Recommendations for Relief Valves on Gas Carriers

(Third Edition)

SIGTTO

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***The Society of International Gas Tanker and Terminal Operators (SIGTTO)** is a non-profit making organisation dedicated to protect and promote the mutual interests of its members in matters related to the safe and reliable operation of gas tankers and terminals within a sound environment. The Society was founded in 1979 and was granted consultative status at the International Maritime Organization in November 1983.*

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Recommendations for Relief Valves on Gas Carriers

SIGTTO

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Introduction and Scope

1. Introduction and Scope

1.1 Introduction

Relief valves perform a safety critical function. Proper design and robust maintenance procedures are essential to ensure that this equipment will function as required. The purpose of this document is to provide information to support this goal.

This document is the third edition of SIGTTO's guidance on relief valves and it updates the previous edition, *An Introduction to the Design and Maintenance of Cargo System Pressure Relief Valves on Board Gas Carriers (1998).*

1.2 Scope

These recommendations are for liquefied petroleum gas (LPG) carriers 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.

These recommendations do not apply to existing ships, and there is no suggestion that existing ships should be altered.

It is recognised that some gas carrier designs may not be able to conform to all of the recommendations in this document. However, this document is intended to serve as a starting point with a view to minimising differences as much as possible.

SIGTTO gratefully acknowledges the assistance of *FUKUI SEISAKUSHO CO., LTD.* and the Anderson Greenwood Crosby business unit of Emerson in the production of this document.

2

Relief Valve Types

2. Relief Valve Types

This document provides guidance on pilot operated relief valves (PORVs) and spring loaded relief valves (SLRVs) used in the cargo system of a gas carrier. The guidance in this document is not applicable to other areas of the ship, such as the engine room and other non-cargo related equipment.

2.1 Pilot Operated Relief Valves

A PORV consists of a main valve and a pilot valve.

The main valve has an unbalanced diaphragm or piston (unbalanced member). The system pressure is applied to the top of the piston or diaphragm via the pilot. As the area at the top of the piston or diaphragm is larger than the area at the bottom, the net force on the disc from these pressures is downwards, so the valve remains closed.

The net force is directly proportional to the system pressure. When the set pressure is reached, the pilot valve opens, venting the space above the piston or diaphragm and the disc lifts, pushed upwards by the system pressure. See Figures 1 and 2 for examples of these forces on piston and diaphragm type relief valves.

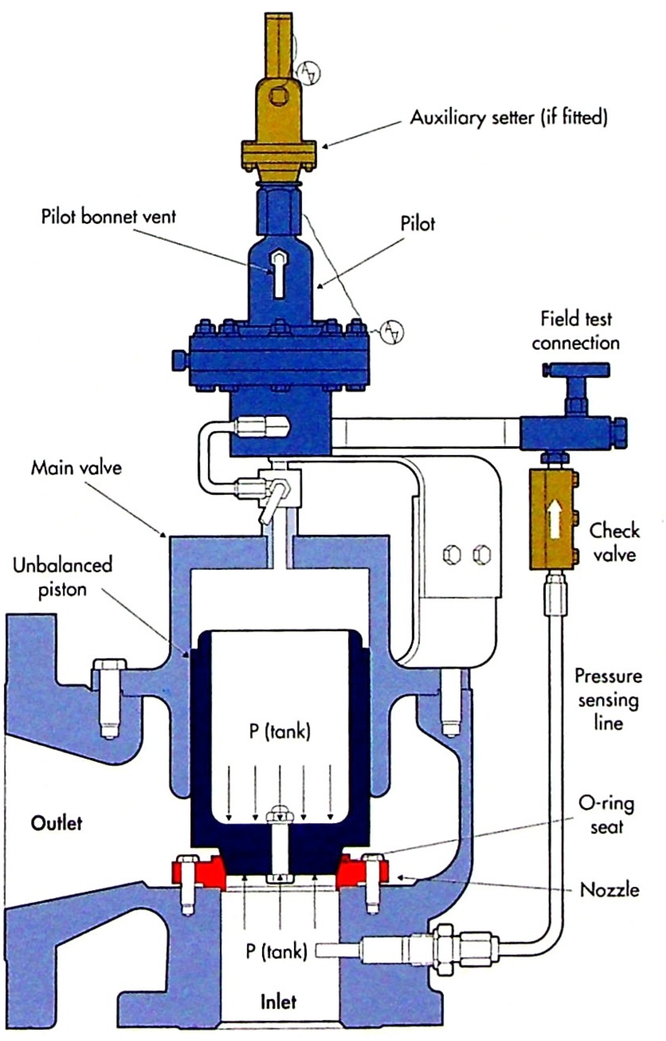


Figure 1: Piston type pilot operated relief valve

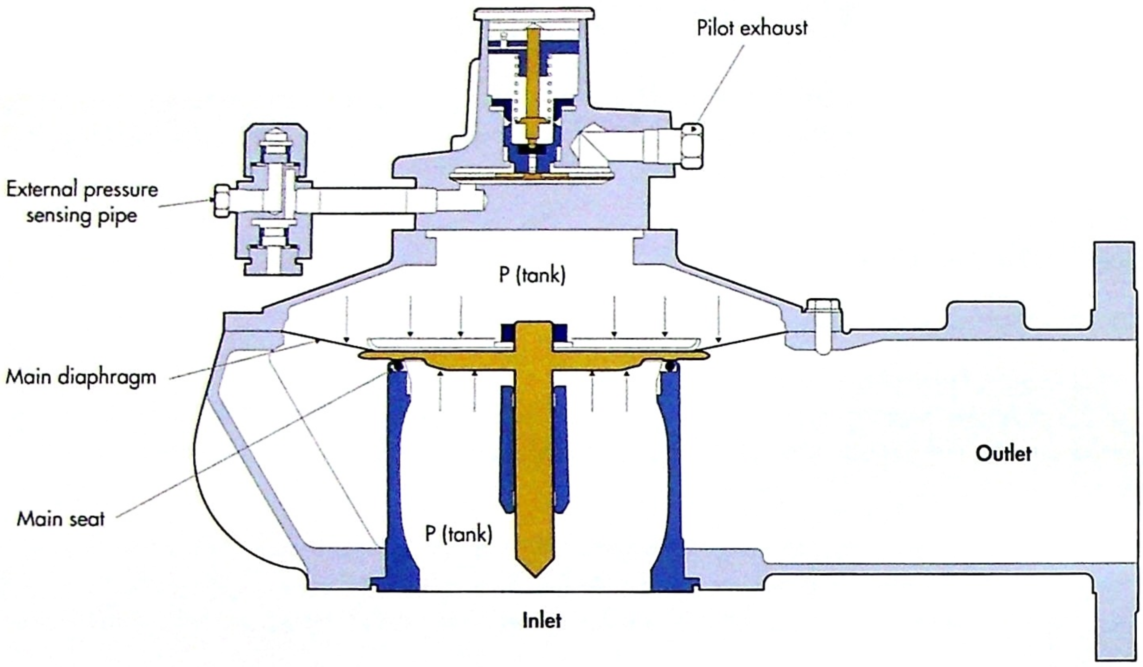


Figure 2: Diaphragm type pilot operated relief valve

2.1.1 Working principles

The ratio of the unbalance of the piston or diaphragm (moving member) usually ranges from 1.2 : 1 to 3.0 : 1. This means that the area on the top side of the piston is larger than the seating area.

For example, with a 2 : 1 imbalance, the area of the top side is two times that of the seating area. If the set pressure is 0.7 MPag and the seat area is 12 cm^2, then the net force holding the seat closed, immediately prior to opening, is 84 kg.

Upward force = 12 cm^2 x 7 kg/cm^2 = 84 kg

Seating force = 168 – 84 = 84 kg

The net seating force is equal to the upward force only in cases where the imbalance in areas is 2 : 1.

Downward force = 2(12 cm^2 x 7 kg/cm^2) = 168 kg

Therefore, net force holding relief valve shut = 168 – 84 = 84 kg

For the example relief valve to open, the pilot valve must de-pressurise the space on the top side of the piston to a pressure equal to 50% of the inlet pressure. When that occurs, the forces are in balance and the relief valve is on the threshold of opening. As the pressure on the top of the piston continues to vent to atmosphere, the piston will move upwards and the pressure will remain constant during this period. When the pilot closes, the top cavity is re-pressurised and the piston closes.

As the tank pressure increases and rises closer to set pressure, the net sealing force is increased until the relief valve opens due to the pilot venting the pressure off the larger area.

For simplicity, in this above example it has been assumed that 0.1 MPag = 1 kg/cm^2.

2.1.2 Pop and modulating actions

The pilot valve controls the pressure in the top cavity above the diaphragm or piston. Depending on the type of pilot valve, or the way it is set up, the pilot valve may control this pressure in two different ways that will make the main valve opening characteristics completely different.

Pop action

The pilot valve controls the pressure in the top cavity so that it is at either full pressure or no pressure. When the set pressure is reached, the pilot valve completely discharges (vents) the pressure in the top cavity so that the main valve opens fully every time the set pressure is reached in the system.

Advantages of pop action:

- Full opening force at set pressure means that the main valve can open despite small blockages, such as may be caused by ice or dirt.

Disadvantages of pop action:

- Full release of process fluid every time the main valve opens, whatever the reason. As the main valve opens fully each time it is activated, it may cycle (open/close) if the flow required by the protected system is lower than the flow that the valve is capable of discharging, causing chattering of the valve. Chattering may cause damage to the valve seat and disc.

Modulating action

The pilot valve regulates the pressure in the top cavity proportionally to the pressure increase in the protected system. In this way the main valve opens only to the amount that is required to relieve the overpressure. The main valve will not reduce the pressure in the system, but will keep it at a safe level in accordance with the IGC Code (Reference 1). The cause of overpressure must be eliminated for the main valve to close.

Advantages of modulating action:

- Reduced amount of fluid released to atmosphere
- reduced risk of chattering: a large valve can relieve very small flow without cycling
- reduced noise and less stress on piping
- suitable for all sorts of fluid states: gas, liquid, two-phase flow.

Disadvantages of modulating action:

- The force at opening the main valve may be less than on a pop action, making it more difficult to overcome any blockages, such as may be caused by ice or dirt.

2.2 Spring Loaded Relief Valves

In SLRVs (Figure 3), the valve disc seating force is applied by a coil spring onto the top of the piston or valve disc.

As the system pressure increases under the valve disc, the net valve seating force is reduced. Once open at the setting pressure, additional pressure rise is required to further lift the valve disc and release a greater quantity of fluid. The opening of the relief valve and the amount of opening depends on the opposing spring force. Any back pressure will also tend to close the valve due to flow downstream of the relief valve.

It is more difficult to set an exact set pressure on SLRVs than on PORVs. This is because SLRVs have less sealing force as the pressure rises to its set pressure. This is particularly true at low pressures.

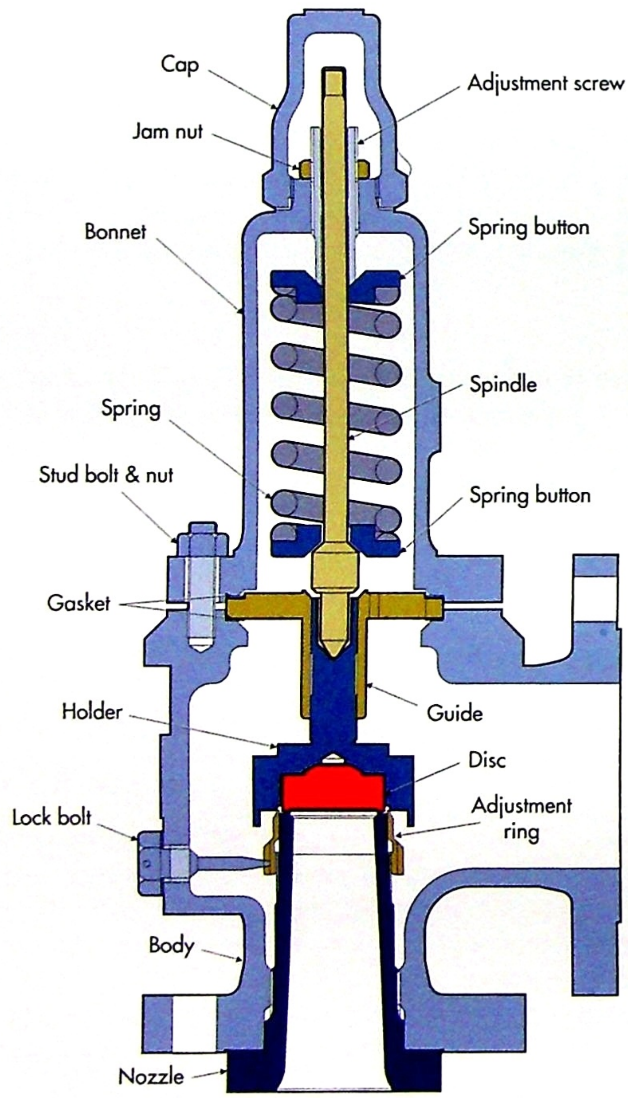


Figure 3: Spring loaded relief valve

2.3 Comparison of Pilot Operated and Spring Loaded Relief Valves

2.3.1 Pilot operated relief valves

As the force holding the valve disc closed becomes zero at the set pressure, the relief valve pops open and fully lifts under the thrust exerted by the gas. It then lifts more or less as required by the system, depending on the type of pilot, and whether it has a pop or modulating action.

2.3.2 Spring loaded relief valves

Once lifted, the SLRV disc can be raised further only by an increase in pressure above the set pressure. This is because the compression of the spring requires an additional force above the static pressure caused by the flow downstream of the relief valve.

Typically, SLRVs have a blowdown ring that enables control of the speed of opening and its blowdown, so that these valves will normally be fully opened within 10% above their set pressure, and reclosed within less than 10% below their set pressure.

Figure 4 illustrates the differences.

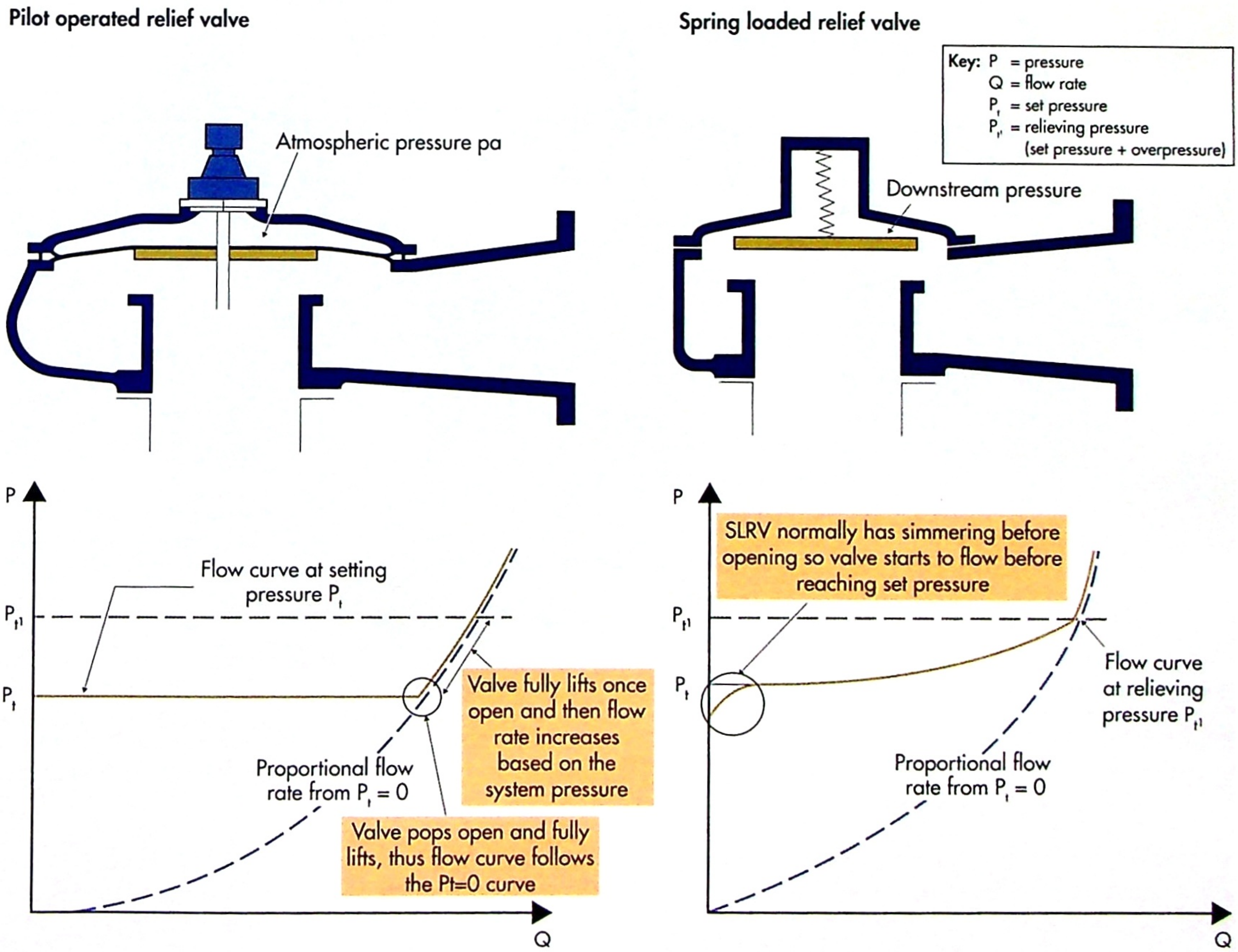


Figure 4: Characteristics of pilot operated and spring loaded relief valves

2.4 Vacuum Operation of Pilot Operated Relief Valves

For vacuum protection of low pressure cargo tanks, typically membrane tanks, PORVs are usually preferable. SLRVs are not usually suitable.

Vacuum protection on PORVs can be provided in different ways, which are described below.

2.4.1 Weight of disc

If the vacuum at which the relief valve must open is relatively low (eg -0.001 MPag), this setting can usually be obtained by the weight of the disc of the PORV, as shown in Figure 5.

As the vacuum drops in the tank, it also drops in the top cavity above the diaphragm or piston. Due to the difference in areas between the top cavity and the seat of the valve, at the set vacuum the upward force caused by the vacuum will be sufficient to overcome the weight of the disc and lift it up to allow air to come into the tank.

This characteristic makes it possible to have only one valve for both functions: pressure protection controlled by the pilot of the valve and vacuum protection controlled by the weight of the valve disc.

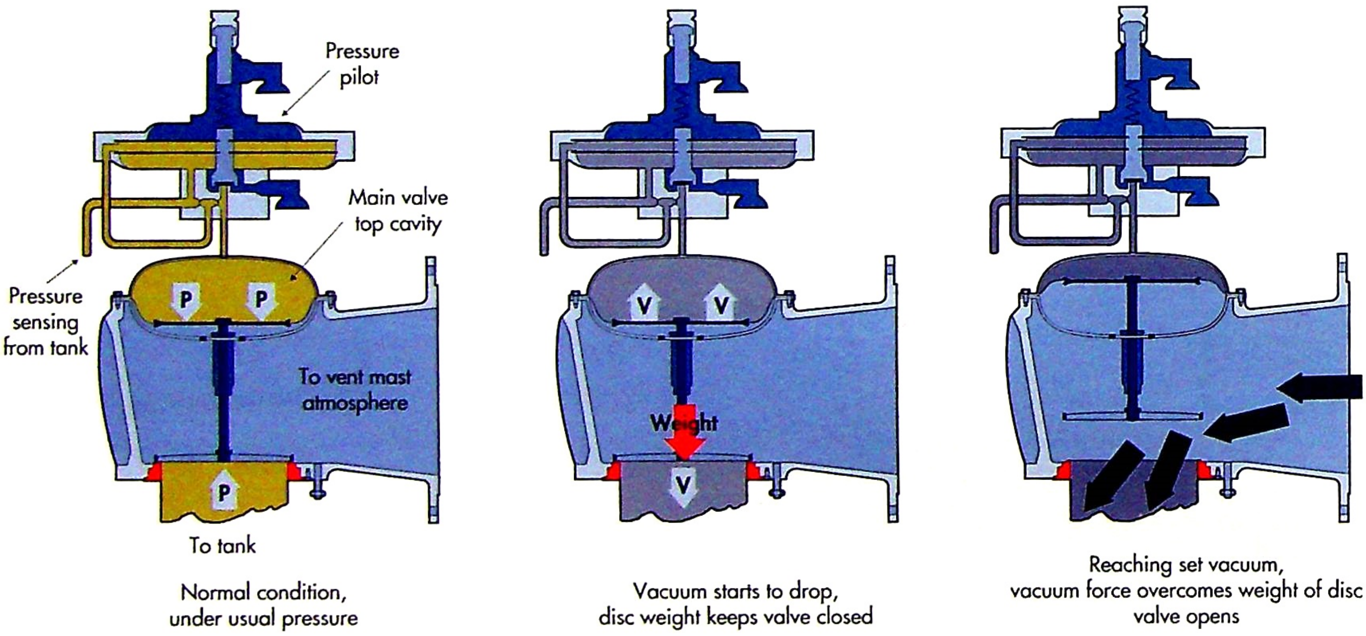


Figure 5: Vacuum operation from weight of disc

2.4.2 Additional vacuum pilot

If the vacuum at which the relief valve must open is lower (eg -0.005 MPag), it is usually not practical to adjust the weight of the disc sufficiently to reach this required vacuum setting. A special vacuum pilot can be added to the PORV to obtain this low vacuum setting (Figure 6).

The relief valve will then have two pilots: one controlling the opening and closing of the main valve during a pressure event, and the other, the vacuum pilot, controlling the operation of the main valve during a vacuum event. With a vacuum and pressure pilot, one PORV can provide both vacuum and pressure protection.

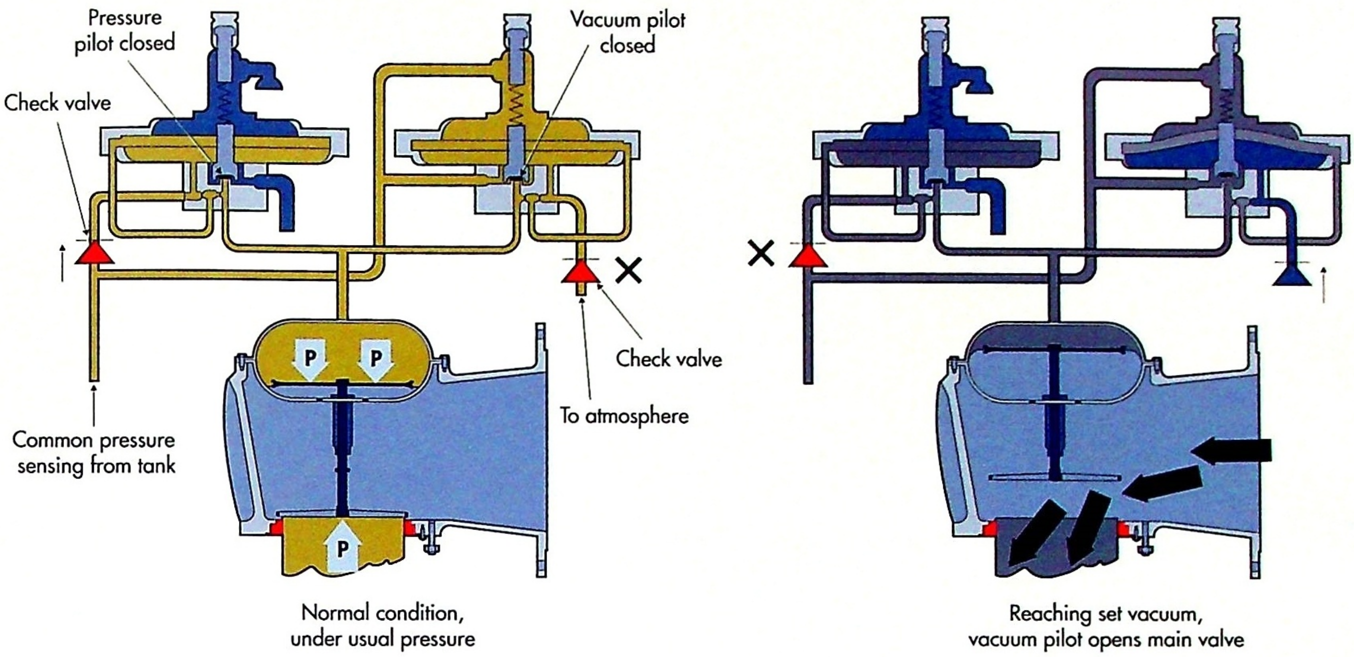


Figure 6: Vacuum operation with additional vacuum pilot

2.4.3 Separate pilot operated relief valve

In some other cases, a separate PORV set to open only on vacuum (normally with a vacuum pilot) may be provided for vacuum protection.

In this configuration, the tank will be fitted with two sets of valves: one set for pressure protection only and another set for vacuum protection. This configuration is normally found on floating LNG facilities, where the relief valve will have to relieve through a flare system. It cannot be used for vacuum protection as vacuum relief valves need to be connected directly to atmosphere to allow air to enter the tank to reduce the vacuum.

2.4.4 Backflow preventer

If the PORV is designed to operate on pressure only, with no vacuum operations, the relief valve may be specified with a *backflow preventer,* also called *a vacuum block*. This can keep the relief valve tightly closed when vacuum occurs in the tank or the insulation space.

This is only applicable to PORVs, due to the differential area between main valve diaphragms and main valve seats. It is not necessary for SLRVs, which naturally remain closed under vacuum.

3

Relief Valve Requirements

3. Relief Valve Requirements

3.1 General Requirements

The IGC Code (Reference 1) requires at least two relief valves of equal capacity to be fitted to any cargo tank. The types of relief valves most commonly fitted are SLRVs or PORVs. PORVs may be found on Type A, B and C cargo tanks and membrane cargo tanks. SLRVs are only found occasionally on Type C cargo tanks. SLRVs are commonly found on most cargo handling pipework.

Unless agreed with the relief valve manufacturer, the IGC Code specifies back pressure limitations for the different types of relief valve as follows:

1. For unbalanced relief valves: up to 10% of maximum allowable relief valve setting (MARVS).
2. For balanced relief valves: up to 30% of MARVS.
3. For PORVs: up to 50% of MARVS.

The maximum allowable pressure in the vapour space of Type A cargo tanks, prismatic Type B cargo tanks and membrane cargo tanks is 0.07 MPag. The Moss spherical Type B cargo tanks can also accept higher pressures of up to around 0.2 MPag, but only for emergency offloading. However, the normal operating pressure for Types A, B and membrane cargo tanks is generally 0.025 or 0.035 MPag. Type C cargo tanks are pressure vessels and are generally designed to operate at high pressures that can be in excess of 2 MPag.

The use of PORVs on Type A, B and membrane cargo tanks ensures reliable and accurate operation at the prevailing low pressure conditions. Their use on Type C cargo tanks, for example, may be necessary due to a possible high level of back pressure that would prevent the use of SLRVs, or to allow several relief settings to be achieved using the same valve. This may be done by fitting one or more auxiliary setters. Annex 1 shows the typical sequence to change the set pressure of a PORV using an auxiliary setter.

Auxiliary setters are also used to change the set pressure of the PORVs on Moss spherical Type B cargo tanks to reach the emergency offloading set pressure, and on floating storage and regassification units (FSRUs) to change the set pressures between sailing and static conditions of the ship.

PORVs with adjustable settings may be provided for two reasons:

1. They may be used to provide a higher set pressure than normal, but not exceeding MARVS during cargo handling. This is sometimes referred to as *harbour* setting.
2. They can improve the loading limits of Type C cargo tanks.

By causing relief valves to lift at pressures below those required to avoid over-stressing of the tank structure, ie below MARVS, the reference temperature, used to determine the tank filling limit, can be reduced. This reduces the difference between reference temperature and loading temperature and consequently reduces the cargo *shut out* volume.

If a relief valve is set to lift at pressures lower than MARVS, the reference temperature that is used to determine the tank filling limit is reduced. Thus the difference between the reference temperature and the loading temperature is reduced, and this consequently reduces the *shut out* volume.

Such adjustment may not be required for Type C cargo tanks that have an adequate vent system (see IGC Code 8.2.18 (Reference 1)). Further information can be found in *Application of Amendments to Gas Carrier Codes Concerning Type C Tank Loading Limits* (Reference 2).

A proper record should be kept of any changes to a relief valve setting, and the tank high pressure alarms should be adjusted accordingly.

The IGC Code (Reference 1) requires all pipelines, or components which may be isolated when full of liquid, to be provided with relief valves to allow for thermal expansion of the liquid. These relief valves typically relieve into cargo tanks. Alternatively, they may be taken to a vent stack via liquid collecting pots with, in some cases, a level switch alarm and a liquid vaporising source.

3.2 Basic Design Requirements

The basic requirements of relief valve design should take into account accidental over-pressurisation and accidental overheating of the tank contents.

Over-pressurisation should be prevented, while keeping the amount of gas discharged through the relief valve to a minimum, for reasons of personnel safety, environmental protection and economy. The valve should, therefore, be designed to shut off at a pressure just below its opening pressure, once the over-pressurisation has been relieved.

Accidental overheating will result in vaporisation of the liquid and increased pressure, which can only be safely reduced by discharge of gas through the relief valve. Classification Societies typically have defined tank design rules that fix the amount of gas to be discharged as a function of the liquid volume in the tank, the dimensions of the tank and the thermal insulation of the tank. These rules create a requirement for high gas flow rates.

Relief valves should be designed to meet the following requirements:

- Provide an effective seal until the pre-set opening pressure (set pressure) is reached. Soft seats are recognised to provide a more effective seal than metal seats (see Section 4.3.2, point 6)
- a precise and clean release of gas is to be achieved irrespective of cargo temperature
- once the pressure has been released, the valve should reclose at a pressure no less than 2% of MARVS below its set pressure + any inlet piping pressure losses, to guarantee the stable operation of the relief valves. This blowdown, if practical for the operation of the protected system, can be extended to 10 or even 15% below the set pressure
- frosting that may occur due to ambient conditions should not affect the valve's operation
- particularly for low relief valves, the seat materials should be such that they will not stick together over time
- operation of the valve should not be affected by the movement and vibrations of the ship
- the valve should not repeatedly open at the prescribed set pressure
- any back pressure in the vent piping system should be taken into account during selection and sizing of the valve so that it does not impede the full flow of the valve.

The capacity of a given relief valve is governed by various factors, including pressure, temperature and the fluid being handled. A general formula for the capacity of a relief valve is given below and shows how this is affected by these factors:

$$W = CK\,AK_bP\sqrt{\frac{M}{TZ}}$$

where:

W = rated capacity of the valve (kg/hr)
C = gas constant of fluid (function of Cp/Cv)
Cp = Specific Heat in constant pressure

P = flowing pressure = set pressure + 20% (IGC requirement) – inlet pressure losses + atmospheric pressure (kPa Absolute)

Cv = Specific Heat in constant volume
K = discharge coefficient (from manufacturer)
A = area of valve orifice (mm^2)
K_b = correction factor for back pressure (from manufacturer)
M = molecular weight of gas
Z = compressibility factor of the gas
T = absolute temperature of fluid at inlet to valve (K)

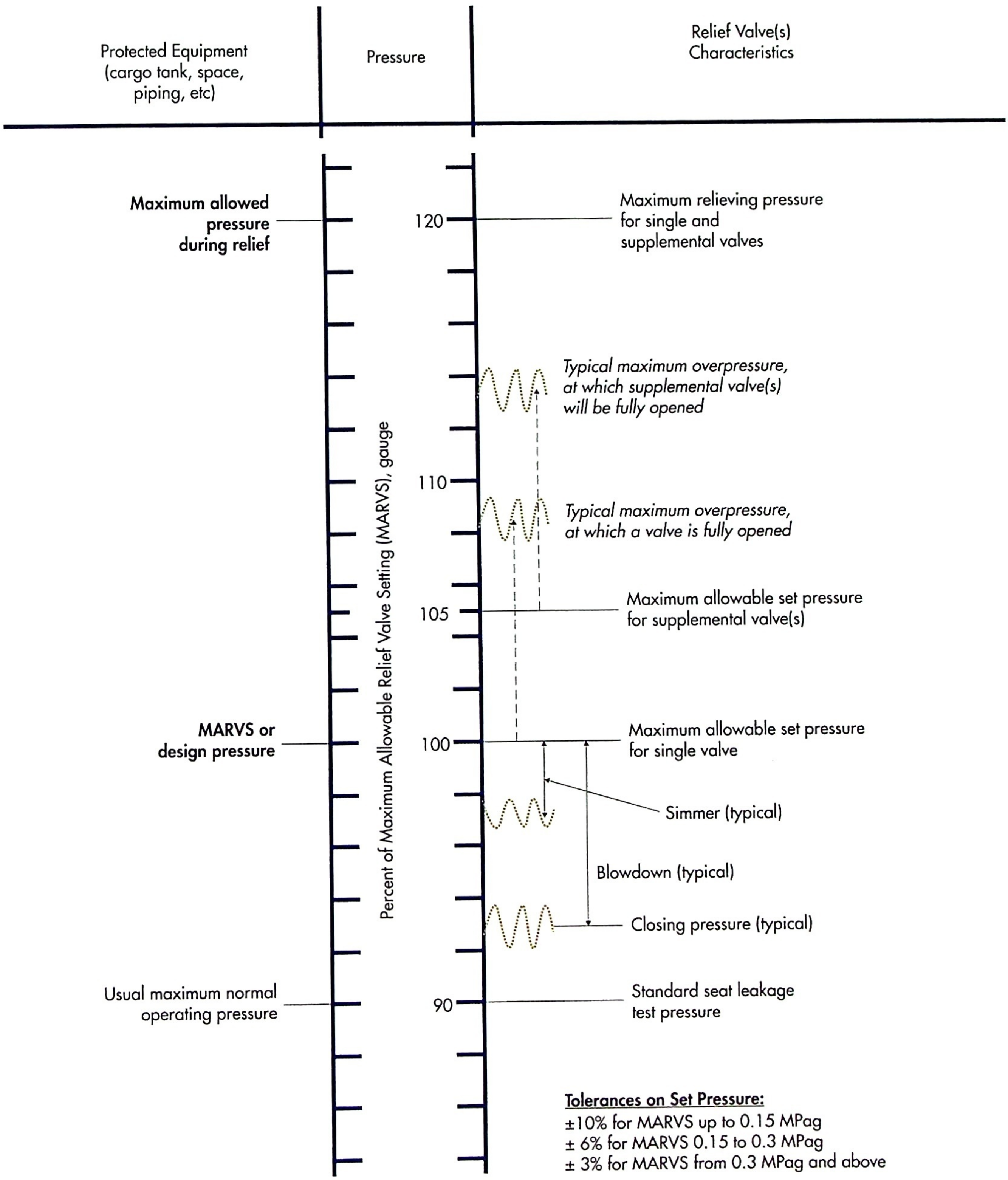


Figure 7: Pressure levels

3.3 Installation Design

The sizing of relief valves is stipulated by the various flag States based on the IGC Code and, as such, is beyond the scope of this publication. However, problems in service can often be alleviated by proper valve design selection, material selection, good pipework design and installation practices. Different designs of relief valves are usually necessary for different fluid types, gas or liquid.

Most valve manufacturers recommend that each valve has a separate expansion bellows fitted in the vent line, before joining a common header. Failure to observe this requirement can result in unacceptable loads being transmitted via the vent lines, due to thermal contraction and expansion. This may impose undue loads on, or cause malfunction of, one or both valves.

Pipework should always be adequately supported. There should not be any piping load on the relief valves in any circumstances as relief valves are not pipe fittings and any stress imposed on the valve body may cause adverse situations such as:

- Increase in set pressure, or even blocking of the opening of the relief valve
- seat leakage, even at very low pressures
- the relief valve becoming stuck open and not able to re-close.

Depending on the grades of stainless steel used in construction, painting for corrosion prevention may or may not be required. If it is necessary to paint the relief valves, the coatings should be applied carefully, as numerous malfunctions of relief valves have been caused by the blockage of small orifices by paint.

Supervision during construction and re-installation (if removed for overhaul) should ensure that there is no undue stress imposed on the relief valves due to poorly fitted and supported pipework. Pipework should also be thoroughly internally inspected for the absence of any debris prior to the fitting or refitting of the valves.

Flange bolting should be properly torqued, in the correct pattern, to ensure adequate sealing. For some relief valves, manufacturers may recommend some specific torque values and patterns. If not, refer to the relevant flange standard.

Cargo tank relief valves relieve into one or more vent masts. Vent mast drains should be provided and should be checked regularly to ensure there is no accumulation of liquid, such as rain water or condensates, in the stack. Accumulation of liquid can have the effect of altering the relief valve setting. This is caused by the resulting increased back pressure from the vaporising liquid or the freezing of accumulated water. It can also cause seat leakage due to accumulated dirt, scale, etc around the seat.

3.4 Materials

Classification Society rules specify the materials allowed to be used for ship construction. Relief valve materials are covered by these rules.

Relief valves in the cargo system are exposed to the environment, so they are typically made from a suitable material such as stainless steel. Due to the surface finish of the cast valve bodies, sea salts and other corrosive elements may be deposited on the external surfaces of the valves. Pickling and passivating of these cast parts is recommended to reduce the risk of surface corrosion issues.

The IGC Code and the Classification Societies also stipulate various mandatory testing on the material of the main pressure parts, depending on the service conditions of the relief valve, such as a service temperature lower than -55°C.

While atmospheric corrosion is a concern, there are also risks of galvanic corrosion, particularly for tanks made of aluminium. This is because the aluminium piping flange connected to the inlet of the stainless steel relief valve will cause corrosion of the aluminium, as both materials have widely different electrode potentials.

4

Recommendations

4. Recommendations

4.1 Selection and Design

- The type of relief valve should be selected taking into account the type of service, expected cargoes, worst case expected vibration levels and worst case expected exposure to the elements
- relief valve materials should be suitable for the type of service, expected cargoes, worst case expected vibration levels and worst case expected exposure to the elements
- cargo tank relief valves should be fitted with individual expansion bellows fitted in the vent line before joining the common header.

4.1.1 Inlet piping

To enable safe operations and to avoid excessive pressure drop across the relief valve, the inlet pipework should be such that:

- Flow area of the piping is larger than the flow area of the relief valve
- bends and fittings are minimised as much as possible.

4.1.2 Discharge piping

- Separate expansion bellows should be fitted in the vent line before joining a common header
- pipework should be adequately supported to ensure that there is no piping load on the relief valve under any circumstances
- the nominal diameter of the discharge piping should be equal or larger than the nominal diameter of the outlet connection of the relief valve
- bends and fittings along the piping should be minimised as much as possible
- the pipework from the relief valve to the vent mast, or cargo tank, should be as short as possible.

For further guidance, see *API STD 520 – Sizing, Selection, and Installation of Pressure-Relieving Devices, Part II – Installation* (Reference 3).

4.2 Operational

- Ship staff responsible for the maintenance and operations of relief valves are recommended to attend a manufacturer's training course
- ship staff should be familiar with the operation of the relief valves fitted on their ship. In particular they should be aware of what to do if a relief valve malfunctions
- vent masts should be kept free of rainwater accumulation and checked regularly
- when pressure settings on the relief valves are temporarily changed, the cargo tank high pressure alarms should be adjusted accordingly
- whenever auxiliary setters are used for more than one pressure setting, a proper record should be kept of any changes in the pilot valve springs, with the pilot assembly cap always reseated after such changes. A record should also be kept of the use of auxiliary setters.

4.3 Maintenance

4.3.1 Maintenance frequency

Table 1 provides a frequency matrix by relief valve type for various preventative actions. The combination of maintenance functions described requires action by both the ship's crew and repair yard personnel. They may also require input from the manufacturer or their designated service representative.

Valve Type	Frequency	Preventative Action
Cargo tank relief valve – pilot operated or spring type	During each loading	Visual inspection for leaks from external fittings and connections
	Continuously monitored	Seat leakage detection to be carried out by way of gas detection in vent line if fitted, and visual checks for icing of outlet or by observing *shimmering* at vent outlet
	Every six months	Verify integrity of security seals
		Visual inspection of external surface for presence of corrosion or cracks
		Ensure all external bolting, fasteners and mounting brackets are torqued to manufacturer's instructions
	Annually	Verify free operation using field test kit
	Special survey (every five years)	Verify calibration of all spring settings, pilots and auxiliary setter devices
		Verify proper operation and seat tightness of all valves in a clean environment with proper testing arrangements
		Inspect internals of valves for wear, corrosion and the presence of soft seal lubricants. Any adverse signs shall require inspection of all valves and maintenance as necessary
		Verify valve maintenance history is logged and updated as necessary
		Advise manufacturer of actions taken so as to allow them to update their records

Liquid line piping relief valve – pilot operated or spring type	Each loading	Visual inspection for leaks on all external fittings and connections. Verify lifting lever is free
		Seat leakage detection to be carried out by way of visual checking for outlet flange frosting
	Every six months	Verify integrity of security seals
		Visual inspection of external surfaces for presence of corrosion or stress cracks
		Ensure all external bolting, fasteners and mounting brackets are torqued to manufacturer's instructions
	Annually	Verify free operation using field test kit
	Special survey (every five years)	Verify proper operation and seat tightness of all valves
		Inspect internals of valves. Inspect for wear, corrosion and damage to soft seals. Any adverse signs shall require an inspection of all relief valves and repair as necessary
		Verify presence of valve maintenance history log and update as necessary
		Advise manufacturer of actions taken so as to allow them to update their records
Pilot operated hold/ insulation/inter-barrier space relief valve	Every six months	Visual observance of leaks. All external fittings and connections to be checked
		Internal visual inspection for the purposes of leakage detection
		Verify integrity of security seal for spring adjusting screw chamber
		Visual inspection of external surfaces for presence of corrosion or stress cracks
		Ensure all external bolting, fasteners and mounting brackets are torqued to manufacturer's instructions
	Annually	Verify free operation using field test kit
	Special survey (every five years)	Verify calibration of all spring settings
		Verify proper operation and seat tightness
		Inspect internals of valves for wear, corrosion and the presence of soft seal lubricants. Any adverse signs shall require inspection of all relief valves and repair as necessary
		Verify presence of valve maintenance history log and update as necessary
		Advise manufacturer of actions taken so as to allow them to update their records

Table 1: Frequency of preventative maintenance actions for various types of relief valves

Table 2 provides an action matrix by various valve types that can be applied during time at sea and also during repair period overhauls. These actions are generic in nature and are not intended to conflict with instructions of any particular manufacturer, who should be consulted in case of apparent conflict, doubt or uncertainty.

Component	Preventative Actions
Pilot	1. Verify proper calibration in accordance with manufacturer's instructions. Calibration tolerances are dependent on MARVS: +/-10% for MARVS up to 0.15 MPag +/-6% for MARVS 0.15 MPag to 0.3 MPag +/-3% for MARVS 0.3 MPag and above. See IGC Code (Reference 1) Upon completion of adjustments, security seal to be fitted and witnessed by a Classification Society's surveyor
	2. Inspect for external corrosion, water entry and integrity of external thread and bolts against stress corrosion cracking
	3. Upon disassembly, all *soft goods* (seals, gaskets, seats, diaphragms etc) should be changed, or at five year intervals
	4. If fitted with auxiliary setters, verify nameplate serial number of pilot(s) matches all auxiliary setters
Auxiliary setters	1. Verify the serial number matches the pilot
	2. Verify the calibration is within IMO prescribed limits Calibration tolerances are dependent on MARVS: +/-10% for MARVS up to 0.15 MPag +/-6% for MARVS 0.15 to 0.3 MPag +/-3% for MARVS 0.3 MPag and above. See IGC Code (Reference 1) Upon completion, sealing of adjustments should be witnessed by a Classification Society's surveyor
	3. Verify the spindle is straight and undamaged
	4. Inspect the mounting threads for damage and repair as necessary
	5. Return device to a safe, clean, dry storage area
Field test connection	1. Verify the valve is free to operate by cycling to the two or three positions
	2. Inspect for any external corrosion and damage
	3. Verify the return to correct and normal operating position
	4. Lock device in correct position
Backflow preventer	1. As per manufacturer's instruction, verify proper device operation without leakage under normal operation
	2. Ensure all external bolting is torqued to manufacturer's recommendations
	3. Lubricate the seals as per manufacturer's instructions, at every yard period and replace diaphragm or elastomers every five years. If the device leaks, the most likely cause is soft seat failure and the seals should be replaced

Vacuum block	1. This device is functionally identical to the backflow preventer and the same actions are recommended
Impulse line filter or vaporiser	1. This device has no moving parts. Drain condensate during every ship yard maintenance period
Main valve of pilot operated relief valve	1. Inspect the condition of all external bolting and fasteners every five years. Replace if signs indicate the onset of stress corrosion cracking. Bolting and fasteners that are of lesser quality than austenitic stainless steel (316) should be replaced every 10 years
	2. Test the main seat sealing integrity. Confirm leakage rate as per manufacturer's instructions, typically zero leakage at 90% of set pressure after one minute, but this can vary depending on the type of valve and working conditions
	3. 100% of all of these valves should be inspected at each regular shipyard maintenance period. Replace all elastomer seals and diaphragms of valves that have been broken down for inspection. In service polytetrafluoroethylene (PTFE) or similar plastic seals should be replaced every 10 years. In service non-PTFE or similar plastic seals should be replaced every five years
	4. Inspect flange gasket surfaces for signs of damage and or corrosion
	5. Inspect internal metal parts for signs of wear and corrosion. Replace as instructed by manufacturer
	6. Inspect for any external corrosion and damage, especially at the tube fittings and other threaded connections
	7. Inspect the pressure tubing for kinks and other damage. Replace immediately if any damage is noted
	8. Inspect all bolting and pilot mounting brackets for proper tightness. Consult manufacturer for proper torque values
Direct spring loaded valves	1. Verify the calibration is within IMO prescribed limits Calibration tolerances are dependent on MARVS: +/-10% for MARVS up to 0.15 MPag +/-6% for MARVS 0.15 MPag to 0.3 MPag +/-3% for MARVS 0.3 MPag and above. See IGC Code (Reference 1) Upon completion, sealing of adjustments to be witnessed by the ship's Classification Society If fitted, usually the blowdown ring must be adjusted to a specific position to enable proper calibration of the set pressure of the valve on the test bench. The blowdown ring will then have to be returned to its original position after the test. Refer to the manufacturer's instructions
	2. Verify the seat tightness. Zero leakage at 90% set pressure is acceptable for soft seated valves For valves with set pressures greater than 0.345 MPag (50 psig), the seat tightness shall be determined with the test pressure at the valve inlet held at 90% of the set pressure For valves with set pressures at 0.345 MPag (50 psig) or less, the test pressure shall be held at 0.0345 MPag (5 psi) less than the set pressure. *API STD 527 – Seat Tightness of Pressure Relief Valves,* (Reference 4)

	3. Verify the blowdown ring position is as per the manufacturer's original setting. Note that blowdown is not usually checked due to lack of sufficient volume to perform a functional check
	4. When the valve is disassembled, all parts should be inspected for corrosion and wear. Soft seals should be replaced whenever the valve is disassembled for inspection
	5. Test gags should be located and verified to be in good working order. Test gags should never be left installed on the valve as it causes the relief valve to be inoperative. Test gags should be stored in a warehouse, away from the valve, to avoid any misuse
	6. Inspect the condition of all external bolting and fasteners at least every five years. Replace if signs indicate the onset of stress corrosion cracking. Bolting and fasteners that are of lesser quality than stainless steel should be replaced at least every 10 years
	7. Inspect flange gasket surfaces for signs of damage and corrosion, apply corrective action if required. Replace gaskets on each occasion that the valve is removed. Ensure replacement gasket is of the correct material and size

Table 2: Preventative maintenance actions for cargo tank relief valves and their associated equipment

4.3.2 Relief valve maintenance and inspection

Regular maintenance is essential to ensure that relief valves will function correctly. Particular attention should be given to any trace of corrosion on internal parts of the valve that could affect the opening characteristics of the valve. All personnel involved in the operation of cargo systems protected by relief valves should be familiar with their purpose, function, normal operation and maintenance requirements.

The following points should be taken into consideration when inspecting and overhauling relief valves:

1. The manufacturer's instructions should be followed as a minimum.
2. Only original equipment manufacturer's (OEM) spare parts should be used.
3. Before removing relief valves, check cargo records and health and safety data sheets for any possible decontamination requirements.
4. Relief valves should be handled with care and always transported in the upright position. This is particularly relevant when being transported between the clean workshop and ship. Before transport, the openings of the valve should be temporarily sealed to prevent contamination. Cleanliness levels (if used) should be maintained. Each valve should be tagged and a corresponding tag used to mark the position from which it was taken.
5. When removed for overhaul, each valve should be put on the test rig, tested, and results recorded prior to dismantling and overhauling.
6. When the valve is on the test rig it should be fitted with a bubble tester (Figure 8) to enable determination of the seat tightness and the exact point at which it starts to lift. Seat tightness is generally quoted in bubbles per minute (bpm). For soft seat valves, 0 bpm is the norm. For metal valve seats, refer to *API STD 527 – Seat Tightness of Pressure Relief Valves* (Reference 4). These figures generally apply at 90% of set pressure. Always refer to the manufacturer's instructions.

7. Relief valves should be tested with dry air or nitrogen as this gives an indication of very small leaks through the bubble tester. Valves operating on gas application should never be tested on water. Testing a gas valve on water will not give correct results and water can stay trapped inside the valve after testing. This can cause the valve to malfunction afterwards, particularly it the valve is intended for low temperature service. Valves that are in liquid service should be tested with liquid.

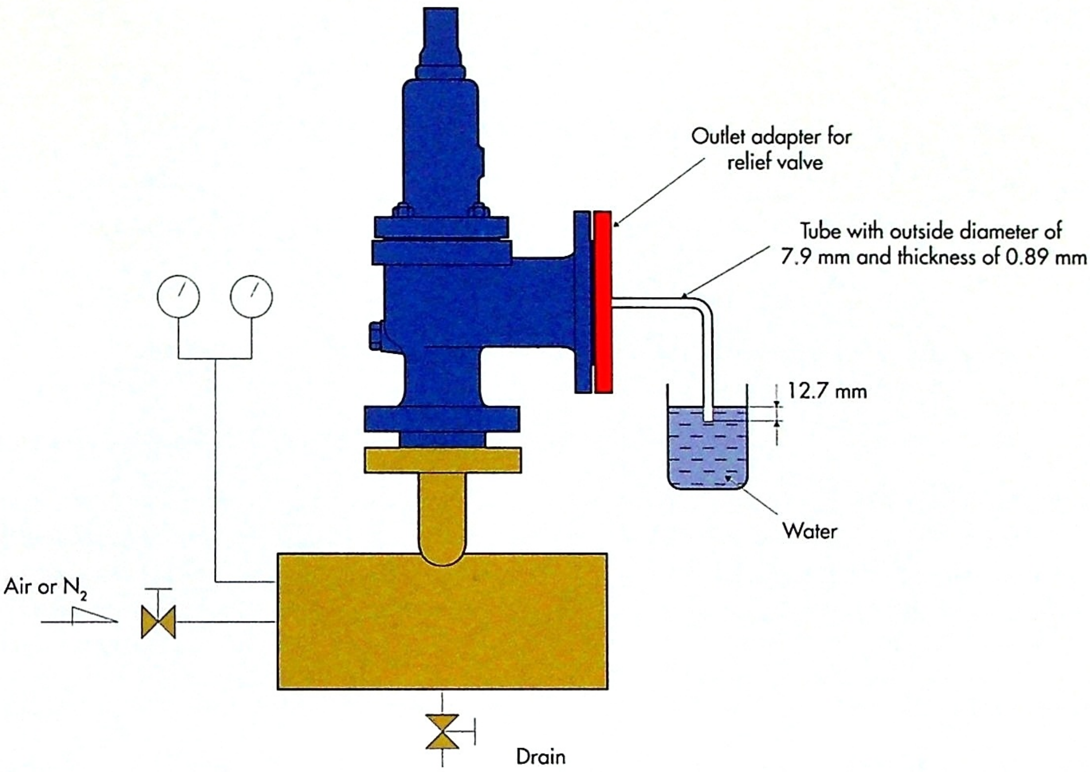


Figure 8: Standard bubble tester

8. Flange bolting should be properly torqued, in the correct pattern, to ensure adequate sealing. Manufacturers may recommend specific torque values and patterns. If not, refer to the relevant flange standard.
9. Records should be kept for all relief valves, preferably within the ship's planned maintenance system.
10. Never attempt to lap the valve nozzle to the disc. See Annex 2 for maintenance guidance for metal to metal seats.
11. Accuracy and repeatability of the set pressure will only be possible to achieve if the test rig has sufficient surge volume. This is particularly true with SLRVs, where leakage may occur at 90% of set pressure and significant simmer at 95% set pressure. A small test volume and feed rate may never be able to push the valve past the simmer point and, subsequently, the valve will be set at a pressure higher than intended. An air hose connected to the valve inlet flange should not be used as this configuration will not be able to provide adequate volume to properly test the valves.

12. There is no accepted standard for surge tank capacity. Figure 9 shows a graph of surge tank volume related to valve orifice area. It is published in the *National Board Inspection Code*, Part 4, Supplement 5 (Reference 5).

    For example, using Figure 9, a 150 mm NB SLRV with an orifice area of 100 cm² and a design blowdown of 10%, a surge tank of 2 m³ would be required. This is a facility that few test shops would have. An advantage of PORVs is that they only require a small surge volume (in the order of 10 litres), due to the small capacity of the pilot.

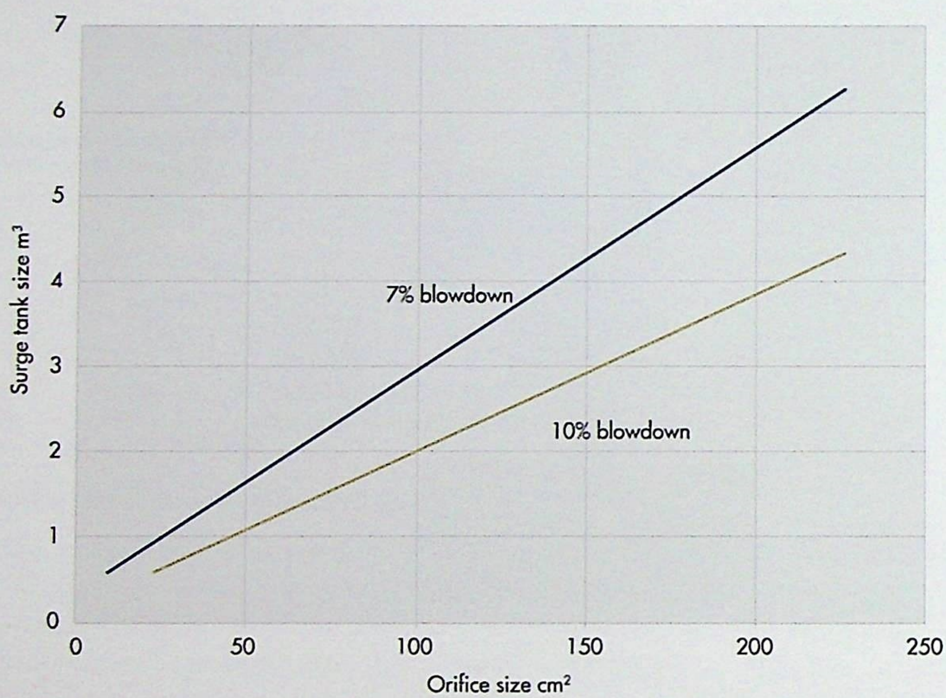


Figure 9: Spring loaded relief valves: recommended test rig surge tank size for air or gas service

13. Relief valves should be overhauled and tested in a clean environment, using clean tools and trained personnel.
14. The valve discharge outlet should be positioned to prevent exposure of personnel to a sudden blast of air, water or other projectiles from the valve. Ear protection may also be required when testing high pressure valves.

The figures in Table 3 are usually applicable for set pressures above 0.1 MPag (15 psig). For lower set pressures, refer to the manufacturer's recommendations.

Valve Set Pressure		Maximum Allowed Leakage Rates					
		Effective Orifice Sizes 1.98 cm² (0.307 sq. in) and Smaller			Effective Orifice Sizes Above 1.98 cm² (0.307 sq. in)		
MPag	PSIG	Bubbles/min	cm³/min	cu. in/min	Bubbles/min	cm³/min	cu. in/min
0.103 – 6.9	15 – 1,000	40	11.81	0.72	20	5.90	0.36
10.3	1,500	60	18.06	1.10	30	9.03	0.55
13.8	2,000	80	23.61	1.44	40	11.81	0.72
17.2	2,500	100	29.86	1.82	50	14.58	0.89
20.7	3,000	100	29.86	1.82	60	18.06	1.10
27.6	4,000	100	29.86	1.82	80	23.61	1.44
41.4	6,000	100	29.86	1.82	100	29.86	1.82

Table 3: Typical maximum seat leakage rates for metal seated relief valves

4.4 Maintenance and Care of Diaphragms

Diaphragm failure, either main or pilot, will result in the relief valve opening and, at least initially, an uncontrollable release of cargo. Diaphragms should be examined and renewed at regular intervals. When determining maintenance intervals, consideration should be given to the cargo tank operating pressure and the aggressiveness of the products being carried. Maintenance intervals may be modified in the light of operating experience.

Spare diaphragms should be stored as per manufacturer's instructions to ensure they have a long shelf life.

For relief valves fitted with metallic diaphragms, manufacturer's instructions on inspection and replacement should be observed. Generally, these will have longer shelf and service lives.

Care should be taken to ensure that the spare diaphragm is fitted the right way up.

All diaphragms are recommended to be changed at the ship's first refit after delivery due to the wear and tear imposed during commissioning and testing. Afterwards, they should be inspected at each following special survey and replaced at the special survey following that. This cycle should then continue throughout the ship's life.

4.5 Routine Testing

Cargo tank relief valves are critical safety equipment and should be tested as per manufacturer's instructions. Manufacturers should provide clear instructions on the interval and procedure for testing. The testing should include, but not necessarily be limited to, the pilot and the main valve.

The testing routine should be included in the ship's planned maintenance routines. Testing of cargo tank relief valves should only be carried out under a permit to work. Testing may require the use of a *field test kit*.

4.6 Field Test Kit

PORVs should be fitted with a *field test connection* (FTC). This enables a field test kit to be connected. A field test kit arrangement is shown in Figure 10.

A typical field test kit consists of:

- A bottle of compressed gas (nitrogen typically)
- a pressure regulator to drop the pressure to acceptable levels
- a calibrated test pressure gauge
- a flexible hose to connect the gas bottle to the FTC on the relief valve to be tested
- the various fittings required to connect everything.

While one field test kit on board is usually sufficient to test all the PORVs of the ship, there should be an adequate set of different pressure gauges to cover all the various set pressures of the relief valves.

The field test kit is a precision instrument and should be handled and stored carefully.

For further information on the inspection and maintenance of relief valves, *API RP 576 – Inspection of Pressure-Relieving Devices* (Reference 6) is recommended.

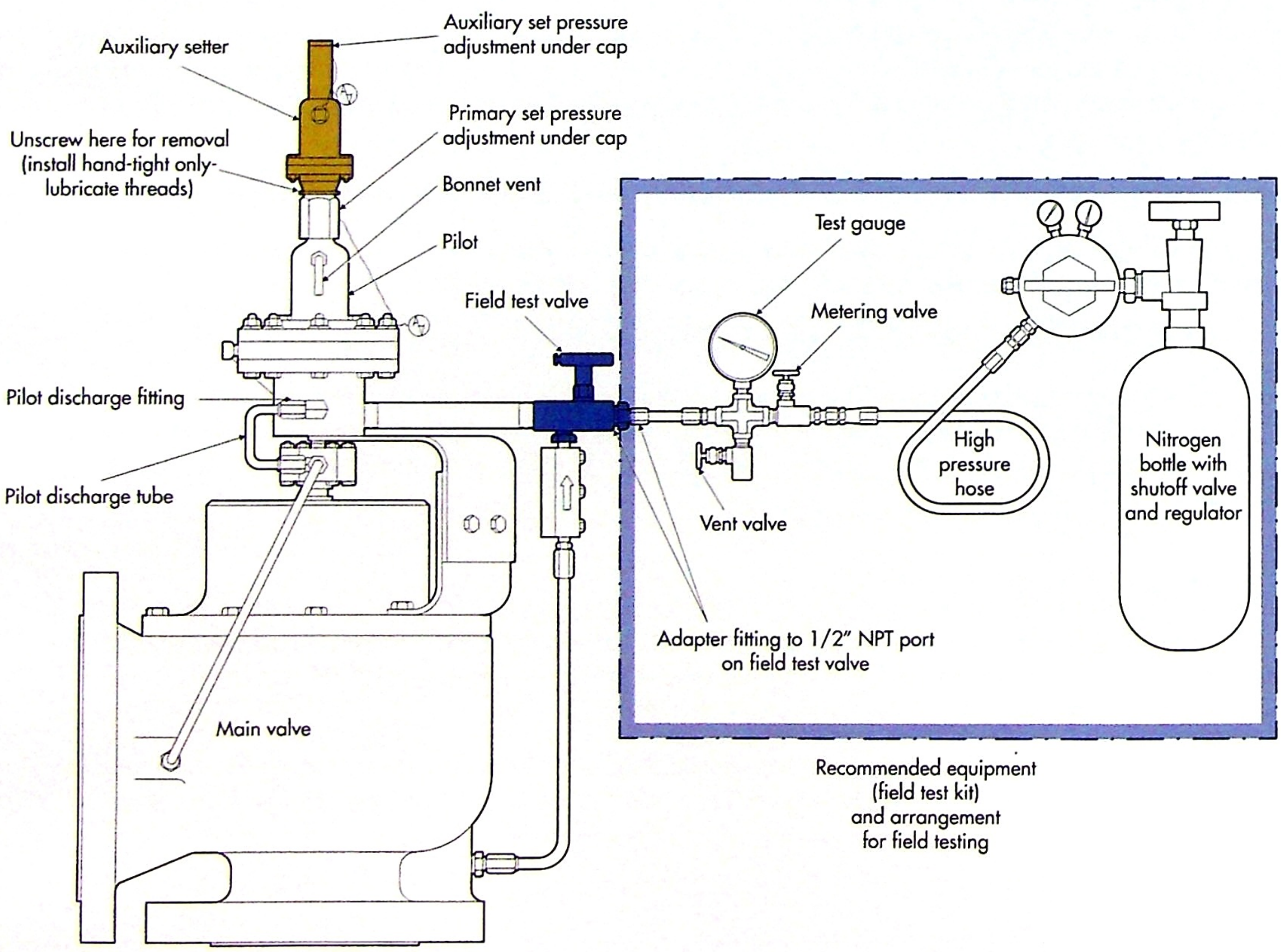


Figure 10: Field test kit arrangement for field testing

5

Operating Problems and Faults

5. Operating Problems and Faults

5.1 Operating Problems

5.1.1 Chattering

Chattering can occur when the volume of the tank is too small in relation to the capacity of the relief valve. As a result, the *process fluid* will not have sufficient kinetic energy to keep the relief valve open. This is corrected by addressing the design issue.

Chattering can also be caused by the incorrect setting of the valve blowdown adjustment ring or by excessive back pressure in the discharge pipe.

5.1.2 Seat leakage after lifting and reseating

Seat leakage could be caused by small debris trapped in the relief valve seating surfaces. This can usually be resolved by operating the relief valve a few times to try to blow away the debris. This may be carried out on a test bench or by operating the valve lifting lever where fitted.

Use of the lifting lever on a SLRV typically requires the presence of an inlet pressure of at least 70% of its set pressure. Manufacturer's instructions should be referred to before using the lever. Repeated use of the lifting lever may damage the relief valve.

If the debris cannot be cleared by operating the relief valve, then it may have to be dismantled and cleaned.

On SLRVs, seat leakage may also be caused by the lifting lever if it was incorrectly fitted. This may be fixed by popping the relief valve on the test bench.

5.1.3 Leakage in operation

Seat leakage may be the result of the following issues:

1. **Set pressure too close to the operating pressure:** PORVs can remain tight at operating pressures very close to the set pressure, typically 95% or higher. For SLRVs it is advisable to keep the operating pressure lower than 90% of the set pressure.
2. **Damaged spring or wrong spring fitted:** this results in it not being possible to obtain repeatability of the set pressure. If a spring is knocked or dropped, a weak spot may be created. This could develop into a crack while the spring is compressed. Corrosion will also weaken the spring and a corroded spring will usually have to be replaced.
3. **Damaged or leaking seals:** this can be caused by poor maintenance or chemical attack of the seals by the cargo fluid if the material of the seals is not compatible.
4. **Accumulation of condensates:** if condensates are not drained, they can accumulate in the body of the relief valve and cause valve leakage. Relief valves outlets should always be cleared of any condensates by draining the exhaust line.
5. **Blockage by solidified CO_2:** CO_2 may solidify into small particles when the relief valve opens and flows, blocking the valve from reseating tightly.

6. **Piping stress on the valve:** this should have been addressed at the design and installation stage. To check for piping stress, unbolt the outlet piping flange from the valve. If the leakage stops, or reduces significantly, then piping stress is the likely cause of the leakage and should be corrected.
7. **Incorrect fitting of auxiliary setter:** check that the correct auxiliary setter is used (correct pressure, correct serial number, etc) and that it is properly fitted on the pilot as per manufacturer's instructions.

5.2 Faults

5.2.1 Reverse flow

A PORV can open and have reverse flow if the pressure in the vent line exceeds the pressure in the cargo system. This may occur if the discharged fluids vaporise in the mast. Where necessary a backflow preventer may be fitted to prevent this from occurring.

A backflow preventer should not be fitted on PORVs that will also need to open on vacuum, such as cargo tank relief valves on membrane tanks.

5.2.2 Blockage of sensing tube

Ships carrying cargoes that require polymerisation inhibitors, such as butadiene, may encounter problems with blockage of the sensing tube between the cargo system and the pilot valve.

This should normally be addressed at design stage, such as by selecting the proper relief valve configuration or by heat-tracing of the lines.

5.2.3 Trapped gas

During cargo change operations, trapped gas in the pilots and dome chambers of the cargo tank relief valves should be purged. Suitable arrangements and procedures should be made to allow for this operation.

A typical example is that failure to purge propylene gas from the pilot and dome chamber of relief valves is likely to result in mixing of propylene and butadiene after the loading of a butadiene cargo. This could result in polymerisation of the butadiene, causing problems with the operation of the cargo tank relief valves.

5.2.4 Chloride pitting

Balanced bellows type of relief valves commonly use stainless steel as the bellows material. This is liable to suffer from chloride pitting, eventually resulting in barely visible holes in the material, causing leakage and early lifting of the valve.

Bellows should always be inspected very thoroughly at times of overhaul. Other materials, more suitable for marine atmosphere, can also be specified at design stage.

5.2.5 Paint blockage

Applying too much paint may result in the blockage of small orifices such as bonnet vents, which can adversely affect performance of the valve.

5.3 Chloride Stress Corrosion Cracking

Some components in PORVs, such as bolts, nuts, tube fittings and caps, can suffer from chloride stress corrosion cracking. Failure of these components in service could result in the spurious opening of a relief valve.

The cause of this problem is usually a combination of a high concentration of chlorides from sea water, relatively high metal temperatures (65°C) due to solar radiation and the use of certain grades of austenitic stainless steel for the valve components.

It is recommended that these components are carefully inspected during regular maintenance periods, particularly the bolting, and replaced immediately if any corrosion is found, or if there is any doubt.

5.4 Emergency Closure of Relief Valves

In the event of failure of a cargo tank relief valve, ships are now required to have safe means of emergency isolation. Procedures for this emergency isolation should be provided in the cargo operating manual.

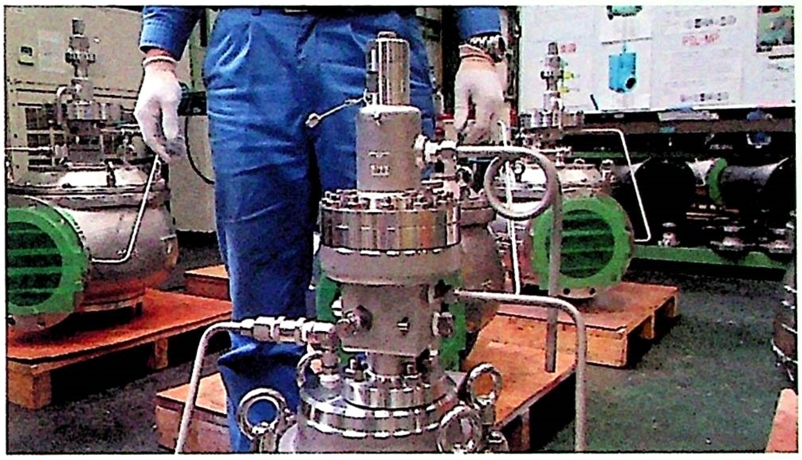
Refer to the IGC Code Chapter 8.2.9 for the full text of this requirement (Reference 1).

Annexes

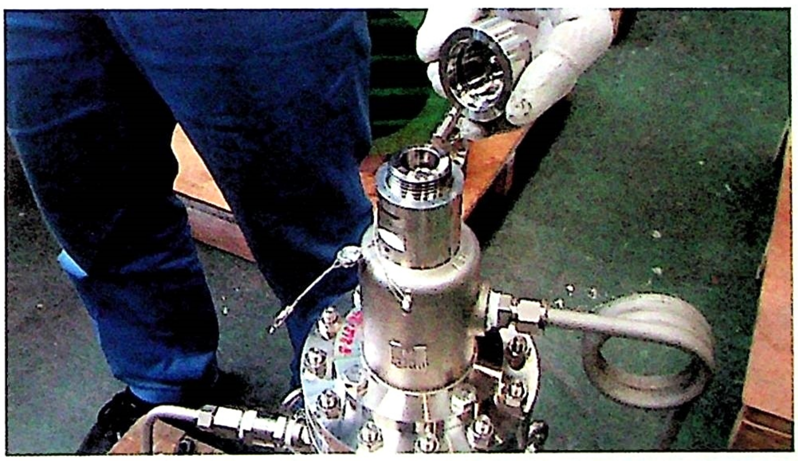
Annex 1 – Auxiliary Setter Installation Procedure

(Fukui PSL-MP Model)

1. Before installing the primary pilot valve:

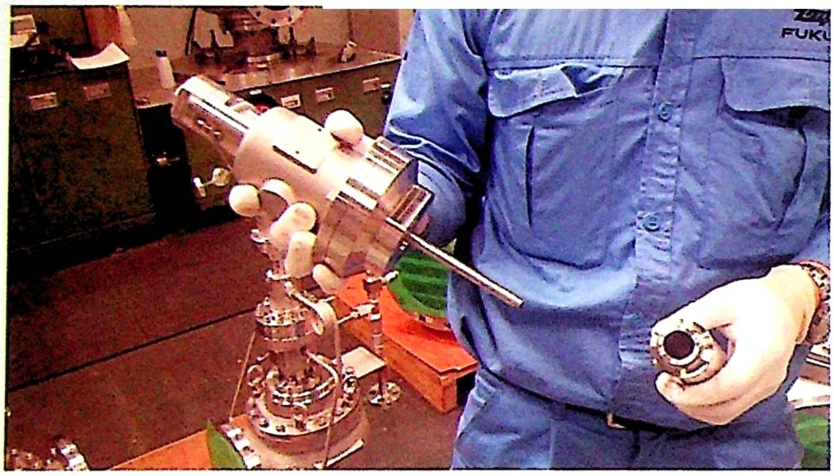


2. Remove cap from the primary pilot valve:

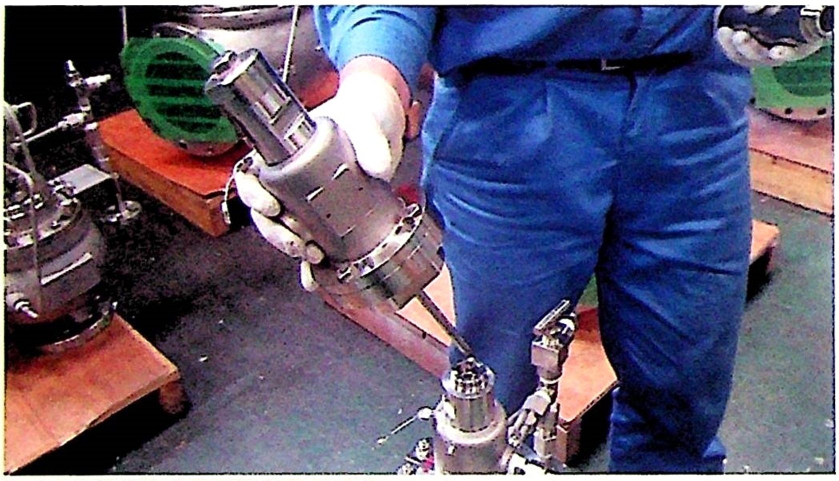


3. Auxiliary setter. Make sure to match the tag number between auxiliary setter and pilot valve:

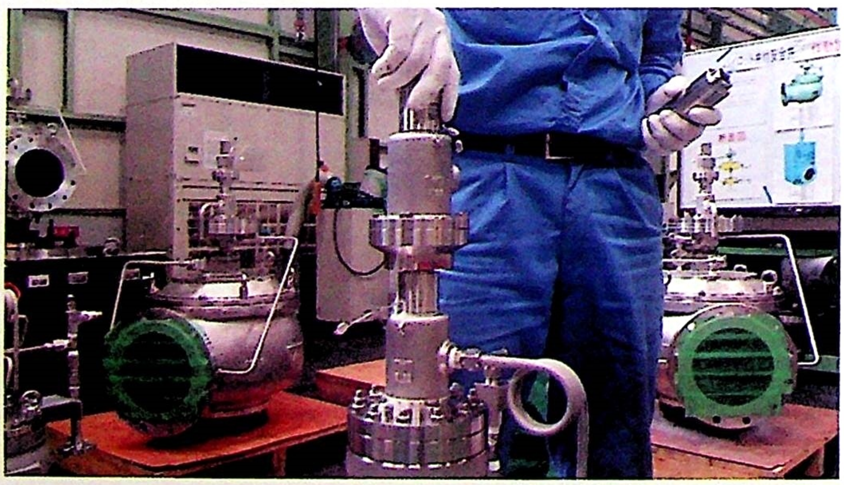
4. Remove rod cover from the auxiliary setter:



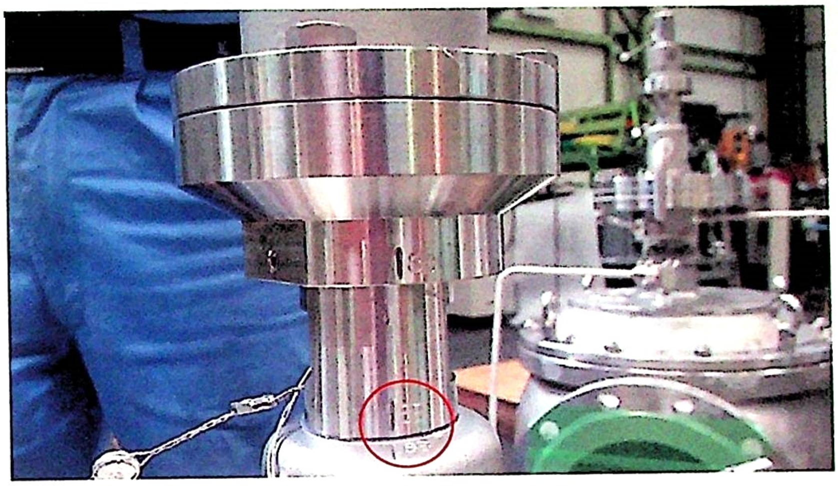
5. Install the auxiliary setter into the top of the pilot valve:



6. Screw in until hand tight:



7. Tighten with wrench to align with the matching mark (circled in red):



Annex 2 – Metal to Metal Valve Seats

Precautions and guidance for lapping metal to metal valve seats

Reconditioning of the seat surface may be accomplished by lapping with a flat cast iron ring lap coated with grade no. 1000 silicone carbide compound or its equivalent. The following precautions and guidance should be followed by maintenance personnel when lapping seats:

1. Keep work materials clean.
2. Always use a fresh lap. If signs of wearing (out of flatness) are evident, recondition the lap. Reconditioning of laps is accomplished by lapping them on a flat lapping plate. The lapping should be done with a figure-eight motion as indicated in Figure A1. To ensure the best results when lapping seats, the laps should be reconditioned after each usage and checked with an optical flat.
3. Apply a very thin layer of compound to the lap. This will prevent rounding off the edges of the seat.
4. Keep the lap squarely on the flat surface and avoid any tendency to rock the lap, as this causes rounding of the seat.
5. When lapping, keep a firm grip on the part to prevent the possibility of dropping it and damaging the seat.

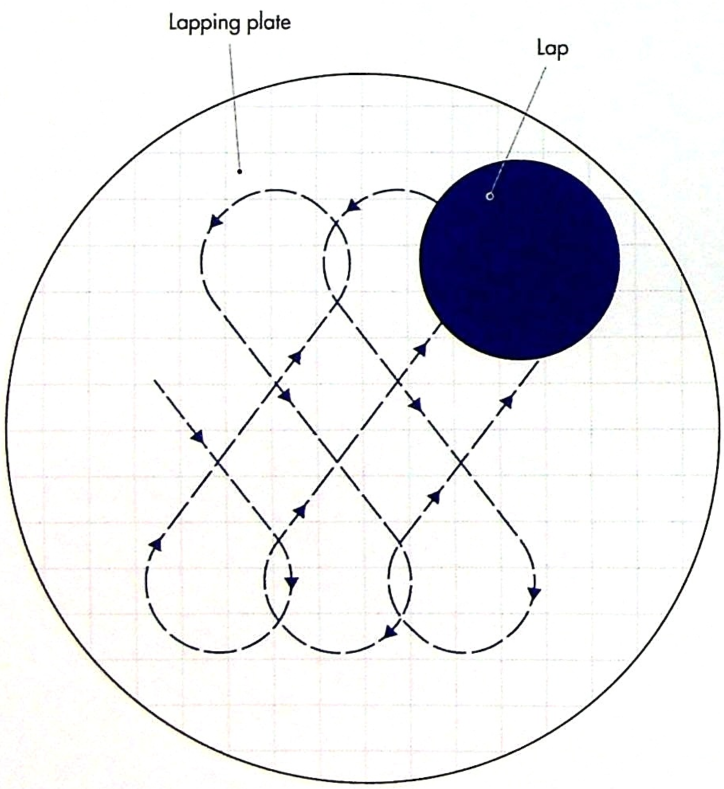


Figure A1: Motion for lapping metal to metal valve seats

6. Lap using an eccentric or figure-eight motion in all directions, while at the same time applying uniform pressure and rotating the lap slowly.

7. Replace the compound frequently after wiping off the old compound and apply more pressure to speed the cutting action of the compound.
8. To check the seating surfaces, remove all compound from both the seat and the lap. Shine the seat with the same lap using the lapping motion described above. Low sections on the seating surface will show up as a shadow in contrast to the shiny portion. If shadows are present, further lapping is necessary and only laps known to be flat should now be used. Only a few minutes will be required to remove the shadows.
9. When the lapping is complete, any lines appearing as cross scratches can be removed by rotating the lap (which has been wiped clean of compound) on the seat about its own axis.
10. The seat should now be thoroughly cleaned using a lint-free cloth and a cleansing fluid.

Annex 3 – Glossary of Terms and Abbreviations

API American Petroleum Institute

Auxiliary Setter A device that enables the set pressure of a pilot operated relief valve (PORV) to be temporarily increased without the need for changing its initial setting. It is also known as a *complementary setter*

Back Pressure The pressure existing at the outlet of a relief valve due to pressure in the discharge system

Backflow Preventer This is fitted to the PORV to prevent the valve from opening due to back pressure in the vent line. It usually consists of one or two check valves fitted in the supply tube to the pilot valve and/or in the supply tube from the pilot valve to the main valve. It sometimes called a *vacuum block* as it also blocks the PORV from opening in case of vacuum at the inlet of the valve

Blowdown The difference between actual popping pressure of a relief valve and actual closing pressure, expressed as a percentage of set pressure or in pressure units

bpm Bubbles per minute

C Celsius

Chatter Abnormal, rapid reciprocating motion of the movable parts of a relief valve in which the valve disc contacts the seat

Closing Pressure The value of decreasing inlet pressure at which the valve disc re-establishes contact with the seat or at which lift becomes zero

Coefficient of Discharge The ratio of the measured relieving capacity to the theoretical relieving capacity of a relief valve

Disc The pressure retaining movable element of a relief valve that effects closure

FTC Field Test Connection. This device can be added to PORVs to test the settings of the pilot valve *in the field* without removing the valve from the piping

IACS International Association of Classification Societies

IMO International Maritime Organization

K Kelvin

kg Kilogram

Lift The actual travel of the disc away from closed position when a valve is relieving

LNG Liquefied Natural Gas

LPG Liquefied Petroleum Gas

MARVS Maximum Allowable Relief Valve Setting of a cargo tank (gauge pressure)

MPag Megapascal gauge

NB Nominal Bore

Nozzle A pressure containing element, which constitutes the inlet flow passage and includes the fixed portion of the seat closure

OEM Original Equipment Manufacturer

Opening Pressure The value of increasing inlet pressure of a relief valve at which there is a measurable lift, or at which the discharge becomes continuous

Overpressure A pressure increase over the set pressure of a relief valve, usually expressed as a percentage of set pressure

Pilot Valve An auxiliary valve that actuates the main relieving valve of a PORV

Popping Pressure The value of increasing inlet pressure at which the valve disc moves in the opening direction at a faster rate than the corresponding movement at higher or lower pressures. It applies only to relief valves on compressible fluid service

PORV Pilot Operated Relief Valve

psig Pounds per square inch, gauge

PTFE Polytetrafluoroethylene is a synthetic fluoropolymer of tetrafluoroethylene

Relieving Pressure Set pressure plus overpressure

Seat The pressure containing contact between the fixed and moving portions of the pressure containing elements of a valve

Security Seal A lead or plastic seal, used to prevent unauthorised adjustment of a relief valve or an auxiliary setter

Set Pressure The value of increasing inlet pressure at which a relief valve displays one of the operational characteristics defined under *opening pressure* or *popping pressure*

Simmer Audible or visible escape of fluid between the seat and disc at an inlet static pressure below the popping pressure and at no measurable capacity. It applies to safety or safety relief valves on compressible fluid service

SLRV Spring Loaded Relief Valve

Annex 4 – Reference List

1. IMO – International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)
2. SIGTTO/IACS – Application of Amendments to Gas Carrier Codes Concerning Type C Tank Loading Limits
3. API STD 520 – Sizing, Selection, and Installation of Pressure-Relieving Devices, Part II – Installation
4. API STD 527 – Seat Tightness of Pressure Relief Valves
5. National Board of Boiler and Pressure Vessel Inspectors – National Board Inspection Code, Part 4: Pressure Relief Devices, Supplement 5
6. API RP 576 – Inspection of Pressure-Relieving Devices