Managing risk through best practices in valve selection for LNG liquefaction plants

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Valve selection for liquefaction plants directly impacts safety and reliability. Leakage of liquefied hydrocarbons or the unreliable performance of the facility can lead to unplanned shutdowns.

This paper is an overview of best practices to assist the specifying engineer to minimize risks related to valves for LNG service and be aware of the relative advantages and disadvantages of common designs. The material is based on industry experience.

Valve selection directly impacts plant safety and reliability. Leakage of liquefied hydrocarbons or unreliable performance can lead to catastrophe or unintended maintenance.

The focus will be on the ball and butterfly valves predominantly used for isolation in the LNG industry. Other valves like gate or globe valves with limitations in providing tight shut off, high emissions or otherwise unsuitable for cryogenic service are not discussed.

Related Risks

Risks related to on-off valves and the isolation of LNG can be reduced to these areas:

1. Seat leakage
2. Body leakage
3. Failure to operate on demand

We will examine each of these areas in detail.

Seat leakage

Seat leakage can have numerous causes. Assuming the valve originally passed a cryogenic leak test such as BS6364, the most common cause of leakage is wear.

High wear valves such as position seated ball valves have a concentric motion that wipes the contact between seat and ball across 90 degrees every time operated. Eventually friction wears the thermoplastic seat, causing leakage.

Modern torque seated valves use eccentric motion which limits wear by avoiding friction between disc/ball and seat until closure.

Leakage is also seen at low pressure in valves that rely process pressure for sealing energy such as floating ball valves. The specifying engineer needs to be aware at lower pressures there can be substantial leakage.

Trunnion mounted ball valves rely on upstream pressure along with springs to provide sealing energy. If pressure is low leakage increases.

Dynamic seals

These ball valves also require dynamic seals between seat and body providing an additional leak path and point of failure.

Torque seated valves have static seals between the seat and body. Dynamic seals are not required between seat and body, eliminating a point of leakage and failure.

Engineers should be aware that there are substantial differences in how valves utilizing process pressure for sealing perform versus torque seated.

The latter utilize mechanical sealing from the stem instead of relying on process pressure and/or springs. Torque seated valves do not leak at low pressures or thermal cycling.

Adams Armaturen of Germany, originator of the Triple Offset Valve was contacted for comment on LNG applications.

"Adams originally designed these

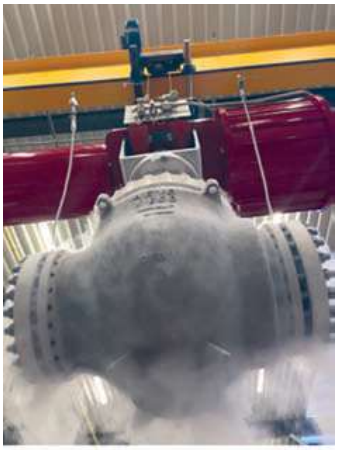

Figure 1: Cavity free, low wear and bidirectional eccentric ball valve for Cove Point liquefaction project after cryogenic testing. (Courtesy of Advanced Engineering Valves)

valves to deliver a better concept for sealing than the prevailing technologies," the company said.

"Almost 50 years later our non-wiping, torque seated and cavity free valves deliver long-lasting, safe and bidirectional shutoff on LNG.

"Clients deserve and have been promised safe and simple valves for sealing potentially hazardous fluids such as LNG. Torque seated valves such as those manufactured by Adams are proven in the market," it added.

In summary seat leakage is minimized through:

1. Eccentric low wear valves that do not wipe sealing elements until closure.
2. Torque seated valves not relying on process pressure for sealing.

Most ball valves available in the market don't satisfy the above conditions. Fortunately in the last two decades there has been an introduction of torque seated eccentric ball valves designed for LNG service.

Figure 4: Butt weld with side entry port triple eccentric valve. (Courtesy Adams Armaturen)

Figure 2: Split body ball valve with leak paths exposed to pipe stress

Eccentric ball valves offer the same type of advantages long provided by triple eccentric butterfly valves to sizes where ball valves are more economical or higher capacities are required.

The author contacted the Managing Director of one of the firms manufacturing these eccentric ball valves for a comment on why the valves were developed.

Francis Carpio, Managing Director of Advanced Engineering Valves of Belgium, said: "We saw an urgent need for better ball valves for LNG service.

"Triple Eccentric Butterfly valves had emerged as a superior technology for LNG isolation. We set out to bring the same simplicity, reliability and safety in a ball valve package."

Measures

In March 1977 in Algeria at the Camel LNG plant, a worker was frozen to death by the release of 1,500-2,000 cubic metres of LNG through a valve body.

While ignition did not occur creating a wider catastrophe it shows the importance that all precautions be taken to avoid LNG release during valve selection.

Body leakage can be best avoided by:

1. Uni-body construction with top or side entry and avoiding body flanges subject to pipe stresses.
2. Welding valves in line with 100 percent X- rays of welds.
3. DIB should use a single body, two obturator arrangement eliminating unnecessary connections.

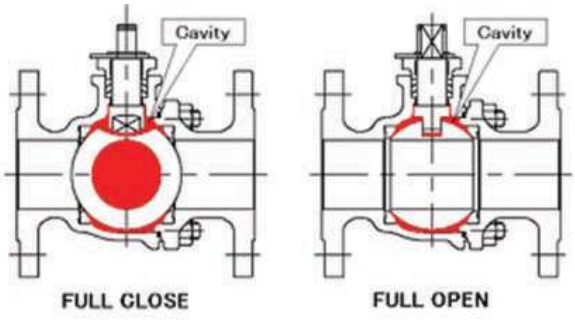

Figure 3: Trapped liquefied hydrocarbons can expand and disable a valve. Such an event can then even rupture seals or the body of the valve itself

Operating

Applications involving LNG require the special consideration of whether there can be trapped cavities of fluid within the valve body.

If LNG is trapped within cavities in the valve when thermal expansion occurs this can exert tremendous force as the volume occupied by liquid is 1/600th of the gaseous state. The expansion force is sufficient to plastically deform the soft parts, disable operation and even rupture the valve body.

Gate valves and conventional ball valves can create these types of dangerous trapped cavities. Steps must be taken to ensure the ability to safely relieve pressure if fluid expansion occurs.

The simplest method for pressure relief is a hole connecting the cavity to the upstream piping rendering the valve unidirectional.

Piping becomes unnecessarily complicated and operator error creates risk if operation of the valve is misunderstood. It is important to understand that unidirectional valves are not fire safe in the reverse direction.

Identified

Unidirectional valves must be identified clearly in the P&ID and at site to minimize chances of improper operation. In the field identification can be difficult as the plate is often installed under insulation. This can confuse plant operators during valve maintenance activities or operation.

Another approach to cavity venting in ball valves is to use self-relieving seats. This design raises serious questions to how the responsible engineer validates whether the valve can relieve at the correct pressure, in the correct direction and with sufficient capacity at cryogenic temperatures.

Specifications

API 6D, the specification for pipeline ball valves, covers self-relieving seats but does not cover cryogenic applications. The cavity relief testing is done at ambient and cannot validate a design to be used at cryogenic conditions with a liquefied gas that can expand in volume 600X.

BS6364, the specification for valves for cryogenic service, while mentioning that self-relieving seats can be used do not provide an appendix for validating the design during testing.

The specifying engineer must design his or her own requirements for testing and validation of the self-relieving seat done in conjunction with cryogenic testing to ensure safety in the field.

For safety, the conservative practice for valves with a cavity requires bleeding

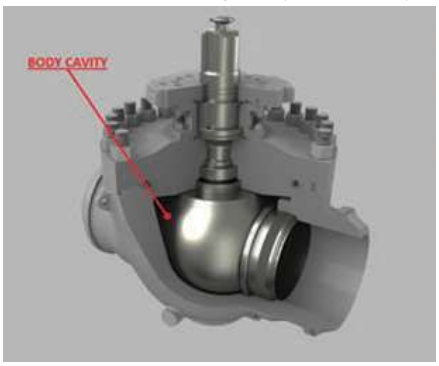

Figure 5: Conventional ball valve with cavity

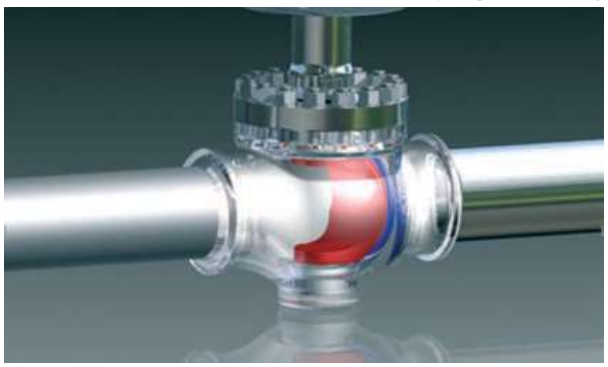

Figure 6: Eccentric cavity free ball valve

prior to any maintenance activity. The bleed provision (bleed to atmosphere or a closed drain) & bleed valve location (outside the insulation) must be considered by the engineer.

Self-relieving seat designs also rely on dynamic seals between seat and body (lipseals) that can become brittle at cryogenic temperatures and lead to catastrophic failure.

Torque seated valves do not have cavities therefore do not require pressure relief strategies or bleeding. The designs are single seated, cavity free, fully bidirectional and the seat is fixed to the body with a static gasket.

Several categories of risk (inoperability, catastrophic seal failure, operator error) are eliminated and operation simplified when using modern torque seated valves.

Conclusions

Best practices evolve over time as technology develops, experience is gained, and standards evolve. The LNG industry is still lacking a comprehensive design standard for cryogenic valves.

Until such a time that a comprehensive standard covering all concerns emerges, engineers working within the LNG industry must study the subject matter and try to ascertain the best practices of experienced experts.

As we have reviewed, safety relies on being able to reliably control LNG. The ideal valves to accomplish this should have the following characteristics:

- Non-wiping, low wear
- Torque sealing independent of process pressure
- Bidirectional avoiding operator error and complicated piping
- One piece weld end body
- Cavity free

Modern valve manufacturers have developed low wear, eccentric action, torque seated, fully bidirectional, cavity free ball and butterfly valves with unibody construction ideal for LNG service.

While technology will continue to develop these valves substantially improve safety and performance today as compared to gate valves and conventional ball valves of earlier generations. ■