

SIGTTO

Society of International Gas Tanker & Terminal Operators Ltd

Recommendations for Valves on Liquefied Gas Carriers

Second Edition



Recommendations for Valves on Liquefied Gas Carriers

(Second Edition 2023)



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Introduction and Scope

1. Introduction and Scope

1.1 Introduction

This document reviews current valve design standards and provides a summary of key requirements. The document provides recommendations that address specific issues, improving safety and environmental protection.

This new document combines and replaces the previous editions, *The Selection and Testing of Valves for LNG Applications* (2008) and *The Selection and Testing of Valves for LPG Applications* (2012). This update benefits from advancements in safety philosophy, technological improvements and lessons learnt.

1.2 Scope

These recommendations are for liquefied petroleum gas (LPG) and liquefied natural gas (LNG) carriers. For the purposes of this document, the term LPG refers to liquefied gas cargoes carried between the temperature range of 0°C to -104°C, which include cargoes such as ammonia, ethane, etc. The term LNG is used for cargoes carried at an approximate temperature of -162°C. For cargoes that may react with valve components, the guidance in this document is useful but there may be additional considerations due to the nature of the product.

This document is intended for valve manufacturers, shipyards and ship owners. The level of technical detail assumes that the reader is familiar with the design and operation of liquefied gas carriers. Not all concepts are simplified or explained at an introductory level.

Selection and Design of Valves and Assemblies

2. Selection and Design of Valves and Assemblies

This chapter provides an overview of valve standards and valve assemblies.

2.1 Valve Types

Valves used on gas carriers typically comply with the IGC Code¹ and the International Association of Classification Societies (IACS) Unified Requirements G3². The following information may influence the selection of a valve:

- Type of cargo
- function within the process system
- maximum operating and design pressure
- minimum and maximum operating and design temperature.

To simplify the presentation of information in this document, valves are grouped into three categories: Types A, B and C. Figure 1 shows the three categories, which are based on valve design temperature range.

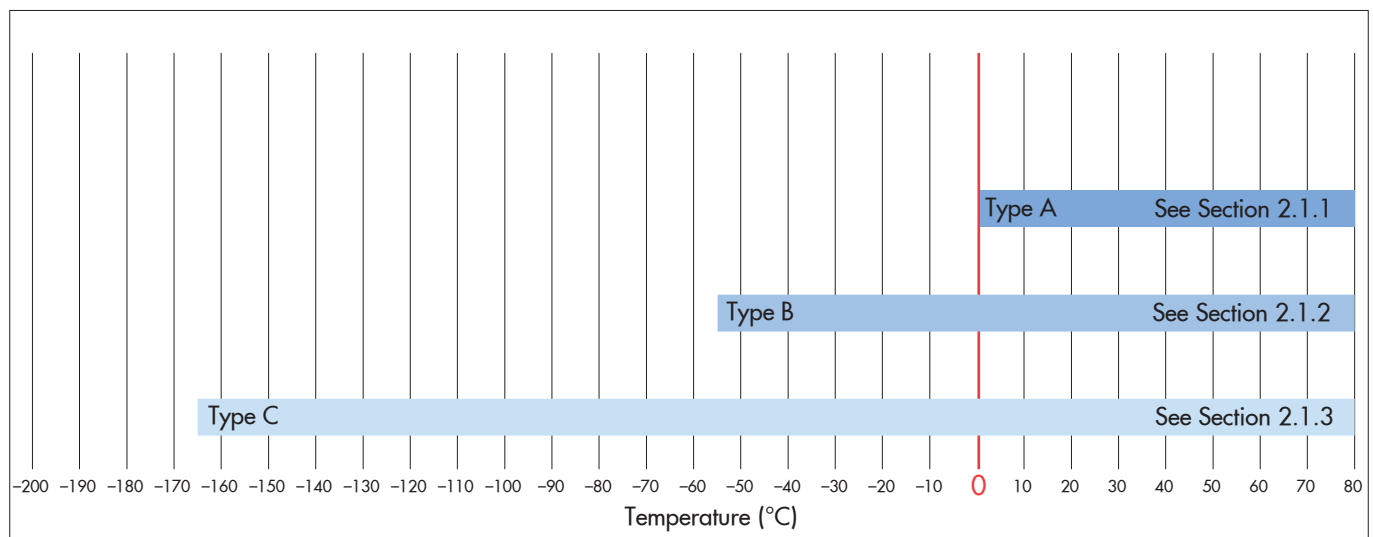


Figure 1: Valve design temperature range

The next sections list standards that are applicable for each valve type. Some types of valves may have project-specific requirements that are outside the ranges shown in Figure 1. For such applications the owner may need to specify additional requirements to those listed in the valve standards and Classification Society rules.

¹ IMO – International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)

² IACS – Unified Requirement G3 – Liquefied gas cargo and process piping

2.1.1 Type A valve

Type A refers to valves with a design temperature range of 0°C to 80°C. This valve type is typically designed according to one of the following standards, depending on the valve's function and the cargo it is used with:

- ASME B16.34 – Valves – Flanged, Threaded and Welding End
- API 609 – Butterfly Valves: Double-flanged, Lug- and Wafer-type, and Butt-welding Ends
- ISO 17292 – Metal ball valves for petroleum, petrochemical and allied industries
- ISO 15761 – Steel gate, globe and check valves for sizes DN 100 and smaller, for the petroleum and natural gas industries
- ISO 10631 – Industrial valves – Metallic butterfly valves
- ISO 10434 – Bolted bonnet steel gate valves for the petroleum, petrochemical and allied industries.

2.1.2 Type B valve

Type B refers to valves with a design temperature range of -55°C to 80°C. Type A and B valves typically share the same basic design using the standards for Type A valves listed above. An example of Type A and Type B valves is given in Figure 2.

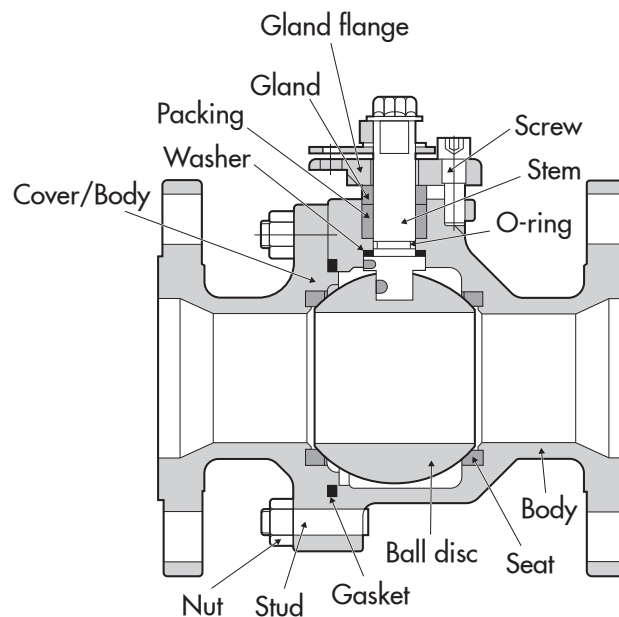


Figure 2: Example of Type A and B valves

Type B valves may use different materials and quality control measures for the fabrication of the valve. Seals used in Type B valves may have different designs and use different materials.

2.1.3 Type C valve

Type C refers to valves with a design temperature range of -165°C to 80°C . Due to the low cargo temperature this valve has an extended bonnet when compared to Type A and B valves.

The extended bonnet's length is critical to ensuring that the temperature of the stem packing stays within the operating range. The extended bonnet's minimum length is based on ISO 28921-1 and depends on the following:

- Valve size
- minimum design temperature
- if a cold box is installed
- if it is a rising stem or quarter-turn type.

MSS SP 134³ may be used to design the valve. Figure 3 is an example of a Type C valve.

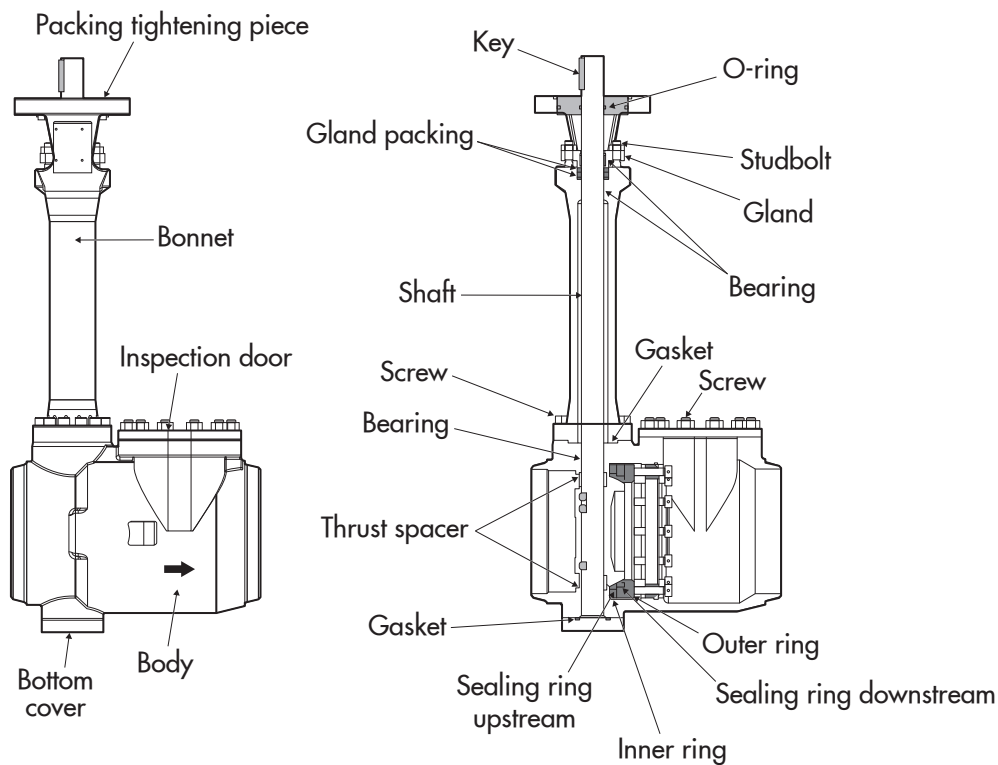


Figure 3: Example of a Type C valve

In addition to Type A and B valve standards, Type C valves should typically comply with:

- ISO 28921-1 – Industrial valves – Isolating valves for low-temperature applications – Part 1: Design, manufacturing and production testing
- ISO 28921-2 – Industrial valves – Isolating valves for low-temperature applications – Part 2: Type testing.

³ MSS – SP 134 – Valves for Cryogenic Service, including Requirements for Body/Bonnet Extensions

2.2 Design of Valves and Assemblies

2.2.1 Valve assembly

A *valve assembly* refers to the valve and connected parts, such as the actuator, gearbox if installed, positioners or other instrumentation. Valve parts and materials should be documented in a technical drawing.

It is good practice to design valve assemblies as a single operating unit as this helps with the selection of compatible parts, which can minimise the risk of failure. A valve assembly should be selected based on its function and interface. It should be capable of withstanding the expected design conditions. An example of an actuated valve assembly and its parts is shown in Figure 4.

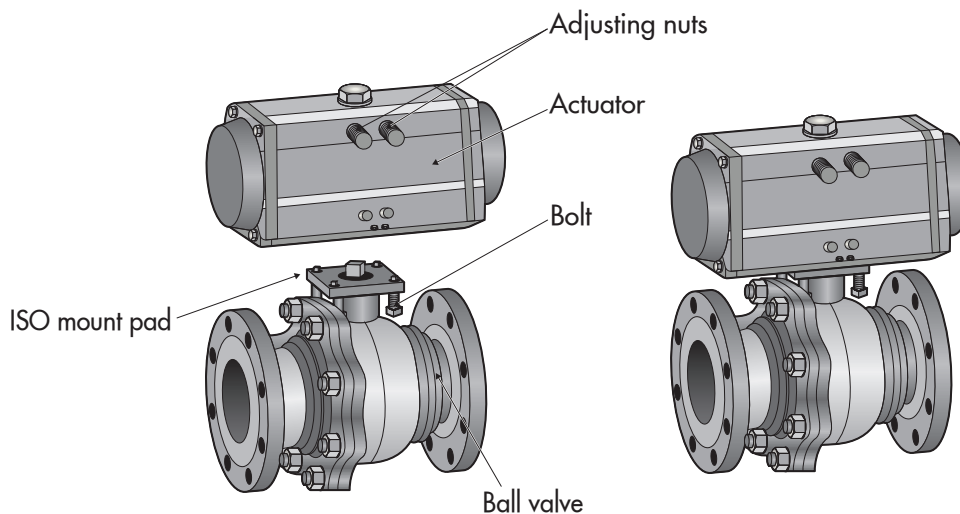


Figure 4: Actuated valve assembly parts

The main types of valves that can be selected for an assembly include, but are not limited to:

- Ball
- gate
- globe
- check (non-return)
- butterfly.

2.2.2 Actuator selection

Required torque is the maximum torque used by an actuator to open or close a valve. For certain applications, required torque should consider resistance from fluid flowing through the valve.

All actuators should be selected with a minimum safety factor of 1.25 of the required torque. Critical valves, such as the emergency shutdown valves (ESDVs), should be fitted with an actuator that has a minimum safety factor of 2 of the required torque.

2.2.3 Stem design

Maximum allowable stem torque (MAST) should be higher than the maximum torque that the operating mechanism can deliver. Adequate safety factors should be included in the calculation.

The stem design should include an anti-blowout feature, which prevents the stem from being projected out by the effect of the internal pressure in the event of its rupture.

2.2.4 Valve and actuator interface

A poor valve and actuator interface can lead to valve failure. The interface should follow ISO 5210⁴ or ISO 5211⁵, as applicable. These standards provide the attachment requirements of actuators to valves. The valve interface flange connection should be selected to withstand the maximum torque that the actuator can deliver.

2.2.5 Local visual indication

Valves should have a local visual indication of the *closing element*. The purposes of local indication are to help with calibration of remote indicators and enable positive local verification. A mark on the shaft, the shaft shape or a physical indication element may be used to indicate this position. The indication should be permanent in nature and should not be capable of being dislodged over the service life of the valve.

2.2.6 Internal liquid lock

Some valves can be damaged if liquid cargo expands while trapped inside. To prevent this, the valve body and bonnet should have relief paths where required. To avoid wrong installation, the relief discharge location on unidirectional valves should be clearly indicated, as shown in Figure 5. For Type C valves this is addressed in ISO 28921, but this may need to be considered separately for Type B valves.

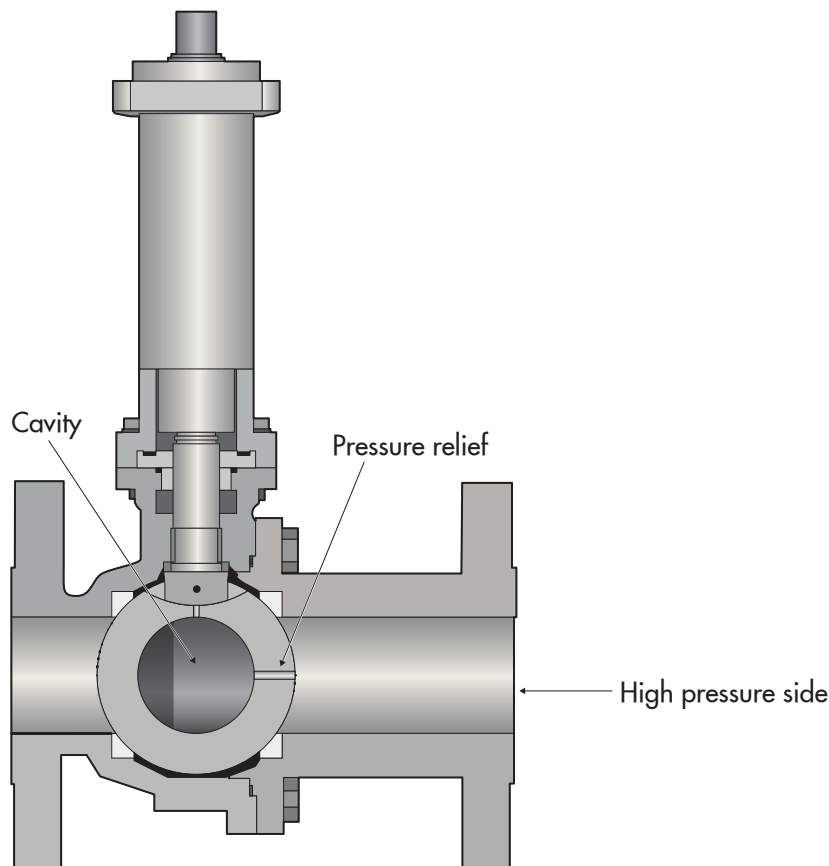


Figure 5: Example of unidirectional valve with lock-in cavity and pressure relief

⁴ ISO – 5210 – Industrial valves – Multi-turn valve actuator attachments

⁵ ISO – 5211 – Industrial valves – Part-turn actuator attachments

2.2.7 Valve drain plug

Bottom drain plugs on a valve body should be avoided whenever possible because of their potential to leak.

2.2.8 Emergency shutdown valves

ESDVs should include the following features:

- Remote operation
- indication of valve and actuator position
- independent and fail-safe
- local manual closure
- maximum closing time of 25 to 30 seconds from time of activation⁶
- fire safe tested valve to ISO 10497⁷, API STD 6FA⁸ or API STD 607⁹, with consideration of IACS Unified Interpretations GC24¹⁰.

2.2.9 Bidirectional and unidirectional valves

Bidirectional valves are designed to allow flow and pressure in both directions. Typically, these valves have a preferred direction of flow or pressure. Unidirectional valves are designed to be tight from one direction only.

⁶ SIGTTO – ESD Systems

⁷ ISO – 10497 – Testing of valves – Fire type-testing requirements

⁸ API – STD 6FA – Standard for Fire Test of Valves

⁹ API – STD 607 – Fire Test for Quarter-turn Valves and Valves Equipped with Nonmetallic Seats

¹⁰ IACS – Unified Interpretations GC24 – Fire Test for Emergency Shutdown Valves

2.2.10 Manual valves

Typical manual valve designs limit the force required for operation to around 360N. Some valve designs can use a gearbox to reduce the force required to acceptable levels. Gearboxes should have a minimum safety factor of 1.25 of the required torque. An example of a manual valve assembly is shown in Figure 6.

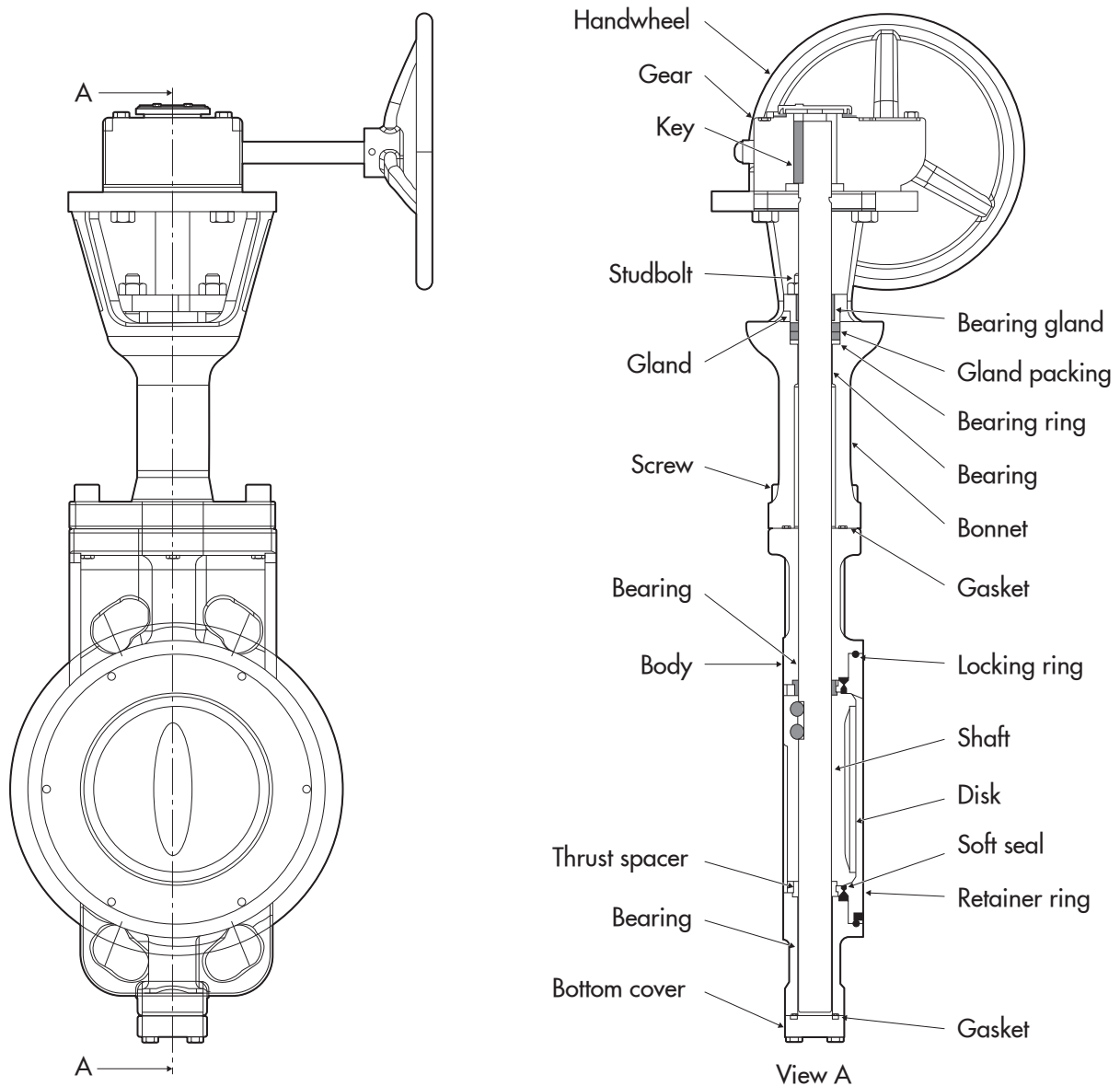


Figure 6: Example of a manual valve assembly

2.2.11 Isolation valve for cargo tank pressure relief valve

The selection of isolation valves under IGC Code 8.2.9 should be subject to the recommendations of the pressure relief valve (PRV) manufacturer and *Recommendations for Relief Valves on Gas Carriers*¹¹.

PRVs are typically designed and tested to operate in laminar flow. The pressure relief system's operation should not be affected by the installation of the isolation valve. The following should be noted:

- The isolation valve's bore size should be larger than the PRV flow area
- the turbulence generated by the isolation valve should be within acceptable levels, as determined by the PRV manufacturer
- the pressure drop generated by the isolation valve should be within acceptable levels, as determined by the PRV manufacturer.

Isolation valves should have a mechanical locking system to prevent the inadvertent full or partial closure of the valve. These valves should have visual position indication as well.

¹¹ SIGTTO – Recommendations for Relief Valves on Gas Carriers

Materials and Fabrication

3. Materials and Fabrication

To help reduce the likelihood of incidents, such as malfunction or valve damage leading to loss of cargo containment, suitable design and materials should be selected for the conditions that the valve will function in.

3.1 Valve Material

The IGC Code Chapter 6 states the metallic materials allowed, which are summarised in Figure 7. The material and grades selected should be compatible with the cargoes carried. In Chapter 17 of the IGC Code, there are additional prescriptive considerations, depending on the cargo.

Type A and B valves may be manufactured from high alloy steels that are resistant to marine corrosion. These include nickel and austenitic steels. If valves are manufactured from carbon-manganese steels, they may need suitable coatings to protect against corrosion. Coatings should be inspected and maintained during the lifetime of the valve.

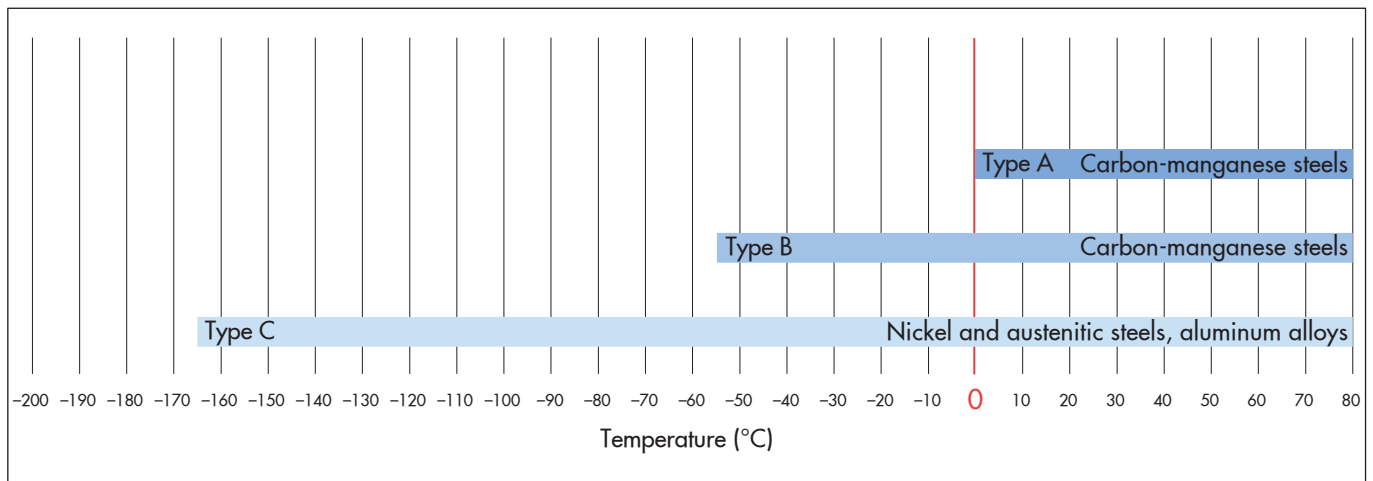


Figure 7: Materials for valve types

The strength of the valve is mainly determined by the geometry of the design, the material of construction and its thickness. Valve bodies and bonnets are not necessarily constructed to the same thickness in all sections. Valve standards typically specify the minimum thickness for different valve sizes. Manufacturers may provide thicker sections for additional safety or simplicity of construction.

Another approach is a detailed analysis of the pressure containment parts. Figure 8 shows an example of a Von Mises stress plot from evaluation against plastic collapse.

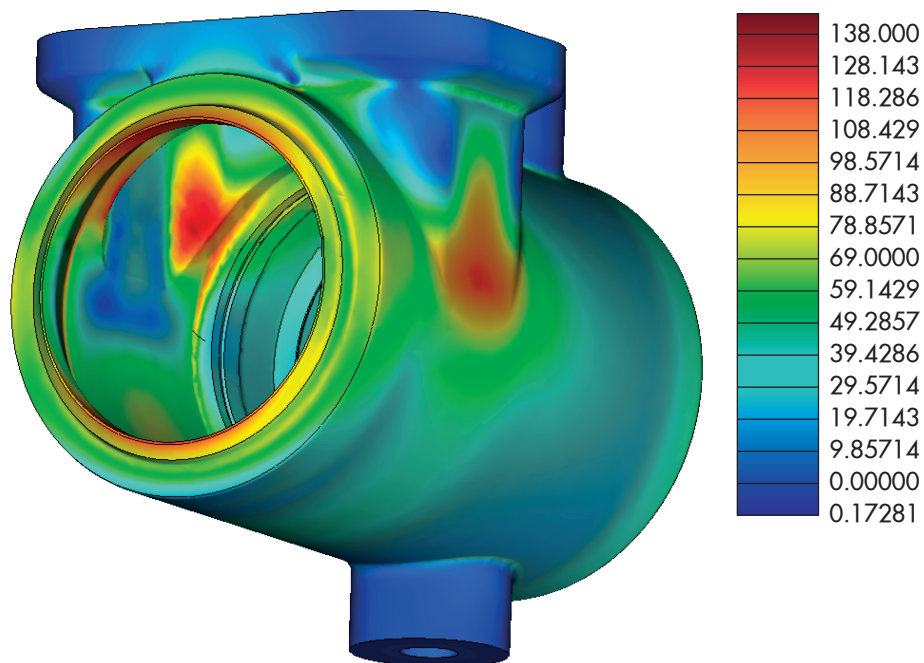


Figure 8: Von Mises stress plot (MPa)

The thicker the valve materials are, the larger the difference in the mechanical properties such as strength and toughness. Thicker materials will also create a larger temperature differential within the parts of the valve. Rapid cooldown can damage the valve by, for example, cracking of the casting.

Thermal shock assessments can be made to prove the suitability of a valve at low temperature conditions, typically applicable for Type C valves. This is done by determining the temperature profile and stress levels across the thickness of the pressure containment parts and comparing them against the material's allowable stresses and strains.

Figure 9 shows the surface temperature of a butt-welded valve subjected to -196°C fluid. Manufacturer supplied cooldown rates should be consulted to prevent valve damage or malfunction.

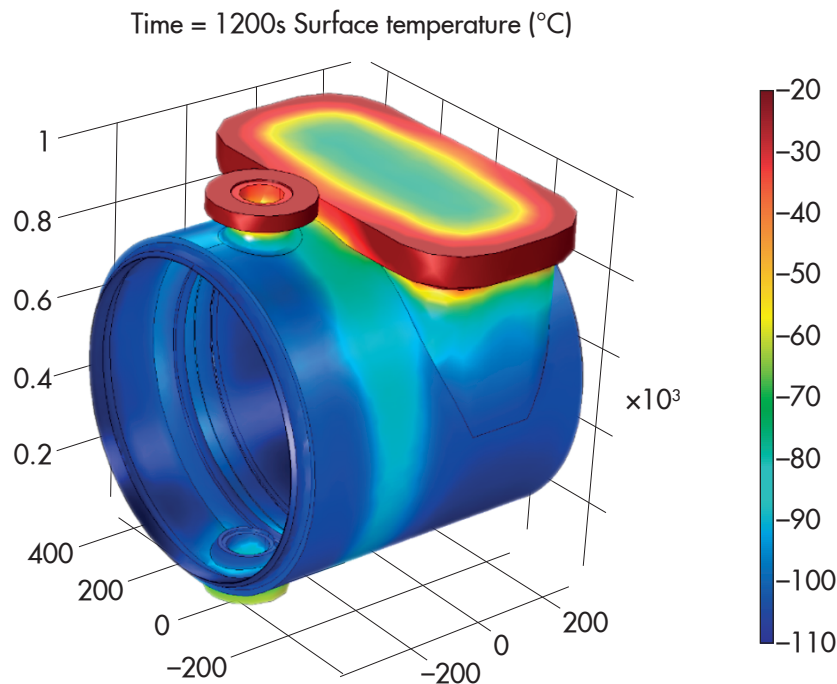


Figure 9: Surface temperature distribution during cold shock simulation

Valves should be manufactured according to Classification Society requirements, which are based on the IGC Code Chapter 6 and IACS Unified Requirements W1¹², W2¹³, W26¹⁴ and W35¹⁵. The applicable valve standard should also be followed for materials, fabrication aspects and quality assurance. Materials containing asbestos should not be used.

3.2 Seals and Packing

Stem sealing system and packing materials should be compatible with the valve stem material, surface smoothness and the cargo. For high-pressure applications, additional checks should be made to ensure they are suitable for the intended application.

3.3 Environmental Conditions

The selection of valve assembly materials should consider the operating environment of the ship. Enclosures or casings can be used to protect certain components, such as instrumentation and electronics.

Non-metallic materials should only be used if they are robust and do not degrade under ultraviolet light, heat or other environmental conditions.

¹² IACS – Unified Requirements W1 – Materials and welding for ships carrying liquefied gases in bulk and ships using gases or other low-flashpoint fuels

¹³ IACS – Unified Requirements W2 – Test specimens and mechanical testing procedures for materials

¹⁴ IACS – Unified Requirements W26 – Requirements for welding consumables for aluminium alloys

¹⁵ IACS – Unified Requirements W35 – Requirements for NDT suppliers

3.4 Corrosion Resistance

Valve assemblies may be fabricated of materials that are susceptible to corrosion. Some manufacturers may use coatings to protect these components. Care should be taken to prevent moisture from seeping into internal components.

Different materials may be used to fabricate the valve assembly, so care should be taken to prevent galvanic corrosion.

3.5 Valve Inspection

Valve and assembly components can degrade due to the effect of cargo, the marine environment or normal use over time. Inspection regimes should consider the risk of failure of these components. Where enclosures and coatings are used for protection against corrosion, these should also be inspected to ensure effectiveness.

Post-Fabrication Testing and Installation

4. Post-Fabrication Testing and Installation

This chapter provides a summary of testing recommendations for valves and valve assemblies after manufacturing. Post-fabrication testing ensures that valve assemblies meet the functionality and quality requirements. Classification Societies are typically part of the process, including design approval, fabrication, and testing surveillance. The approval and surveillance should be documented.

4.1 Inspection and Testing

4.1.1 Prototype valve flow characteristics

The flow characteristic of a valve is the relationship between the capacity and stem travel. The closing element design affects how the valve capacity changes as the valve moves through its complete travel. This relationship is not linear.

The manufacturer should certify the flow characteristics of all three valve types based on tests according to recognised standards such as EN 1267¹⁶.

4.1.2 Testing for Type C valves

All Type C valves should be prototype tested to ISO 28921-2. A minimum of 10% of the valve production lot should be tested at equal or lower than the minimum design temperature following the procedures within ISO 28921-1.

4.1.3 Production testing

All valves should be production tested according to the applicable valve standard and ISO 5208¹⁷. Use of the optional tests in ISO 5208 should be discussed and agreed on between the owner and manufacturer.

4.1.4 Valve assembly inspection and testing

All valve assemblies should be inspected to confirm that they are in good order and that they are fabricated and assembled according to approved documentation. The testing should confirm that the valve assemblies meet their functionality and quality requirements. As-built drawings should be produced.

A typical acceptance test covers the following items:

- Smooth open and close operation
- open and close direction
- correct valve and actuator indication and positioning
- valve torque is within a pre-defined minimum and maximum value
- open and close actuating time
- ESDVs and other safety valves checked for fail-safe action
- unidirectional and bidirectional valves installed in the recommended direction
- pressure relief is directing to the low-pressure side
- communication with local and remote systems.

¹⁶ EN – 1267 – Industrial Valves – Test of flow resistance using water as test fluid

¹⁷ ISO – 5208 – Industrial valves – Pressure testing of metallic valves

4.2 Transportation and Storage

The manufacturer should provide sufficient instructions for safe transportation and storage of the valves. It is essential to follow these instructions to ensure that the valves are protected during transportation and storage to prevent damage. It is good practice to keep valves and valve assemblies in the original manufacturer's packaging until they are installed on board.

If valve assemblies are stored before installation, storage procedures should be provided for the valve and actuator, or the valve assembly. These procedures may recommend opening and closing valves, moving actuators, energising electrical equipment, or the use of desiccant products.

4.3 Installation

Prior to installation, valve assemblies should be cleaned and inspected. Installation should be carried out according to the manufacturer's recommendations and Classification Society rules. Unidirectional and bidirectional valves should be installed in the preferred direction of flow or pressure.

Maintenance and Inspection

5. Maintenance and Inspection

Structured systems should be in place to ensure that cargo valves are maintained in good condition. This is essential to ensure the integrity of the cargo and fuel supply system.

Due to the hazardous nature of liquefied gas cargoes, small leaks or defects or malfunction of valves are not acceptable. Failing to implement effective maintenance and repair procedures on valve assemblies can contribute to a major incident. Systems should be in place to ensure that leaks and malfunctioning valves are raised as a non-conformance and should remain flagged until resolved.

5.1 Manufacturer Support

Manufacturers should ensure that the valve assembly can be serviced and maintained over the lifetime of the valve. Service and maintenance should be carried out by the manufacturer or by qualified and approved third party organisations.

Manufacturers should provide sufficient information for operation, inspection, testing and calibration of valve assemblies. Clear guidance should be provided to the owner on which parts of the valve assembly are suitable for maintenance by the ship staff, and what maintenance is recommended to be carried out by qualified service providers.

5.2 Structured Systems

The ship's planned maintenance system (PMS) is a structured system that should cover inspection and maintenance of valve assemblies. The PMS philosophy is typically guided by manufacturer and Classification Society requirements and should consider the following for each valve:

- Function in the system
- frequency of use, which affects wear and tear
- corrosive effects of the cargo
- exposure to, and severity of, the environment.

There should be clear instructions in the ship's PMS to identify what maintenance is authorised for the ship staff and what should be performed by qualified service providers. There should also be clear instructions to the ship staff to seek clarification from the owner when in doubt.

Ship staff performing the maintenance should be suitably trained and competent for the task. Such training may be provided by the valve manufacturer.

The owner should have written procedures to ensure that the service provider is approved by the manufacturer, and that the approval is valid at the time of the service request. Adequate information on maintenance carried out should be provided by the service provider and retained by the ship as records.

5.3 Inspection

Visual inspection during cargo operations can help to identify the condition of valve assemblies. Particular attention should be paid to areas subject to corrosion.

Stem seals should be maintained in good order to prevent water from entering and cargo leaking to the atmosphere. Malfunction can occur due to leaking of cargo through the seals resulting in freezing of the stem or other parts. Valves in intermittent service are more likely to have this problem.

Awareness of common issues with actuators may improve maintenance schemes and continuous improvement measures. When performing maintenance, it is important that actuators are kept dry to prevent internal corrosion.

The correct operation of automation and the actuator should be verified as part of the routine operation of the ship. A strategy can be provided potentially as part of the pre-arrival checks.

5.4 Critical Spares

Critical parts are typically those used to guarantee the pressure containment ability of the valve. For safety valves, critical parts should also include those parts related to the functionality of the valve, such as the actuator, positioning and other instrumentation required to execute the safety function. Identification of the critical parts should be discussed with the manufacturer.

The maintenance strategy and spares on board should include these critical spares. Spare parts should be of the same specification as the originals and maintain the same function and integrity of the valve assembly. Spare parts that are common to multiple valves can reduce the number of spares on board.

Greenhouse Gas Emissions

6. Greenhouse Gas Emissions

Methane and carbon dioxide are considered to be greenhouse gases (GHGs) and it is important to minimise emissions through valve design where possible. Fugitive emissions are defined as emissions to the atmosphere caused by loss of tightness of an item that is designed to be tight¹⁸.

GHG emissions should be a key consideration during the selection process for valves as the design of the valves and the materials used can affect emissions. Although welded joints are, typically, expected to leak less than flanged joints, it is still essential to ensure that the valve assembly is accessible for inspection and maintenance.

To help with the effectiveness of an owner's GHG management plan, useful guidance on measurement, testing and qualification is available in standards such as ISO 15848-1¹⁹. This standard evaluates external leaks from stem seals and body joints but does not include end connection joints. Where specified, testing carried out by the manufacturer should also comply with ISO 15848-2²⁰.

It is important that the valve assembly design and installation on board allows for access by leak detection equipment. The leak detection equipment (eg a probe) should be able to access the relevant areas without dismantling parts of the valve, or valve assembly.

Figure 10 shows the potential sources of fugitive leaks on a welded ends valve.

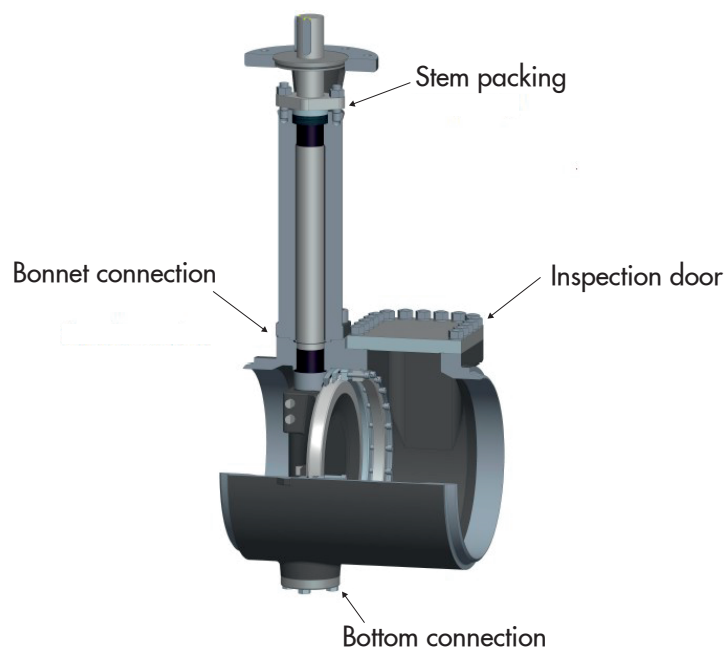


Figure 10: Potential sources of fugitive leaks on a buttwelded butterfly Type C valve

¹⁸ EN – 15446 – Fugitive and diffuse emissions of common concern to industry sectors. Measurement of fugitive emission of vapours generating from equipment and piping leaks

¹⁹ ISO – 15848-1 – Industrial valves – Measurement, test and qualification procedures for fugitive emissions - Part 1: Classification system and qualification procedures for type testing of valves

²⁰ ISO – 15848-2 – Industrial valves – Measurement, test and qualification procedures for fugitive emissions Part 2: Production acceptance test of valves

Annexes

Annex 1 – Glossary of Terms and Abbreviations

API American Petroleum Institute

ASME American Society of Mechanical Engineers

C Celsius

ESDV Emergency Shutdown Valve

GHG Greenhouse Gas

IACS International Association of Classification Societies

IMO International Maritime Organization

ISO International Organization for Standardization

LNG Liquefied Natural Gas

LPG Liquefied Petroleum Gas

MAST Maximum Allowable Stem Torque

MPa Megapascal

MSS Manufacturers Standardization Society of the Valve and Fittings Industry

N Newton

NDT Non-Destructive Testing

PMS Planned Maintenance System

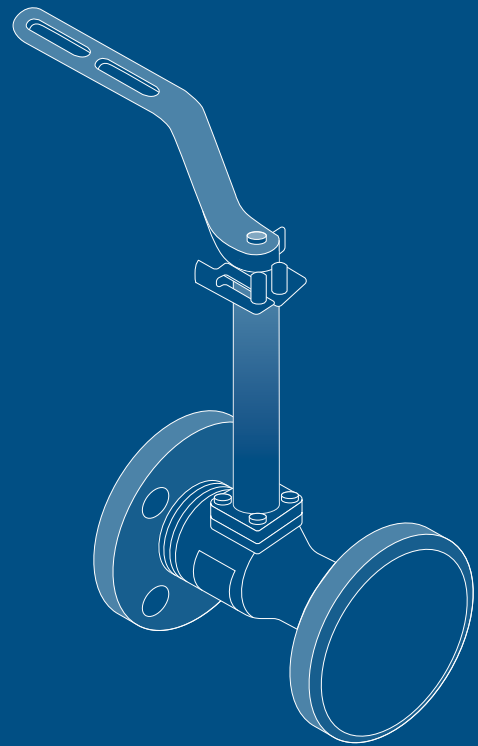
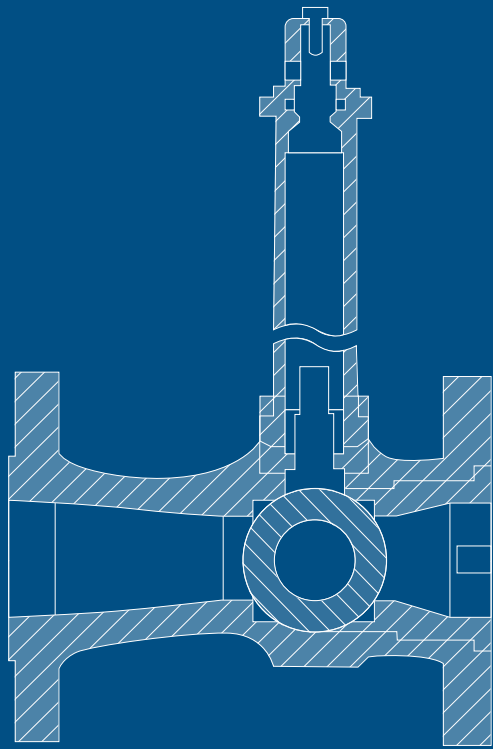
PRV Pressure Relief Valves

s Second

Valve Assembly Refers to the valve and connected parts, such as actuators, gearbox if installed, positioners, or other instrumentation

Annex 2 – Reference List

- IMO – International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)
- IACS – Unified Requirements G3 – Liquefied gas cargo and process piping
- ASME – B16.34 Valves – Flanged, Threaded, and Welding End
- API – 609 – Butterfly Valves: Double-flanged, Lug- and Wafer-type, and Butt-welding Ends
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- ISO – 10434 – Bolted bonnet steel gate valves for the petroleum, petrochemical and allied industries
- ISO 28921-1 – Industrial valves – Isolating valves for low-temperature applications – Part 1: Design, manufacturing and production testing
- MSS – SP 134 – Valves for Cryogenic Service, including Requirements for Body/Bonnet Extensions
- ISO 28921-2 – Industrial valves – Isolating valves for low-temperature applications – Part 2: Type testing
- ISO – 5210 – Industrial valves – Multi-turn valve actuator attachments
- ISO – 5211 – Industrial valves – Part-turn actuator attachments
- SIGTTO – ESD Systems
- ISO – 10497 – Testing of valves – Fire type-testing requirements
- API – STD 6FA – Standard for Fire Test of Valves
- API – STD 607 – Fire Test for Quarter-turn Valves and Valves Equipped with Nonmetallic Seats
- IACS – Unified Interpretations GC24 – Fire Test for Emergency Shutdown Valves
- SIGTTO – Recommendations for Relief Valves on Gas Carriers
- IACS – Unified Requirements W1 – Material and welding for ships carrying liquefied gases in bulk and ships using gases or other low-flashpoint fuels
- IACS – Unified Requirements W2 – Test specimens and mechanical testing procedures for materials
- IACS – Unified Requirements W26 – Requirements for welding consumables for aluminium alloys
- IACS – Unified Requirements W35 – Requirements for NDT Suppliers
- EN – 1267 – Industrial Valves – Test of flow resistance using water as test fluid
- ISO – 5208 – Industrial valves – Pressure testing of metallic valves
- EN – 15446 – Fugitive and diffuse emissions of common concern to industry sectors. Measurement of fugitive emission of vapours generating from equipment and piping leaks
- ISO – 15848-1 – Industrial valves – Measurement, test and qualification procedures for fugitive emissions – Part 1: Classification system and qualification procedures for type testing of valves
- ISO – 15848-2 – Industrial valves – Measurement, test and qualification procedures for fugitive emissions – Part 2: Production acceptance test of valves



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