SAMPO Workshop 27 - 28.11.2019

Environmental Qualification of Isolation Valves on Ringhals 3 and 4

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VATTENFALL

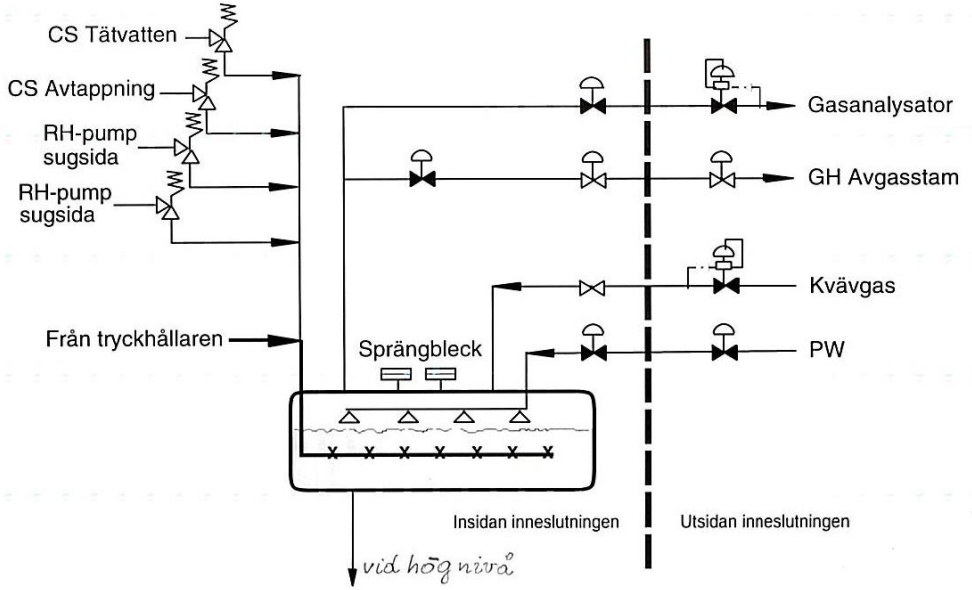
Repetition

- Last year I had a presentation about environmental qualification of a number of scale valves containing EPT and natural rubber membrane (diaphragm)
- These valves should retain their tightness function during the planned operating time and 6 months after a postulated accident scenario (not include core melting scenario). Operation time was historically 12 years for these valves
- This presentation gives a brief short repetition from last year and present results of the tests made during the environmental qualification

Repetition

- *Each line that is connected to a closed system inside the containment is provided with at least one containment isolation valve located outside the containment. For lines normally in operation, it is an automatic valve or is capable of remote manual operation. For lines normally not in operation, it is a locked closed valv.*

- On Ringhals is two valves on each line, one inside of containment and one outside of containment



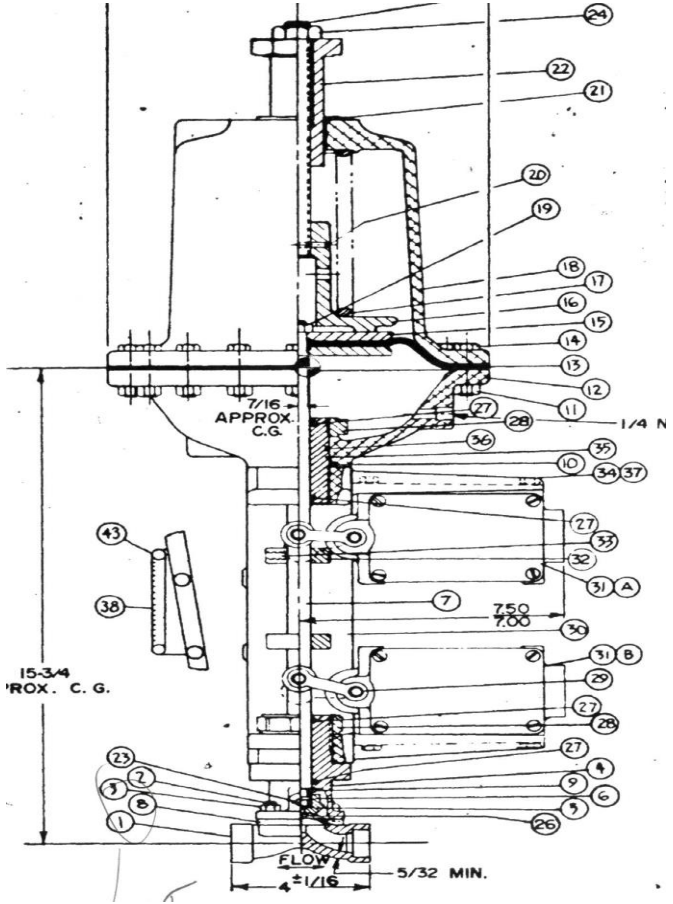
Figur 1.8 Avblåsningstanken med anslutningar

The valves covered with this environmental qualification

• Internal pneumatic isolation valves				Nr. Maneuver
- 313 V8093A Grinnell (blow of PRZ)	3/4”	9,5 mm	gas	40/year
- 342 V7105 Grinnell RCDT	3/8”	9,5 mm	gas	20/year
- 342 V7109 Grinnell RCDT	3/4”	9,5 mm	gas	10/year
- 342 LCV 1003 Grinnell RCDT	3”	41,0 mm	water	50/ year
- 345 V2254 Siers (pneumatic/ manual) floor drainage	3”	32,0 mm	water	25/year
• Internal hand operated isolation valves				
- 735 V4104 Siers manual reactor pool to RWST	4”		gas	10/year
- 735 V4109 Siers manual RWST to reactor pool	2”		gas	10/year

Grinell valv

Pneumatic valve
Closes with spring force when the air is released.
membrane "E.P.T" = EPDM



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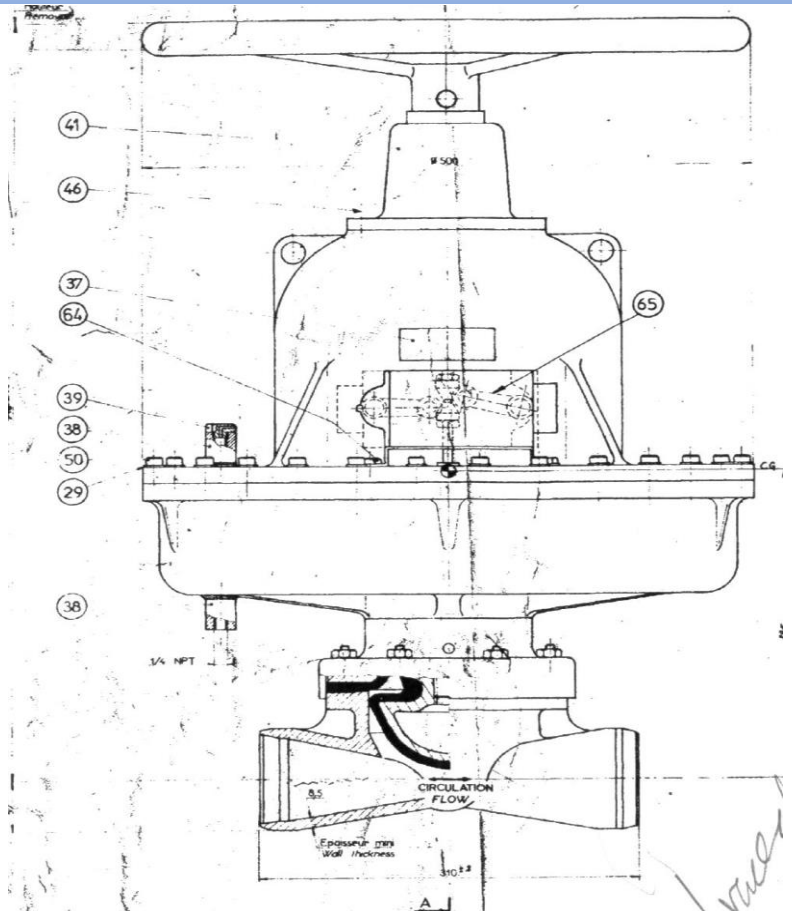
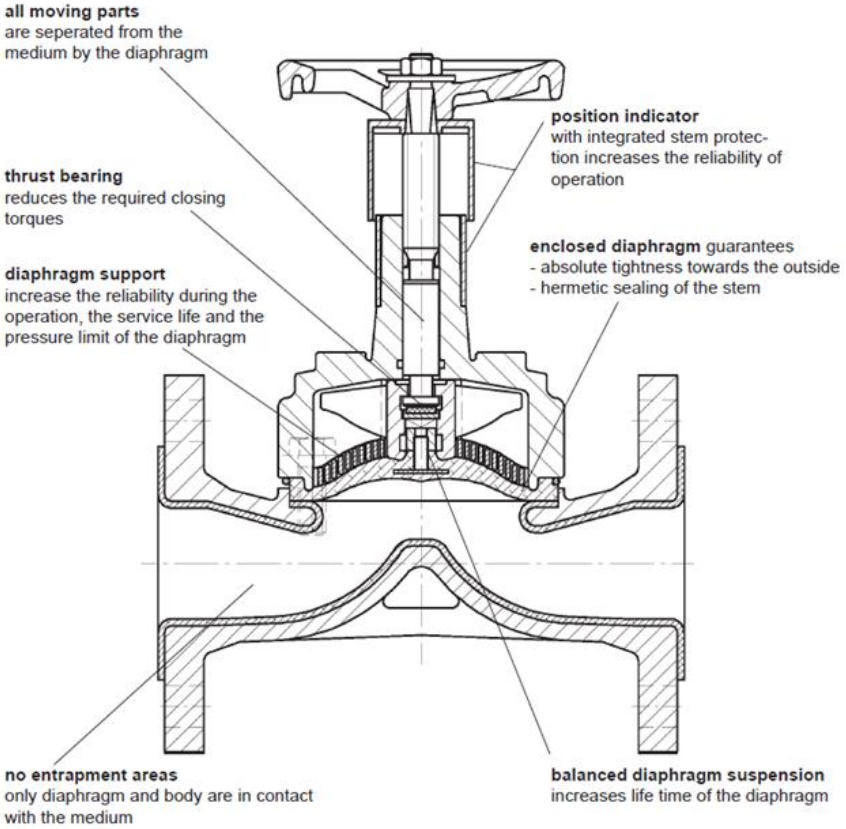
Siers valv

Diaphragm in natural ruber (NR)



KSB-Sisto valv



We decided to test one more diaphragm from KSB-Sisto valve for use in the future and to have a replacement valve if some of them we use today can't be environmental qualified.

Diaphragm is in EPDM

Grinell –diaphragm reinforced with PA6

Konkav side

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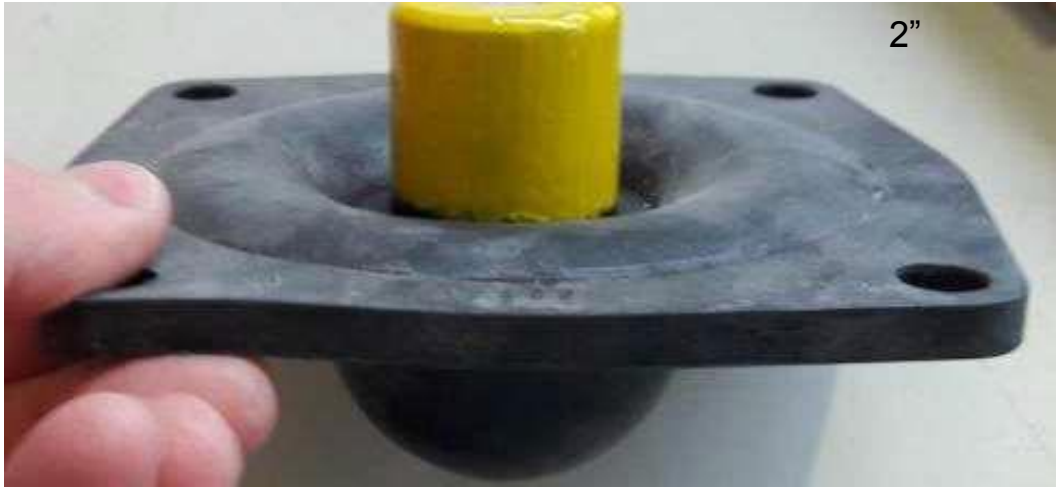
Siers –diphragm natural rubber without reinforcement



Diphragm from valve 40741V4170
after 20 years in use.

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KSB-Sisto diaphragm DN50 EPDM without reinforcement

Seal area

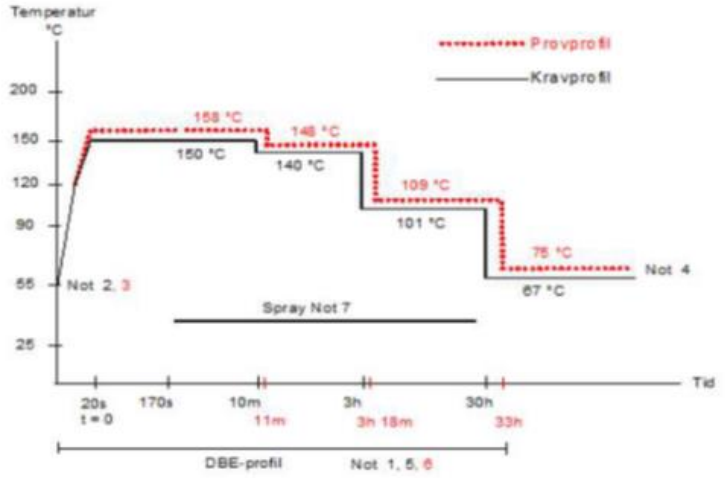
Acceptance criteria

We did not have the opportunity to age complete valves, expose them to a failure scenario and then test if they hold tight. Therefore, it was decided to age only diaphragms and examine them for the following acceptance criteria:

- Tensile strength / extension before break should not be significantly less than 50% of values for not aged diaphragm
- The increase of the indenter module should not be greater than 50% after the planned operating time according to the maintenance interval compared to new un-aged membranes
- The increase of the indenter module should not significantly exceed 100% after aging corresponding to the planned operating time followed by long-term failure scenario (6 months)
- No cracking should occur after the aging process and the rubber should still feel enough soft and elastic.
- Based on these acceptance criteria an assessment is made if the valves can be expected to hold tight during long-term failure scenario

Beteckning / Document	Utgåva / Issue	Datum
KBE EP-154	4 (S)	2017

PWR, haverimiljö i reaktorinneslutningen



Not

1 Angivna värden för temperatur och tryck ska uppnås eller överskridas. 100 % RH gäller för hela krav- respektive provprofilen. Stig- och falltider ska vara kortast möjliga.

2 Stigtider: max 20 s till 150°C. Tiden t = 0 startar vid 150°C.

3 Stigtider: max 20 s till 158°C. Tiden t = 0 startar vid 158°C.

4 Post DBE-provtid enligt Teknisk Specifikation.

5 Trycket 0,455 MPa abs ska hållas i minst 3h.

6 Trycket 0,5 MPa abs ska hållas i minst 3h 18m

7 Spray startar vid t=0 + 170s och slutar vid 30h

For the aging, three different environmental profiles were discussed:

1. According to SAR (the temperature in containment during normal operation does not exceed 40 ° C, relative humidity is 10%, ionizing radiation 2 mGy / h and pressure 1.1 - 1.2 bar (a). Under the accident scenario, the following conditions apply:
   - 140 ° C, 0 - 30 min
   - 130 ° C, 30 minutes - 3 hours
   - 100 ° C, 3 hours - 10 hours
   - 80 ° C, 10 hours - 22 hours
   - 67 ° C, 22 hours - 400 hours (16 days)
   - 40 ° C, 400 hours - 720 hours (30 days)
   - 36 ° C, 30 days - 6 months
   - Gamma radiation absorbed dose in air, incl. spray, 6 months 240 KGy

2. The temperature in containment during normal operation does not exceed 55 ° C; pressure, humidity and ionizing radiation are the same as in the first approach.
   - 150 ° C, 0-10 minutes
   - 140 ° C, 10 minutes - 3 hours
   - 101 ° C, 3 hours - 30 hours
   - 67 ° C, 30 hours - 30 days
   - 36 ° C after 30 days (given 27 ° C in the sea) - 6 months
   - Gamma radiation absorbed dose in air, incl. spray, 6 months: 264 KGy

3. Third approach: temperature and exposure time under failure scenario follows the conservative profile (dashed line) in KBE-EP 154 and applies to KSB-Sisto and Grinell. The requirements according to KBE-EP 154 (edition 4 (S)) are normally governing when procuring new components.

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Thermal and radiation aging

Diaphragm	Aging profile	Simulated environment		Behandl. Miljö Arhenius		Heat aging at **115°C**		Heat aging		Failure aiging*	Heat aging		Longer aging	
		Year	Temp.	Hours	Temp	From - to	Hours	from - to	Time Hours		From- to	Time hours	Time hours	Corresponding to operating time
Grinell 264kGy Sisto 264KGy	EP154 12 år	12	55	**1326**	115	5okt 12:20 – 29 nov 15:50	**1323**	14feb 13:10 25feb 08:22 at **90°C**	**258**	150°C 10 min 140°C 2h50min 101°C 27 h	26feb 16:44 27feb 13:04 at **90°C**	**20h 50min**	98 h at 90°C	**At 55°C 1497,569 h= 62 days 9h 34 min**
Grinell 240kGy Sisto 240 kgY	Realistically 12 År	12	40	**1774,17**	90	8okt 10:15 – 21dec 07:40	**1773**	14feb 13:10 25feb 08:22 at **90°C**	**258**	140°C 30 min 130°C 2h30min 100°C 7h	26feb 16:44 28mars 12:50 at **90°C**	44h (125h)	182 h at 90°C (261h)	**At 40°C 15464,282h= 1 yar 279 days 8 h och 17 min**
Grinell Sisto Siers 120kGy Siers 240kGy	Real 6 år 120kGy Real 6 år 120kGy Real 6 år 120kGy Real 6 år 240kGy	6	40	**1830**	80	5okt 13:30 20dec 16:30	1827	14feb 12:20 25feb 07:50 at **80°C**	259	140°C 30 min 130°C 2h30min 100°C 7h	28feb 08:16 5 mars 14:15 at **80°C**	126 h	138 h at 80°C	**At 40°C** 3964 h= 165 days 4h 30 min
Siers 264 kGy	Realistically 6 år	6	55	**3440**	90	8okt 10:15 20dec 16:30	1773	14feb 13:10 25feb 08:22 at **90°C**	258	150°C 10 min 140°C 2h50min 101°C 27	26 feb 16:44 3 maj 07:15 vid **90°C** omfattas även provning under haveri.			

IFE Institut for energiteknik

480 hours x 0,5kGy/h= 240 kGy measured dose 239,1 kGy

480 hours x 0,55kGy/h= 264 kGy measured dose 267,0 kGy

312 hours x 0,4kGy/h= 124,8 kGy measured dose 123,4 kGy

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Mean values from tensile testing of only rubber according to ISO 37 at 23 ° C

Attribute		Siers new	Siers 240 kGy not thermal	Siers 120 kGy 80°C	Siers 240 kGy 80°C	Siers 20 years in operation
Max. tensile strength [MPa]	Mean value	19,60	17,38	7,85	8,93	6,33
	Standard-deviation	1,63	1,49	0,78	0,64	0,98
Elongation at break [%]	Mean value	353,0	323,8	140,4	114,6 (32,5%)	100,2 (28,4%)
	Standard-deviation	57,7	28,9	18,3	8,7	8,3

Attribute		Sisto new	Sisto 264 kGy not thermal	Sisto 120 kGy 80°C	Sisto 240 kGy 90°C	Sisto 264 kGy 115°C
Max. tensile strength [MPa]	Mean value	14,78	14,06	13,41	12,73	12,76
	Standard-deviation	1,17	1,11	1,06	1,03	0,35
Elongation at break [%]	Medelvärde	288,4	191,7	248,3	206,7	195,2 (67,7%)
	Standard-deviation	21,8	10,3	17,4	13,9	13,5

Egenskap		Grinnell nytt	Grinnell 240 kGy ej term	Grinnell 120 kGy 80°C	Grinnell 240 kGy 90°C	Grinnell 264 kGy 115°C
Max. tensile strength [MPa	Medelvärde	14,50	13,26	13,62	13,01	12,56
	Standard-deviation	0,73	0,31	1,01	0,82	0,94
Elongation at break [%]	Medelvärde	586,5	312,0	443,1	417,0 (71,1%)	334,9 (57,1%)
	Standard-deviation	77,8	14,4	14,6	26,8	21,9

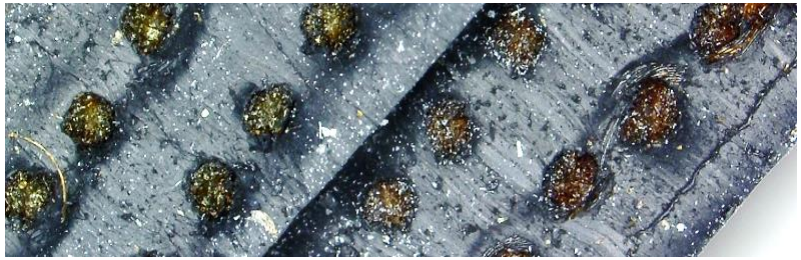
Mean values of tensile test of reinforced rubber (Grinnell) 23 ° C

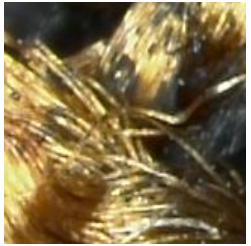
	Max. tensile strength [MPa]		Elongation at break [%]	
	Mean value	Standard deviation	Mean value	Standard-deviation
Grinnell with reinforcement new	**26,34**	1,99	**103**	12,8
Grinnell with reinforcement 264 kGy 115°C	**9,86**	1,41	**57,1 (55,4%)**	7,2

Indentermodul

Diaphragm Grinnell	Indentermodul
Grinnell new	8,55
Griennell only irradiated 240kGy	10,3
Grinnell after thermal 80°C	8,8
Grinnell after thermal 90°C	9,1
Grinnell after thermal 115°C	18,4*
Grinnell 80°C and 120 kGy	9,8
Grinnell 90°C and 240 kGy	10,8
Grinnell 115°C and 264 kGy	13,0
Grinnell 80°C and 120 kGy and accident scenario	9,8
Grinnell 90°C and 240 kGy and accident scenario	10,2
Grinnell 115°C and 264 kGy och accident scenario	11,55 35,1%

Diaphragm Siers	Indentermodul
Siers new	10,1
Siers only irradiated 240kGy	10,7
Siers after thermal 80°C	12,85
Siers after thermal 90°C	25,2
Siers 80°C and 120 kGy	14,2
Siers 80°C and 240 kGy	13,7 36,1%
Siers 90°C and 264 kGy	28,95
Siers 80°C and 120 kGy and accident scenario	17,0
Siers 80°C and 240 kGy and accident scenario	20,7 105,6%
Siers 90° and 264kGy and accident scenario	138,2





Aged reinforcement

Grinnell, new compared to aged 12 years at 55 ° C 264KGy

Visually, no cracking has been detected. Siers membrane aged at 90 °C and 264kGy cracks when bendning

Indentermodul

Diaphragm KSB-Sisto	Indentermodul
Sisto new	10
Sisto only irradiated 264kGy	11,55
Sisto after thermal 80°C	10,35
Sisto after thermal 90°C	10,55
Sisto after thermal 115°C	11,4
Sisto 80°C and 120 kGy	11,5
Sisto 90°C and 240 kGy	12,5
Sisto 115°C and 264 kGy	13,4
Sisto 80°C and 120 kGy and accident scenario	11,3
Sisto 90°C and 240 kGy and accident scenario	11,3
Sisto 115°C and 264 kGy and accident scenario	12,55 25,5%

All membranes have felt soft and elastic enough. The assesment was that Grinell membranes can be considered environmentally qualified for 12 years in operation and Siers for 6 years in operation, followed by a postulated accident scenario.

Conclusions

- There is some conservatism in the aging procedure for Grinnell membranes. This partly because longer aging times and partly because a conservatively selected activation energy of 0.8eV. Activation energy for EPDM products is usually higher. For example, for similar membranes (M1 Compound EPDM-F1-082514), ITT Engineered Valves uses activation energy 2.0 eV at accelerated thermal aging. Temperature 115 ° C, used in accelerated aging, is slightly too high and thus conservative for EPDM rubber and to high for reinforcement in nylon (PA6)

- There is some conservatism in the aging procedure for Siers membrane due to longer aging times (just over 165 days corresponding to 40 ° C operating temperature). temperatures more project made a priority choice based on existing timeframes. Lower aging temperatures for natural rubber are preferred. Siers membranes aged at 90 ° C have completely hardened and tensile testing was not possible while the indenter module increased exponentially at the end of the aging cycle

- There is some conservatism in the aging procedure for KSB-Sisto membranes. This partly because longer aging time and partly because a conservatively selected activation energy of 0.8eV. Activation energy for EPDM products is usually higher

- We have not examined membranes with regard to composition

Conclusions

- Sequentially accelerated aging used in the present case, described in this report, is also linked to some non-conservative assumptions:
- The aging has been carried out in a stress-free state, while membranes in the plant are periodically or continuously exposed to stresses in the material.
- Accelerated radiation aging is carried out at room temperature. It is known that aging effects on radiation are more noticeable at higher temperatures. At low dose rates during normal operation, the temperature and oxygen in the environment are dominant stress factors, while at higher dose rates it is the radiation that affects aging most. Temperature and radiation do not interact during aging.
- All valves are exercised during operation in the plant, while membranes that have accelerated aging have not been exercised.
- With accelerated aging at higher temperatures, it is not possible to exclude so-called DLO effect. This means that oxygen is consumed in the surface layer of the test object and does not diffuse throughout the bulk mass, with the surface aging more than the middle.
- For membranes in contact with borated water / steam, this environmental effect has not been investigated. Although both EPDM and natural rubber have good water resistance. The water is able to diffuse into the rubber material. For both natural and EPDM rubber, this results in some swelling over time, which means that the volume increases slightly and the rubber becomes slightly softer which is positive for sealing function. The negative effect is that wear properties can be worse