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Petrochemicals, millennials and automation

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Sealing the standards for LNG

Developing a new generation of seat-to-body seals for cryogenic trunnion mounted ball valves to exceed LNG industry leakage rate standards

With the liquefied natural gas (LNG) industry representing a high business potential for valve manufacturers, trunnion mounted ball valves (TMBV) are being used extensively for cryogenic service.

The performance requirements for valves handling LNG are among the most demanding in any industry, especially with regard to low-temperature performance at temperatures of around -163° C, bubble-tight seat sealing, and stringent fugitive emissions requirement. These cryogenic service applications are governed by several industry and IOC standards: BS6364, ISO 28921-2, Total GS EP PVV 150and Shell SPE MESC 77-300.

BS6364 from the British Standard Institution is the most commonly used standard for valve cryogenic testing in the LNG industry, but it is also the oldest (having not been revised since 1984). As a result, the standard's maximum allowable seat leakage rate remains the highest among other standards (see Figure 1). IOC and Shell standards in particular have designated their valves more in line with the technological progress of the valve industry. As indicated in Figure 1, the maximum allowable seat leakage specified by Shell MESC SPE 77-300 is half of the most severe international standards. In addition to extreme low leakage rate, Shell requires very severe high temperature cycling.

Why are there such ambitious requirements for cryogenic applications and how do valve companies handle these types of requirements?

Top entry trunnion mounted ball valves are widely used in the LNG liquefaction supply chain, mostly in the medium size range. TMBV design and construction codes refer mostly to API 6D with ASME B 16-34 being used for pipeline and process applications, however, special consideration should be taken with regard to the body cavity relief to avoid over pressurisation when the valve is closed. Thermal cycling of LNG in the line can create a catastrophic failure considering that LNG takes 600 times its volume when it reaches the gaseous state. To minimise the risk of leakage, TMBV manufacturers have developed a device called a "Self-Relieving Seat", providing what is normally referred to as a Single Piston Effect (SPE), for which seat-to-body seals are critical components to ensure the valve integrity within the operating temperature range.

As a result of these stringent conditions, TMBV manufacturers are seeking out companies who can upgrade the leakage performance and integrity of their valves at -162°C, companies such as Saint-Gobain Seals, who are developing next generation seat-to-body seals that meet and surpass the leakage requirements given by Shell MESC SPE 77-300. This allows TMBV manufacturers to bring environmental and production confidence to an industry where safety is the first priority.

How are these next generation sealing solutions developed?

Using their OmniSeal PTFE rotary lip seals, Saint-Gobain Seals launched an internal research and development project to develop and pre-validate new single piston seat seals in full accordance with Shell MESC SPE 77-300 test protocol. The following were their internal testing capabilities (Figure 2):

- Pressure up to 420 bar He
- Temperature from -196°C to +150°C
- 2 mockups available: 3" and 8"

At this stage, it is important to notice that there are two possible leak paths that account for seat leakage. For TMBV, the seat tightness is ensured by a seat insert pressed against the ball and seat seal, commonly called seat-to-body seal (see Figure 3).

Based on input from major cryogenic TMBV manufacturers, the decision was made to set up a leak rate target for a seat seal at 25% of Shell MESC SPE 77-300

Figure 2: Saint-Gobain Seals Cryogenic Test

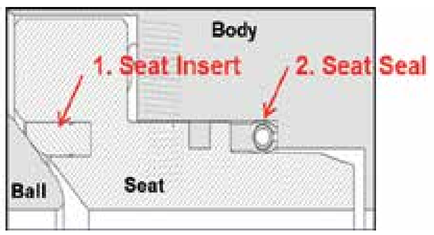
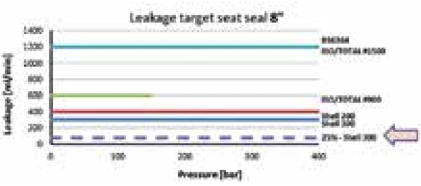


Figure 3: TMBV Single Piston Effect seat design, Saint-Gobain Cryogenic Test Rig



Specifications	BS6364	ISO 28921-2& Total GS EP PVV 150	Shell SPE MESC 77-300
Maximum allowable seat leakage (soft-seated)	100 mm³/s x DN	50 mm³/s x DN <= class 900 100 mm³/s x DN <= class 900	25 mm³/s x DN (=1.5 ml/min x DN)

Figure 1 : Maximum seat leakage rate

standard, giving 75% for leakage through the seat insert. Maximum seat leakage specified by Shell is MESC SPE 77-300 for 8" TMBV= 300 ml/min is 75ml/min for seat seals, and 225ml/min for seat inserts.

Saint-Gobain Seals' main objectives for their R&D project:

- Understand the seal key design parameters to exceed SHELL MESC 77-300 leakage requirement
- Understand the impact of valve hardware and size on leakage performance
- Provide a new solution to fit into existing TMBV seat configuration
- Define clear design rules to cover the entire cryogenic TMBV range of applications up to class #2500

The main challenges to overcome when designing lip seals for cryogenic TMBV seat seal application were:

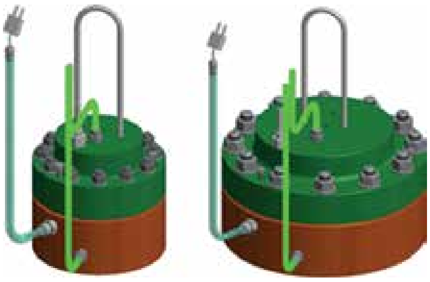
- Shrinkage of the lip seal
- Misalignment in the valve trim
- Roughness of sealing surfaces
- Ease of seal installation
- Seat must be free to move for over-pressure body cavity relief
- Shell MSEC SPE 77-300 pre-heating cycle at 120°C or 150°C does not allow the usage of materials commonly used for cryogenic temperature

A two-part development programme through parametric study was implemented to understand the key application parameters and FEA design optimisation.

Jacket Materials	Jacket Design	Spring
CTE Transition temp Hardness	Profile Finish Interference	Shape Load Deflection

1. Parametric study:
Each parameter was then identified that could affect seal performance at cryogenic temperature. For each parameter, tests were conducted to understand their impact on leakage.

i. The team selected four thermoplastic jacket materials to assess and quantify the impact of cryogenic conditions. The material selection was based on analytical data and mockup testing at elevated temperature followed by cryogenic testing.
ii. Jacket design was optimised in order for ease of installation while ensuring optimal tightness even in misaligned conditions. Tests were performed on 3" and 8" mockups.
iii. Multiple spring configuations were characterised with load/deflection curves at room and cryogenic temperatures.



2. FEA (Finite element analysis) design optimisation:
All selected jacket materials were fully characterised so that they could utilise their proprietary polymer material model in order to run FEA thermo-mechanical validation.

FEA input:
i. Material parameters from characterisation of spring and jacket
ii. Large strain formulation
iii. Hardware shrinkage
iv. Shell MESC SPE 77-200 test protocol (installation, pre-heating, pressurisation, cooling)

Seal designs were evaluated based on the evolution of interaction between sealing force and contact length with the hardware.

What was the conclusion of Saint-Gobain Seals' testing?

The extensive test programme combining the efforts and expertise of design engineering and research & development teams has resulted in the pre-validation on 3" and 8" mockups of a new generation of lip seals in full accordance with Shell MESC SPE 77-300 test protocol: the most stringent LNG industry specification.

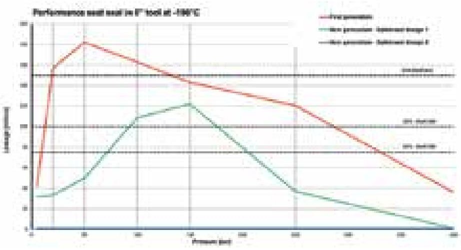
The graph below shows the evolution of performance obtained through the testing programme.

- The red curve shows the leakage rate with previous generation of Cryogenic Single Piston Effect Seat Seal
- The green curve shows the performance obtained with first design optimisation
- The blue curve shows the near zero-leakage performance measured with latest design optimisation

The new Cryogenic Single Piston Effect seat seal surpasses the requirement of Shell MESC SPE 77-300, since the team were not able to measure any leakage through the flowmeter.

This new generation of design brings the performance of lip seals to the next level with remarkable benefits to manufacturers of Cryogenic Trunnion Mounted Ball Valves:

- Ranging from -196°C to +150°C
- Up to class 2500 (420 bar)
- Able to cope with 0.4mm misalignment of valve trim
- Roughness of hardware sealing surface Ra 0.2-0.4µm
- No need to modify the hardware/valve seat concept. No additional parts required.
- Cost-effective design rules have been defined by pressure class, temperature and size.



How can Saint-Gobain Seals' research apply to other applications?

The above data collected for a wide range of pressure and temperature through FEA and application testing on many parameters such as jacket profiles, springs and hardware conditions provides a much better understanding of their interaction. The outcome of the parametric study has been translated into design rules that could be applied by application engineering teams to address other challenging applications not limited to Cryogenic Trunnion Mounted Ball Valves, but toward applications where a high level of stringent tightness is required on a wide temperature range, e.g., fugitive emission valves, space applications for propulsion and ground support systems and life sciences equipment. ▮

For more information:
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