Various Questions on Swelling Seal application and use Ref: RP/2014 Engineering. Feb -002

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A High level Look at the effects of well conditions and operational factors of the performance of 2 nd Generations elastomers and Products developed and supplied in OBLIQUE swelling seal systems. Author R.W.Hibberd - Ruma Products BV Holland 2014

The Effects of well mechanics and operations on the performance of our Q-Spectrum Elastomers

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Pre-Amble

Customers and potential customers often have questions and concerns regarding the use of and the way elastomers and seals work or have been designed and developed. What factor is important for them and what is less important. To answer a few of these points the following document has been created.

Acid and H2S resistance

Acid Resistance

Acid resistance of the base elastomer is not an issue, the base elastomer if correctly developed does not react with acids. The problems experienced by Aramco in the past were the result of using elastomers that swell due to the swell medium being used being SAP (Super Absorbent Polymer). Because the suppliers of most of the frac packers do not create their own elastomers, or even manufacture their own products they do not have the technical background to know effects of fluids on the elastomers so were not aware of the fact that SAP breaks down in a pH environment lower than about pH 4 or that it decays at temperatures above 90-100 C. Ruma as the designer of the compound tests its compounds in the lab to ensure Acid is not a problem. Our compounds which contain other ingredients show differing results on Acid testing, some have an increased swell rate, other slow down or will crimp slightly depending upon how much they were swollen at the time of acid being pumped. However once the acid has passed they will revert to their previous state and show no permanent damage. SAP once affected is effectively destroyed and will never recover. For further details we refer to the acid test as described in Appendix I.

H2S resistance

H2S affects the elastomers in two ways, as it is often dissolved in the production water (potentially with CO2) the water is acidic so the effects above can be seen on SAP related elastomers. The second way it affects the elastomer is that H2S reacts with elastomers that have been vulcanised with Sulphur, our Q-Spectrum coloured elastomers do not and have not been vulcanised with Sulphur. They are a second generation elastomer and utilise a more advanced and own alternate technology.

In none of the above in normal use is either acids or H2S a problem.

To answer the points raised here starting with the last one first.

Cool Down

To understand the effect of cool down in a system you first have to understand the effect of warming up on the system. In a system with tubular and swelling seals the first thing that happens is that the tubular diameter increases and the length increases, the elastomer undergoes a similar effect. Hydrostatic pressure also has an effect on both components. At temperature the seal swells and then seals the hole, locking the length change of the tubular into the system. Any cooling on the system will have the greatest effect on the shortening of the tubular versus the warm situation

We model the effects of temperature and Hydrostatic on the seal assembly as a part of our geothermal work, see attachment. The effects on the OD is minimal even when not taking the effect of diameter increase caused by Tubing ballooning into account on the seal. However the greatest effect is that of tubing shortening due to cooling. This shortening has an effect on the loading of the swelling seal which manifests itself in an increased loading on the BONDING between the elastomer and the pipe. As a manufacturer of industrial rollers (up to 3 meter diameter and 8 meter lengths) where sheet metals are being transported at elevated temperatures as well as high speed bonding is the most crucial part of this process. The bonding process developed for swelling seal has been created to reflect this high demand and crucial system. It is specific for the elastomer type and sort as well as the metallurgy of the base pipe. 13Cr has another bonding requirement to 4140. Water swell is different to Oil swelling and high temperature bonding is different to low temperature. Failure to develop a good bonding will result in the elastomer releasing under load. As in welding the bonding is stronger than the elastomer. As in the above statement for Acid and H2S few of the suppliers are even aware of what bonding is and how it works, the result is extremely poor quality bonding and a nonchalant view on its significance.

Equipment Pressure Rating

Pressure rating of Swell seals is problematic to define. In a mechanical packer the rating is determined by the myriad of individual component that constitute the body of the seal as well as the sealing element. It is worth noting that the sealing element is commonly 8-12 inches long even in very high pressure ratings.

For swelling seals the pressure rating is determined by the OCTG rating being used. The seal itself has a different rating and this is heavily dependent upon two factors, how central the seal is in the hole and how little the washout in the hole is along with the mechanics of the rock. In a holes with a casing the latter is not important. However what is important is how the system is being tested and exactly what the procedure for this is as well as the fluid being used. For water swelling seals two different things need to be understood and applied in the testing. The seal swells by a diffusion gradient being created between the inside of the elastomer and the fluid outside of the elastomer. In a water swelling elastomer temperature and salinity determine the rate and absolute swell of the elastomer. Absolute swell is the amount of swell that occurs against time for that situation. Irrespective of how thick the elastomer is it will never swell more than this amount in a certain time.

Example: A 10 mm thick sample swells 5mm in X days. If it were 20 mm thick it would still only swell this same 5 mm. So it is vital not to talk about % swell in an application in this example in the first the swell is 50% and in the second it is only 25%. But the swell is still the same amount.

In the swelling sweet water is being extracted from the system and enters the elastomer causing it to swell. If distilled water were to be used the diffusion gradient would be at its maximum for that water and elastomer combination. As the salinity of the brine is increased the diffusion gradient actually decreases and swell rate and absolute swell decrease too. Secondary to this as the temperature increases so does the diffusion gradient. So in a sweet water application an elastomer would swell slower at 20 Celsius that the same water and elastomer combination at 100 Celsius.

This all has to be born in mind when testing a swelling seal. If it is being tested with a brine, the salinity of the brine will change as the sweet-water is being extracted from the brine and pulled into the elastomer. This has to be taken into account with pressure tests, otherwise the risk is being taken that the elastomer has NOT swollen as much as it was believed to have with the obvious effect on the results.

A service company customer conducted full scale qualification tests with our Q-Seal Fitted with our second generation Q-Spectrum Elastomer with a 6ft 5,625inch OD seal on a 4,5 inch tubing in a 6 inch casing which was pressure tested to +/- 7,000 psi with a 1% pressure drop in 1 hour measured over the seal. The test system was the limiting factor on the pressure rating. Increasing the length is often used to increase the pressure rating of the seals so pressure ratings in excess of 10,000 psi are not seen as a technical problem for a Fracture seal.

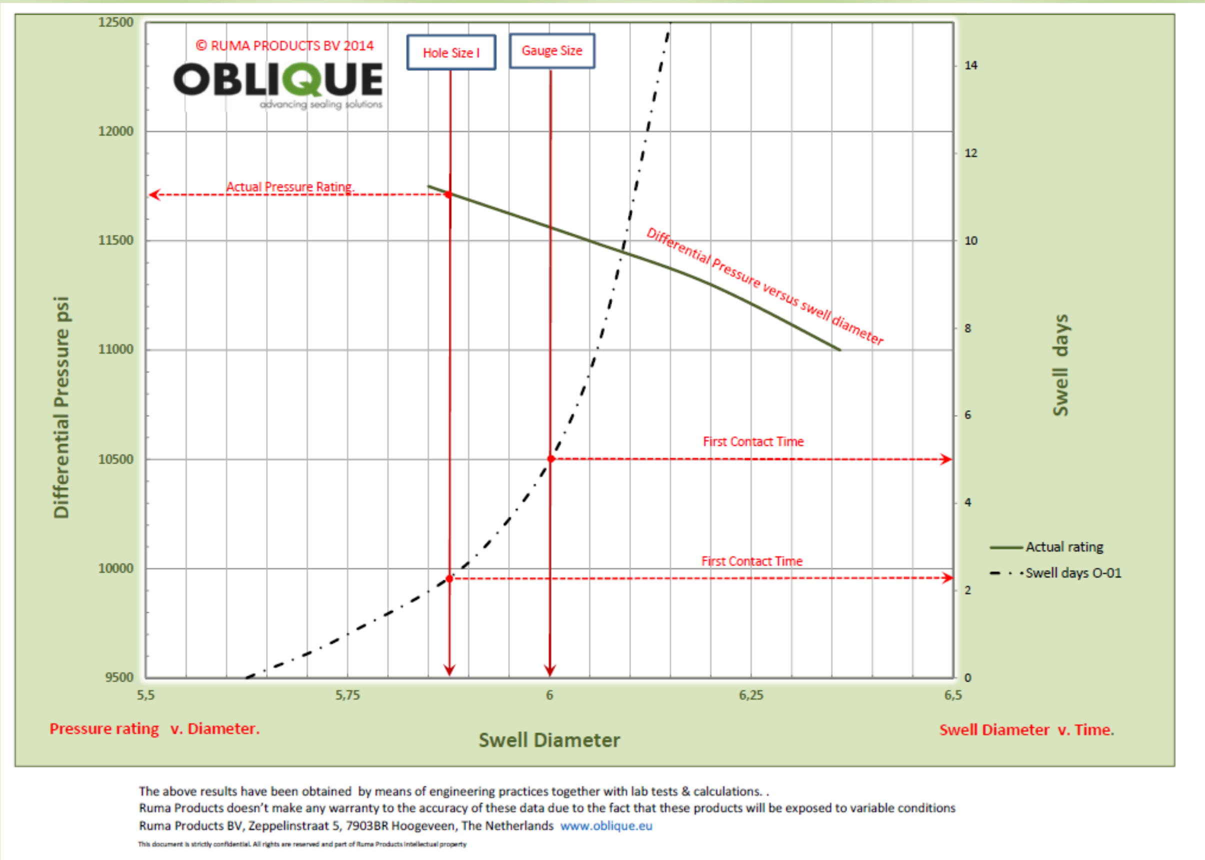

Fig. Performance curves

Effects of Temperature on Bonded seal systems

	Temperature	130	C
Thermal Expansion Coefficient Rubber	0,00023	/C	
Thermal Expansion Coefficient Steel	0,000014	/C	
Compressability	0,0000068	lb/ft2	

Rubber Thickness	14	mm	Swell % Nom	34%
Rubber Type	water		Swell % W-	21%
Depth	1200	m	Swell % W+	45%
Fluid SG	1,06		OD Seal	5,603

Casing Size	7	inch	177,800	mm
Casing weight	35	lbs/ft		
Tubing Size	4,5	inch	114,300	mm
Tubing Weight	11,8	lbs/ft		

Casing	Nom		Min		Max	
Outer Diameter	7,000	inch	6,965	inch	7,070	inch
Nominal Wall Thickness	0,4980	inch	0,481	inch	0,533	inch
casing ID	6,004	inch	5,892	inch	6,123	inch
Mid 20C	6,502	inch	6,429	inch	6,596	inch
Mid Elevated	6,512	inch	6,439	inch	6,606	inch
wall Thickness	0,4988	inch	0,481	inch	0,534	inch
130 C casing ID	6,013	inch	5,957	inch	6,073	inch

Tubing	Nom		Min		Max	
Outer Diameter	4,500	inch	4,478	inch	4,545	inch
Nominal Wall Thickness	0,250	inch	0,239	inch	0,273	inch
Tubing ID	4,000	inch	3,940	inch	4,069	inch
Mid 20 C	4,250	inch	4,209	inch	4,307	inch
Mid elevated	4,257	inch	4,215	inch	4,314	inch
Wall Thickness	0,250	inch	0,239	inch	0,273	inch
130 C Outer Diameter	4,507	inch	4,454	inch	4,587	inch

Clearance								
20 C	0,752	Inch	0,707	Inch		0,789	Inch	
Clearance with Rubber	0,187	Inch	0,143	Inch		0,224	Inch	
130 C	0,753	Inch	0,752	Inch		0,743	Inch	
Clearance with Rubber	0,189	Inch	0,187	Inch		0,178	Inch	
	Nom		Min (-)		0,5%	Max (+)		1,0%
Rubber	14,000	mm	13,930	mm		14,140	mm	
Elevated temp	14,354	mm	14,282	mm		14,498	mm	
After compression	14,341	mm	14,270	mm		14,485	mm	

		Casing	Tubing	Rubber	Clearance	
+	Worst case	6,073	4,454	14,270	12,569	mm
-	Worst case	5,957	4,587	14,485	5,847	mm
	Nominal	6,013	4,507	14,341	9,578	mm

Rubber Thickness 14 mm
OD Seal 5,603 inch
Rubber Type water
Temperature 130 C

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RUMA Customer:
Test
Well Number: Proposal

Date: 20 January 2014
RUMA Products, HOOGEVEEN
Calculation Update Nr 0

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RUMA SWELLING RUBBER
APPLICATION CALCULATOR
Version 1a
October 2009
Swelling Geothermal Applications
RUMA Products, HOOGEVEEN

3.0 Authorisation

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Appendix I TEST REPORT ACID ON ELASTOMERS (X1 AND X2)

Below graph and table show the effect on elastomers X1 and X2 after the test fluid is changed from salt to acid (CHOOH).

Compound X1

This one shows huge swell in 0.5% NaCl to over 1000% and after change to acid the elastomer collapses completely.

Compound X2

This one swells about 150% in 20% salt at 80°C and after changing to acid shows an increase in swell to over 800% with a decrease to 750% in time.

To go from 800% to 750% the elastomer takes approx. 100 days

Note: The acid has not been replaced/refreshed during the test period.

Time 1 (days)	X1 in 0,5%NaCl	X2 in 20% NaCl	X1 in 20% CHOOH	X2 in 20% CHOOH
0,0	0	0		
1,0	212,5	51,65		
3,0	651,5	100,7		
7,0	1013	154,8	1013	154,8
14,0			442,5	829,4
21,0			404,2	883,3
28,0			364,2	859,4
35,0			360	823,2
42,0			316,5	797,8
49,0			288,9	793,2
63,0			228,3	777,2
95,0			166,3	772,1
121,0			143,1	755,3
149,0			124,0	756,8