5 OPERATION

5.1 INTRODUCTION TO THE OPERATION OF VALVES

The integrity management of valves within the upstream and downstream industries can be impacted, either directly or indirectly, by how the valves are operated. This therefore means that organisations should consider how their valves are operated, and what impact this may have on their integrity management.

There are many different designs and types of valves. Some differences may not be obvious to plant operators, who may inadvertently operate valves in such a way as to damage the valve and prevent it from performing its intended function.

5.2 TYPE OF OPERATION

5.2.1 Direct manual operation of valves

This is the simplest way to operate a valve and it involves the direct manual operation of the valve using a lever or a hand-wheel. From an integrity management perspective, this simplicity has the advantage of fewer parts which can fail and which require maintenance.

However, if manually operated valves are not suitably located then it is more likely that the valves will not be operated correctly and this may result in integrity issues. Therefore, manual operation may not be the most suitable for valves that have to be frequently operated, or those where access is restricted. These considerations should include not just the access and egress, but also such factors as whether there is good footing and the height that the hand-wheel/lever is located at in relation to the operator. This is because it can be much harder to operate a valve if the operator is not stable or has to bend down or reach up to access the hand-wheel.

The direct manual operation of certain rotary motion valves, such as butterfly valves, may lead to the fluid's motion moving the valve's disc unexpectedly if the fluids forces on the disc exceed the valves friction forces. Therefore, consideration should be given to the need to lock the valve in the desired position (see 5.2.3).

For linear valves to be manually operated, a stem thread is used to convert the rotary torque to a linear thrust, with the pitch of the thread determining how many turns and the associated torque that is required to move the obturator.

The size of the hand-wheel or lever is another factor that should be taken into account as the larger the wheel/lever then the easier it will be for the valve to be operated.

It is important that the operating mechanism is suitably designed so that the valve can be safely operated. If the pitch of the thread is too large, or the hand-wheel is too small, then this can lead to too large a torque being required for the operator to easily operate the valve. This can lead to the operator using inappropriate equipment (such as scaffold poles or wheel keys) to operate the valve, which can lead to damage to the valve. Conversely, if the pitch is too small or the hand-wheel is too large then this can result in excessive forces being applied to the valve.

If any valve requires excessive force to operate then this should be investigated to determine the cause of the issue and appropriate action taken such that the valve can be safely and appropriately operated.

Wedge gate, globe valves and triple offset butterfly valves require a given force/torque to ensure the required sealing stress between the seat and obturator is achieved for shutoff. Other valve types require the obturator to be correctly positioned relative to the seat for the best shutoff performance. Overtightening of these valve types will result in increased leakage as they travel beyond their optimum shutoff point. Operators need to be aware of this and the valves that this applies to (see 5.3.2 and 8.6.4).

5.2.2 Manual operation via a gearbox

If the torques required to directly operate the valve are too great to be practicable, then a gearbox can be used. However, it is important for the integrity management of the valves that the correct type of gearbox is selected.

Rack and pinion and worm gearboxes are often used for rotary motion valves, such as ball, plug or butterfly valves. They have the advantage that the valve cannot turn the gearbox as they are self-locking.

Bevel and spur gearboxes are often used for linear motion valves. Spur gears have the input and output drive in the same orientation, but bevel gears have the additional advantage that the input drive is at a right angle from the output drive, which can help with access for the operator.

It is also important that a suitable gearing ratio is used so that the gearbox provides a suitable amount of reduction in the torque that is required to operate the valve. This is important with regard to the integrity management of the valve, as if there is too great a mechanical advantage provided by the gearbox, it may be possible for the operator to overload the valve and damage internal components such as the seats or disc.

If operators use pneumatic tools on a manual valve, care needs to be taken as pneumatic tools may damage the valves due to the torque magnification of the gearbox.

5.2.3 Locking manually operated valves

One advantage of many designs of manually operated valves is that they can be locked in position to prevent unauthorised operation. Organisations should consider whether this is a requirement for the valves in question, and if so they should fit a suitable locking mechanism where required.

The decision as to whether a valve should be locked in position will depend on several factors, in particular:

- the potential impact if the valve is operated when it should not be;
- the likelihood that the valve may be operated in error, and
- the frequency that the valve will need to be operated.

The requirement to lock valves in a fixed position and the controls for this should be documented such as in the company isolation standard and the site P&IDs.

5.2.4 Operation of valves using an actuator

An important consideration regarding the operation of valves is whether an actuator will be used. An actuator provides a means of remotely controlling the opening and closing of the valve (see 2.6).

Actuators can be used to centrally operate a valve via, for example, a distributed control system. These systems can operate via either:

– a separate control actuator where the switch gear is remotely located away from the actuator, or
– an integral control actuator which is self-contained with the motor switch gear within the actuator.

Having decided that an actuator will be used to operate the valve, it is important to ensure that the actuator is suitable to safely operate the valve as intended. A key factor in this is the environmental conditions within which the actuator will be positioned. This includes whether it will be operated within a hazardous area (see 3.2.2), and the environmental conditions it will be exposed to, such as sea water (see 3.2.4).

Consideration should also be taken of factors such as the differential pressure that the valve has to be operated against (see 5.4.2). While it is important that the actuator is sufficiently sized to deal with the differential pressure, oversizing the actuator can lead to unnecessary costs, and also installation and maintenance issues due to the increased size and weight.

Another factor to be considered when operating a valve using an actuator is the need for sensors to detect the movement and stop at predefined positions and torque settings. This means that the actuator should be set up and maintained in conjunction with the valve's limit positions and torque requirements.

The operation of the valve using an actuator should also consider whether there is a requirement for the actuator to be fitted with safety features such as overload protection.

Consideration should also be given to whether there is a need for features such as the actuated valve needing to fail-safe in the event of loss of power. Fail-safe valves usually have a spring which moves the valve obturator to the safe position if power is lost. This safe position needs to be determined, with typical positions being fully-open, fully-closed or stay-in-position (see 2.6.5).

If fail-safe valves are used, then organisations should recognise that the actuators are fitted with a spring which is highly compressed when the valve is in its normal operating mode. This means that if the spring housing fails then this can lead to a significant hazard as the stored energy in the spring is released. This failure could occur due to deterioration of the fixing bolts or spring housing (corrosion etc.), or during maintenance activities. It is therefore important to ensure that all actuators which contain springs are maintained in line with the manufacturers' recommendations, to prevent deterioration and subsequent released energy due to spring failure.

5.2.4.1 Example of a failure of a spring return pipeline ESDV

The actuator spring end plate retaining tie rods failed due to corrosion, leading to the spring being released from the ESDV actuator. This made the platform primary isolation device inoperable.

Where identified valves are defined as safety critical elements (SCEs) or where release of the spring could present a risk of injury to personnel or damage to plant, duty holders should make these a priority for inspection/modification.

HSE Safety Bulletin – *Failure of pipeline emergency shut-down valve HID 3-2010*

Manual operation of actuated valves may also be required in some circumstances, such as if there is a power failure, and therefore organisations should consider whether hand-wheels also need to be included. One consideration with regard to this is whether the manual operation will act via the actuator's gearing, as failure of the gearing would mean that the valve was not able to be operated either via the actuator or manually.

5.3 OPERATING KNOWLEDGE AND UNDERSTANDING

5.3.1 Provision of operational information by supplier

Another potential issue impacting integrity management is when the original suppliers do not provide sufficient information on how to satisfactorily operate the valves. A typical situation can be when the suppliers only provide a generic product manual which covers a number of design variations, rather than specific details for the valve that has been supplied.

Organisations therefore need to ensure that they require the supplier to provide sufficient information regarding the specific valve that has been supplied so that the valve can be safely and appropriately operated. This involves the supplier instructions for installation, operation and maintenance of the valve being provided and organisations putting arrangements in place within the operation plant instructions and maintenance provisions.

5.3.2 Operator knowledge and understanding

A key factor for the integrity management of valves is the operational knowledge and understanding of the individuals operating the valves.

Knowledge and understanding of the various design types and the required operation for all of the valves on a plant may be limited. In some cases there may be an expectation that all valves of a specific type operate the same way, when this is not the case. Therefore, the required operation of a specific valve may not be carried out correctly, resulting in the valve not providing the required function, or being damaged by maloperation (resulting in the need for repair or replacement of the valve).

Simple examples include:

- operating a valve against a high differential pressure, for which the valve had not been specified (see 5.4.2);
- rotating quarter turn valves the wrong way leading to damage to hand-wheels, levers and stems;
- applying insufficient torque to develop and provide a tight isolation shutoff, such as for expanding wedge gate valves;
- application of excessive torque which damages valve seating and allows through leakage, and
- actuator, gearbox or hand lever removal that also removes the stem retention mechanism or affects the gland sealing.

See section 8 for more details on knowledge, training and understanding.

5.3.3 Use of incorrect fittings

Another way that operating a valve can lead to integrity issues is when fittings are incorrectly used. For example, by injecting the wrong sealant into plug valves, thereby increasing operating torques, or injecting grease into an emergency stem seal rather than into a seat grease fitting, thereby causing over-pressure and rupture of the stem seal.

Integral DB&B valves may have multiple fittings. Using the wrong fitting may lead to a circumstance where an operator inadvertently fails to prove an isolation e.g. by checking the ball cavity and not the bleed cavity between obturators.

Replacing with wrong fittings may result in thread issues, galvanic corrosion, etc. Therefore these should be replaced with like-for-like fittings.

It is therefore important that people working on valves are suitably competent for all of the tasks they have to perform regarding a given valve, including the use of associated fittings.

5.3.4 Failure to replace caps or plugs

Linked to the incorrect use of fittings is the issue of failing to reinstate caps or plugs to valve fittings, for example for bleeds or injection fittings. Safe operation is then reliant on e.g. check valves to provide a seal. Failure to replace caps may therefore result in product leakage in service.

Organisations should ensure that all individuals are fully aware of the importance of replacing all caps and plugs once they have completed their tasks. Organisations should also consider the benefit of including checks that plugs and caps have been correctly replaced as part of their general plant inspections.

5.4 ACTUAL OPERATION IN-SERVICE

In many cases the actual operation of valves in service can differ from that anticipated during the design and specification process.

5.4.1 SSOW

Organisations should also ensure that there is an SSOW in place to ensure that the risks associated with operating the valves are sufficiently controlled. See Annex E for more details.

5.4.2 Operating a valve against a high differential pressure

Fluids move through a valve due to the differential between the upstream and downstream pressures. The valve itself can also create a pressure differential due to friction losses as the fluid flows through the valve. If the pressure differential is below the vapour pressure of the liquid, this can cause cavitation (generation and subsequent implosion of vapour bubbles within the liquid), flashing (generation of pockets of vapour within the liquid) and excess vibration.

Issues such as cavitation can cause problems, including damage to the valve, associated equipment and pipework, and a loss in efficiency of the system as these issues absorb significant amounts of energy and therefore require more pumping.

Therefore, wherever practicable, valves should be selected so that cavitation does not cause a significant problem for the system. This can usually be achieved by ensuring that the pressure differential remains above the liquid's vapour pressure.

High differential pressure across control valves can cause significant levels of vibration to be developed within the valve if the flow of fluid through the trim is not controlled. This can happen in valves that are not suffering from cavitation or any other operational issues. Control valves in severe service can be subject to unacceptable mechanical (vibration) loads even if they have been correctly specified for their process duty. Multi-stage pressure let down trims are often required in high differential pressure situations. These trims allow the high pressure differential to be broken down incrementally as the fluid travels through the trim, controlling the velocity of the fluid as it exits the trim, and minimising the levels of mechanical loading and vibration generated.

5.4.3 Incorrect use of a valve

It is important that a suitable valve is used for the required function (see 2.4 for more details). If a valve is used for the 'wrong function' then this can lead to integrity issues, including damage to the valve and failure to provide the required function (such as isolation).

Examples of using valves for the wrong function can include:

- Using an isolation valve in a partial open position for flow control as this can damage seats and increase the potential for erosion, cavitation and vibration. This erosion can compromise the integrity of the pressure shell.
- Using an isolation valve for level control, due to the high demand of 'on/off' operation on the isolation valve.
- Using a control valve for a situation which requires a tight shut-off.

5.4.4 Different frequency of operation

Another potential integrity management issue occurs when the valves are operated more frequently than intended as this can cause excessive valve wear or damage.

In addition, some maintenance may be based on the number of operations and therefore will be required more frequently than anticipated.

In contrast, integrity issues can also arise when valves are operated less frequently than intended. Some valves (such as isolation valves) may only need to be operated once or twice in their lifetime. This can result in valves becoming seized or stuck such that they cannot perform their function when required.

Therefore, organisations need to ensure that when specifying their valves, the frequency of operation is considered and suitable valves selected (see 3.3.4). In addition, where necessary, appropriate measures should be introduced to manage any potential operational issues (such as a programme to periodically operate infrequently operated valves or carry out maintenance to ensure operability).

Organisations should also ensure that they consider and manage any significant changes to the frequency with which valves are operated as part of their MoC system (see Annex D).

5.4.5 Design cases

Another issue, in particular for control valves, can be that all of the design cases for a valve may not have been considered and specified.

For example, control valves which are sized for a maximum C_v but which may be used for plant start-up and transient 'severe service' operations. This can result in the valve being oversized for some actual operational requirements, leading to vibration, noise, cavitation and potential damage to the valve and associated systems due to erosion and fatigue of pipework.

Passing control valves due to erosion may result in similar situations.

5.4.6 Operating cases

Integrity management issues can occur if all of the operating cases have not been identified and specified during design as this can result in unsuitable valves being used. This can be a particular issue for control valves.

For example, a valve may be specified with an incorrect actuator sizing, with the actuator either being insufficient or excessive for the valve's actual use in service.

5.4.7 'Non-routine' plant operations

'Non-routine' plant operations may affect the integrity of the valve, in particular if they have not been considered during the design and specification process (see section 3). Organisations should therefore ensure that all valves are fit-for-purpose before carrying out any non-routine operations or ensure that an appropriate risk assessment and controls are implemented.

5.4.8 Fluid composition changes

Over the life of the valve, the fluid composition may change over time. For example, there may be changes to:

- production fluids' chemistry;
- oil/water content;
- H_2S;
- CO_2;
- mercury, and
- solids/scale.

These changes may impact the valve's integrity such that the valve is no longer suitable for the planned operations, or that changes to the integrity management arrangements are required.

This can be a particular issue to identify if the changes are gradual with significant changes occurring over several years.

Therefore, organisations should ensure that they have a suitable MoC process and that this is used to manage all changes which may impact the operation of the valve. See Annex D for more details.

Organisations should monitor deteriorating, replaced or overhauled valves to verify the causes of failure and ensure lessons learned can be used to prevent deterioration of further valves.

5.4.9 New developments

During the life of a plant, new developments may be routed through the original plant. This may result in the valve being operated while being exposed to compositions, pressures, and temperatures that differ from those used for the original design/specification.

These changes may impact the valve's integrity such that the valve is no longer suitable for the planned operations, or that changes to the integrity management arrangements are required. Therefore, organisations should ensure that they have a suitable MoC process and that this is used to manage all changes which may impact the operation of the valve. See Annex D for more details.

This could include the use of new products used for chemical inhibition.

5.4.10 Plant aging/deterioration

During the life of the plant, the internal/external fabric condition of the plant may deteriorate and this may affect the integrity of valves. For example:

– Internal line corrosion – causing corrosion product to be deposited within valves resulting in damage to valves.
– External corrosion affecting stems and seals (leaks and operating torque).
– Failure of in-line components which may then become stuck in valves (e.g. filters and thermowells).
– Foreign objects (such as items left inside pipework during maintenance) which may become stuck or damage valves.

The aging/deterioration of the plant could impact the integrity of the valves, and organisations should have measures in place for managing this issue. See Annex D for more details.

5.5 MALOPERATION OF VALVES

There can also be occasions where there is maloperation of a valve to overcome operational issues.

5.5.1 Seized or sticking valves

Valves may become hard to operate, particularly valves which are infrequently operated. When this occurs, personnel may use excessive torque to attempt to operate the seized or sticking valve, resulting in damage to the valve or gearbox. This excessive force may be generated using a variety of methods including:

– manual methods, such as by using scaffold poles;
– air tools, such as an impact wrench or 'windy gun', and
– dedicated pneumatic tools supplied for operating valves.

Organisations should therefore ensure that wherever possible the integrity management systems are suitable to prevent the valves becoming seized or stuck in the first place.

In addition, they should ensure that all personnel are aware of the correct procedures to follow in the event of a valve becoming stuck and that the incorrect use of tools is not an acceptable method for addressing the issue.

5.5.2 Alternative means of operating a valve

Another potential cause of maloperation is when an alternative means of operating a valve for which the valve was not designed is attempted. This may include:

– applying hydraulic/pneumatic pressure in the reverse direction within an actuator, or
– bypassing the filter/regulator and PSV on the pneumatic/hydraulic supply to an actuator, thereby over-pressurising the actuator.

Organisations should therefore ensure that all personnel are aware of the correct procedures to operate each type of a valve.

5.5.3 Use of thread sealant

Another potential issue can be due to the inappropriate use of thread sealant. There are basically two sealing methods commonly used:

– PTFE tape, and
– anaerobic liquid.

Issues regarding the use of thread sealant include:

– addressing leakage from screwed threads which do not match (i.e. national pipe thread (NPT) into a British Standard Pipe (BSP)), and
– insufficient curing time being allowed for thread sealant prior to start-up.

Care is needed to ensure that the fitting details of all threaded fittings are checked and the correct application of sealant or tape is used.

Organisations should therefore ensure that the root causes regarding the inappropriate use of thread sealant are identified and addressed. This should include competent personnel:

– identifying when there is a need to use a sealant on screwed connections;
– identifying the type of sealant to be used, and
– applying the sealant.

5.5.3.1 PTFE tape

PTFE tape is available in a range of different thicknesses and densities, with thicker/denser tape requiring fewer layers and providing better sealing performance than those that are less thick/dense.

When applying the PTFE tape, care should be taken to ensure that neither excessive nor insufficient tape is applied. Excessive layers of tape may impact the effectiveness of the threads, such that the connection may part under pressure. Insufficient tape may lead to galling (when pressure and friction cause threads to seize) and leakage.

PTFE tape should not be applied ahead of the first thread to prevent 'flakes' of tape accumulating inside the valve or pipework and blocking equipment such as filters.

Some organisations have chosen to prohibit the use of PTFE tape entirely.

5.5.3.2 Anaerobic sealants

Anaerobic sealants are liquid sealants requiring a curing period (varying from three to 72 hours). If pressure is applied before curing is complete then the sealant may initially appear to hold pressure, but may leak later during service.

Compatibility between the sealant and the process fluid should be checked as the compound may dissolve if used for certain applications containing solvents.

Organisations should therefore ensure that they are aware of product compatibilities and curing times whenever using anaerobic sealants.

Further guidance on the use of thread sealants can be found within the EI *Guidelines for the design, installation and management of small bore tubing assemblies*.

5.6 ACTIVITIES ADVERSELY IMPACTING VALVE INTEGRITY

Organisations should be aware that certain plant operation and maintenance activities can adversely affect valve integrity.

5.6.1 Non-routine operations

Non-routine operations may affect the integrity of the valve. One example is the need to prepare the plant for isolation and reinstatement, to prepare for breaking containment. This may require a drain, flush, purge, vent (DFPV) sequence. The fluids used to flush the systems may not have been anticipated within the original material selection (for example the use of water and its quality). This flush fluid may lead to issues or it may become trapped within the systems in low points, causing dead legs during normal operation.

Another non-routine operation that may adversely affect valve integrity is external maintenance on surrounding plant, including periodic testing of firefighting systems. Testing of firefighting systems may deluge valves and associated equipment with water (including sea water on some plants), and this may not have been considered during the original design/specification. This may cause damage to the valves and result in leakage or accelerate corrosion.

Another non-routine activity that can impact valve integrity can be fabric maintenance of plant, as this may result in debris (such as grit blast, scale etc.) being dispersed onto the valve, which can cause corrosion or become entrained in the valve stem causing mechanical damage and leaks.

Sea water leaks from adjacent systems may deposit water on valves where it can collect and evaporate. This may leave salt deposits and increase the potential for external crevice corrosion or chloride-induced stress corrosion cracking (SCC) of stainless steel. See HSE reports RR298 *Chloride stress corrosion cracking in duplex stainless steels in the absence of oxygen* and RR902 *Chloride stress corrosion cracking in austenitic stainless steels.*

Organisations should therefore ensure that valve integrity is considered when planning non-routine operations and that suitable measures are put in place to protect the valve and any associated equipment.

5.6.2 Resetting stops on a valve/plug loading screws

Issues can also occur when resetting stops on a valve. With this operation, if the individual does not know how to carry out the task correctly, it can result in valves being set up so that they are not fully open or closed. This can result in cavitation, vibration and damage to the valve and associated equipment and pipework.

Adjusting plug valve loading screws on site may result in 'taper-lock' of the valve which will result in valve seizure. Manufacturer recommendations should be consulted prior to carrying out this activity.

Organisations should therefore ensure that anyone setting stops on a valve is suitably competent to carry out the task (see section 8).

5.6.3 Set-up of the control system

An incorrect set-up of the control system can result in maloperation of the valve. This incorrect set-up can be due to:

- incorrect or insufficient set-up of the plant control system (e.g. control loop tuning), and
- incorrect set-up of the valve's 'control panel' which provides feedback to the control system (e.g. boosters, position feedback, hysteresis).

This can result in continuous operation (opening/closing) of a control valve causing wear to the stem.

It is therefore important for organisations to ensure that all control systems are correctly set up before the valve is put into operation.

5.6.4 Deterioration in the control system

In relation to control valves, deterioration in the control system may also cause maloperation of the valve. This could be due to:

- Plant hydraulic/pneumatic supply quality deterioration due to such issues as pressure, contamination etc.
- Drift or deterioration of valve 'control panel' components. For example, Solenoid Operated Valves (SOVs) or vents may not function, which would then impair the operation of the main valve (i.e. preventing a 'fail' position being reached).
- Wear or slippage of a feedback device, which would then provide incorrect feedback to the control system.

Organisations should therefore be aware of the potential deterioration of the control systems, and put in place suitable integrity arrangements in relation to the control system such that the systems continue to operate as intended.