Novel Cryogenic SPE seal Designs

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Novel SPE Seal Design for Cryogenic Ball Valves

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Novel SPE Seal Design for Cryogenic Ball Valves

Presentation Overview

Introduction

Fundamentals of a spring energised seal

Sealing at cryogenic temperatures

Current cryogenic seal designs

Cryogenic sealing with novel designs

Test Results

What is next?

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Novel SPE Seal Design for Cryogenic Ball Valves

Introduction

Reducing fugitive emissions is key to operators

Leaks carry an economic cost

Many small leaks add up to large emissions

<u>Improved safety</u>

Methane emissions contribute to climate change

<u>First time good seal results at FAT</u>

Fundamentals of a spring energised seal

Required seating stress for leak free operation

- Rough surface finish requires high seating stress
- Sealing gas requires high seating stress
- Cryogenic temperature requires high seating stress
- Standard seals at best, create 6 N load per mm seal circumference
- Depending on seal contact shape, 6 N/mm >>> 6 MPa seating stress at best.

Fundamentals of a spring energised seal

Required seating stress for leak free operation

A seating stress equal to or close to the yield strength would be good.

- The jacket material will begin to flow and plug eventual crevice's.
- The actual seal contact area will come closer to the geometric contact area

What are we up against?

Sealing Helium at Liquid Nitrogen temperatures.

How small is a Helium atom? Rounded up a little, Helium atoms have a diameter of 0.1 nanometer.

Comparison with a soccer goal and ball.

A soccer goal measures 7.32 by 2.44 meters and the ball 0.22 meters.

Reducing the soccer ball to the size of a Helium atom equals a shrinkage factor of $2.2*10^9$

Applying this factor to the goal size reduces the size to 0.00333 by 0.00111 microns.

An excellent surface finish would be 0.3*0.1 microns or a factor of 100 worse.

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What material property changes are seen while cooling down to LN2?

Yield Strength PTFE	E modulus Polymers	Hardness
To 110 MPa at -196°C	To +5 GPa at -196°C	To 450 MPa @ -196°C
↑	↑	↑
From RT and 9 MPa	From RT and 0,6 GPa	From 33 MPa @ Rt

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What material property changes are seen while cooling down to LN2?

PTFE Yield Strength, E modulus and hardness increase almost 10 fold

From RT and 9 MPa ➔ **To 110 MPa at -196°C**

To compensate the increase in hardness,

- a similar increase in seating stress may be wanted.
- so from 6N/mm to may be 60N/mm.

While not possible this would also be impractical.
The dynamic seat would be hard to move.

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What material property changes are seen while cooling down to LN_2?

Fluoropolymers used in cryo valves would also shrink a factor 10 more than the surrounding metal bodies.

This leads to

- a reduction in seating stress at the outer diameter of the groove.
- a reduction in seating stress between the spring coils gaps.

Sealing at cryogenic temperatures related to valve behaviour

A seal can only perform optimal when;

- ❖ The load generated is/and stays at its desired maximum
- ❖ This load is uniformly distributed over the entire seal circumference.

To achieve this;

- ❖ The bore diameter & shaft diameter needs to be centric at assembly
- ❖ This centricity needs to be maintained at operating conditions.

What can cause deviations;

- ❖ Differential shrinkage of the components
- ❖ Ovalisation of body versus the dynamic seat

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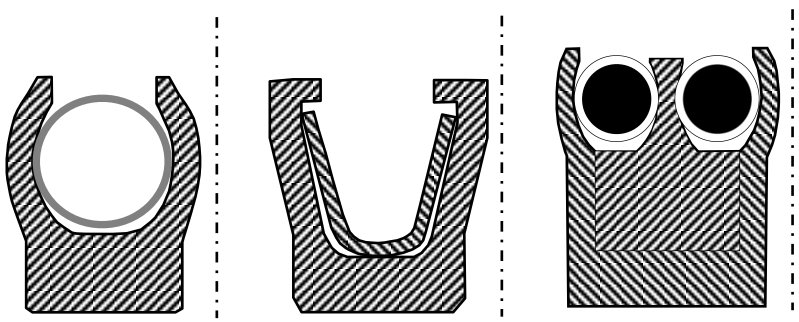
Current cryogenic seal designs



Typical examples

- Virgin modified PTFE jacket
- Carbon filled polymer
- Strong or "double coil" spring
- Double cavity with strong spring
- Helical or V shape springs
- Anti back pressure device

Novel SPE Seal Design for Cryogenic Ball Valves

Acceptance criteria 8" full bore. MESC SPE 77/300 February 2016

Seat + Seal leakage
1,5 ml/min at rated pressure

Acceptable leak rate equals

1.5 ml/min x 200mm = 300 ml/min. (6" DN >> 225 ml/min.)

or

25 mm^3/s X 200 mm = 5000 mm^3/s. (6" DN >> 3750 mm^3/s.)

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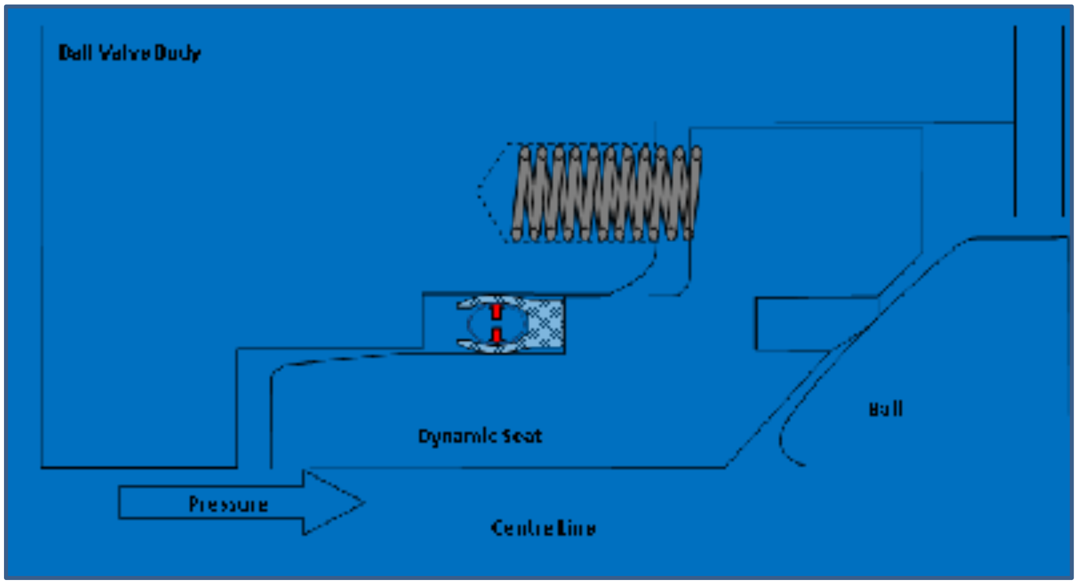
Current cryogenic SPE seal designs



Typical SPE Seal Design

- Shrinkage reduces OD-lip seating load
- Spring coil gaps have negative impact on seating stress.
- Shrinkage increases ID-lip seating load

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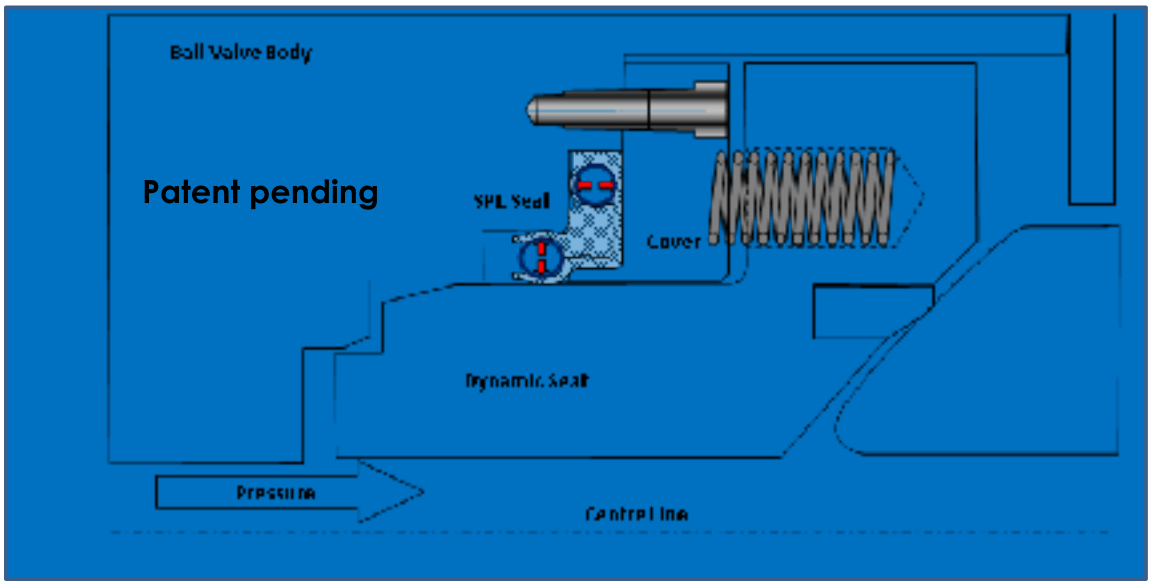

Novel SPE Seal Design

- Integrated radial & axial seal
- Body sealing by face seal
- Seat sealing by radial seal
- Each seal has it own spring
- Load and resulting drag can be optimized

Leak performance at least 10 times better than MESC SPE 77/300

Novel SPE Seal Design for Cryogenic Ball Valves

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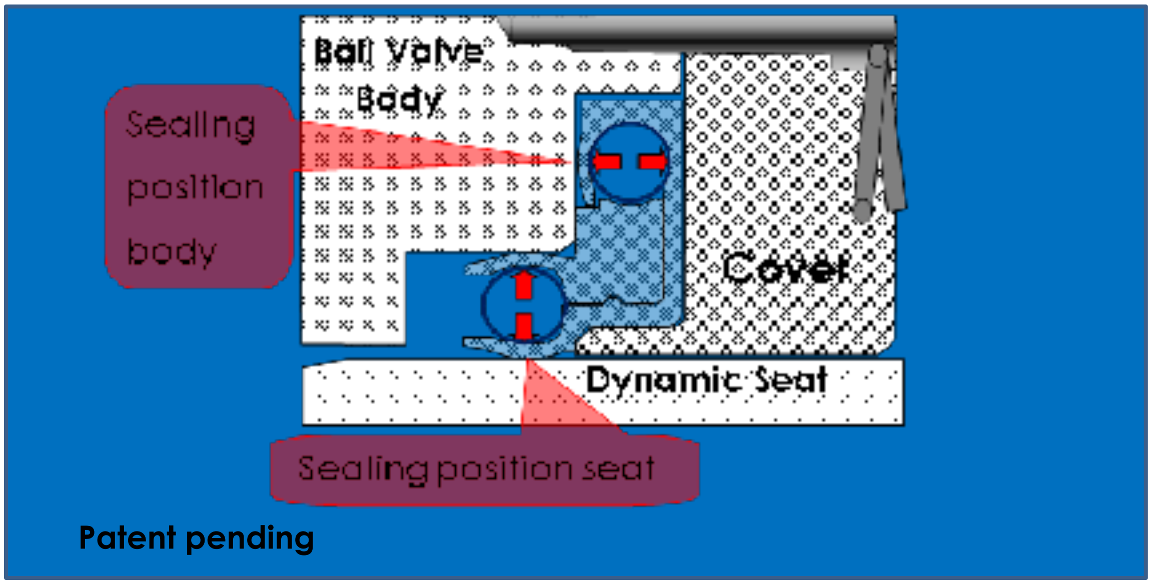

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Novel SPE Seal Design for Cryogenic Ball Valves

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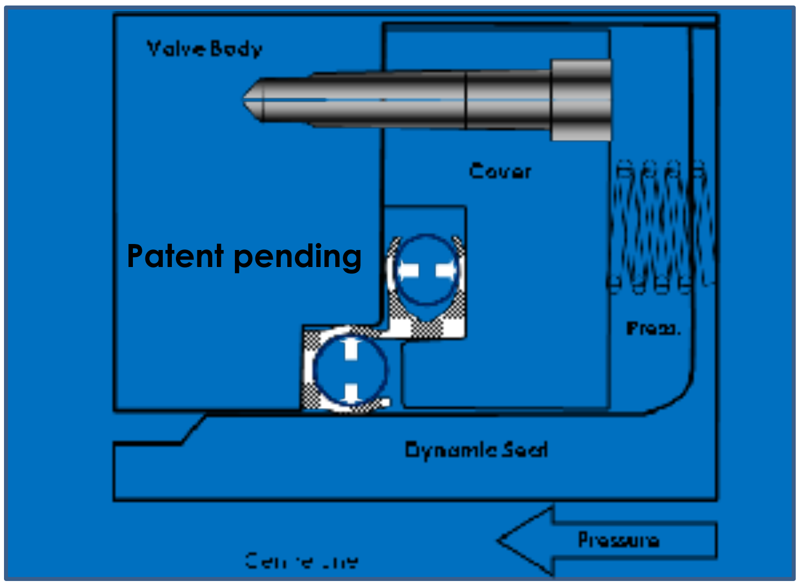


- Variation on the novel design whereby the seal is located on the downstream position. (one direction valve)
- Would prevent bleed off in the downstream direction.
- Lower bolt force required

Novel SPE Seal Design for Cryogenic Ball Valves

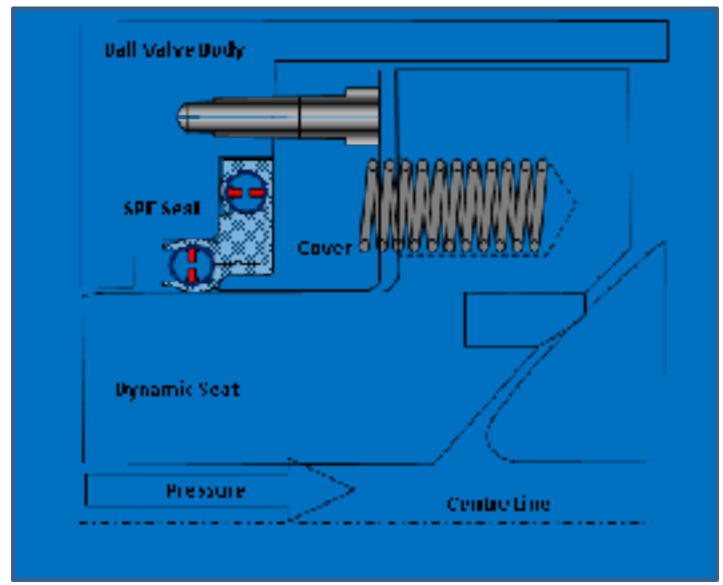
Test results by a renomated valve manufacturer

Test Conditions

Pressure: 0- 100 Bar

Temperature Range: RT to -196°C

Valve used 8” full bore # 1500 class



Patent pending

Test results by a renomated valve manufacturer

Gas	Medium	100%	N_2				He	N_2
Temperature			20°C	-50°C	-100°C	-150°C	-196°C	RT
Side	P(bar)	T(min)	Leakage in ml/min					
A	2	5	0	0	0	0	0	0
A	10	5	0	0	0	50	0	0
A	20	5	0	0	0	100	315	0
A	50	5	0	0	0	80	450	0
A	100	5	0	0	0	110	-	0

8” valve mock-up, Seal ID: 227 mm surface finish 0,1 Ra

Test results by a another renomated valve manufacturer

Gas	Medium	100%	N_2	He	N_2
Temperature:			20° C	-196°C	RT
Side	P(bar)	T(min)	Leakage in ml/min		
A	3	5	0	1,4	0
A	20	5	0	46	0
A	50	5	0	67,5	0
A	100	5	0	102	0

Difference versus previous

6” valve versus 8 inch valve

The seal lips for the second test have been changed / improved a little.

6” valve mock-up, Seal ID = 177 mm surface Ra = 0,4

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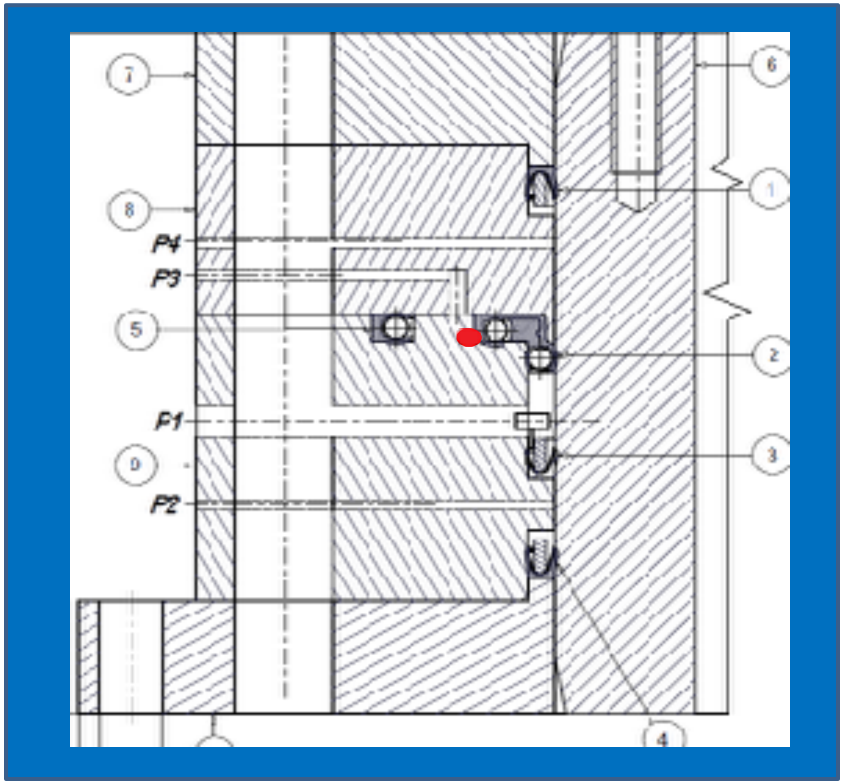
Cryo test program by 3P Engineering, witnessed by third party, Bureau Veritas



Seal description

1, 4 & 5 Secondary seals

Seal 2 = special Cryo SPE seal

Seal 3 = standard SPE seal

P1 = Pressure line

P2, line to measure total leak of standard seal

P3, measures the leak over the face seal

P4, measures the ID lip leak of the special seal

Red dot = temp sensor position

Surface finish body 0,3 Ra shaft <0,15 Ra

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Test specimen
Special SPE as depicted in the sketch (1)

Material: Modified PTFE & UHMW PE

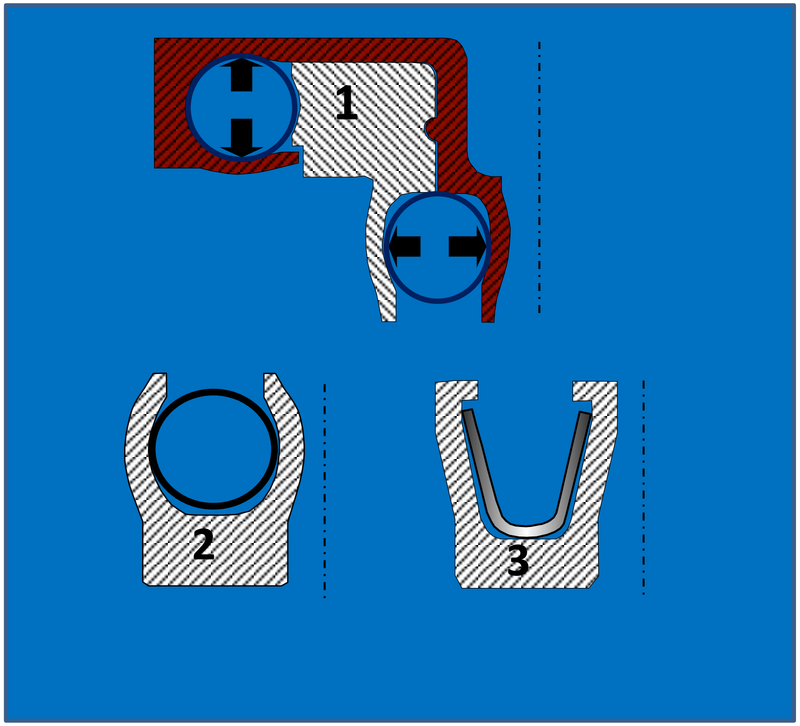
Standard Seal Helical Spring (2)

Material: Modified PTFE & UHMW PE

Standard Seal V-Spring (3)

Material: Modified PTFE

Shaft diameter : 228 mm-XS 3/16 inch



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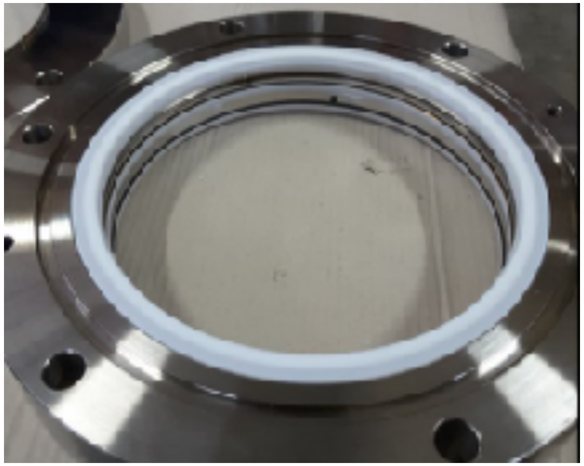
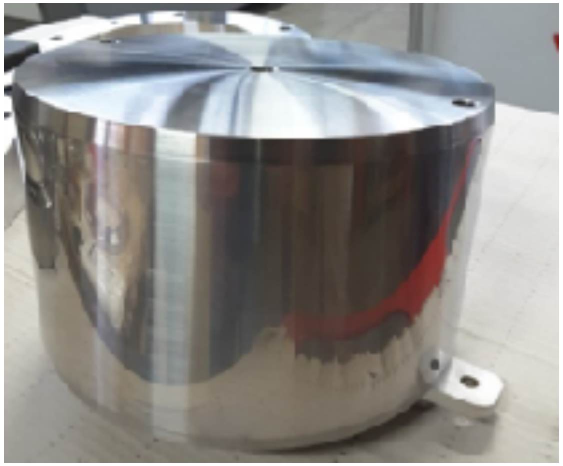
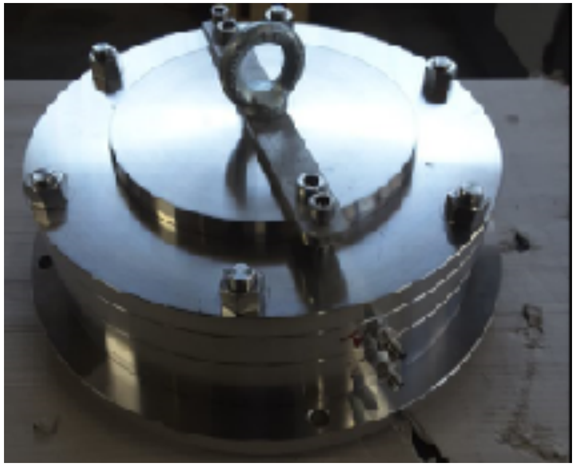
Test Fixture View

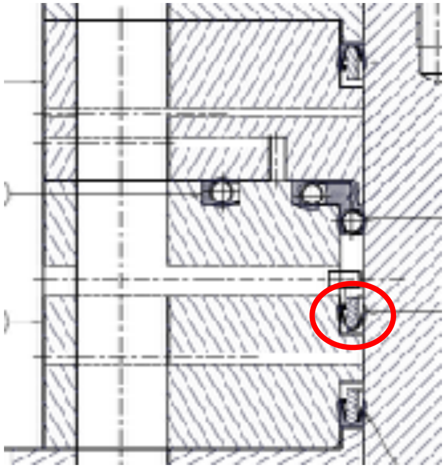




Novel SPE Seal Design for Cryogenic Ball Valves

Results Cryo test program by 3P Engineering, witnessed by third party, Bureau Veritas

Standard Seals, both helical and V-spring loaded seals leaked above 1 liter/min.
As of 50 bar He and -170°C leak > 1000 ml/min
As of 25 bar He and -196°C leak > 1000 ml/min

The results for the standard seals in the following slides are for a V-spring loaded seal with a non –standard outer lip design.

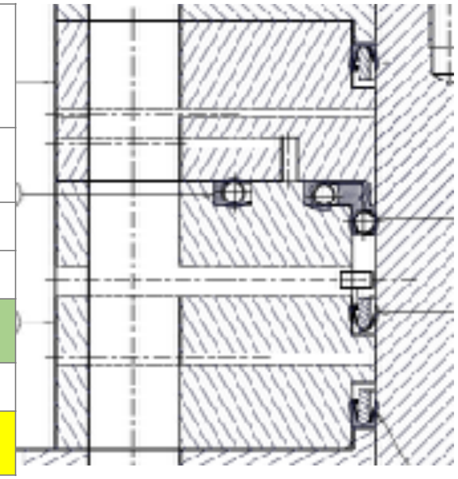


8" test fixture, 227 mm seal ID, surface finish 0,1 Ra

Novel SPE Seal Design for Cryogenic Ball Valves

Results Cryo test program by 3P Engineering, witnessed by third party, Bureau Veritas

Description	Roomtemp., He , Sniffing E-06 mbar.l/s			Temperature -100°C, Medium GHe ml/min					
Cryo design F10 12	1 Bar	10 Bar	25 Bar	1 Bar	5 Bar	10 Bar	25 Bar	50 Bar	100 Bar
Leak @ Seal OD	5,60	6,00	10,00	0	0	0	0	0	0
Leak @ Seal ID	5,60	8,00	8,00	0	0	0	0	0	0
Leak @ Seal ID + OD	Sum			0	0	0	0	0	0
Special V seal									
Leak @ Seal OD + ID	5,60	10,00	20,00	0	4	10	27	30	32



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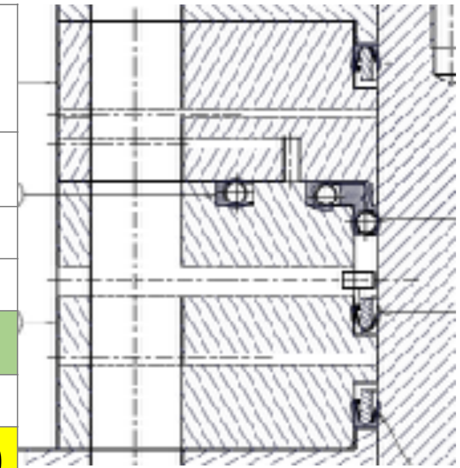
Description	Roomtemp., He , Sniffing E-06 mbar.l/s			Temperature -170°C, Medium GHe ml/min					
Cryo design F10 12	1 Bar	10 Bar	25 Bar	1 Bar	5 Bar	10 Bar	25 Bar	50 Bar	100 Bar
Leak @ Seal OD	5,60	6,00	10,00	0	0	0	0	3	8
Leak @ Seal ID	5,60	8,00	8,00	0	0	0	0	3	16
Leak @ Seal ID + OD	Sum			0	0	0	0	6	24
Special V seal									
Leak @ Seal OD + ID	5,60	10,00	20,00	4	38	50	69	99	390

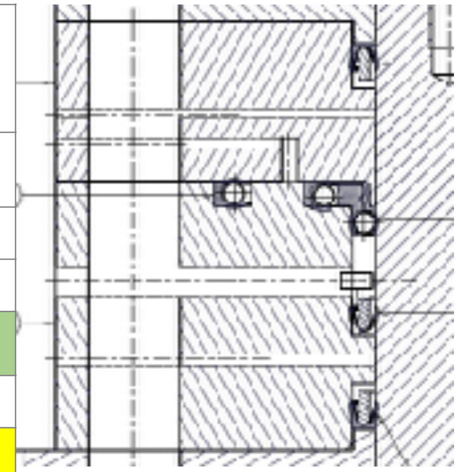


8" test fixture, 227 mm seal ID, surface finish -shaft<0,15 Ra –body = 0,3 Ra .
Max. allowed leak = 300 ml/min.

Novel SPE Seal Design for Cryogenic Ball Valves

Results Cryo test program by 3P Engineering, witnessed by third party, Bureau Veritas

Description	Roomtemp., He , Sniffing E-06 mbar.l/s			Temperature -196°C, Medium Ghe ml/min					
Cryo design F10 12	1 Bar	10 Bar	25 Bar	1 Bar	5 Bar	10 Bar	25 Bar	50 Bar	100 Bar
Leak @ Seal OD	5,60	6,00	10,00	0	0	0	0	3,2	10
Leak @ Seal ID	5,60	8,00	8,00	0	2	3,2	6	9	25
Leak @ Seal ID + OD	Sum			0	2	3.2	6	12,2	35
Special V seal									
Leak @ Seal OD + ID	5,60	10,00	20,00	13	55	57	85	99	400



8" test fixture, 227 mm seal ID, surface finish -shaft<0,15 Ra –body = 0,3 Ra .
Max. allowed leak = 300 ml/min.

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Conclusions

- **This novel SPE design complies with and exceeds current leak specifications**
- The novel SPE seal has potential to “0” leak at normal LNG operation conditions.
- The design requires an additional part for the valve.
    - The extra cost related to this design can be offset by:
        - easier and less costly finishing at the bore location
        - first time success with FAT
        - no surprises at end customer
- Better finish at seal lips and valve surface will yield better seal performance.
- Seal design, careful handling and assembly are key to success.
- A clean and dust free assembly environment would be good.

Novel SPE Seal Design for Cryogenic Ball Valves

What is next?

Optimizing seal geometry & Springload

To target "zero" leakage

Reduce seat drag as far as possible

For maximum seat tightness

Optimize material properties

For extended life

Possible use as a shaft seal

Reduce torque

Novel SPE Seal Design for Cryogenic Ball Valves

Q & A

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