The Selection and Testing of Valves for LPG Applications.

Contents

Note: This document applies only to valves installed on LPG vessels; however it can provide guidance to valves at LPG terminals. This document is designed to be a supplemental guide to work in conjunction with the relevant codes and standards for LPG valves and does not seek to override them.

Scope

This document is intended to offer guidance to designers and operators on the general requirements for valves for Liquefied Petroleum Gas (LPG) service, where valves are generally designed for an operating temperature range from – 55^{0}C to + 80^{0}C Some valves such as those on compressor exhausts may reach temperatures in the region of +150 °C and should be specified accordingly. This guidance is primarily intended for application to LPG ships, but may be applied throughout the LPG industry as appropriate. Nothing in this document seeks to override any national or international standards and codes that may be applicable to these valves. For cryogenic valves (those operating below -80^{0}C) there is further guidance in the SIGTTO publication “The Selection and testing of valves for LNG Applications”.

Where the term ‘LPG’ as used in this document also it may be read as being applicable to liquefied “chemical gases” within the same temperature range (for example propylene, butadiene, vinyl chloride & ammonia); these chemical gases may have different requirements in respect of construction details, material used for seats, sealing, gland and joints.

Introduction

For low temperature systems, specific design requirements apply to ensure that a valve will work effectively. For example the valve design should take into consideration thermal expansion and contraction and still provide a tight shut off without leakage across the seat whilst ensuring that the valve design meets relevant design codes and standards. The design needs to consider factors such as minimising the mass in the casting in order to improve cool down times and ensuring that the operation of the valve gland and gland seal area are not affected by the lowest operating temperature.

This document aims to introduce the fundamentals of low temperature valve design and testing in general and considers the minimum technical requirement in more detail. The standards offered as examples are European Committee for Standardisation, (CEN), standards. However, the appropriate national codes or standards and Class requirements should be referred to where applicable, or where they are more stringent. The major codes and standards on this subject are referenced in the bibliography.

When selecting a valve for LPG service it is important to ensure that the valve is designed and manufactured to the relevant standard / code and is appropriate for the working pressure, application and the system considered. Codes of practice such as the Liquefied Gas Handling Principles may also contain useful information (Ref 1).

It should be noted that some alloys and materials used in valves may contain substances such as copper, zinc, rubber and plastics that are not compatible with all gas carrier cargoes. Care should be taken to ensure that the valves are selected and maintained to be compatible with all cargoes listed on the Certificate of Fitness.

Valve Design for LPG Service

When designing LPG systems, the basic engineering design criteria should apply to the decisions on where to place valves and their function – such as isolation, flow control (throttling), or sampling. The principle differences between valves used for low temperature duty compared with those in ambient temperature systems arise from the nature of low temperature fluids themselves and the special hazards of handling them.

“Liquid lock” in the valve body is a feature where, by the action of closing the valve, some liquid becomes trapped in a cavity within the valve body. Liquefied gases at low temperature, thus trapped, may exert sufficient pressure, on warming and expansion, to cause plastic deformation of components, or, ultimately rupturing with associated risk to personnel.

Valves fitted with internal relief to overcome this “liquid lock” phenomenon are usually marked with an “upstream” and “downstream” label or an arrow cast into the body. It is essential to make sure the valves are fitted the right way round. Manifold valves, (which are bi-directional) should, if they are marked with a single arrow have the arrow pointing outboard, or have the downstream side outboard. Note the presence of such indication does not, of itself, guarantee a satisfactory valve design.

When ordering replacement seats for cargo valves, it is important to specify the duty intended (e.g. operating temperature range and list of cargoes to be handled) because makers may use different materials for the products being carried in valves that are externally identical.

One other important consideration during the design stage is the decision to fit flanged or welded valves. Low temperature systems may experience transient leakage from flanges when cooling down – especially large diameter systems. In order to minimise this potential leak risk it is recommended that so far as practicable flanges in the line are minimised. Consideration should be given to ensuring that essential maintenance – such as seat repair or replacement – can be carried out if it is decided to weld the valve into the line.

Other design considerations that are specific to low temperature systems are “plugging” due to ice or hydrate formation and brittle fracture of materials unsuitable for low temperature applications. Hydrates could prevent a valve closing or a plug could block the line making it appear as if the line had been fully drained, similarly Inadvertent opening of a drain valve could cause cold liquid to spray unexpectedly onto a steel structure and cause “brittle fracture”.

Some valves are fitted with bottom drain plugs, this provides additional risk of leakage and potential brittle fracture of underlying deck. These should not be fitted unless there is a clearly defined need to drain the valve, and any such drain should be fitted with a blank flange or a closure plug.

Cargo sampling valve requirements

Connections used to take liquid cargo samples should have two valves at least 500mm apart, the upstream valve should be an isolating valve and the downstream a slow control valve such as a needle valve. Further guidance is available in the SIGTTO publication "Liquefied Petroleum Gas Sampling Procedures" Ref 2.

Vapour sampling fittings on tanks designed to operate at near atmospheric pressure may have single sample valves with blanked or plugged outlets. On type C tanks a single valve may be used provided it is constructed with an orifice type flow restrictor of not more than 1.5mm diameter. Such vapour sampling points should be clearly identified and marked "Not to be used for liquid sampling"

Effect of extended bonnet and spindle

Low temperature valves are often of an extended bonnet & shaft design. There is no specific temperature where this is applied, but most designers adopt this layout for cargoes below – 55^0C. Valves with extended spindles and bonnets are normally used in ethane, ethylene and LNG service, and occasionally for LPG low temperature applications.

The purpose of the extended spindle design is to provide a temperature gradient such that the sealing and operating arrangements are significantly warmer than the valve body. This allows the seal arrangement to work at or near ambient temperature conditions and reduces the likelihood of cold burns to the operator. This is achieved through the heat gradient over distance and by design allowing a small amount of product to enter the lower part of the bonnet, this then evaporates and aids in preventing further product ingress.

It is important that the valve stem seals are maintained in good order to prevent water entering and potential mal-operation of the valve through freezing of the internals. Valves which are most likely to suffer this problem are those that are in intermittent service.

Extended spindles can only work correctly if fitted at or near the vertical position. It is also important that the bonnet is positively fixed to the body so that it can not be unscrewed accidentally when the valve is opened, as could happen if the bonnet were simply threaded into the valve body.

Valve Actuator Selection

All automated valves including control, on/off and throttling type should be designed to accept and support the actuator selected. (e.g. linear, quarter turn and planetary torque control type). Consideration should be given to the method of operation, pneumatic or hydraulic including required signals and control. The actuator should be designed and approved to the appropriate Ingress Protection (IP) rating according to IEC 60509 or equivalent and suitable for marine use. Electrically operated actuators and control systems should be suitable for the hazardous area in which they are located. The actuator should be able to work in extreme winter conditions and harsh marine environment.

It is recommended that the valve and actuator are sourced and supplied as a unit to ensure they are compatible and setup to work with each other.

During construction and maintenance actuators should be kept in a dry environment to prevent corrosion of internal parts. When assembling the actuator to the valve it should be ensured that it is mated to the same valve that it came from to ensure that settings such as torque, range of movement etc are correct for that specific valve. Particular care should be given to ensuring glands, “O” rings, and other sealing and securing arrangements have not been damaged.

Specific Consideration for Emergency Shut-Down (ESD) Valves

The normal design conditions set out in the IGC Code must be complied with, especially in terms of local & remote actuation, avoidance of pressure surge and positive closure of the product flow.

The design of ESD valves should be such that the valve spindle is positively connected to the valve plug such that the valve cannot remain open when the actuator is in the closed position, or indicating closed. (Ref. 3)

It is recommended that valves that are required to perform an ESD function are “fire safe” in accordance with ISO10497.

Design Considerations for valves in LPG service.

When selecting a valve it is important to ensure that it is designed and manufactured to the relevant standard or code; this may require compliance with more than one standard or code.

For general design features specific to LPG requirements see table below.

ELEMENT	DESIGN FEATURES
Stem sealing device. (Gland packing at the top of the extension)	There should be compatibility between the packing material and surface smoothness of the valve stem.
Bonnet Joints Attaching the valve cover to valve body	The valve should be designed to take into account the thermal stresses in transient state occurring during cool down and warm up operation.
Screw Mechanism	Should limit potential seizure due to materials used. Anti-galling austenitic stainless steel prevents seizure and valve failure when used with correct packing
Stem/shaft/spindle retention. (Applies to valves with stem/shaft/spindle that may be subject to pressure).	Each valve stem/shaft/spindle should be fitted with a device such that it cannot come apart or eject the stem/shaft/spindle in normal operation.
Liquid lock in the stem/shaft/spindle area	The valve should be designed in such a way that liquid lock cannot occur when the valve is in the fully open position. The design should be free from trapping

ELEMENT	DESIGN FEATURES
when the valve is in the full open position	LPG in any cavity regardless of the position of the disk/plug. Any space where liquid lock could occur should be fitted with a safety device to prevent over pressurisation. LPG should not be released to the atmosphere under normal conditions.
Disc / Plug, mechanism to seal the valve	Disc / Plug should be fixed to the stem with vibration-proof connection. In order to prevent seat damage the plug mechanism should, where possible, not rotate on a metal to metal seat, as this allows sealing faces to remain stationary during final closing.
Valve connections	. Flange connections should be minimised as far as possible Such welded valves & lines should be able to be maintained in situ.
Bolting, studs and nuts	All material selected must be suitable for marine use and should not be susceptible to galvanic corrosion
Flow Path	The valve type and size should be selected to minimise the pressure differential across the valve.
Valve Automation	The valve must be installed so it is able to support the weight of the actuator in all conditions, including vibration and acceleration due to motion in a seaway It may be necessary to fit local supports and to strengthen the pipeline in way of the valve – especially in branch locations.
Valve Material	Materials used in the construction of valves should be compatible with all cargoes listed on the certificate of fitness.

Valve Testing

The IGC Code (5.3.2.1) specifically requires tightness testing for cargo valves that are to be used for service temperatures below – 55^0C. For systems working at temperatures above that limit, normal classification society requirements are applied.

It is recommended that each type and size of valve operating at temperatures above – 55^0C should be subjected to seat tightness and operational testing over the full range of operating temperatures & pressures up to the rated design pressure of the valve. Some valves may be “tight” when subject to high pressures and or temperatures, but experience significant leakage when operated at lower pressures and or temperatures.

The first valve in a series and for each size should undergo extensive testing to ensure that it operates correctly throughout the full range and combination of pressure and temperature that the valve could experience in service.
Subsequent valves should be randomly selected and tested at design conditions and the extremes of their operating envelope.

The following general tests are carried out on all valves, but this document will concentrate on the tests specifically required for low temperature valves

Shell strength test.

Hydrostatic or Pneumatic test to 1.5 X Maximum Design Allowable Working Pressure.

Shell leak test.

Pneumatic test to 1.1 X Maximum Allowable Working Pressure.

Seat leak test.

Pneumatic test to 1.1 X Maximum Allowable Working Pressure.

LPG Valves should be tested in accordance with the guidance above – with logical amendments in respect of minimum design temperatures and the following standards:-

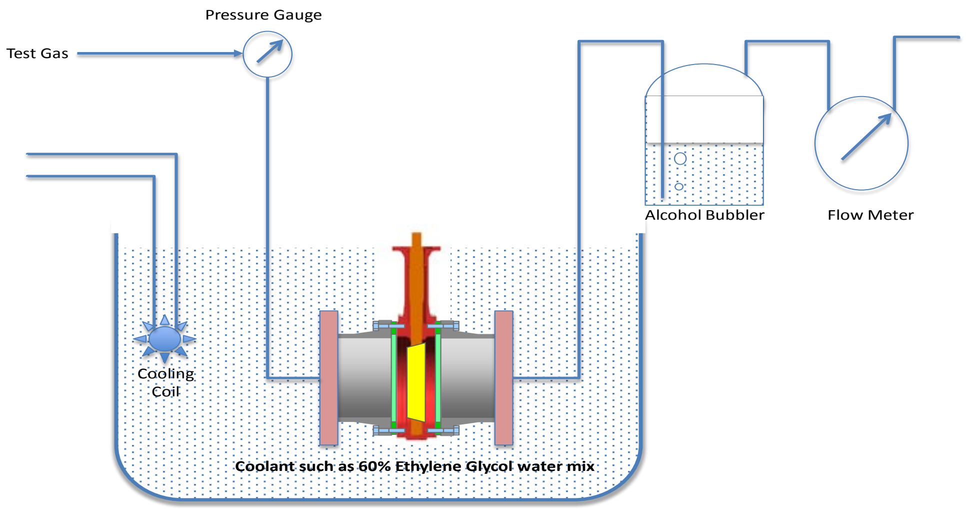
BS EN 12266-1:2003 Industrial valves. Testing of valves. Pressure tests, test procedures and acceptance criteria. Mandatory requirements

BS EN 12266-2:2002. Industrial valves. Testing of valves. Tests, test procedures and acceptance criteria.

Guidance to Inspectors When Testing Low Temperature Valves

It is recommended that third party inspection is utilised during low temperature valve testing for Class approval. The valve material traceability should be in accordance class rules and regulations

A third party inspector is also required to ensure that the valve test system is strictly in accordance with the relevant test procedure and there are no leakages (pin holes in pipe work) extra pipe work, bypass systems, heaters or other mechanisms that would affect the accuracy of the readings and results recorded. It is also important to review the calibration of the measuring equipment to ensure good working order and accuracy. The calibration of the measuring equipment should be traceable to a recognised national standard.



Test Fluid E.g.
R404A

Pre-test equipment checks

It is important that the third party inspector checks the testing apparatus to ensure serviceability and.

- Check the piping of the equipment to ensure that it complies with the standard piping diagram.
- Pressure gauges are calibrated.
- *Open all the flow valves and the valve under test, to ensure that there are no restrictions in the system i.e. helium is ejected from the outlet vent. During this check the flow meter and bubbler should be disconnected to prevent damage*.

Checking for liquid lock in the stem of the low temperature globe valve.

This test may/should be conducted in addition to the low temperature sealing test and will demonstrate if there is liquid lock in the stem when the valve is in the fully open position.

- Blank the valve inlet and outlet
- Connect a suitable air supply (not exceeding the working pressure of the valve) to the valve inlet
- Open the valve and allow air to enter the valve body
- Fully open the valve until the hand-wheel will not rotate any further i.e. "back-seated"
- Disconnect the air supply and vent the pressure in the valve body
- Submerge the valve in a water bath and close the valve.
- Air bubbles rising from the valve will indicate that air was trapped in the stem and thus LPG could also be trapped leading to serious overpressure and failure of the valve extension.

Valve and Actuator maintenance and service

The valve and actuator manufacturers should provide guidance on maintenance procedures and intervals, such guidance should be incorporated in to the vessels maintenance schedule. Valves that are in intermittent service or in particularly harsh environments may need to have an enhanced maintenance plan.

Current Codes Standards & Material Requirements Referencing Valves for LPG Service:

For a valve to work effectively in low temperature LPG service conditions the design must take into consideration both pressure and thermal conditions and still provide a tight shut off without leakage. The material mass in the casting design may be minimised to improve cool down times and still meet the requirements of the casting specifications.

Valve materials should be as per the relevant standards, and be suitable for the products to be carried. Materials used should be suitable for marine application, cargoes to be carried and not set up an electrolytic couple in excess of 250mV,

LPG valves shall comply with the appropriate product standards, this document should be read in conjunction with BS EN 1626 and ANSI B31.3. These standards cover all aspects of valve design, manufacturing and testing for use with extreme cold LPG applications. .

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

Valves must comply with the appropriate valve product standards such as:

ASME IX and ASME V---------- Non-destructive testing

BS EN ISO 10434:2004 -------- Bolted bonnet steel gate valves for the petroleum, petrochemical and allied industries

BS EN 1868:1975+A1:1990------- Specification for steel check valves (flanged and butt-welding ends) for the petroleum, petrochemical and allied industries

BS 1873:1975 --------------------- Specification for steel globe and globe stop and check valves (flanged and butt-welding ends) for the petroleum, petrochemical and allied industries

BS EN ISO 17292:2004 -------- Metal ball valves for the petroleum, petrochemical and allied industries

BS EN 13709:2010 -------------- Industrial valves. Steel globe and globe stop and check valves

BS EN 15761:2002 -------------- Steel gate, globe and check valves for sizes DN 100 and smaller, for the petroleum and natural gas industries

BS5154:1991 ---------------------- Specification for copper alloy globe, globe stop and check, check and gate valves

BS EN 12288:2003 -------------- Industrial valves. Copper alloy gate valves

BS EN 593:2004------------------ Industrial valves. Metallic butterfly valves

BS 5154:1991 --------------------- Specification for copper alloy globe, globe stop and check, check and gate valves

BS EN 12288:2003 -------------- Industrial valves. Copper alloy gate valves

BS EN 593:2009------------------ Industrial valves. Metallic butterfly valves

BS EN 12266-1:2003------------ Industrial valves. Testing of valves. Pressure tests, test procedures and acceptance criteria. Mandatory requirements

BS EN ISO 10497:2010 -------- Testing of valves. Fire type-testing requirements

ASME B16.34-2009-------------- Valves-Flanged, Threaded and Welding End:

ISO 21011 ------------------------- Cryogenic Vessels – Valves for Cryogenic Service

ISO 28921-1 (Draft) Isolating valves for Low Temperature Application

Bibliography

Ref 1 – Liquefied Gas Fire Hazard Management on Ships and Terminals - SIGTTO
Ref 2 – Liquefied Petroleum Gas Sampling Procedures - SIGTTO
Ref 3 – MAIB - Report on the Investigation of a major LPG Leak from the gas carrier "Ennerdale" whilst alongside Fawley Marine Terminal. May 2007

Appendix A Considerations During Construction and Maintenance Periods

Construction:

In order to ensure compatibility actuators should be approved by the valve manufacturer and setup during the Factory Acceptance Tests (FAT).

Suggested actions to minimise problems with valves after installation.

- Work with the yard to ensure the makers' list includes only valve suppliers acceptable to you.
- Where possible valves and actuators (manual or powered) should be provided by the valve manufacturer and tested as a unit before leaving the factory. Valve and actuator to be marked to ensure correct actuator is mated to the corresponding valve.
- After FAT, remove all actuators and ensure stored in a clean dry environment.
- Protect valve internals from heat damage during installation if necessary for those valves that will be welded permanently into pipelines
- Valve suppliers should be used to re-fit, hook up and commission valves after heavy engineering is completed. (The valve can still be operated manually if required)
- Ensure site teams are aware of the potential problems and daily checks are carried out
- Check for water ingress before installation
- Check cables and glands, ensure they are the same size
- Check the wiring has been done correctly
- Ensure the cable is not under tension and enough cable has been provided for easy reach to gangways or deck when actuators are removed from the valve headwork
- Any modification or change to the actuator is done with the approval of the valve supplier or by the valve supplier

Examples of problems found during construction:

Installation

- Destruction or damage of the cable gland plug (before wiring)
- Wrongly connected Cable Gland
- Use of Sealants (cable and gland not the same size/incompatible)
- Cable Gland not tightened properly after installation of the cable

Commissioning

- Actuators with gaskets and O rings damaged or missing
- Wired incorrectly
- Actuators re positioned in order to fit in a space
- Setting modifications (Torque and potentiometer settings changed or incorrect)
- Poor communication with the control room/system (CCR not communicating correctly with the actuator, providing incorrect position data)

In Service

Suggested actions to minimise problems with valves during service:

- Follow Manufacturers' guidelines for operation and maintenance
- Consider appropriate training from valve & actuator supplier if necessary
- Ensure Instruction Manuals are on board
- Ensure good house-keeping,
- Ensure maintenance schedules included in Planned Maintenance System
- Regularly check operation of automation/actuators
- Check studs and nuts
- Be aware of materials exposed to the possibility of galvanic corrosion
- Ensure correct spares inventory held

Examples of problems with valves during service:
Leaking valves can be identified by frost creep past the valve seat and/or in the gland area, causes of leakage may include:

- Continuous leakage due to damage or wear to the valve seat
- Manual valve will not open/close fully – due to corrosion, over-tightened gland nuts or debris/hyrdrates under the seat
- Problems with connections, studs and nuts or metal fatigue.

Examples of problems with actuators

- Actuator will not open the valve –Torque setting incorrect
- Actuator will not close the valve -Seat leakage or damage
- Actuator does not communicate correctly with the CCR / VRC – water ingress, cable damage
- Actuator will not engage manual override – Check lever
- Galvanic corrosion – Wrong material

Example maintenance schedule (Note – schedules will differ between different valve types and manufacturers):

5 year docking	10 year docking	15 year docking	20 year docking	25 year docking
Replace all gland and bonnet gaskets manufactured from soft material Overhaul all actuators Check Studs nuts and bolts Hydraulics General maintenance	Same as five years Check and replace cables Check and replace actuators if required Replace studs, nuts and bolts Check connections Check seats	Same as five years UT scanning of castings Possible Replacement of actuators Check for metal fatigue VRC and hydraulics	Same as five and ten years	Same as five and fifteen years