approved by the Administration. Each intended loading arrangement shall be shown on a separate cargo handling plan. Cargo handling plans shall show the entire cargo piping system and the locations for installation of the blank flanges needed to meet the above piping separation requirements. A copy of each approved cargo handling plan shall be kept on board the ship. The International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk shall be endorsed to include references to the approved cargo handling plans.

17.18.25 Before each initial loading of these products, and before every subsequent return to such service, certification verifying that the required piping separation has been achieved shall be obtained from a responsible person acceptable to the port Administration and carried on board the ship. Each connection between a blank flange and pipeline flange shall be fitted with a wire and seal by the responsible person to ensure that inadvertent removal of the blank flange is impossible.

17.18.26 The maximum allowable loading limits for each tank shall be indicated for each loading temperature that may be applied, in accordance with 15.5.

17.18.27 The cargo shall be carried under a suitable protective padding of nitrogen gas. An automatic nitrogen make-up system shall be installed to prevent the tank pressure falling below 0.007 MPa gauge in the event of product temperature fall due to ambient conditions or malfunctioning of refrigeration system. Sufficient nitrogen shall be available on board to satisfy the demand of the automatic pressure control. Nitrogen of commercially pure quality (99.9% by volume) shall be used for padding. A battery of nitrogen bottles, connected to the cargo tanks through a pressure reduction valve, satisfies the intention of the expression "automatic" in this context.

17.18.28 The cargo tank vapour space shall be tested prior to and after loading to ensure that the oxygen content is 2% by volume or less.

17.18.29 A water-spray system of sufficient capacity shall be provided to blanket effectively the area surrounding the loading manifold, the exposed deck piping associated with product handling and the tank domes. The arrangement of piping and nozzles shall be such as to give a uniform distribution rate of 10//m^2/min. The arrangement shall ensure that any spilled cargo is washed away.

17.18.30 The water-spray system shall be capable of local and remote manual operation in case of a fire involving the cargo containment system. Remote manual operation shall be arranged such that the remote starting of pumps supplying the water-spray system and remote operation of any normally closed valves in the system can be carried out from a suitable location outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the areas protected.

17.18.31 When ambient temperatures permit, a pressurized water hose ready for immediate use shall be available during loading and unloading operations, in addition to the above water-spray requirements.

17.19 Vinyl chloride

In cases where polymerization of vinyl chloride is prevented by addition of an inhibitor, 17.8 is applicable. In cases where no inhibitor has been added, or the inhibitor concentration is insufficient, any inert gas used for the purposes of 17.6 shall contain no more oxygen than 0.1% by volume. Before loading is started, inert gas samples from the tanks and piping shall be analysed. When vinyl chloride is carried, a positive pressure shall always be maintained in the tanks and during ballast voyages between successive carriages.

17.20 Mixed C4 cargoes

17.20.1 Cargoes that may be carried individually under the requirements of this Code, notably butane, butylenes and butadiene, may be carried as mixtures subject to the provisions of this section. These cargoes may variously be referred to as "Crude C4", "Crude butadiene", "Crude steam-cracked C4", "Spent steam-cracked C4", "C4 stream", "C4 raffinate", or may be shipped under a different description. In all cases, the material safety data sheets (MSDS) shall be consulted as the butadiene content of the mixture is of prime concern as it is potentially toxic and reactive. While it is recognized that butadiene has a relatively low vapour pressure, if such mixtures contain butadiene they shall be regarded as toxic and the appropriate precautions applied.

17.20.2 If the mixed C4 cargo shipped under the terms of this section contains more than 50% (mole) of butadiene, the inhibitor precautions in 17.8 shall apply.

17.20.3 Unless specific data on liquid expansion coefficients is given for the specific mixture loaded, the filling limit restrictions of chapter 15 shall be calculated as if the cargo contained 100% concentration of the component with the highest expansion ratio.

17.21 Carbon dioxide: high purity

17.21.1 Uncontrolled pressure loss from the cargo can cause "sublimation" and the cargo will change from the liquid to the solid state. The precise "triple point" temperature of a particular carbon dioxide cargo shall be supplied before loading the cargo, and will depend on the purity of that cargo, and this shall be taken into account when cargo instrumentation is adjusted. The set pressure for the alarms and automatic actions described in this section shall be set to at least 0.05 MPa above the triple point for the specific cargo being carried. The "triple point" for pure carbon dioxide occurs at 0.5 MPa gauge and -54.4°C.

17.21.2 There is a potential for the cargo to solidify in the event that a cargo tank relief valve, fitted in accordance with 8.2, fails in the open position. To avoid this, a means of isolating the cargo tank safety valves shall be provided and the requirements of 8.2.9.2 do not apply when carrying this carbon dioxide. Discharge piping from safety relief valves shall be designed so they remain free from obstructions that could cause clogging. Protective screens shall not be fitted to the outlets of relief valve discharge piping, so the requirements of 8.2.15 do not apply.

17.21.3 Discharge piping from safety relief valves are not required to comply with 8.2.10, but shall be designed so they remain free from obstructions that could cause clogging. Protective screens shall not be fitted to the outlets of relief valve discharge piping, so the requirements of 8.2.15 do not apply.

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.

17.21.5 All materials used in cargo tanks and cargo piping system shall be suitable for the lowest temperature that may occur in service, which is defined as the saturation temperature of the carbon dioxide cargo at the set pressure of the automatic safety system described in 17.21.1.

17.21.6 Cargo hold spaces, cargo compressor rooms and other enclosed spaces where carbon dioxide could accumulate shall be fitted with continuous monitoring for carbon dioxide build-up. This fixed gas detection system replaces the requirements of 13.6, and hold spaces shall be monitored permanently even if the ship has type C cargo containment.

17.22 Carbon dioxide: reclaimed quality

17.22.1 The requirements of 17.21 also apply to this cargo. In addition, the materials of construction used in the cargo system shall also take account of the possibility of corrosion, in case the reclaimed quality carbon dioxide cargo contains impurities such as water, sulphur dioxide, etc., which can cause acidic corrosion or other problems.

CHAPTER 18

OPERATING REQUIREMENTS

Goal

To ensure that all ship staff involved in cargo operations have sufficient information about cargo properties and operating the cargo system so they can conduct cargo operations safely.

18.1 General

18.1.1 Those involved in liquefied gas carrier operations shall be made aware of the special requirements associated with, and precautions necessary for, their safe operation.

18.1.2 A copy of the Code, or national regulations incorporating the provisions of the Code, shall be on board every ship covered by the Code.

18.2 Cargo operations manuals

18.2.1 The ship shall be provided with copies of suitably detailed cargo system operation manuals approved by the Administration such that trained personnel can safely operate the ship with due regard to the hazards and properties of the cargoes that are permitted to be carried.

18.2.2 The content of the manuals shall include, but not be limited to:

.1 overall operation of the ship from dry-dock to dry-dock, including procedures for cargo tank cooldown and warm-up, transfer (including ship-to-ship transfer), cargo sampling, gas-freeing, ballasting, tank cleaning and changing cargoes;

.2 cargo temperature and pressure control systems;

.3 cargo system limitations, including minimum temperatures (cargo system and inner hull), maximum pressures, transfer rates, filling limits and sloshing limitations;

.4 nitrogen and inert gas systems;

.5 firefighting procedures: operation and maintenance of firefighting systems and use of extinguishing agents;

.6 special equipment needed for the safe handling of the particular cargo;

.7 fixed and portable gas detection;

.8 control, alarm and safety systems;

.9 emergency shutdown systems;

.10 procedures to change cargo tank pressure relief valve set pressures in accordance with 8.2.8 and 4.13.2.3; and

.11 emergency procedures, including cargo tank relief valve isolation, single tank gas-freeing and entry and emergency ship-to-ship transfer operations.

18.3 Cargo information

18.3.1 Information shall be on board and available to all concerned in the form of a cargo information data sheet(s) giving the necessary data for the safe carriage of cargo. Such information shall include, for each product carried:

.1 a full description of the physical and chemical properties necessary for the safe carriage and containment of the cargo;

.2 reactivity with other cargoes that are capable of being carried on board in accordance with the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk;

.3 the actions to be taken in the event of cargo spills or leaks;

.4 countermeasures against accidental personal contact;

.5 firefighting procedures and firefighting media;

.6 special equipment needed for the safe handling of the particular cargo; and

.7 emergency procedures.

18.3.2 The physical data supplied to the master, in accordance with 18.3.1.1, shall include information regarding the relative cargo density at various temperatures to enable the calculation of cargo tank filling limits in accordance with the requirements of chapter 15.

18.3.3 Contingency plans in accordance with 18.3.1.3, for spillage of cargo carried at ambient temperature, shall take account of potential local temperature reduction such as when the escaped cargo has reduced to atmospheric pressure and the potential effect of this cooling on hull steel.

18.4 Suitability for carriage

18.4.1 The master shall ascertain that the quantity and characteristics of each product to be loaded are within the limits indicated in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk required by 1.4, and in the Loading and Stability Information booklet required by 2.2.5, and that products are listed in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk as required under section 4 of the certificate.

18.4.2 Care shall be taken to avoid dangerous chemical reactions if cargoes are mixed. This is of particular significance in respect of:

.1 tank cleaning procedures required between successive cargoes in the same tank; and

.2 simultaneous carriage of cargoes that react when mixed. This shall be permitted only if the complete cargo systems including, but not limited to, cargo pipework, tanks, vent systems and refrigeration systems are separated as defined in 1.2.47.

18.4.3 Where products are required to be inhibited, the certificate required by 17.8 shall be supplied before departure, otherwise the cargo shall not be transported.

18.5 Carriage of cargo at low temperature

When carrying cargoes at low temperatures:

.1 the cooldown procedure laid down for that particular tank, piping and ancillary equipment shall be followed closely;

.2 loading shall be carried out in such a manner as to ensure that design temperature gradients are not exceeded in any cargo tank, piping or other ancillary equipment; and

.3 if provided, the heating arrangements associated with the cargo containment systems shall be operated in such a manner as to ensure that the temperature of the hull structure does not fall below that for which the material is designed.

18.6 Cargo transfer operations

18.6.1 A pre-cargo operations meeting shall take place between ship personnel and the persons responsible at the transfer facility. Information exchanged shall include the details of the intended cargo transfer operations and emergency procedures. A recognized industry checklist shall be completed for the intended cargo transfer and effective communications shall be maintained throughout the operation.

18.6.2 Essential cargo handling controls and alarms shall be checked and tested prior to cargo transfer operations.

18.7 Personnel training

18.7.1 Personnel shall be adequately trained in the operational and safety aspects of liquefied gas carriers as required by the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, as amended, the International Safety Management Code and the Medical First Aid Guide (MFAG). As a minimum:

.1 all personnel shall be adequately trained in the use of protective equipment provided on board and have basic training in the procedures, appropriate to their duties, necessary under emergency conditions; and

.2 officers shall be trained in emergency procedures to deal with conditions of leakage, spillage or fire involving the cargo and a sufficient number of them shall be instructed and trained in essential first aid for the cargoes carried.

18.8 Entry into enclosed spaces

18.8.1 Under normal operational circumstances, personnel shall not enter cargo tanks, hold spaces, void spaces or other enclosed spaces where gas may accumulate, unless the gas content of the atmosphere in such space is determined by means of fixed or portable equipment to ensure oxygen sufficiency and the absence of toxic atmosphere.

18.8.2 If it is necessary to gas-free and aerate a hold space surrounding a type A cargo tank for routine inspection, and flammable cargo is carried in the cargo tank, the inspection shall be conducted when the tank contains only the minimum amount of cargo "heel" to keep the cargo tank cold. The hold shall be re-inerted as soon as the inspection is completed.

18.8.3 Personnel entering any space designated as a hazardous area on a ship carrying flammable products shall not introduce any potential source of ignition into the space, unless it has been certified gas-free and is maintained in that condition.

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.

18.10 Cargo emergency shutdown (ESD) system

18.10.1 ***General***

18.10.1.1 A cargo emergency shutdown system shall be fitted to stop cargo flow in the event of an emergency, either internally within the ship, or during cargo transfer to ship or shore. The design of the ESD system shall avoid the potential generation of surge pressures within cargo transfer pipe work (see 18.10.2.1.4).

18.10.1.2 Auxiliary systems for conditioning the cargo that use toxic or flammable liquids or vapours shall be treated as cargo systems for the purposes of ESD. Indirect refrigeration systems using an inert medium, such as nitrogen, need not be included in the ESD function.

18.10.1.3 The ESD system shall be activated by the manual and automatic initiations listed in table 18.1. Any additional initiations shall only be included in the ESD system if it can be shown that their inclusion does not reduce the integrity and reliability of the system overall.

18.10.1.4 Ship's ESD systems shall incorporate a ship-shore link in accordance with recognized standards.

18.10.1.5 A functional flow chart of the ESD system and related systems shall be provided in the cargo control station and on the navigation bridge.

18.10.2 ***ESD valve requirements***

18.10.2.1 General

18.10.2.1.1 The term *ESD valve* means any valve operated by the ESD system.

18.10.2.1.2 ESD valves shall be remotely operated, be of the fail-closed type (closed on loss of actuating power), be capable of local manual closure and have positive indication of the actual valve position. As an alternative to the local manual closing of the ESD valve, a manually operated shut-off valve in series with the ESD valve shall be permitted. The manual valve shall be located adjacent to the ESD valve. Provisions shall be made to handle trapped liquid should the ESD valve close while the manual valve is also closed.

18.10.2.1.3 ESD valves in liquid piping systems shall close fully and smoothly within 30 s of actuation. Information about the closure time of the valves and their operating characteristics shall be available on board, and the closing time shall be verifiable and repeatable.

18.10.2.1.4 The closing time of the valve referred to in 13.3.1 to 13.3.3 (i.e. time from shutdown signal initiation to complete valve closure) shall not be greater than:

$$\frac{3600U}{LR} \quad \text{(second)}$$

where:

U = ullage volume at operating signal level (m^3);

LR = maximum loading rate agreed between ship and shore facility (m^3/h).

The loading rate shall be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the loading hose or arm, the ship and the shore piping systems, where relevant.

18.10.2.2 Ship-shore and ship-ship manifold connections

One ESD valve shall be provided at each manifold connection. Cargo manifold connections not being used for transfer operations shall be blanked with blank flanges rated for the design pressure of the pipeline system.

18.10.2.3 Cargo system valves

If cargo system valves as defined in section 5.5 are also ESD valves within the meaning of 18.10, then the requirements of 18.10 shall apply.

18.10.3 ***ESD system controls***

18.10.3.1 As a minimum, the ESD system shall be capable of manual operation by a single control on the bridge and either in the control position required by 13.1.2 or the cargo control room, if installed, and no less than two locations in the cargo area.

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.

18.10.3.3 Cargo machinery that is running shall be stopped by activation of the ESD system in accordance with the cause and effect matrix in table 18.1.

18.10.3.4 The ESD control system shall be configured so as to enable the high-level testing required in 13.3.5 to be carried out in a safe and controlled manner. For the purpose of the testing, cargo pumps may be operated while the overflow control system is overridden. Procedures for level alarm testing and re-setting of the ESD system after completion of the high-level alarm testing shall be included in the operation manual required by 18.2.1.

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.

18.10.4 ***Additional shutdowns***

18.10.4.1 The requirements of 8.3.1.1 to protect the cargo tank from external differential pressure may be fulfilled by using an independent low pressure trip to activate the ESD system, or, as minimum, to stop any cargo pumps or compressors.

18.10.4.2 An input to the ESD system from the overflow control system required by 13.3 may be provided to stop any cargo pumps or compressors' running at the time a high level is detected, as this alarm may be due to inadvertent internal transfer of cargo from tank to tank.

18.10.5 ***Pre-operations testing***

Cargo emergency shutdown and alarm systems involved in cargo transfer shall be checked and tested before cargo handling operations begin.

18.11 Hot work on or near cargo containment systems

18.11.1 Special fire precautions shall be taken in the vicinity of cargo tanks and, particularly, insulation systems that may be flammable or contaminated with hydrocarbons or that may give off toxic fumes as a product of combustion.

18.12 Additional operating requirements

Additional operating requirements will be found in the following paragraphs of the Code: 2.2.2, 2.2.5, 2.2.8, 3.8.4, 3.8.5, 5.3.2, 5.3.3.3, 5.7.3, 7.1, 8.2.7, 8.2.8, 8.2.9, 9.2, 9.3, 9.4.4, 12.1.1, 13.1.3, 13.3.6, 13.6.18, 14.3.3, 15.3, 15.6, 16.6.3, 17.4.2, 17.6, 17.7, 17.9, 17.10, 17.11, 17.12, 17.13, 17.14, 17.16, 17.18, 17.19, 17.21, 17.22.

CHAPTER 19

SUMMARY OF MINIMUM REQUIREMENTS

Explanatory notes to the summary of minimum requirements

Product name *(column a)*	The product name shall be used in the shipping document for any cargo offered for bulk shipments. Any additional name may be included in brackets after the product name. In some cases, the product names are not identical with the names given in previous issues of the Code.
(column b)	*Deleted*
Ship type *(column c)*	1: Ship type 1G (2.1.2.1) 2: Ship type 2G (2.1.2.2) 3: Ship type 2PG (2.1.2.3) 4: Ship type 3G (2.1.2.4)
Independent tank type C required *(column d)*	Type C independent tank (4.23)
Tank environmental control *(column e)*	Inert: Inerting (9.4) Dry: Drying (17.7) - : No special requirements under the Code
Vapour detection *(column f)*	F: Flammable vapour detection T: Toxic vapour detection F+T: Flammable and toxic vapour detection A: Asphixiant
Gauging *(column g)*	I: Indirect or closed (13.2.3.1 and .2) R: Indirect, closed or restricted (13.2.3.1, .2, .3 and .4) C: Indirect or closed (13.2.3.1, .2 and .3)
(column h)	*Deleted*
Special requirements *(column i)*	When specific reference is made to chapters 14 and/or 17, these requirements shall be additional to the requirements in any other column.
Refrigerant gases	Non-toxic and non-flammable gases

Unless otherwise specified, gas mixtures containing less than 5% total acetylenes may be transported with no further requirements than those provided for the major components.

a ***Product name***	*b*	*c* ***Ship type***	*d* ***Independent tank type C required***	*e* ***Control of vapour space within cargo tanks***	*f* ***Vapour detection***	*g* ***Gauging***	*h*	*i* ***Special requirements***
Acetaldehyde		2G/2PG	-	Inert	F + T	C		14.4.2, 14.3.3.1, 17.4.1, 17.6.1
Ammonia, anhydrous		2G/2PG	-	-	T	C		14.4, 17.2.1, 17.12
Butadiene (all isomers)		2G/2PG	-	-	F + T	C		14.4, 17.2.2, 17.4.2, 17.4.3, 17.6, 17.8
Butane (all isomers)		2G/2PG	-	-	F	R		
Butane-propane mixture		2G/2PG	-	-	F	R		
Butylenes (all isomers)		2G/2PG	-	-	F	R		
Carbon Dioxide (high purity)		3G	-	-	A	R		17.21
Carbon Dioxide (Reclaimed quality)		3G	-	-	A	R		17.22
Chlorine		1G	Yes	Dry	T	I		14.4, 17.3.2, 17.4.1, 17.5, 17.7, 17.9, 17.13
Diethyl ether*		2G/2PG	-	Inert	F + T	C		14.4.1, 14.4.2, 17.2.6, 17.3.1, 17.6.1, 17.9, 17.10, 17.11.2, 17.11.3
Dimethylamine		2G/2PG	-	-	F + T	C		14.4, 17.2.1
Dimethyl Ether		2G/2PG			F + T	C		
Ethane		2G	-	-	F	R		
Ethyl Chloride		2G/2PG	-	-	F +T	C		
Ethylene		2G	-	-	F	R		
Ethylene oxide		1G	Yes	Inert	F +T	C		14.4, 17.2.2, 17.3.2, 17.4.1, 17.5, 17.6.1, 17.14
Ethylene oxide-propylene oxide mixtures with		2G/2PG	-	Inert	F +T	C		14.4.2, 17.3.1, 17.4.1, 17.6.1, 17.9, 17.10, 17.18

a ***Product name***	*b*	*c* ***Ship type***	*d* ***Independent tank type C required***	*e* ***Control of vapour space within cargo tanks***	*f* ***Vapour detection***	*g* ***Gauging***	*h*	*i* ***Special requirements***
ethylene oxide content of not more than 30% by weight*								
Isoprene* (all isomers)		2G/2PG	-	-	F	R		14.4.2, 17.8, 17.9, 17.11.1
Isoprene (part refined)*		2G/2PG	-	-	F	R		14.4.2, 17.8, 17.9, 17.11.1
Isopropylamine*		2G/2PG	-	-	F +T	C		14.4.1, 14.4.2, 17.2.4, 17.9, 17.10, 17.11.1, 17.15
Methane (LNG)		2G	-	-	F	C		
Methyl acetylene-propadiene mixtures		2G/2PG	-	-	F	R		17.16
Methyl bromide		1G	Yes	-	F + T	C		14.4, 17.2.3, 17.3.2, 17.4.1, 17.5
Methyl chloride		2G/ 2PG	-	-	F + T	C		17.2.3
Mixed C4 Cargoes		2G/2PG	-	-	F + T	C		14.4, 17.2.2, 17.4.2, 17.4.3, 17.6, 17.20
Monoethylamine*		2G/2PG	-	-	F + T	C		14.4, 17.2.1, 17.3.1, 17.9, 17.10, 17.11.1, 17.15
Nitrogen		3G	-	-	A	C		17.17
Pentane (all isomers)*		2G/2PG	-	-	F	R		17.9, 17.11
Pentene (all isomers)*		2G/2PG	-	-	F	R		17.9, 17.11
Propane		2G/2PG	-	-	F	R		
Propylene		2G/2PG	-	-	F	R		
Propylene oxide*		2G/2PG	-	Inert	F + T	C		14.4.2, 17.3.1, 17.4.1, 17.6.1, 17.9, 17.10, 17.18

a ***Product name***	*b*	*c* ***Ship type***	*d* ***Independent tank type C required***	*e* ***Control of vapour space within cargo tanks***	*f* ***Vapour detection***	*g* ***Gauging***	*h*	*i* ***Special requirements***
Refrigerant gases		3G	-	-	-	R		
Sulphur dioxide		1G	Yes	Dry	T	C		14.4, 17.3.2, 17.4.1, 17.5, 17.7
Vinyl chloride		2G/2PG	-	-	F + T	C		14.4.1, 14.4.2, 17.2.2, 17.2.3, 17.3.1, 17.6, 17.19
Vinyl ethyl ether*		2G/2PG	-	Inert	F + T	C		14.4.1, 14.4.2, 17.2.2, 17.3.1, 17.6.1, 17.8, 17.9, 17.10, 17.11.2, 17.11.3
Vinylidene chloride*		2G/2PG	-	Inert	F + T	C		14.4.1, 14.4.2, 17.2.5, 17.6.1, 17.8, 17.9, 17.10

* This cargo is also covered by the IBC Code.

APPENDIX 1

IGC CODE PRODUCT DATA REPORTING FORM

Characteristics of products proposed for transport on the IGC Code ships

1 PRODUCT IDENTITY

Product name

The product name should be used in the shipping document for any cargo offered for bulk shipments. Any additional name may be included in brackets after the product name.

1.1 Other names and identification numbers

Main trade name : _____
Main chemical name : _____
Chemical formula : _____
C.A.S number : _____
EHS number : _____
BMR number : _____
RTECS number : _____

1.2 Associated synonyms

Structure

Synonym name	Type

1.3 Composition

Component name	%	Type

2 Physical properties

Property	Units	Qual	Lower value	Upper value	Reference/ comments
Molecular weight					
Density at 20°C	(kg/m^3)				
Flash point (c.c.)	(°C)				
Boiling point	(°C)				
Water solubility at 20°C	(mg/l)				
Vapour pressure at 20°C	(Pa)				
Auto-ignition temperature	(°C)				
Explosion limits	(% v/v)				
MESG	(mm)				

3 Relevant chemical properties

Water reactivity (0 - 2)

0 = No reactivity
1 = Reactive
2 = Highly

Details

Does the product react with air to cause a potentially hazardous situation (Y/N)

If so, provide details

Reference

Is an inhibitor or stabilizer needed to prevent a hazardous reaction? (Y/N)

If so, provide details

Reference

4 Mammalian toxicity

4.1 Acute toxicity		Qual	Lower value	Upper value	Species	Reference/ comments
Oral (mg/kg)	LD_{50}					
Dermal (mg/kg)	LD_{50}					
Inhalation (mg/l/4h)	LD_{50}					

4.2 Corrosivity and irritation

	Units	Qual.	Lower Value	Upper Value	Reference/ Comments
Skin corrosion time	(hours)				

	Resultant observation	Species	Reference/ Comments
Skin irritation (4-hour exposure)			
Eye irritation			

Not irritating, slightly irritating, mildly irritating, moderately irritating, severely irritating or corrosive

4.3 Sensitization

			Reference/Comments
Respiratory sensitizer (in humans)	(Y/N)		
Skin sensitization	(Y/N)		

4.4 Other specific long-term effects

			Reference/Comments
Carcinogen	(Y/N)		
Mutagen	(Y/N)		
Toxic to reproduction	(Y/N)		
Other long term	(Y/N)		

4.5 Other relevant mammalian toxicity

5 Proposed carriage requirements

Column in the IGC Code	Property	Value
c	Ship type	
d	Type C independent tank required	
e	Control of vapour space within cargo tank	
f	Vapour detection	
g	Gauging	
i	Special requirements	

APPENDIX 2

MODEL FORM OF INTERNATIONAL CERTIFICATE OF FITNESS FOR THE CARRIAGE OF LIQUEFIED GASES IN BULK

INTERNATIONAL CERTIFICATE OF FITNESS FOR
THE CARRIAGE OF LIQUEFIED GASES IN BULK

(Official seal)

Issued under the provisions of the

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

under the authority of the Government of

.....
(full official designation of country)

by.....
(full designation of the competent person or organization recognized by the Administration)

Particulars of ship[1]

Name of ship	.....
Distinctive number or letters	.....
IMO number[2]	.....
Port of registry	.....
Cargo capacity (m^3)	.....
Ship type[3] (Code paragraph 2.1.2)	.....
Date on which keel was laid or on which the ship was at a similar stage of construction or, in the case of a converted ship, date on which conversion to a gas carrier was commenced	.....

The ship also complies fully with the following amendments to the Code:

.....

.....

The ship is exempted from compliance with the following provisions of the Code:

.....

.....

THIS IS TO CERTIFY:

1 That the ship has been surveyed in accordance with the provisions of section 1.4 of the Code.

2 That the survey showed that the construction and equipment of the ship and the condition thereof are in all respects satisfactory and that the ship complies with the relevant provisions of the Code.

3 That the following design criteria have been used:

.1 ambient air temperature .....°C[4]

.2 ambient water temperature.....°C[4]

.3

Tank type and number	Stress factors[5]				Materials[5]	MARVS[6]
	A	B	C	D		
Cargo piping						

Note: Tank numbers referred to in this list are identified on attachment 2, signed and dated tank plan.

.4 Mechanical properties of the cargo tank materials were determined at ....°C[7].

4 That the ship is suitable for the carriage in bulk of the following products provided that all the relevant operational provisions of the Code are observed[8].

Products	**Conditions of carriage (tank numbers, etc.)**	**Minimum temperature**
Continued on attachment 1, additional signed and dated sheets. Tank numbers referred to in this list are identified on attachment 2, signed and dated tank plan.		

5 That, in accordance with 1.4/2.6.2*, the provisions of the Code are modified in respect of the ship in the following manner:

.....

6 That the ship shall be loaded:

.1* only in accordance with loading conditions verified compliant with intact and damage stability requirements using the approved stability instrument fitted in accordance with paragraph 2.2.6 of the Code;

.2* where a dispensation permitted by paragraph 2.2.7 of the Code applies and the approved stability instrument required by paragraph 2.2.6 of the Code is not fitted, loading shall be made in accordance with one or more of the following approved methods:

.i * in accordance with the loading conditions provided in the approved loading manual, stamped and dated ..... and signed by a responsible officer of the Administration, or of an organization recognized by the Administration; or

.ii * in accordance with loading conditions verified remotely using an approved means.....; or

.iii * in accordance with a loading condition which lies within an approved range of conditions defined in the approved loading manual referred to in i above; or

.iv * in accordance with a loading condition verified using approved critical KG/GM data defined in the approved loading manual referred to in i above;

.3* in accordance with the loading limitations appended to this Certificate.

Where it is required to load the ship other than in accordance with the above instruction, then the necessary calculations to justify the proposed loading conditions shall be communicated to the certifying Administration who may authorize in writing the adoption of the proposed loading condition.**

This Certificate is valid until .....
subject to surveys in accordance with 1.4 of the Code.

Completion date of the survey on which this certificate is based: .....
(dd/mm/yyyy)

Issued at .....
(Place of issue of certificate)

.....
(Date of issue)

.....
(Signature of authorized official issuing the certificate)

(Seal or stamp of the authority, as appropriate)

---

* Delete as appropriate.

** Instead of being incorporated in the Certificate, this text may be appended to the Certificate, if duly signed and stamped.

Notes on completion of certificate:

1. Alternatively, the particulars of the ship may be placed horizontally in boxes.

2. In accordance with *IMO ship identification number scheme*, adopted by the Organization by resolution A.1078(28).

3. Any entry shall be related to all relevant recommendations, e.g. an entry "type 2G" shall mean type 2G in all respects prescribed by the Code.

4. The ambient temperature required for the purposes of 4.19.1.1 is to be inserted.

5. The stress factors and materials acceptable under 4.22.3.1 and 4.23.3.1 of the Code are to be inserted.

6. All relief valve settings assigned in accordance with 4.13.2 are to be inserted.

7. Temperatures accepted by the Administration or recognized organization acting on its behalf for the purposes of 4.18.1.3 are to be inserted.

8. Only products listed in chapter 19 of the Code or products that have been evaluated by the Administration in accordance with paragraph 1.1.6.1, or their compatible mixtures having physical proportions within the limitations of tank design, shall be listed. In respect of the latter "new products", any special requirements provisionally agreed under the tripartite agreement shall be indicated in an addendum to the certificate.

ENDORSEMENT FOR ANNUAL AND INTERMEDIATE SURVEYS

THIS IS TO CERTIFY that at a survey required by 1.4.2 of the Code the ship was found to comply with the relevant provisions of the Code.

Annual survey:

Signed: .....
(Signature of duly authorized official)

Place: .....

Date *(dd/mm/yyyy)*: .....

(Seal or stamp of the Authority, as appropriate)

Annual/Intermediate* survey:

Signed: .....
(Signature of duly authorized official)

Place: .....

Date *(dd/mm/yyyy)*: .....

(Seal or stamp of the Authority, as appropriate)

Annual/Intermediate* survey:

Signed: .....
(Signature of duly authorized official)

Place: .....

Date *(dd/mm/yyyy)*: .....

(Seal or stamp of the Authority, as appropriate)

Annual survey:

Signed: .....
(Signature of duly authorized official)

Place: .....

Date *(dd/mm/yyyy)*: .....

(Seal or stamp of the Authority, as appropriate)

* Delete as appropriate.

ANNUAL/INTERMEDIATE SURVEY IN ACCORDANCE WITH PARAGRAPH 1.4.6.8.3

THIS IS TO CERTIFY that, at an annual/intermediate* survey in accordance with paragraph 1.4.6.8.3 of the Code, the ship was found to comply with the relevant provisions of the Code:

Signed: .....
(Signature of duly authorized official)

Place: .....

Date *(dd/mm/yyyy)*: .....

(Seal or stamp of the Authority, as appropriate)

ENDORSEMENT TO EXTEND THE CERTIFICATE IF VALID FOR LESS THAN 5 YEARS WHERE PARAGRAPH 1.4.6.3 APPLIES

The ship complies with the relevant provisions of the Code, and this Certificate shall, in accordance with paragraph 1.4.6.3 of the Code, be accepted as valid until.....

Signed: .....
(Signature of duly authorized official)

Place: .....

Date *(dd/mm/yyyy)*: .....

(Seal or stamp of the Authority, as appropriate)

ENDORSEMENT WHERE THE RENEWAL SURVEY HAS BEEN COMPLETED AND PARAGRAPH 1.4.6.4 APPLIES

The ship complies with the relevant provisions of the Code, and this Certificate shall, in accordance with paragraph 1.4.6.4 of the Code, be accepted as valid until.....

Annual survey:

Signed: .....
(Signature of duly authorized official)

Place: .....

Date *(dd/mm/yyyy)*: .....

(Seal or stamp of the Authority, as appropriate)

---

* Delete as appropriate.

ENDORSEMENT TO EXTEND THE VALIDITY OF THE CERTIFICATE UNTIL REACHING THE PORT OF SURVEY OR FOR A PERIOD OF GRACE WHERE PARAGRAPH 1.4.6.5 OR 1.4.6.6 APPLIES

This Certificate shall, in accordance with paragraph 1.4.6.5/1.4.6.6* of the Code, be accepted as valid until .....

Signed: .....
(Signature of duly authorized official)

Place: .....

Date *(dd/mm/yyyy)*: .....

(Seal or stamp of the Authority, as appropriate)

ENDORSEMENT FOR ADVANCEMENT OF ANNIVERSARY DATE WHERE PARAGRAPH 1.4.6.8 APPLIES

In accordance with paragraph 1.4.6.8 of the Code, the new anniversary date is .....

Signed: .....
(Signature of duly authorized official)

Place: .....

Date *(dd/mm/yyyy)*: .....

(Seal or stamp of the Authority, as appropriate)

In accordance with paragraph 1.4.6.8, the new anniversary date is .....

Signed: .....
(Signature of duly authorized official)

Place: .....

Date *(dd/mm/yyyy)*: .....

(Seal or stamp of the Authority, as appropriate)

* Delete as appropriate.

ATTACHMENT 1
TO THE INTERNATIONAL CERTIFICATE OF FITNESS FOR THE CARRIAGE OF LIQUEFIED GASES IN BULK

Continued list of products to those specified in paragraph 4 of the certificate, and their conditions of carriage.

Products	Conditions of carriage (tank numbers, etc.)	Minimum temperature

Date: ……
(as for Certificate)

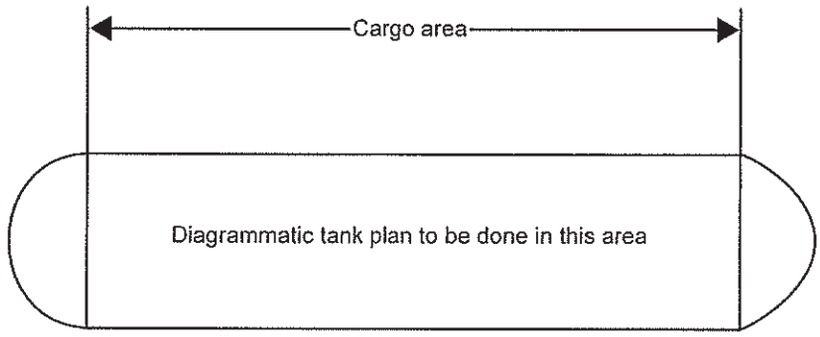
……
(Signature of official issuing the Certificate and/or seal of issuing authority)

ATTACHMENT 2
TO THE INTERNATIONAL CERTIFICATE OF FITNESS FOR THE CARRIAGE OF LIQUEFIED GASES IN BULK

TANK PLAN (specimen)

Name of ship:

Distinctive number or letters:



Date: ..... (dd/mm/yyyy) (as for Certificate)

..... (Signature of official issuing the Certificate and/or seal of issuing authority)

APPENDIX 3

EXAMPLE OF AN ADDENDUM TO THE INTERNATIONAL CERTIFICATE OF FITNESS FOR THE CARRIAGE OF LIQUEFIED GASES IN BULK

Addendum to Certificate No.:	Issued at: dd/mm/yyyy
Issued in pursuance of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as amended, under the authority of the Government of: ……	

Name of ship	Distinctive number or letters	IMO number	Port of registry	Cargo capacity (m^3)	Ship type

THIS IS TO CERTIFY:

That the ship meets the requirements for the carriage in bulk of the following product(s), provided that all relevant operational provisions of the Code are observed:

Product	Conditions of carriage (tank numbers, etc.)	Minimum temperature	MARVS

The transportation of this product is permitted between the following countries:

The issuance of this Addendum is based on document: ……

The Tripartite Agreement for this product is valid until: (dd/mm/yyyy)……

This Addendum will remain in force until: (dd/mm/yyyy)……

Place and date of issue: (dd/mm/yyyy)……

Signed: ……
(signature of authorized official)

APPENDIX 4

NON-METALLIC MATERIALS

1 General

1.1 The guidance given in this appendix is in addition to the requirements of 4.19, where applicable to non-metallic materials.

1.2 The manufacture, testing, inspection and documentation of non-metallic materials should in general comply with recognized standards, and with the specific requirements of this Code, as applicable.

1.3 When selecting a non-metallic material, the designer should ensure that it has properties appropriate to the analysis and specification of the system requirements. A material can be selected to fulfil one or more requirements.

1.4 A wide range of non-metallic materials may be considered. Therefore, the section below on material selection criteria cannot cover every eventuality and should be considered as guidance.

2 Material selection criteria

2.1 Non-metallic materials may be selected for use in various parts of liquefied gas carrier cargo systems based on consideration of the following basic properties:

.1 insulation – the ability to limit heat flow;

.2 load bearing – the ability to contribute to the strength of the containment system;

.3 tightness – the ability to provide liquid and vapour tight barriers;

.4 joining – the ability to be joined (for example by bonding, welding or fastening).

2.2 Additional considerations may apply depending on the specific system design.

3 Properties of materials

3.1 Flexibility of insulating material is the ability of an insulating material to be bent or shaped easily without damage or breakage.

3.2 Loose fill material is a homogeneous solid generally in the form of fine particles, such as a powder or beads, normally used to fill the voids in an inaccessible space to provide an effective insulation.

3.3 Nanomaterial is a material with properties derived from its specific microscopic structure.

3.4 Cellular material is a material type containing cells that are either open, closed or both and which are dispersed throughout its mass.

3.5 Adhesive material is a product that joins or bonds two adjacent surfaces together by an adhesive process.

3.6 Other materials are materials that are not characterized in this section of the Code and should be identified and listed. The relevant tests used to evaluate the suitability of material for use in the cargo system should be identified and documented.

4 Material selection and testing requirements

4.1 *Material specification*

4.1.1 When the initial selection of a material has been made, tests should be conducted to validate the suitability of this material for the use intended.

4.1.2 The material used should clearly be identified and the relevant tests should be fully documented.

4.1.3 Materials should be selected according to their intended use. They should:

.1 be compatible with all the products that may be carried;

.2 not be contaminated by any cargo nor react with it;

.3 not have any characteristics or properties affected by the cargo; and

.4 be capable to withstand thermal shocks within the operating temperature range.

4.2 *Material testing*

The tests required for a particular material depend on the design analysis, specification and intended duty. The list of tests below is for illustration. Any additional tests required, for example in respect of sliding, damping and galvanic insulation, should be identified clearly and documented. Materials selected according to 4.1 of this appendix should be tested further according to the following table:

Function	Insulation	Load bearing structural	Tightness	Joining
Mechanical tests		X		X
Tightness tests			X	
Thermal tests	X			

Thermal shock testing should submit the material and/or assembly to the most extreme thermal gradient it will experience when in service.

4.2.1 Inherent properties of materials

4.2.1.1 Tests should be carried out to ensure that the inherent properties of the material selected will not have any negative impact in respect of the use intended.

4.2.1.2 For all selected materials, the following properties should be evaluated:

.1 density; example standard ISO 845; and

.2 linear coefficient of thermal expansion (LCTE); example standard ISO 11359 across the widest specified operating temperature range. However, for loose fill material the volumetric coefficient of thermal expansion (VCTE) should be evaluated, as this is more relevant.

4.2.1.3 Irrespective of its inherent properties and intended duty, all materials selected should be tested for the design service temperature range down to 5°C below the minimum design temperature, but not lower than -196°C.

4.2.1.4 Each property evaluation test should be performed in accordance with recognized standards. Where there are no such standards, the test procedure proposed should be fully detailed and submitted to the Administration for acceptance. Sampling should be sufficient to ensure a true representation of the properties of the material selected.

4.2.2 Mechanical tests

4.2.2.1 The mechanical tests should be performed in accordance with the following table.

Mechanical tests	Load bearing structural
Tensile	ISO 527 ISO 1421 ISO 3346 ISO 1926
Shearing	ISO 4587 ISO 3347 ISO 1922 ISO 6237
Compressive	ISO 604 ISO 844 ISO 3132
Bending	ISO 3133 ISO 14679
Creep	ISO 7850

4.2.2.2 If the chosen function for a material relies on particular properties such as tensile, compressive and shear strength, yield stress, modulus or elongation, these properties should be tested to a recognized standard. If the properties required are assessed by numerical simulation according to a high order behaviour law, the testing should be performed to the satisfaction of the Administration.

4.2.2.3 Creep may be caused by sustained loads, for example cargo pressure or structural loads. Creep testing should be conducted based on the loads expected to be encountered during the design life of the containment system.

4.2.3 Tightness tests

4.2.3.1 The tightness requirement for the material should relate to its operational functionality.

4.2.3.2 Tightness tests should be conducted to give a measurement of the material's permeability in the configuration corresponding to the application envisaged (e.g. thickness and stress conditions) using the fluid to be retained (e.g. cargo, water vapour or trace gas).

4.2.3.3 The tightness tests should be based on the tests indicated as examples in the following table.

Tightness tests	**Tightness**
Porosity/Permeability	ISO 15106 ISO 2528 ISO 2782

4.2.4 Thermal conductivity tests

4.2.4.1 Thermal conductivity tests should be representative of the lifecycle of the insulation material so its properties over the design life of the cargo system can be assessed. If these properties are likely to deteriorate over time, the material should be aged as best possible in an environment corresponding to its lifecycle, for example operating temperature, light, vapour and installation (e.g. packaging, bags, boxes, etc.).

4.2.4.2 Requirements for the absolute value and acceptable range of thermal conductivity and heat capacity should be chosen taking into account the effect on the operational efficiency of the cargo containment system. Particular attention should also be paid to the sizing of the associated cargo handling system and components such as safety relief valves plus vapour return and handling equipment.

4.2.4.3 Thermal tests should be based on the tests indicated as examples in the following table or their equivalents:

Thermal tests	Insulating
Thermal conductivity	ISO 8301 ISO 8302
Heat capacity	x

4.2.5 Physical tests

4.2.5.1 In addition to the requirements of 4.19.2.3 and 4.19.3.2, the following table provides guidance and information on some of the additional physical tests that may be considered.

Physical tests	Flexible insulating	Loose fill	Nano-material	Cellular	Adhesive
Particle size		x			
Closed cells content				ISO 4590	
Absorption/Desorption	ISO 12571	x	x	ISO 2896	
Viscosity					ISO 2555 ISO 2431
Open time					ISO 10364
Thixotropic properties					x
Hardness					ISO 868

4.2.5.2 Requirements for loose fill material segregation should be chosen considering its potential adverse effect on the material properties (density, thermal conductivity) when subjected to environmental variations such as thermal cycling and vibration.

4.2.5.3 Requirements for a material with closed cell structures should be based on its eventual impact on gas flow and buffering capacity during transient thermal phases.

4.2.5.4 Similarly, adsorption and absorption requirements should take into account the potential adverse effect an uncontrolled buffering of liquid or gas may have on the system.

5 Quality assurance and quality control (QA/QC)

5.1 *General*

5.1.1 Once a material has been selected, after testing as outlined in section 4 of this appendix, a detailed quality assurance/quality control (QA/QC) programme should be applied to ensure the continued conformity of the material during installation and service. This programme should consider the material starting from the manufacturer's quality manual (QM) and then follow it throughout the construction of the cargo system.

5.1.2 The QA/QC programme should include the procedure for fabrication, storage, handling and preventive actions to guard against exposure of a material to harmful effects. These may include, for example, the effect of sunlight on some insulation materials or the contamination of material surfaces by contact with personal products such as hand creams. The sampling methods and the frequency of testing in the QA/QC programme should be specified to ensure the continued conformity of the material selected throughout its production and installation.

5.1.3 Where powder or granulated insulation is produced, arrangements should be made to prevent compacting of the material due to vibrations.

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.

5.2.2 Production sampling and audit method

5.2.2.1 Regular sampling is required during production to ensure the quality level and continued conformity of a selected material.

5.2.2.2 The frequency, the method and the tests to be performed should be defined in QA/QC programme; for example, these tests will usually cover, inter alia, raw materials, process parameters and component checks.

5.2.2.3 Process parameters and results of the production QC tests should be in strict accordance with those detailed in the QM for the material selected.

5.2.2.4 The objective of the audit method as described in the QM is to control the repeatability of the process and the efficacy of the QA/QC programme.

5.2.2.5 During auditing, auditors should be provided with free access to all production and QC areas. Audit results should be in accordance with the values and tolerances as stated in the relevant QM.

6 Bonding and joining process requirement and testing

6.1 ***Bonding procedure qualification***

6.1.1 The bonding procedure specification and qualification test should be defined in accordance with recognized standards.

6.1.2 The bonding procedures should be fully documented before work commences to ensure the properties of the bond are acceptable.

6.1.3 The following parameters should be considered when developing a bonding procedure specification:

.1 surface preparation;

.2 materials storage and handling prior to installation;

.3 covering-time;

.4 open-time;

.5 mixing ratio, deposited quantity;

.6 environmental parameters (temperature, humidity); and

.7 curing pressure, temperature and time.

6.1.4 Additional requirements may be included as necessary to ensure acceptable results.

6.1.5 The bonding procedures specification should be validated by an appropriate procedure qualification testing programme.

6.2 ***Personnel qualifications***

6.2.1 Personnel involved in bonding processes should be trained and qualified to recognized standards.

6.2.2 Regular tests should be made to ensure the continued performance of people carrying out bonding operations to ensure a consistent quality of bonding.

7 Production bonding tests and controls

7.1 ***Destructive testing***

During production, representative samples should be taken and tested to check that they correspond to the required level of strength as required for the design.

7.2 ***Non-destructive testing***

7.2.1 During production, tests which are not detrimental to bond integrity should be performed using an appropriate technique such as:

.1 visual examination;

.2 internal defects detection (for example acoustic, ultrasonic or shear test); and

.3 local tightness testing.

7.2.2 If the bonds have to provide tightness as part of their design function, a global tightness test of the cargo containment system should be completed after the end of the erection in accordance with the designer's and QA/QC programme.

7.2.3 The QA/QC standards should include acceptance standards for the tightness of the bonded components when built and during the lifecycle of the containment system.

APPENDIX 5

STANDARD FOR THE USE OF LIMIT STATE METHODOLOGIES IN THE DESIGN OF CARGO CONTAINMENT SYSTEMS OF NOVEL CONFIGURATION

1 General

1.1 The purpose of this standard is to provide procedures and relevant design parameters of limit state design of cargo containment systems of a novel configuration in accordance with section 4.27 of this Code.

1.2 Limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design conditions identified in section 4.3.4 of this Code. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the requirements.

1.3 The limit states are divided into the three following categories:

.1 Ultimate Limit States (ULS), which correspond to the maximum load-carrying capacity or, in some cases, to the maximum applicable strain, deformation or instability in structure resulting from buckling and plastic collapse; under intact (undamaged) conditions;

.2 Fatigue Limit States (FLS), which correspond to degradation due to the effect of cyclic loading; and

.3 Accident Limit States (ALS), which concern the ability of the structure to resist accident situations.

1.4 Part A through part D of chapter 4 of this Code shall be complied with as applicable depending on the cargo containment system concept.

2 Design format

2.1 The design format in this standard is based on a Load and Resistance Factor Design format. The fundamental principle of the Load and Resistance Factor Design format is to verify that design load effects, L_d, do not exceed design resistances, R_d, for any of the considered failure modes in any scenario:

$$L_d \leq R_d$$

A design load F_{dk} is obtained by multiplying the characteristic load by a load factor relevant for the given load category:

$$F_{dk} = \gamma_f \cdot F_k$$

where:

γ_f is load factor; and

F_k is the characteristic load as specified in part B and part C of chapter 4 of this Code.

A design load effect L_d (e.g. stresses, strains, displacements and vibrations) is the most unfavourable combined load effect derived from the design loads, and may be expressed by:

$$L_d = q(F_{d1}, F_{d2}, ..., F_{dN})$$

where q denotes the functional relationship between load and load effect determined by structural analyses.

The design resistance R_d is determined as follows:

$$R_d = \frac{R_k}{\gamma_R \cdot \gamma_C}$$

where:

R_k is the characteristic resistance. In case of materials covered by chapter 6 of this Code, it may be, but not limited to, specified minimum yield stress, specified minimum tensile strength, plastic resistance of cross sections, and ultimate buckling strength;

γ_R is the resistance factor, defined as $\gamma_R = \gamma_m \cdot \gamma_s$;

γ_m is the partial resistance factor to take account of the probabilistic distribution of the material properties (material factor);

γ_s is the partial resistance factor to take account of the uncertainties on the capacity of the structure, such as the quality of the construction, method considered for determination of the capacity including accuracy of analysis; and

γ_C is the consequence class factor, which accounts for the potential results of failure with regard to release of cargo and possible human injury.

2.2 Cargo containment design shall take into account potential failure consequences. Consequence classes are defined in table 1, to specify the consequences of failure when the mode of failure is related to the Ultimate Limit State, the Fatigue Limit State, or the Accident Limit State.

Table 1: Consequence classes

Consequence class	Definition
Low	Failure implies minor release of the cargo.
Medium	Failure implies release of the cargo and potential for human injury.
High	Failure implies significant release of the cargo and high potential for human injury/fatality.

3 Required analyses

3.1 Three dimensional finite element analyses shall be carried out as an integrated model of the tank and the ship hull, including supports and keying system as applicable. All the failure modes shall be identified to avoid unexpected failures. Hydrodynamic analyses shall be carried out to determine the particular ship accelerations and motions in irregular waves, and the response of the ship and its cargo containment systems to these forces and motions.

3.2 Buckling strength analyses of cargo tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with recognized standards. The method shall adequately account for the difference in theoretical and actual buckling stress as a result of plate out of flatness, plate edge misalignment, straightness, ovality and deviation from true circular form over a specified arc or chord length, as relevant.

3.3 Fatigue and crack propagation analysis shall be carried out in accordance with paragraph 5.1 of this standard.

4 Ultimate Limit States

4.1 Structural resistance may be established by testing or by complete analysis taking account of both elastic and plastic material properties. Safety margins for ultimate strength shall be introduced by partial factors of safety taking account of the contribution of stochastic nature of loads and resistance (dynamic loads, pressure loads, gravity loads, material strength, and buckling capacities).

4.2 Appropriate combinations of permanent loads, functional loads and environmental loads including sloshing loads shall be considered in the analysis. At least two load combinations with partial load factors as given in table 2 shall be used for the assessment of the ultimate limit states.

Table 2: Partial load factors

Load combination	Permanent loads	Functional loads	Environmental loads
'*a*'	1.1	1.1	0.7
'*b*'	1.0	1.0	1.3

The load factors for permanent and functional loads in load combination '*a*' are relevant for the normally well-controlled and/or specified loads applicable to cargo containment systems such as vapour pressure, cargo weight, system self-weight, etc. Higher load factors may be relevant for permanent and functional loads where the inherent variability and/or uncertainties in the prediction models are higher.

4.3 For sloshing loads, depending on the reliability of the estimation method, a larger load factor may be required by the Administration or recognized organization acting on its behalf.

4.4 In cases where structural failure of the cargo containment system are considered to imply high potential for human injury and significant release of cargo, the consequence class factor shall be taken as $\gamma_C = 1.2$. This value may be reduced if it is justified through risk analysis and subject to the approval by the Administration or recognized organization acting on its behalf. The risk analysis shall take account of factors including, but not limited to, provision of full or partial secondary barrier to protect hull structure from the leakage and less hazards associated with intended cargo. Conversely, higher values may be fixed by the Administration or recognized organization acting on its behalf, for example, for ships carrying more hazardous or higher pressure cargo. The consequence class factor shall in any case not be less than 1.0.

4.5 The load factors and the resistance factors used shall be such that the level of safety is equivalent to that of the cargo containment systems as described in sections 4.21 to 4.26 of this Code. This may be carried out by calibrating the factors against known successful designs.

4.6 The material factor γ_m shall in general reflect the statistical distribution of the mechanical properties of the material, and needs to be interpreted in combination with the specified characteristic mechanical properties. For the materials defined in chapter 6 of this Code, the material factor γ_m may be taken as:

1.1 when the characteristic mechanical properties specified by the recognized organization typically represents the lower 2.5% quantile in the statistical distribution of the mechanical properties; or

1.0 when the characteristic mechanical properties specified by the recognized organization represents a sufficiently small quantile such that the probability of lower mechanical properties than specified is extremely low and can be neglected.

4.7 The partial resistance factors γ_{si} shall in general be established based on the uncertainties in the capacity of the structure considering construction tolerances, quality of construction, the accuracy of the analysis method applied, etc.

4.7.1 For design against excessive plastic deformation using the limit state criteria given in paragraph 4.8 of this standard, the partial resistance factors γ_{si} shall be taken as follows:

$$\gamma_{s1} = 0.76 \cdot \frac{B}{\kappa_1}$$

$$\gamma_{s2} = 0.76 \cdot \frac{D}{\kappa_2}$$

$$\kappa_1 = Min\left(\frac{R_m}{R_e} \cdot \frac{B}{A}; 1.0\right)$$

$$\kappa_2 = Min\left(\frac{R_m}{R_e} \cdot \frac{D}{C}; 1.0\right)$$

Factors A, B, C and D are defined in section 4.22.3.1 of this Code. R_m and R_e are defined in section 4.18.1.3 of this Code.

The partial resistance factors given above are the results of calibration to conventional type B independent tanks.

4.8 ***Design against excessive plastic deformation***

4.8.1 Stress acceptance criteria given below refer to elastic stress analyses.

4.8.2 Parts of cargo containment systems where loads are primarily carried by membrane response in the structure shall satisfy the following limit state criteria:

$$\sigma_m \leq f$$

$$\sigma_L \leq 1.5f$$

$$\sigma_b \leq 1.5F$$

$$\sigma_L + \sigma_b \leq 1.5F$$

$$\sigma_m + \sigma_b \leq 1.5F$$

$$\sigma_m + \sigma_b + \sigma_g \leq 3.0F$$

$$\sigma_L + \sigma_b + \sigma_g \leq 3.0F$$

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

$$f = \frac{R_e}{\gamma_{s1} \cdot \gamma_m \cdot \gamma_C}$$

$$F = \frac{R_e}{\gamma_{s2} \cdot \gamma_m \cdot \gamma_C}$$

With regard to the stresses σ_m, σ_L, σ_b and σ_g, see also the definition of stress categories in section 4.28.3 of this Code.

Guidance Note:

The stress summation described above shall be carried out by summing up each stress component ($\sigma_x, \sigma_y, \tau_{xy}$), and subsequently the equivalent stress shall be calculated based on the resulting stress components as shown in the example below.

$$\sigma_L + \sigma_b = \sqrt{\left(\sigma_{Lx} + \sigma_{bx}\right)^2 - \left(\sigma_{Lx} + \sigma_{bx}\right)\left(\sigma_{Ly} + \sigma_{by}\right) + \left(\sigma_{Ly} + \sigma_{by}\right)^2 + 3\left(\tau_{Lxy} + \tau_{bxy}\right)^2}$$

4.8.3 Parts of cargo containment systems where loads are primarily carried by bending of girders, stiffeners and plates, shall satisfy the following limit state criteria:

$$\sigma_{ms} + \sigma_{bp} \leq 1.25F \qquad \text{(See notes 1, 2)}$$

$$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} \leq 1.25F \qquad \text{(See note 2)}$$

$$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} + \sigma_{bt} + \sigma_g \leq 3.0F$$

Note 1: The sum of equivalent section membrane stress and equivalent membrane stress in primary structure ($\sigma_{ms} + \sigma_{bp}$) will normally be directly available from three-dimensional finite element analyses.

Note 2: The coefficient, 1.25, may be modified by the Administration or recognized organization acting on its behalf considering the design concept, configuration of the structure, and the methodology used for calculation of stresses.

where:

σ_{ms} = equivalent section membrane stress in primary structure

σ_{bp} = equivalent membrane stress in primary structure and stress in secondary and tertiary structure caused by bending of primary structure

σ_{bs} = section bending stress in secondary structure and stress in tertiary structure caused by bending of secondary structure

σ_{bt} = section bending stress in tertiary structure

σ_g = equivalent secondary stress

$$f = \frac{R_e}{\gamma_{s1} \cdot \gamma_m \cdot \gamma_C}$$

$$F = \frac{R_e}{\gamma_{s2} \cdot \gamma_m \cdot \gamma_C}$$

The stresses σ_{ms}, σ_{bp}, σ_{bs}, and σ_{bt} are defined in 4.8.4. For a definition of σ_g, see section 4.28.3 of this Code.

Guidance Note:

The stress summation described above shall be carried out by summing up each stress component ($\sigma_x, \sigma_y, \tau_{xy}$), and subsequently the equivalent stress shall be calculated based on the resulting stress components.

Skin plates shall be designed in accordance with the requirements of the Administration or recognized organization acting on its behalf. When membrane stress is significant, the effect of the membrane stress on the plate bending capacity shall be appropriately considered in addition.

4.8.4 Section stress categories

Normal stress is the component of stress normal to the plane of reference.

Equivalent section membrane stress is the component of the normal stress that is uniformly distributed and equal to the average value of the stress across the cross section of the structure under consideration. If this is a simple shell section, the section membrane stress is identical to the membrane stress defined in paragraph 4.8.2 of this standard.

Section bending stress is the component of the normal stress that is linearly distributed over a structural section exposed to bending action, as illustrated in figure 1.

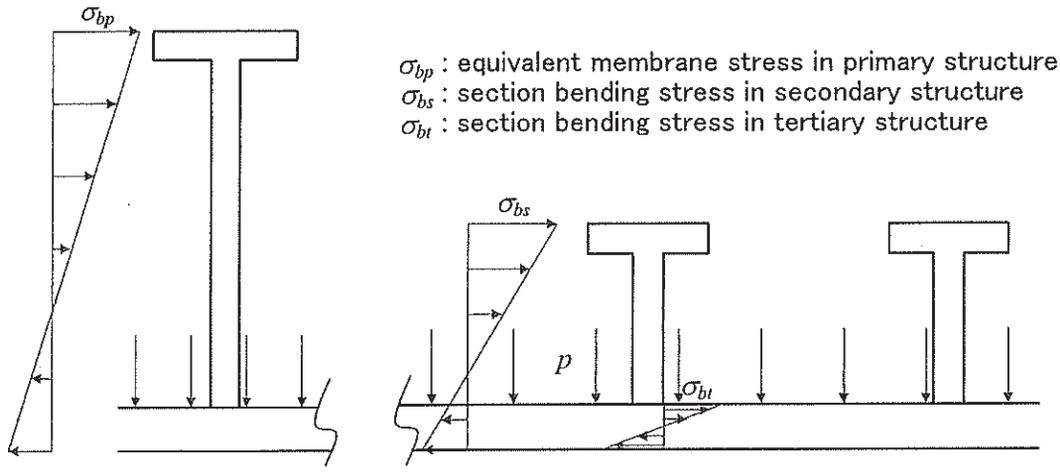


Figure 1: Definition of the three categories of section stress (Stresses σ_{bp} and σ_{bs} are normal to the cross section shown.)

4.9 The same factors γ_C, γ_m, γ_{si} shall be used for design against buckling unless otherwise stated in the applied recognized buckling standard. In any case the overall level of safety shall not be less than given by these factors.

5 Fatigue Limit States

5.1 Fatigue design condition as described in section 4.18.2 of this Code shall be complied with as applicable depending on the cargo containment system concept. Fatigue analysis is required for the cargo containment system designed under section 4.27 of this Code and this standard.

5.2 The load factors for FLS shall be taken as 1.0 for all load categories.

5.3 Consequence class factor γ_C and resistance factor γ_R shall be taken as 1.0.

5.4 Fatigue damage shall be calculated as described in sections 4.18.2.2 to 4.18.2.5 of this Code. The calculated cumulative fatigue damage ratio for the cargo containment systems shall be less than or equal to the values given in table 3.

Table 3: Maximum allowable cumulative fatigue damage ratio

	Consequence class		
C_W	Low	Medium	High
	1.0	0.5	0.5*

Note*: Lower value shall be used in accordance with sections 4.18.2.7 to 4.18.2.9 of this Code, depending on the detectability of defect or crack, etc.

5.5 Lower values may be fixed by the Administration or recognized organization acting on its behalf, for example for tank structures where effective detection of defect or crack cannot be assured, and for ships carrying more hazardous cargo.

5.6 Crack propagation analyses are required in accordance with sections 4.18.2.6 to 4.18.2.9 of this Code. The analysis shall be carried out in accordance with methods laid down in a standard recognized by the Administration or recognized organization acting on its behalf.

6 Accident Limit States

6.1 Accident design condition as described in section 4.18.3 of this Code shall be complied with as applicable, depending on the cargo containment system concept.

6.2 Load and resistance factors may be relaxed compared to the ultimate limit state considering that damages and deformations can be accepted as long as this does not escalate the accident scenario.

6.3 The load factors for ALS shall be taken as 1.0 for permanent loads, functional loads and environmental loads.

6.4 Loads mentioned in section 4.13.9 (Static heel loads) and section 4.15 (Collision and Loads due to flooding on ship) of this Code need not be combined with each other or with environmental loads, as defined in section 4.14 of this Code.

6.5 Resistance factor γ_R shall in general be taken as 1.0.

6.6 Consequence class factors γ_C shall in general be taken as defined in paragraph 4.4 of this standard, but may be relaxed considering the nature of the accident scenario.

6.7 The characteristic resistance R_k shall in general be taken as for the ultimate limit state, but may be relaxed considering the nature of the accident scenario.

6.8 Additional relevant accident scenarios shall be determined based on a risk analysis.

7 Testing

7.1 Cargo containment systems designed according to this standard shall be tested to the same extent as described in section 4.20.3 of this Code, as applicable depending on the cargo containment system concept."

二零一八年六月二十一日於行政長官辦公室

辦公室代主任　盧麗卿

Gabinete do Chefe do Executivo, aos 21 de Junho de 2018. — A Chefe do Gabinete, substituta, *Lo Lai Heng.*

保安司司長辦公室

第 111/2018 號保安司司長批示

保安司司長行使《澳門特別行政區基本法》第六十四條賦予的職權，根據第6/1999號行政法規《政府部門及實體的組織、職權與運作》第四條第二款、第111/2014號行政命令第一款、以及第2/2012號法律《公共地方錄像監視法律制度》第八條以及第十一條第一款、第四款及第六款的規定，且經聽取個人資料保護辦公室具約束力的意見，現作出本批示。

一、批准於下列公共地方（附表）安裝及使用錄像監視系統鏡頭（合共601支）。

二、治安警察局為負責管理有關錄像監視系統的實體。

GABINETE DO SECRETÁRIO PARA A SEGURANÇA

Despacho do Secretário para a Segurança n.º 111/2018

Usando da faculdade conferida pelo artigo 64.º da Lei Básica da Região Administrativa Especial de Macau e nos termos do n.º 2 do artigo 4.º do Regulamento Administrativo n.º 6/1999 (Organização, competências e funcionamento dos serviços e entidades públicas), do n.º 1 da Ordem Executiva n.º 111/2014, do artigo 8.º e dos n.ºs 1, 4 e 6 do artigo 11.º da Lei n.º 2/2012 (Regime jurídico da videovigilância em espaços públicos) e ouvido o parecer vinculativo do Gabinete para a Protecção de Dados Pessoais, o Secretário para a Segurança manda:

1. Autorizo a instalação e utilização de 601 câmaras de videovigilância nos espaços públicos abaixo mencionados (Anexo).

2. O Corpo de Polícia de Segurança Pública (CPSP) é a entidade responsável pela gestão das câmaras referidas.