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Emergency Shut-Down Valve Study: Industry Operating Experiences and Views: The Way Forward

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Emergency Shut-Down Valve Study - Industry Operating Experiences & Views; The Way Forward

J Peters
National Engineering Laboratory
East Kilbride, Glasgow, UK

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EXECUTIVE SUMMARY

This paper describes the findings of a study that was recently undertaken by NEL on behalf of the Offshore Safety Division of the Health and Safety Executive.

Since 1990 (Ref. 1), Emergency Shutdown Valves (ESVs) have been used by the Oil & Gas Exploration industry to safely isolate all pipelines and process plant on production fields/systems, interconnecting pipelines and export lines.

In a worst case situation an ESV is required to close against very high flowrates (velocities) and possibly very high pressure differentials. As safe and reliable operation of ESVs is essential for the industry, a cross-section of valve manufacturer's and operators were contacted to ascertain their views and experiences to date regarding the design, specification, testing and in-service operation of the ESVs. The study concentrated on aspects that affect or could affect the dynamic operation of the valve.

The main study findings are described and discussed. The conclusions identify a number of important points and issues which are performance and safety related. As a way forward it is recommended that these are discussed and debated further by the industry and appropriately resolved or if necessary further actions identified.

1. INTRODUCTION

This study was undertaken by National Engineering Laboratory on behalf of the Offshore Safety Division (OSD) of the Health & Safety Executive (HSE).

Emergency Shutdown Valves (ESVs) are used in the Oil and Gas Exploration and Production industry for the emergency shut-down (usually closure of valves) to safely isolate all pipelines and process plant supplying to or from a platform production/processing unit. The valves are usually required to operate rapidly (relatively fast closure times) under a range of service conditions- differential pressures, flowrates, temperatures and fluids.

These valves were designated ESVs following the findings of the Cullen Inquiry (Ref. 1) in 1990 and the subsequent introduction of the SI 1029 Regulations (Ref. 2) which required Emergency Shut-down Devices (ESDs) to be installed in oil/gas production systems. Although SI 1029 has now been superseded by the Pipeline Safety Regulations (Ref. 3) the valves are still usually referred to as 1029 valves, or ESVs. This study is specifically restricted to valves which were/would have been covered by the SI 1029 Regulations, since some operators when referring to their ESVs also include other 'emergency valves' which are not covered by the SI 1029 Regulations.

In a worst case situation (sudden, significant leakage or even rupture of pipework) ESVs are required to close against very high (excessive) flowrates, resulting in very high local velocities through the valve and also possibly high pressure drops across the valve as it closes. Under these severe dynamic operating conditions, depending upon the local fluid conditions, sonic flow, cavitation, flashing or a combination of these are likely to locally occur at the valve, producing large rapidly changing dynamic forces on the valve internals and within the valve body. As a result, a powerful actuator is fitted to the valve to ensure that the valve can be operated in the worst case conditions.

As the integrity of ESVs and their safe reliable operation is essential for the oil and gas industry, this study was undertaken to ascertain the industries experiences (operators and manufacturers) with the design, specification, testing and operation of ESVs to date, their comments/concerns and identify the way forward. The study concentrates on aspects relating to and influencing the dynamic operation of the valve and excludes the ESV control systems.

2. THE STUDY

2.1 Study Contributors

In consultation with HSE, a cross-section of major Oil & Gas operators in the UK sector of the North Sea were selected and contact made with ESD valve personnel; this often involving discussions with four or more people in the company. The operators who participated and provided data for the study were - Amerada Hess Ltd, British Gas Expro, BP International, Chevron (UK) Ltd, Elf Exploration and Shell Expro. As the operating companies are split into business units, contact was not necessarily made with all the operating units within the company; so consequently not all ESVs within a company may be included.

The following valve manufacturers participated in the study - BEL Valves, Cooper Oil Tool, (Ball Valve Division) France, Petrolvalves, Pibiviesse and Dresser Industries (TK Valve & Grove Italia).

2.2 Study Approach

Contact was first made and meetings held with a cross-section of Operators; details were gathered on the valves that they had installed; their operating experiences and any other comments, concerns and views for the future. The valve manufacturers were then ranked in order of numbers installed and contact then made with the leading manufacturers.

Points covered by the discussions included:

Operator:

- Details of ESD valves installed (under SI 1029)
- Field, Location, Reference ID, Date installed
- Type, Model No, Size
- Functional/technical specification, Standards
- Procurement and selection criteria
- Operating conditions
- Installation, commissioning tests
- In-service testing
- Operational data - Leakage levels
  - Valve opening, closing torques/forces
- Operating experiences, concerns
- Points for further consideration

Manufacturer:

- Details of Design,
- Valve standards
- Finite Element Analysis, structural testing
- Model, Prototype testing undertaken
- Computational modelling, experimental testing undertaken
- Performance, verification testing undertaken by manufacturer or others
- Closure/re-opening tests - individual valves
- Commissioning tests
- Operating experiences, concerns
- Points for further consideration

3. STUDY FINDINGS

3.1 Valve Details

Around 200 ESVs in total were included in the study, supplied by 20 valve manufacturers. The distribution of the valves across the companies is illustrated in Table 1. It can be seen that six valve manufacturers supply around 70% of the valves and that the vast majority of the ESVs are ball valve designs - 89%; the remaining 11% are gate valves.

In terms of size they range from 50 mm (2-inch) nb up to 900 mm (36-inch) nb, with the majority being in the 150- 600 mm (6 -24-inch) nb size range. However there are a significant number of 900 mm (36-inch) nb valves as this is a common large pipeline size.

In terms of pressure rating the bulk of the valves are in the Class 300 to Class 900 - [900 mm (36-inch) nb] range, and some small sizes have higher pressure ratings - up to Class 2500,/API 10,000 rating. The valves are generally relatively big and heavy, particularly when the powerful actuator is also included.

3.2 Pre SI 1029

A significant number of the valves that are now classified as ESVs were originally installed and operational prior to the SI 1029 regulations; in fact some have been installed since the early 80s. In a number of instances, to bring the existing valves up to SI 1029 requirements they were sometimes re-located as well as more powerful and faster actuators and associated control systems being retro-fitted. As a result of uprating the actuator output torque/force it was sometimes also necessary for an up-rated valve stem to be fitted (using a higher grade material and/or a larger cross-section).

3.3 Operating Fluids

These generally fall into one of four categories:

- crude-oil
- gas
- condensates
- multiphase fluid

Some of these fluids are considered clean because they do not contain any or only negligible amounts of sand. However others are 'dirty' containing various levels of sand in the flow stream, resulting in an abrasive fluid.

3.4 Valve Seats, Seals

3.4.1 Materials

The upstream and downstream sealing faces of the valve - the valve seats use either soft seal inserts or hard metal/surface treated metal seats; the split is around 60/40 in favour of soft seals. To some extent each type is considered to have its advantages and disadvantages - depending upon fluid and operating conditions. Fig 1 shows the section through a typical ball valve.

There appears to be no obvious selection route. As well as the technical specification, the selection criteria appears to be also influenced by the experiences and views of those selecting the valve and procurement policy - valve type, price and delivery. However for high differential pressure applications metal seals are often used.

Many Operators prefer to use a soft seal material (eg Nylon, PTFE, PEEK) as they tend to be easier to effect a seal (zero leakage), particularly at low differential pressures and usually require lower operating torque/forces than metal seal valves. The use of elastomeric seals is usually avoided because of the risk of seal damage due to explosive decompression when the valve is fully de-pressurised. Depending upon design detail, soft seals are also more susceptible to blow-out/extrusion under high differential pressure/ high flow applications.

However this has to be balanced against the fact that the soft seals are often more susceptible to the pick-up of pipe-scale, dirt or sand particles resulting in wear and damage to the seal or being embedded in the seal and possible scoring of the face of the ball or gate.

On the other hand, although the hard metal seats (eg Tungsten Carbide, Stellite, Duplex St/steel or Inconel) require higher closing forces to effect a seal, they are usually much more tolerant of dirt/debris being trapped around the seat face. As the metal seats are harder than the dirt, pipe-scale and sand particles, little damage is done to the seat; on re-opening the valve, the dirt/debris is often dislodged and the seat/seal remains effective.

As ESVs are often specified to be piggable, soft seat/seals are considered to be more vulnerable to damage than hard seats/seals.

3.4.2 Cavity relief - bi-directional seals

Many of the ESD valves use uni-directional seals, ie they seal in only one direction and rely predominantly on the fluid pressure to energise the seal. If a fluid - gas or liquid is trapped in the valve body cavity (between the two seals) when the valve is closed, any increase in valve body temperature (eg the sun) will cause the fluid to expand and increase the pressure in the cavity. However because the seals are uni-directional, at least one or both will relieve the cavity pressure to either the upstream or downstream pipework. The valves therefore have in-build over-pressure relief protection, so cavity relief protection was often not considered.

There are now some valves, including ESDs being fitted with bi-directional seals - each seal will seal in each direction. The big 'plus' being that you effectively now have two seals in series within a valve. If one seal fails, you still have the other as back-up.

However, unless an overpressure cavity relief valve/system is fitted to the cavity, if the valve is in the closed position and the temperature is increased, the cavity pressure could dangerously over-pressure the valve and cause a serious or even catastrophic failure of the valve body.

3.5 Actuators

Many of the actuators are hydraulically operated with large compression springs fitted internally which are compressed when the valve is opened. Upon loss of power, the valve will 'fail in the closed' position. The hydraulic actuators have their own associated accumulators/power packs or gas booster packs and control systems.

3.6 Literature Search

A literature search was carried out for any articles/papers associated with the dynamic operation of ESD valves - design, flow modelling, finite element analysis, testing - (model or full size) as well as operating/field experiences etc. Only a few references were found and these were mainly discussing ESD valve designs/developments in broad terms. None of them discussed the dynamic operation of the valves in the 'worst case situation'. A list of the references identified is given in the Appendix.

4. OPERATOR'S EXPERIENCES/PRACTICE

Because of the move by operators for each production unit to be autonomous there isn't one person within a company who has overall ESD responsibility and is familiar with their operating performances. As a result the study required contact and meetings to be arranged with up to four people in a company and they in turn sourced information/data from others within the company. With some companies, valve technical data and ESV operating data appeared to be more readily retrievable from data bases and forthcoming than by others.

Also, with operators increasingly using engineering service companies for valve repair/ replacement, a lot of the valve and ESV maintenance data is with these companies, including in some instances leakage data, as they also undertake these tests for some companies.

4.1 Reliability

So far, since the ESD valves (approx. 200 of them) in the study were installed, the valves themselves have been pretty reliable. Some ESD valves have been in service for more than 15 years and are still performing to original specification (zero leakage) very well. Since installation, only 4 of the 200 valves in the study have required seats/seals to be replaced due to excessive leakage levels. Another two complete valve/actuator units have had to be replaced because they wouldn't operate.

Certainly the experience of all the operators contacted in the study is that the valves themselves are more reliable than the actuators/control systems. There are far more problems with the peripheral items not working/failing - relays, solenoids, hydraulic fluid leaks/loss of pressure, causing the ESV not to operate correctly.

4.2 Specifications/Standards

ESD valves are specified and procured by operators, design contractors, or both together. In all cases, reference is normally made to the valves having to meet either API6D (Ref. 4) or API6A (Ref. 5).

One North Sea Operator also requires that a valve manufacturer's ESV design must successfully complete a hot-oil test programme to qualify it as an approved design.

4.3 Pipeline/Valve Commissioning

The operators all agree that many ESD valves suffer the most damage (most vulnerable) to their seats/seals when the valve/pipework is being first commissioned and when the pipeline is first pigged to clean the line. If there is any dirt/pipeline debris etc this is when the valve has to handle it and the fluid is most contaminated.

Pigging will collect all types of debris and the soft seated valves are considered to be far more vulnerable to damage than the metal-seated valves. Some valves are more prone to damage from pigs than others - particular if they are not fully open - fully aligned bore is essential to protect seats and seals.

Some operators even feel it would be prudent (no one is doing it yet) to change out the seats/seals after commissioning, so that the valve seats/seals are then in A1 condition at the start of their operating life instead of starting with part worn or damaged seats/seals, which will fail sooner rather than later. If it is a clean fluid, once a pipeline is commissioned, dirt/debris presence tends to be minimal. If a dirty (abrasive) fluid, then dirt/debris is always present to some degree and the risk of damage or dirt getting into valve internals (such as seats, seals, trunnion bearings in ball valves) is much higher.

4.4 Operational Data Recorded

Only basic operational data is recorded - principally as required by the former SI 1029 Regs -

- leakage level
- time to operate the valve (planned closure)
- hydraulic operating pressure (sometimes)

Only one operator has some valves which are permanently instrumented; hence whenever the valves are operated, conditions are automatically recorded. The usefulness of the system was not clear; so far it has not been considered beneficial enough for subsequent new ESDs to be instrumented with similar systems.

4.5 Actuator Torque/Force Sizing

Most of the operators specify that the actuator must be rated at either 1.5 or 2.0 X the maximum break torque/force to open a valve (rated design differential pressure across one side of the valve to cavity). However some valves (pre-SI 1029) are installed with actuators rated lower (around 1.3X).

One of the major operators originally specified a value of 3.0X but because the actuators were physically so large and after reviewing requirements further, they reduced the factor to 2.0X.

It is understood that a Norwegian Operator now requires actuators for subsea ESV applications to be rated at 3.0X maximum break torque.

4.6 Seat/Seal Cavity Flushing

As a result of earlier experiences of leak testing in the field giving very variable results (identified as due to dirt/debris build up in the seat/seal cavity and on the seal face), several operators now undertake the practice of first flushing the valve cavity with a greasing/lubricating fluid (to remove dirt/debris) prior to undertaking the statutory seat leak tests. This has resulted in much more consistent seat leakage figures with much less major variation from test to test and valve operation remaining smooth with little jerkiness. Dirt/debris is often evident in the flushing fluid.

In their experience, one operator has certainly found that gas-handling ESD valves are more predictable and consistent with seat leakage tests and closure times than the crude-oil handling valves; they have much more variation in the leakage values (both up and down) and sometimes operating times also.

4.7 Seat Leakage Limits

Some operators considered that the leakage level limits as laid down in SI 1029 were too tight. However, since it has now been withdrawn, some operators have now carried out a Risk Assessment/Safety case on an ESV installation which in some instances has allowed the limit to be revised upwards.

5. MANUFACTURER'S EXPERIENCES AND COMMENTS

5.1 Design

The valves are designed in accordance with industry design/test codes for pressurised products, components, in particular:

ASME /ANSI B31.3	Piping- (Ref. 6)
ASME /ANSI B16.34	Valves - (Ref. 7)

ESD valves are not new purpose built designs. To meet an ESD specification, manufacturers take an existing base design and change mainly the materials of construction to suit the particular operating conditions and requirements specified by the purchaser. Changes will also be made to meet the fast operation and high operating stem torque/force requirement and the resulting stress levels within the valve body. This will probably involve an upgrade in the stem material specification or a larger diameter.

5.1.1 Finite Element Analysis (FEA)

All the manufacturers contacted have each carried out FEA modelling on their valve designs using proprietary software and the results have compared very favourably with good agreement with experimentally derived data.

5.1.2 Small valves

Depending upon the application, it is often very difficult or impossible to get the stem of a 50 mm nb valve to take the 2X torque/force required because of limitations in the physical size/valve design constraints. It is preferable for companies to fit an 80 mm nb valve size in the 50 mm nb pipeline, so that torque/force requirements can be adequately met.

5.2 Seat leakage standard

Several standards/codes are used by the industry for hydrostatic pressure testing and gas pressure testing (as required) for body, stem and seat leakage tests; these include:

API 6D - Pipeline Valves (Ref 4)
API 6A - Wellhead Equipment (Ref 5)
ISO 5208 - Pressure testing for Valves (Ref 8)
MSS-SP61- Pressure Testing Steel Valves (Ref 9)

As a minimum, the leakage test is done at ambient temperature, however some operators request that the valves are also tested at the rated maximum and minimum design temperatures (API6A).

5.3 Seal degradation

There is some evidence that there is a degradation in valve seal performance if a valve is left in the one position for long periods.

5.4 Common specification/testing procedure

Apart from the operating conditions, each operator or engineering design contractor tends to have their own particular specifications/requirements for ESVs. Because of these individual variations in ESV requirements, valve manufacturers would like to have a common agreed standard/ specification for ESVs, together with agreed testing procedures and criteria that the valves are to meet (when new).

Most of the valve manufacturers would like to see operators agree to a common ESD valve specification, together with agreed factory and field testing procedures. Every company, including the certifying authorities seems to have their own interpretation of what test criteria/ procedures and definitions are, because they are ambiguous or there is no agreed industry definition.

Valve manufacturers would like valve purchasers/specifiers to have a better understanding in writing and using valve specifications; what can and cannot be so readily changed - their implications to delivery, price, weight, size and becoming a special.

5.5 Feedback

The manufacturers find it difficult getting any feedback about how their ESVs are performing in the field. People keep moving within operators from one project to another and there is no obvious point of contact. Yes, if a valve is not performing they are sometimes called, but more often they are not. Because of this it doesn't necessarily follow that 'no news is good news.' Even then, it is frequently not the valve but ancillaries causing the problem.

Unless there is feedback to the valve manufacturers on valve performance, the circle cannot be completed to enable manufacturers to assess a valve's performance and be able to provide objective information back to purchasers on valve reliability.

5.6 Planned maintenance

The valve actuator and control equipment must be maintained in good working order according to a planned maintenance programme otherwise ESV performance will deteriorate and it may otherwise fail to operate.

5.7 Re-seat torque

With ball valves it is not very easy to predict the re-seat torque requirement of a valve. It varies somewhat, particularly as the length of service increases. Often it is around 70-75% of the break torque value, however for design purposes a value of 80% is often taken. This is an area in which manufacturers feel more work is required. A better understanding of the mechanisms which cause it to vary and being able to predict more precisely will enable actuators to be sized more accurately.

5.8 Stem Torque/Force

5.8.1 Break-torque test

The break torque test is done with the maximum design differential pressure across the valve seat (in closed position); the upstream pressure at its maximum and the cavity at atmospheric pressure. The valve is suitably instrumented with a high speed chart/ data recorder to measure the maximum torque/force required to break (open) the valve.

5.8.2 Jam test

Some of the manufacturers indicated that they are being asked by some companies to do a 'jam test' on the valve. Basically the valve is 'jammed' fully open and the actuator is then operated to apply its maximum output torque (which is measured). The purpose of this test is questionable as there are other ways of testing an actuator at full output power and of demonstrating that the stem can take the torque/force.

There is concern by some that permanent damage (overloading) may be done to the seals and internals of the valve. The load bearing areas which are in contact with the 'jamming mechanism' may be overloaded and consequently damage the seat/seal areas. As a result several manufacturers decline to undertake this test.

5.9 Actuation

5.9.1 Actuator sizing

ESD valves generally require relatively high torques/forces compared to other valves, so requiring relatively large and powerful actuators. However as one moves up the actuator sizes, the increments in output torque rating become larger, making it more difficult to match a valve's torque requirement to an actuators output. This often results in an 'oversized' actuator being used to meet the specified 1.5 or 2.0 x break-torque requirement. The consequence of an oversized actuator can be significant in several ways- extra cost, larger physical size, extra weight, uprated or larger stem. Some flexibility should be considered for the actuator break torque sizing factor.

Valve manufacturers would like to see an effort put into reducing the power of actuators in the fully open position. Because when fully open, the actuator has compressed the internal spring and the stem torque can reach 8 or 10 times maximum torque requirement.

5.9.2 Sizing considerations

When a manufacturer specifies to an actuator supplier the torque/force requirement, there are a number of factors that have to be taken into account, which all together can be significant, compared to the original break torque figure. Some of these factors include:

- Static break torque requirement
- Dynamic torque requirement
- Effect of fluid temperature on valve torque requirements
- Increase in torque due to long set time
- Running torque
- Increase in torque effort with operating life.
- Speed of operation

5.9.3 Speed of closure

Some valve manufacturers would also like to see an industry guidance rule on the maximum recommended rate of closure(speed) - eg 0.5 secs per inch of valve nominal bore size. Some speeds that are asked for are very fast and it is felt that there must be an optimum. If too fast reliability will suffer, actuator sizes will be even bigger to supply the colossal forces as well as costing more.

Operators had no particular comments on this. Of course the valve minimum closing/opening times have to take into account the individual piping configuration/operating details of each installation.

5.9.4 Spring failure

There have been at least a couple of spring failures in 'spring return' actuators which have been attributed to corrosion which was found on the spring.

6. DYNAMIC OPERATION

6.1 Worst Case Condition

So far discussions to date and a literature search have revealed very little documented data - empirical/experimental, computational flow modelling or otherwise, which clearly illustrates that an ESV will operate under what are considered to be the worst case operating conditions - ie full dynamic flow conditions, for which the valves are specified.

In these conditions, it is assumed that there is a major pipe rupture one side of the valve causing a major (maximum) pressure drop across the valve. This results in very high velocities and dynamic forces being generated inside the valve and on the valve 'closing member'. Because of complex fluid dynamic effects, such as sonic flow, cavitation, flashing and severe swirl/jetting effects, the resultant dynamic force on the valve stem will change very rapidly in magnitude and may even assist rather than oppose the actuator over part of its travel.

6.1.1 Operators experience

None of the operators in the study have had a valve operate in the worst-case condition. Although some of the ESD valves have been operated in 'emergency', but because the differential pressures were very low, no comparison can be made to the 'worst case situation'.

6.2 Earlier Tests

The author is aware that tests done by British Gas (Ref. 10) and by another company into the dynamic operating torques of ball valves, (using natural gas, with differential pressures across the valves ranging from 20 to 60 bar), revealed the following:

a) To re-open the valve to the fully open position, the operating torque can increase by up to 1.3 times the break open torque (for the operating differential pressure across the valve).
b) To close the valve (from fully open), the operating torque reduced and became negative when part closed (the 'flow conditions' driving the actuator; sometimes referred to as vaning), but later reversed itself and remained a good margin below the break torque.

Because these operating conditions are rather limited compared to the emergency case for ESVs it is too early for definite conclusions to be drawn from the tests.

6.3 Break Torque Rating v. Dynamic Torque Requirement.

The important and crucial question, which appears as yet to be unanswered is whether the magnitude of these torque/forces are within the sizing capacity of the actuator fitted. This is a crucial point because the whole point of installing these valves is that they must operate in this emergency situation.

Another important question is what happens to the valve seals? This is because there are different designs and materials used and as some of the seals are exposed to the flow path, there is a distinct possibility that the very high fluid velocities may damage or even remove part of the seal reducing the valve's sealing ability or even causing it to jam and fail to close.

Some further questions and points for consideration and debate with regard to dynamic operation of ESVs and actuator sizing techniques are as follows:

- Do ESD valves all fail in the closing direction?
- How do the forces scale by differential pressure increments and for valve size (nb)?
- Do the forces reach limiting values?
- Does speed of valve travel have much effect on the dynamic forces?
- How do the forces vary over valve opening position for a given valve type?
- For a given valve type, do different seal types have much effect?
- The effect of different fluids/compositions - gases, liquids, multiphase flow, density, viscosities etc.

Some of these effects although additional, may be quite small, others somewhat larger, when comparing to the maximum design differential pressure break torque value; some may even produce reverse forces. However depending upon each ESV's individual operating conditions and valve type etc, the accumulative effect of these factors may significantly affect the maximum force/torque required from the actuator for the 'worst-case' condition.

6.4 In-service Operation

Another point to address is how does the valve operating torques/force change over valve life. If a clean fluid is used, effects are likely to be small. However if a dirty fluid is present, as well as the accumulation of pipeline dirt/debris and pipe cleaning, it is likely that operating forces/torques will increase over time. The big question is what the rate of increase might be, compared to the reserve margin in the actuator? Operating torque/force will also be influenced by the frequency of valve operation.

It is also known that if valves are not operated for long periods, the opening torque can increase by between 10-30% or more on the normal value, depending upon valve design/type.

7. CONCLUSIONS

In summary, the study has identified and raised a number of points for further consideration, discussion and debate by the industry, to ensure the safe, reliable and effective operation of ESVs by the industry.

7.1 The Way Forward

It is anticipated that by having open discussion and debate by the industry on these and other points, that a satisfactory consensus of views and conclusions can be drawn to determine the way forward for using ESVs in the industry. However in some instances it may be that the most appropriate way forward is to set up an industry JIP to resolve a particular issue.

7.2 Points for Further Consideration

7.2.1 Common specification

Operators and design contractors should try to standardise on a common industry specification and standard for ESVs, together with an agreed test procedure and acceptance criteria for new valves.

Industry (valve manufacturers, operators and certifying authorities) should all have an agreed interpretation of definitions; in particular those relating to actuator output torque/force, rating etc, and an awareness of the factors which affect actuator power requirements, depending upon how they are specified. Ideally, standardise on one sizing factor for actuators.

7.2.2 Seat/seal flushing

With a number of operators introducing the practice of cavity seat/seal flushing prior to undertaking a seat leak test (usually annually), this raises a number of issues. How much worse is the seat leakage and operating stem torque/force deterioration if the flushing is not done? In an emergency situation the ESVs cannot first have their seats/seals flushed prior to operation, they have to operate as is. As a result, should the period (one year) between flushings be reduced to ensure that valve seats/seals are in a more favourable condition if an emergency arises?

7.2.3 Dynamic operation in worst case situations

There appears to be little information or hard facts available about the dynamic operation of ESVs in the worst-case situations. What is/are the worst case situations? Does the industry have adequate objective test data, experimental data to ensure that the valve/actuator sizing method (2X break torque) has sufficient over capacity in it to ensure that a valve will safely operate in all the various worst-case scenarios for ESVs? At the same time, an allowance - perhaps significant, should also be made for the inevitable increase in operating torque/force through the valve's service life.

Is there much variation due to seat/seal design and different fluids? Do we have evidence that the seat/seals remain intact during valve closure under the very high local velocities present across the seals? It is no good if the seals are partly damaged/torn off during closure; the valve may jam partly open.

There appear to be a number of important questions which need to be answered to remove areas of doubt and concerns about the operation of ESVs in emergency case situations. Further studies are necessary to define an industry standard for testing ESVs under simulated extreme accident conditions. This will enable the above points and associated issues to be addressed and conclusions later made to remove all doubts and concerns about whether the ESVs will safely operate in emergency conditions.

7.2.4 Static break and re-seat torques/forces

There is a need for better prediction and understanding of valve break and re-seat torque values and how much they vary (increase) in valve service - frequency of operation, length in service and long periods of non-operation.

7.2.5 'Jam-tests'

Are 'jam-tests' necessary? What is its purpose? Can another test be undertaken to demonstrate/ satisfy the same test requirement?

7.2.6 Stainless steel ancillaries

Consider requiring all ancillary plugs, connections, piping to be made from stainless steel to eliminate corrosion problems.

7.2.7 Cavity relief

With the emphasis on good sealing capability, the improvement in seal performance and the introduction by some companies of bi-directional seals, it is essential that provision is made to ensure that any overpressure in the valve cavity is automatically relieved.

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Table 1

ESD VALVE STUDY - Distribution of Valves

Valve * Manufacturer/ Supplier	Ranking	Totals	Operators A	B	C	D	E	F
A	1	50	22	5	-	-	7	16
B	2	24	-	-	-	-	-	24
C	3	19	3	-	-	-	-	16
D#	4	17	-	-	14	3	-	-
E	5	14	-	8	-	3	1	2
F	6	13	3	-	-	-	4	6
G	7	9	-	-	-	-	-	9
H#	8=	5	-	-	-	4	-	1
I	8=	5	-	-	-	4	-	1
J#		2	-	-	-	2	-	-
K		2	2	-	-	-	-	-
L		1	-	-	-	-	-	1
M		4	-	4	-	-	-	-
N		1	-	1	-	-	-	-
O		2	2	-	-	-	-	-
P		1	-	1	-	-	-	-
Q		1	-	1	-	-	-	-
R		2	2	-	-	-	-	-
S		1	-	1	-	-	-	-
T		1	-	1	-	-	-	-
	TOTAL	**185**	**35**	**22**	**14**	**12**	**16**	**86**

* *valves are of ball valve design unless otherwise indicated*
\# *gate valve design*

Contents

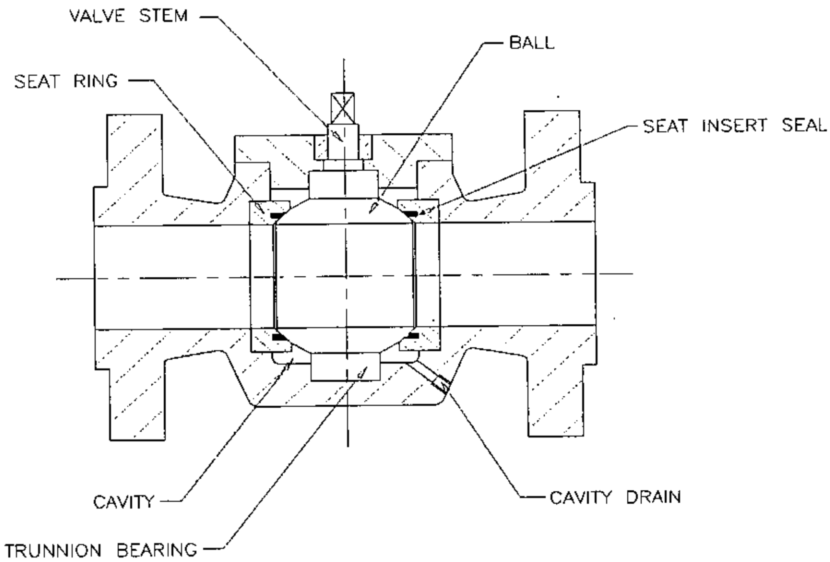

FIG 1 SECTION VIEW – TYPICAL BALL VALVE

Contents

APPENDIX

LITERATURE SEARCH

Below are listed titles of papers/references resulting from a technical literature search of publications into the design, operation and testing of ESD valves or similar.

1 GODARE, W. L., NEVE, C. G. and RARDIN, R. W. Gate valve technology: Designs for the times. Paper No OTC 6737. Presented at 23rd Annual OTC in Houston, Texas, 6-9 May 1991.

2 ERIKSEN, G., BONDEVIK, J. O. and BERGUM, G. First emergency shutdown valve. Paper No OTC 6917. Presented at 24th Annual OTC in Houston, Texas, 4-7 May 1992.

3 STEELE, J. Diverless intervention ball valve system. Paper No 7229. Presented at 25th Annual OTC in Houston, Texas, 3-6 May 1993.

4 BRATLAND, O. Emergency shutdown systems: Improved understanding of design requirements. Paper No OTC 7718. Presented at 27th Annual OTC in Houston, Texas, 1-4 May 1995.

5 FLOOD, B. J. The Variation of Ball Valve Stem Torque Characteristics when Opening and Closing under Flowing Conditions. Workshop on Valve Testing, National Engineering Laboratory, UK, 1992.

6 COOPER, T. A. Pig-train isolation design developed for North Sea ESV work. Presented at Gas Transport Symposium, 29-30 Jan. 1991, Haugesund, Norway.

7 THAYNE, A. Pipeline Incidents Offshore - The UK Experience. Presented at Offshore Pipeline Technology Conf., Amsterdam, 18-19 Feb. 1993.