Low and high temperature elastomeric sealing system for valves in harsh environments

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Abstract

- One of the perennial challenges facing valve manufacturers specifying perfluoroelastomer seals is the need to meet both low temperature and high temperature requirements in a single sealing solution.
- Such seals often also need Rapid Gas Decompression (RGD) certifications such as Norsok M710 rev 3 / ISO 23936-2 / Total GS EP PVV 142 and seal over a temperature range of -54°C to +260°C.
- Back up rings are generally required to prevent even high durometer O-rings extruding.
- One novel solution to this problem is explored here; which relies on a perfluoroelastomer with sufficient extrusion resistance at high temperature to allow the removal of back up rings.
- Removal of back up rings is shown to significantly enhance low temperature sealing performance as well as simplifying assembly, reducing part count and reducing cost.
- Testing on a “state of the art” high pressure high temperature test rig at the Kalrez® European Technical Center is part of the work that will be presented in this paper.

Contents

What valve manufacturers would like from seals in harsh environment valves….

- Excellent chemical resistance (ideally broad)
- High temperature capability
- Low temperature capability
- Rapid Gas Decompression (RGD) resistance to Norsok M710 rev 3 / ISO 23936-2 / Total GS EP PVV 142
- For end users – long seal system life
- All these requirements are often driving FFKM selection.
- But valve makers also would like lowest total costs for systems meeting performance requirements
- This paper shows a novel approach to sealing system design which can reduce total sealing system cost by delivering enhanced performance of FFKM-0090.

Experimental section - Testing equipment & specimens

Testing equipment

The equipment is designed to test o-rings at high & low pressures and temperatures in a gas or in a liquid environment. It consists of a specific autoclave allowing the simultaneous testing of two joints, with a central fluid feed and leakage circuits across each O-ring.

The pressure and the temperature capabilities are:

For liquid: up to 3000Bar (43.5Ksi) from -54°C (-65°F) up to 300°C (572°F).

For gas: up to 1000Bar (14.5Ksi) from -54°C (-65°F) up to 300°C (572°F).

Test specimens

Perfluoroelastomer materials: FFKM-0090, FFKM-F40, FFKM-F41

O-ring size AS 568-325 – 37.47 x 5.33 mm (1.475 x 0.210 in.)

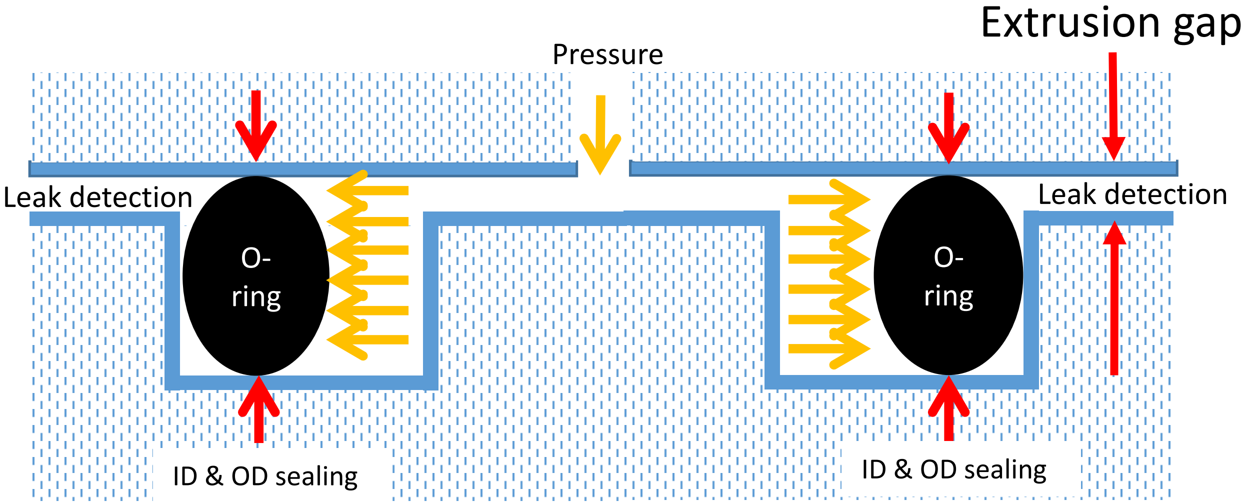
Lubricant: Perfluoropolyether (PFPE)

Source: DuPont

Test in liquid / high temperature

Test conditions:

- Diametrical extrusion gap: 0.1, 0.2, 0.4, 0.6, 0.8 mm.
- Test media: Silicone oil
- Temperatures: 150°C, 204°C, 232°C, 260°C
- Compression: 18%
- Orientation = vertical



The two O-rings are lubricated & mounted on the piston and inserted into the cell, which is then closed.

Set up the desired temperature. These experiments cover 150°C to 260°C (302°F to 500°F) and wait until stabilisation.

After stabilisation (30min), start the ramp in pressure (10 bar/min) until a degradation in seal performance is observed (leak).

Note on repeats: Ideally each test must be repeated three times minimum. Within initial screening, we’re mainly running single data points.

Test in gas / low temperature

Different test methodologies give widely different results. Summarised as:

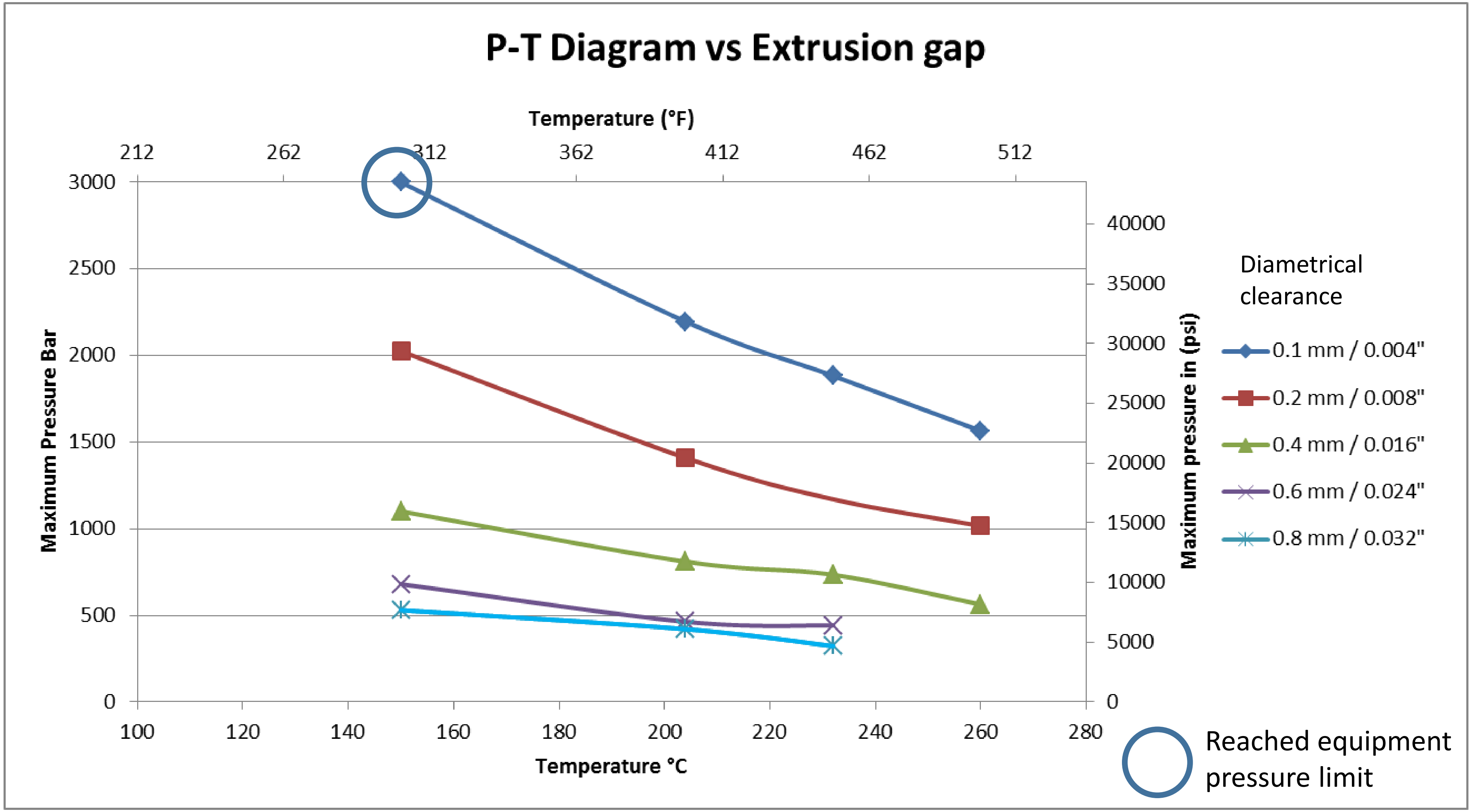
- ❖ Pressurise first – then cool.
- ❖ Cool first - then pressurise.

There is currently no ISO/ASTM standard for low temperature test methodology in elastomers

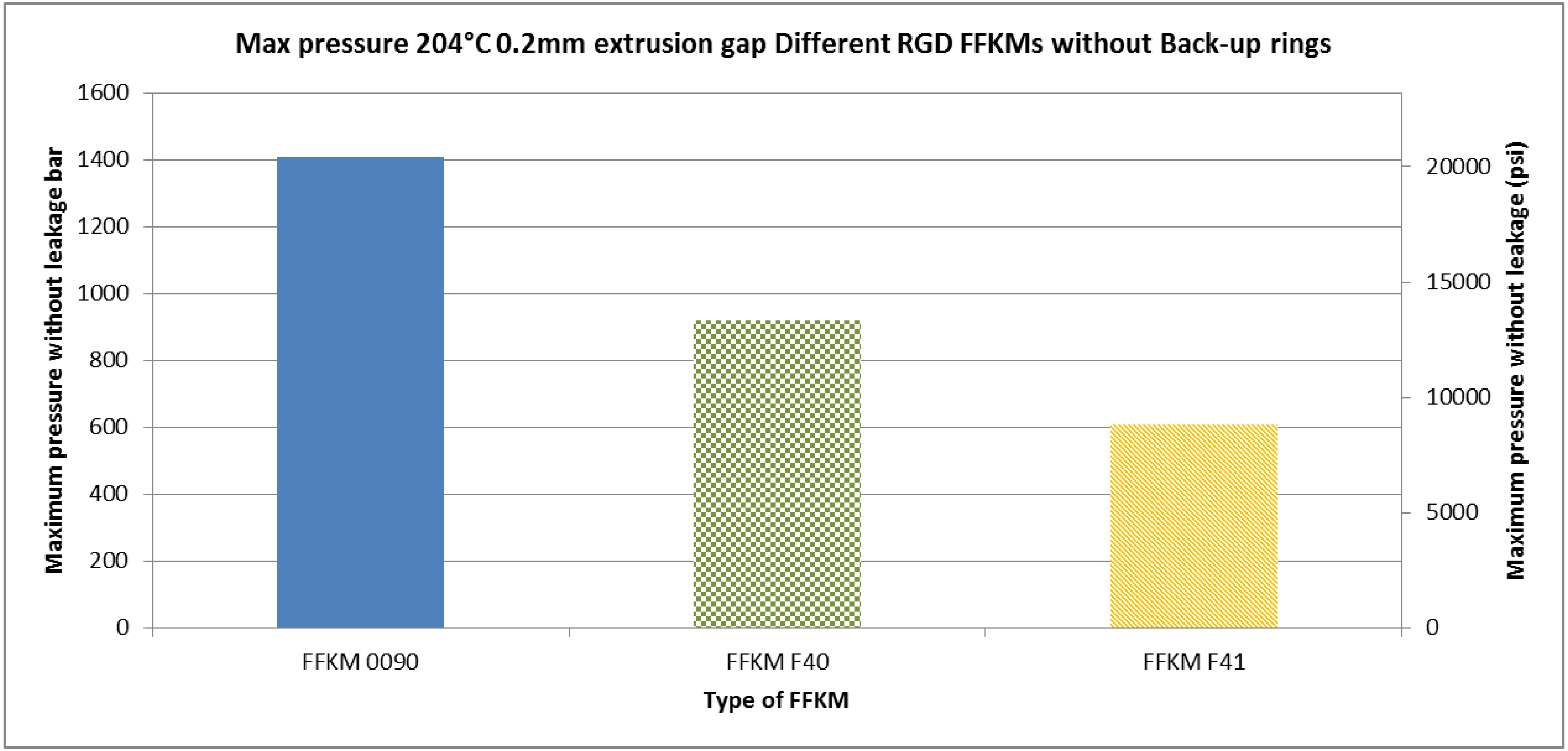
Test conditions:

- Diametrical extrusion gap: 0.2 mm
- Gas: 90% nitrogen; 10% carbon dioxide
- Temperature: from room temperature down to -54°C max
- Compression: 18 %
- Test with and without unfilled poly ether ether ketone (PEEK) back up ring
- Test at 7 bar, 150 bar and 1,000 bar pressure. (~ 0.1 Ksi, 2 Ksi, 15Ksi)
- Full details of various methods are provided within the written paper.

Results: Pressure-Temperature diagram
(vs Extrusion gap FFKM 0090, AS568-325 size)



Results: Alternative major RGD FFKM elastomers

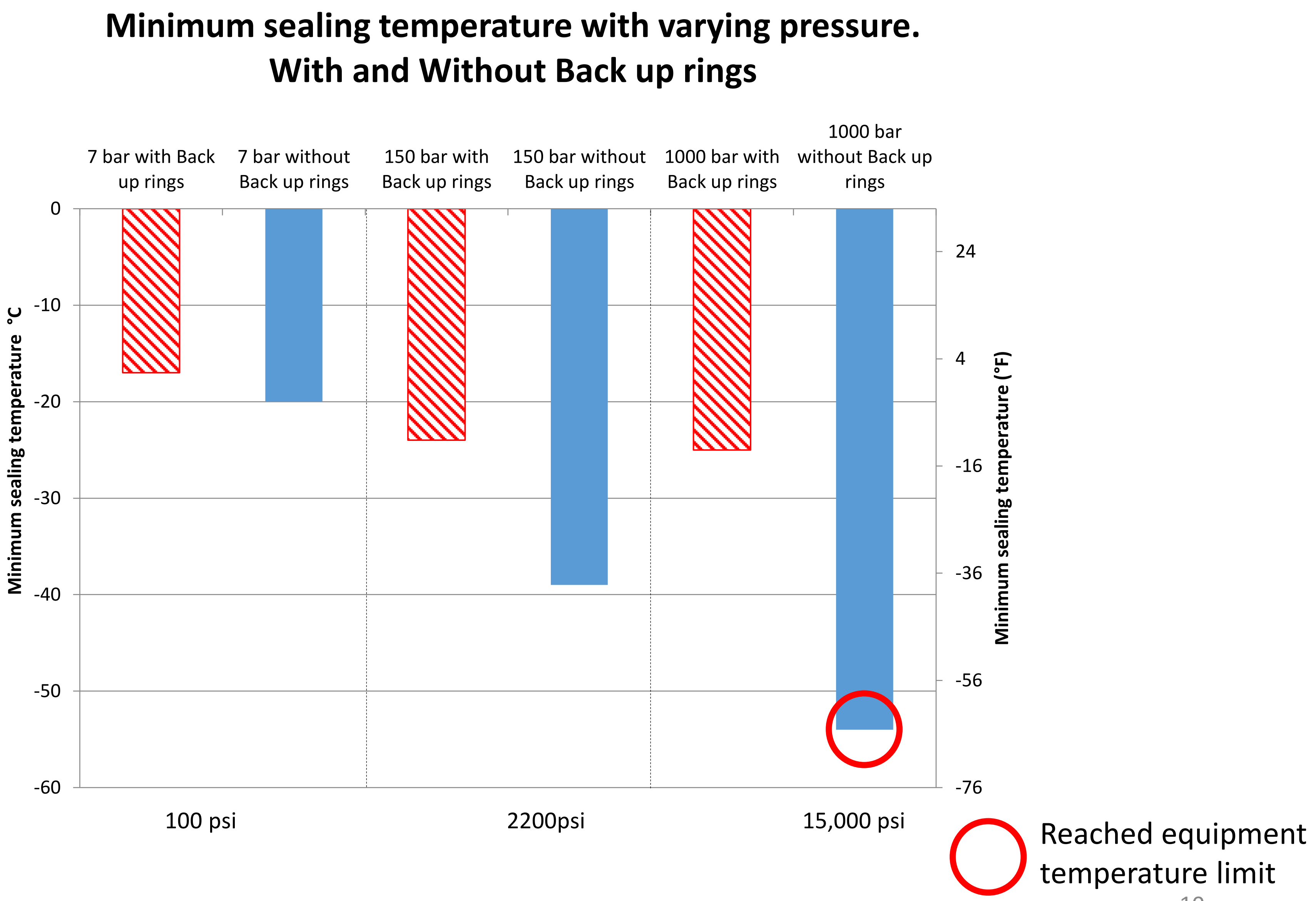


FFKM-0090 exhibits approximately 53% improvement in extrusion resistance vs alternative FFKM

Low temperature test results FFKM 0090

Gas mixture (90% N2/10%CO2)

Low temperature performance of FFKM-0090 is improved when removing back-up rings



Results – Mixed gas at low temperature

Test method	Material	General approach	Test Pressure (bar)	T Leakage °C	Back up rings	Notes
E	FFKM 0090	Pressure first	7	-20°C	No	
E	FFKM 0090	Pressure first	7	-17°C	Yes	
E	FFKM 0090	Pressure first	150	-39°C	No	
E	FFKM 0090	Pressure first	150	-24°C	Yes	
E	FFKM 0090	Pressure first	1000	< -54°C	No	
E	FFKM 0090	Pressure first	1000	-25°C	Yes	
F	FFKM 0090	Cool first	7	-	No	
F	FFKM 0090	Cool first	100	-25°C	No	Matoux: MERL Oilfield Engineering 2012
F	FFKM 0090	Cool first	1000	-	No	
E	FFKM F41	Pressure first	7	-	No	
E	FFKM F41	Pressure first	7	-15°C	Yes	
E	FFKM F41	Pressure first	150	-	No	
E	FFKM F41	Pressure first	150	-15°C	Yes	
E	FFKM F41	Pressure first	1000	-	No	
E	FFKM F41	Pressure first	1000	-35°C	Yes	

Conclusion

Preliminary testing performed in this study, on the "state of the art" high pressure high temperature test rig at DuPont European Technical Center, allows us to conclude that:

- Different test methods of determining low temperature performance lead to a wide spread of results.
- FFKM-0090 shows excellent extrusion resistance without backup rings at high temperature
- Low temperature performance of FFKM-0090 is improved when removing back-up rings.
- FFKM-0090 without back-up rings can be a suitable solution to meet both low and high temperature requirements of valve manufacturers specifying perfluoroelastomer seals.

Removal of back up rings has the additional benefit of simplifying assembly, reducing part count, total sealing system cost and groove length requirements.

Next Steps

- Complete high temperature testing matrix at different gaps and temperatures.
- Complete low temperature testing matrix and different methodologies. (e.g. cool first).

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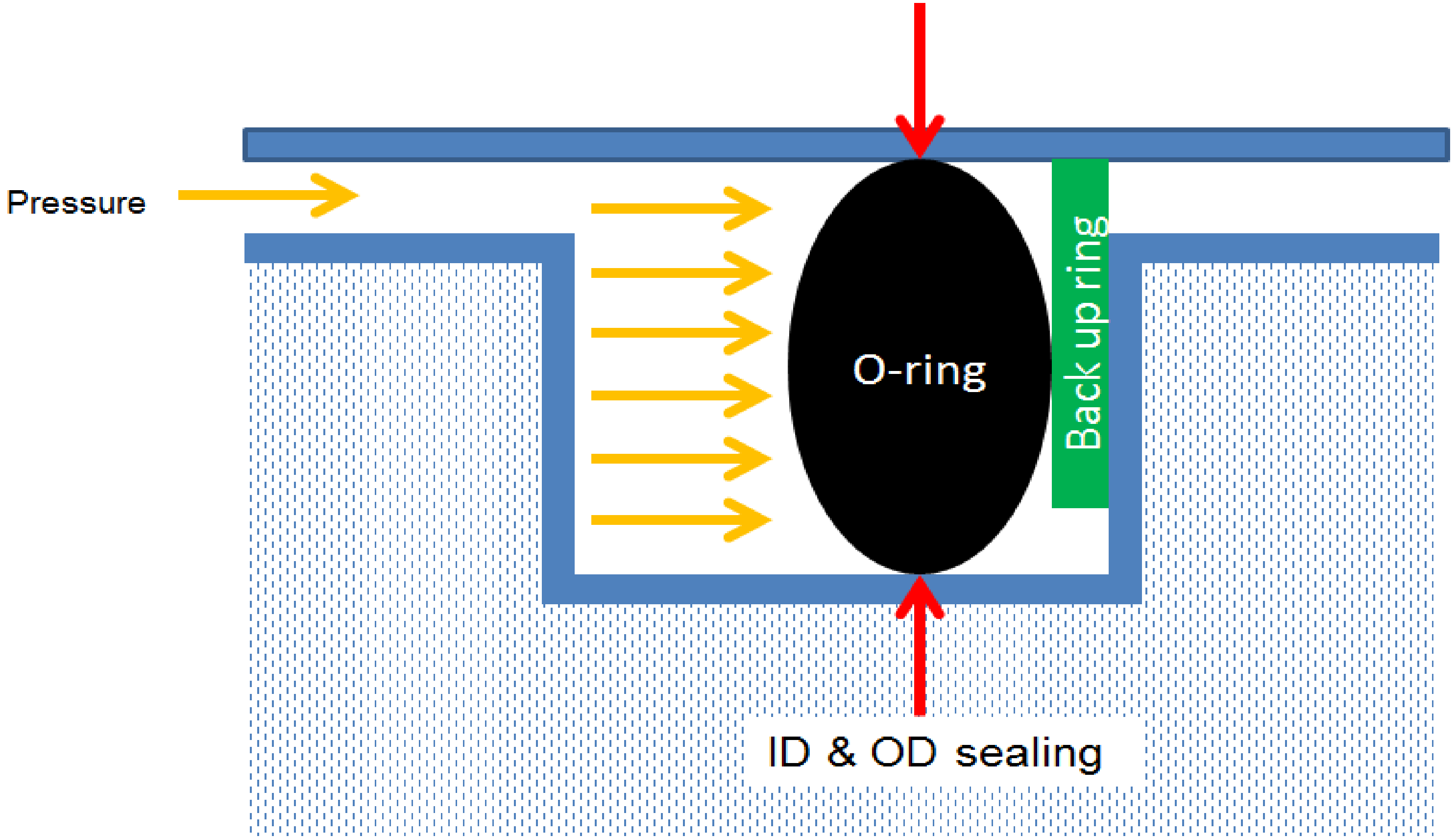
Back-up slides

First understand why seals do not perform at low temperature

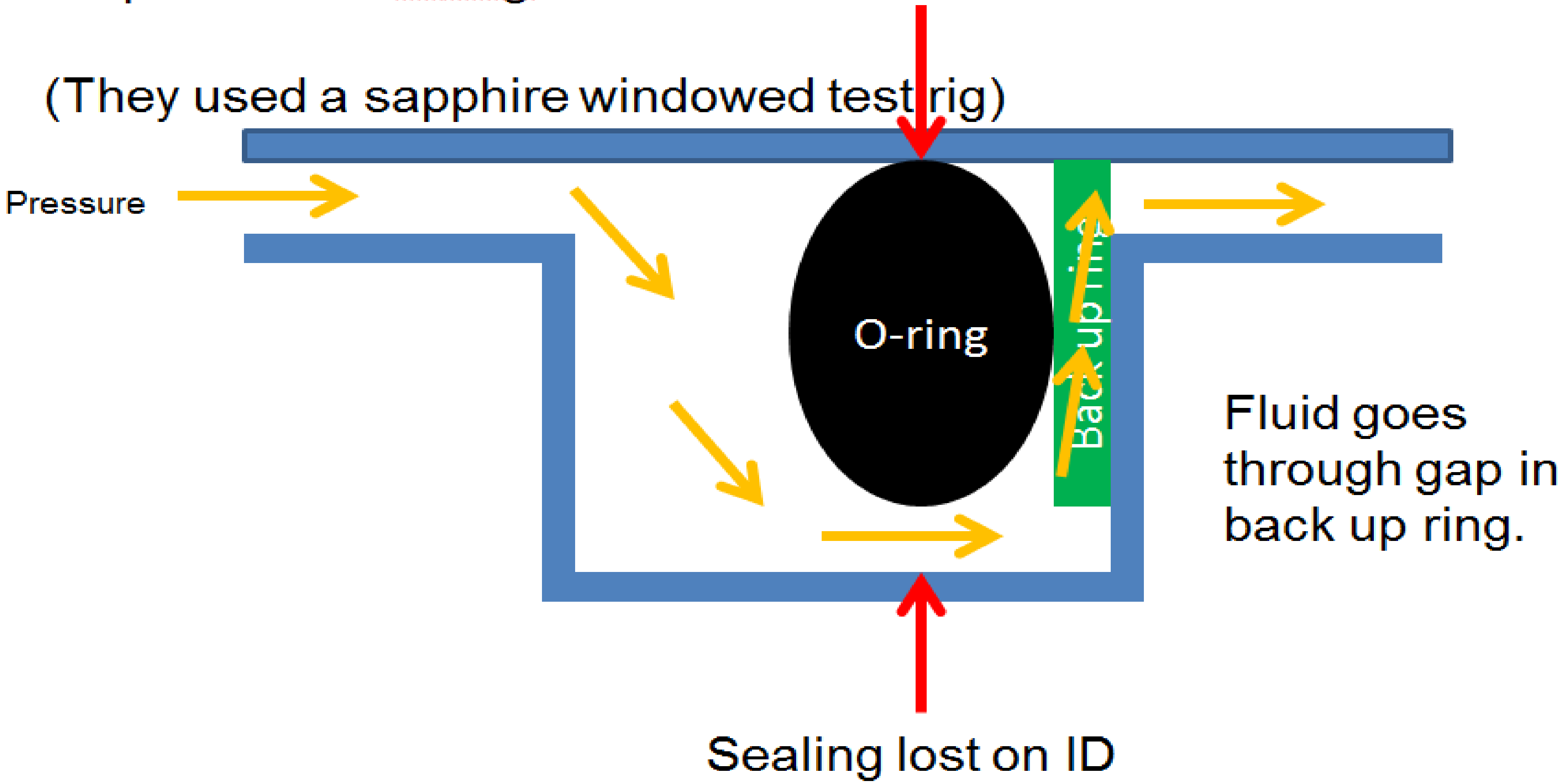
Cooling first, initially seal performs well



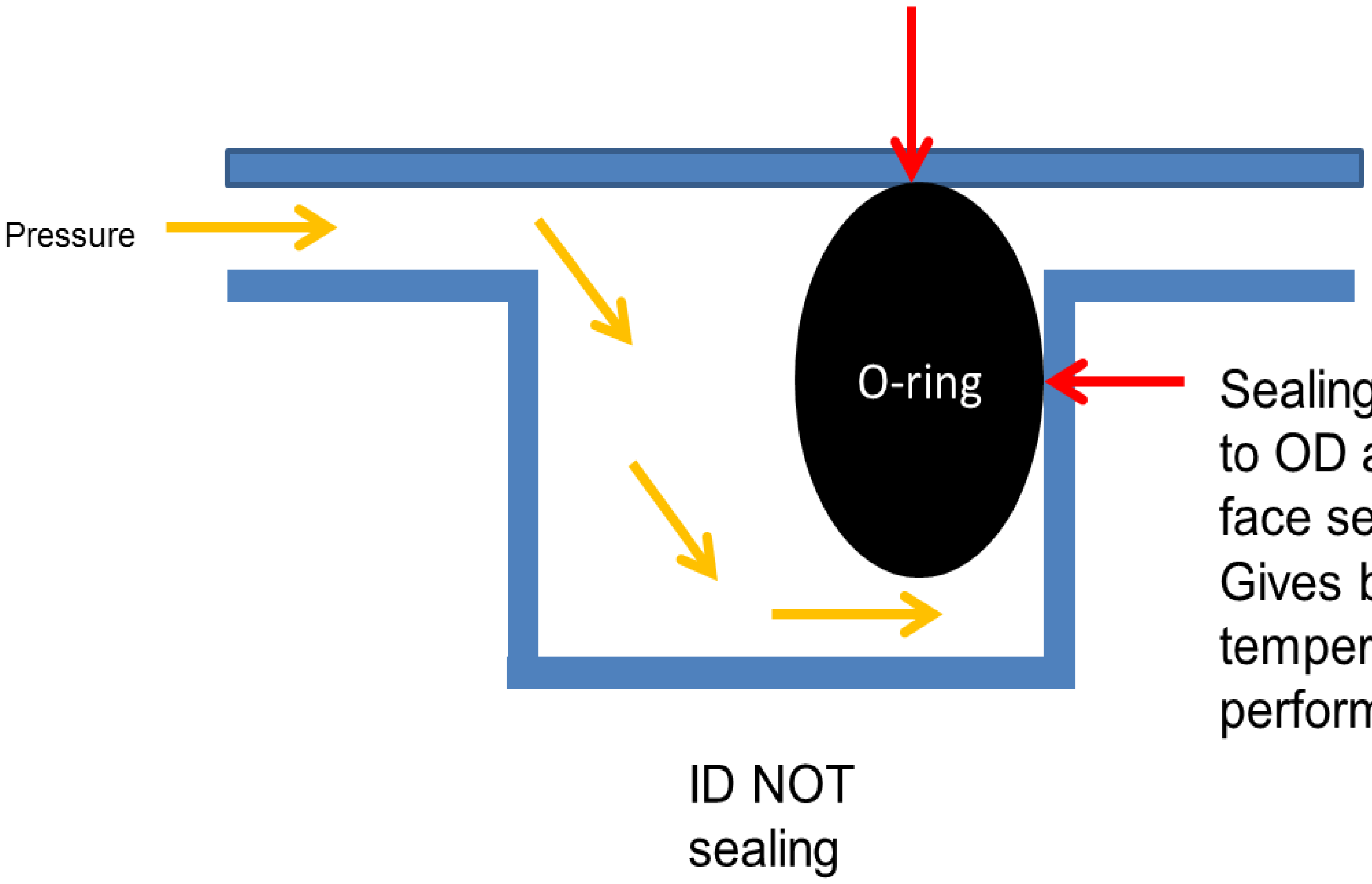
Note Elastomer reduces size w.r.t. temperature much faster than metal

When cooled under moderate pressure, seal breaks contact NOT on the OD as one would expect – but on the ID – as the pressure pushes the o-ring to the outside.

(They used a sapphire windowed test rig)



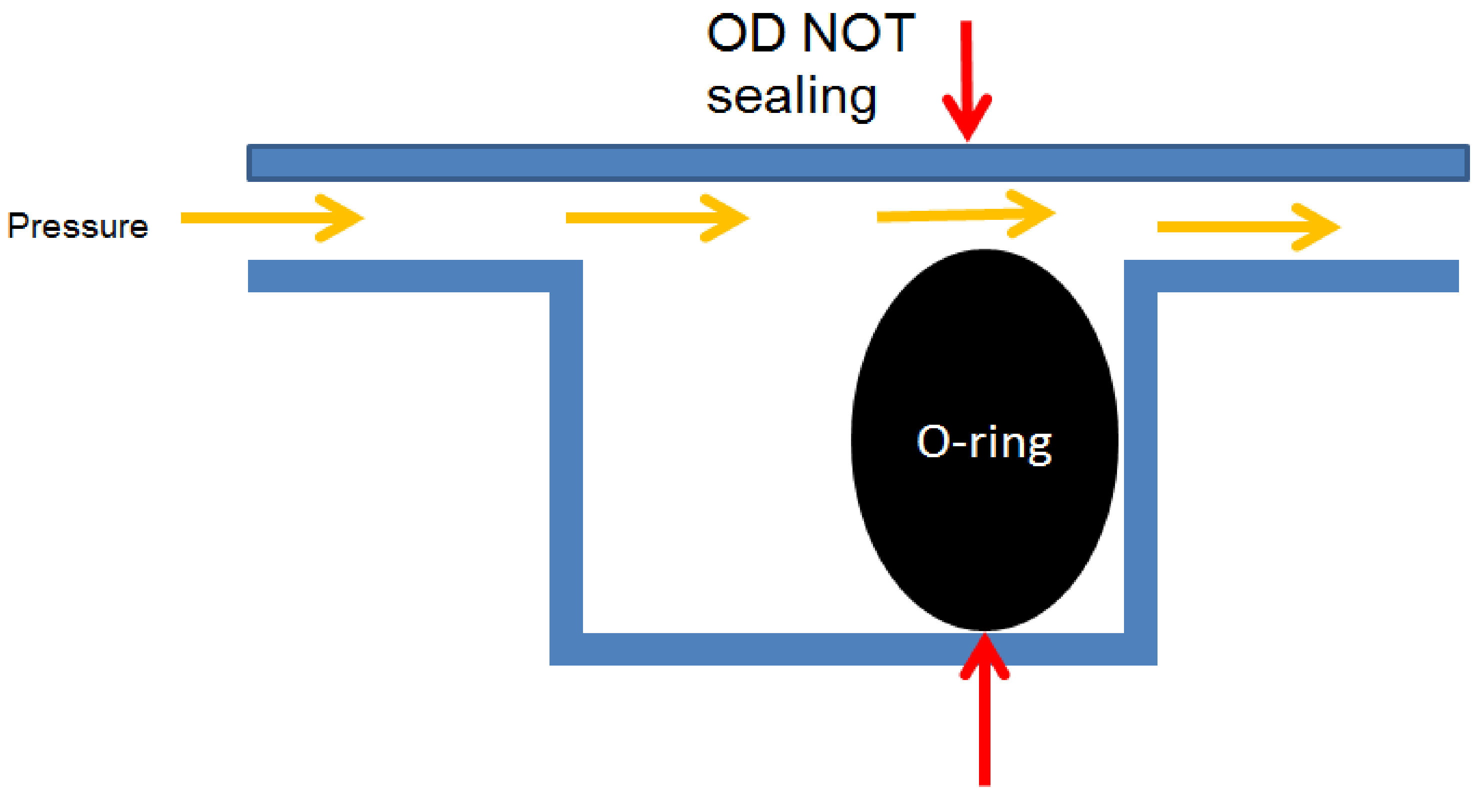
So, why would removal of the back up ring help ?



Sealing switches to OD and back face sealing. Gives better low temperature performance.

Eventually – the system still looses sealing.
Around -25°C at 150bar pressure

There is enough thermal contraction to pull the o-ring from the OD despite the pressure.



Low temperature sealing for Kalrez® 0090

Low pressure (Lab 1)

Test protocol*

- Sample size = AS568-214 o-ring
- Pressurizing test rig with air at 0.4 MPa (60 psi)
- Cycle rig down to -50°C(-58°F) at 0.5°C(33°F)/min
- Record temperature at 3 ccm leakage

- **Kalrez® 0090 = -21°C**

* DuPont proprietary test method

Low temperature sealing for Kalrez® 0090

High pressure (Lab 2)

Test protocol*

- Sample size = AS568-312
- 3 lubricated seals pressurised with 10MPa (1450 PSI) nitrogen at 23°C (73°F)
- Test fixture cooled until leakage recorded by mass flow sensors
- >0.01ccm considered a leak

- **Kalrez® 0090 = -40°C**

* James Walker & Co proprietary test method

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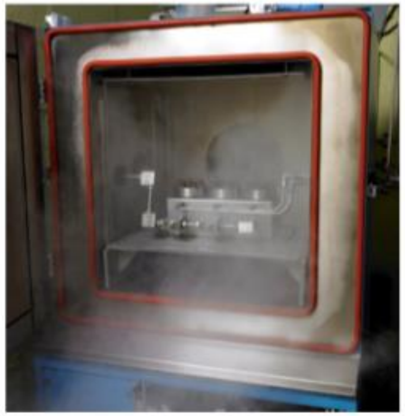
Low temperature sealing for Kalrez® 0090

Low pressure (Lab 2)

Test protocol*

- Sample Size = AS568-312
- 3 lubricated seals cooled to -25°C (-13°F), then pressurized with 10 MPa (1450 PSI) nitrogen
- Leakage recorded by mass flow sensors

- **At -25°C Kalrez® 0090 sealed satisfactorily**



* James Walker & Co proprietary test method

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Description of low temperature test method

Method C

Put in place the two lubricated O-rings on the piston and plug it in the cell.

Close the cell. This operation must be done at room temperature.

Pressurize at 7 or 150 bars, depending on testing pressure we're interested in, and then decrease slowly the temperature till leakage (bubble(s) observed).

Record the ramp rate and the temperature at which the leak is detected.

Go back to room temperature, stop and stabilize.

New samples used for each pressure cycle.

Method E

Similar to Method C, although using the same set of samples to pressurize first at 7 bar , lowering the temperature till leakage, back to room temperature, stabilize, and then up to 150 bar and down in temperature till leakage, back to room temperature, stabilize, and then up to 1000 bar and down in temperature till leakage, with the same set of samples.