SEALING
SOLUTIONS

Trelleborg Sealing Solutions

PROHIPP 4th Year General Meeting

VIC, 26th of May 2008

Topics

4th Reporting Period

- Research / Work performed in WP II and WP III
- Conformity with Work program / Administrative Issues

Full Project

- Objectives
- Research Work / Achievements
- Deliverables
- Exploitable Results

WP II; fluid mechanical analysis 4th RP

T2.3 Coupled Fluid-thermal-mechanical analysis (in co-operation with ITFR)

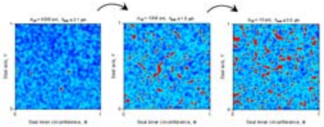
Objective:

Focus in analysis procedures in relation with structural requirements of parts and elements as well as fluid-dynamic aspects related with cylinder performance including seal / oil / surface interactions.

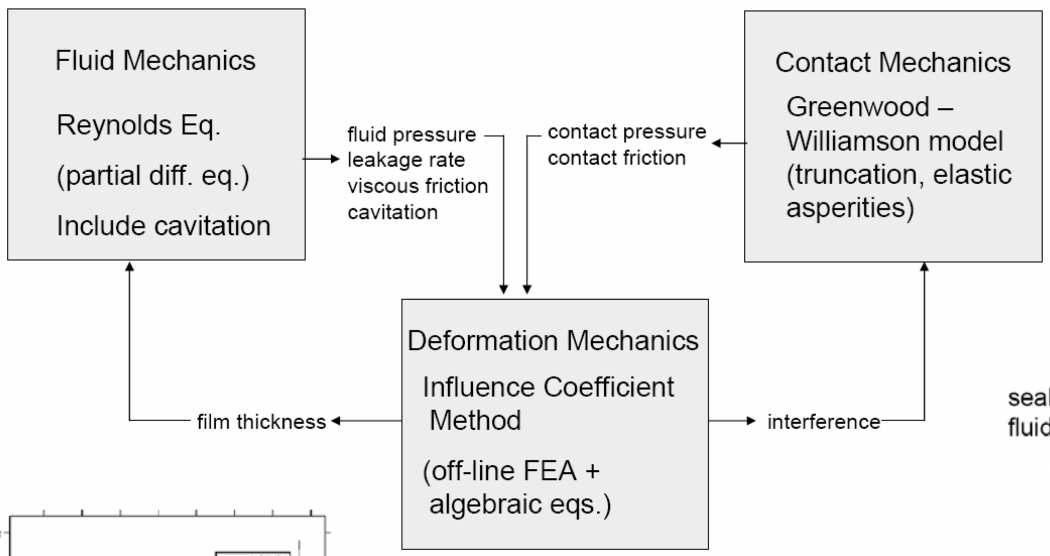
Development of methods and algorithms for the analysis of coupled fluid mechanical interactions in seal-rod/cylinder systems (IFTR) and its verification by tests (TSS).

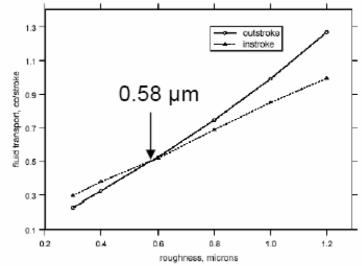
WP II; fluid mechanical analysis 4th RP

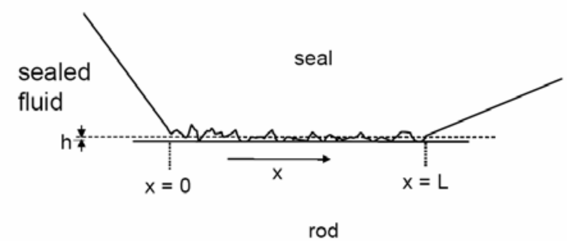
Present Activities on that topic (state-of-the-art):



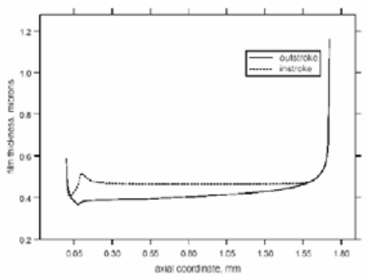
- R. F. Salant and D. Shen. 2002. Hydrodynamic Effects of Shaft Surface Finish on Lip Seal Operation.
- R.F. Salant: Numerical Model of a reciprocating hydraulic rod seal (14th ISC, Stuttgart 2007)







net leakage = fluid transport during outstroke
- fluid transport during instroke



WP II; fluid mechanical analysis 4th RP

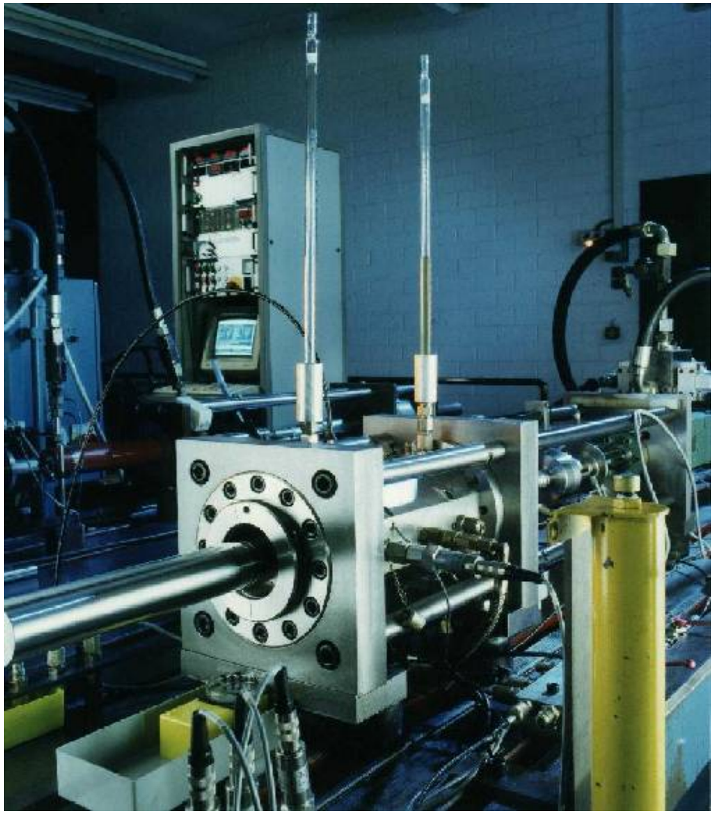
Build Up:

2 x O-rings	50,39 x 3,53
Compound	NBR 70ShA
Groove	50 x 56,3 x 3,8
Gap (behind seal)	0,1 mm radial
Temperature	ambient
Fluid	Shell Tellus 46
Speed*	0,1; 0,2; 0,3 m/s
Pressure	0; 0,2 ; 0,4; 0,6; 1 MPa

*pos. speed (´+´): motion to left side

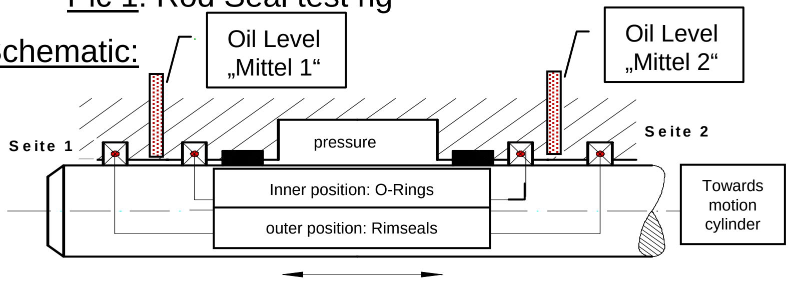
neg. speed (´-´): motion to right side

750 double-strokes each step



Pic 1: Rod Seal test rig

Schematic:



WP II; fluid mechanical analysis 4th RP

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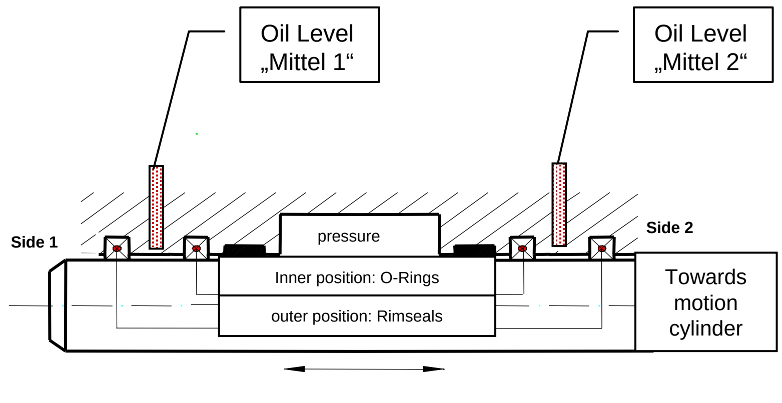
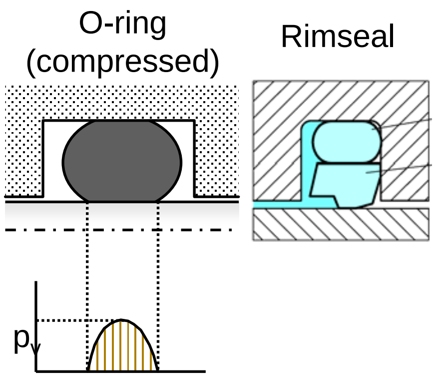
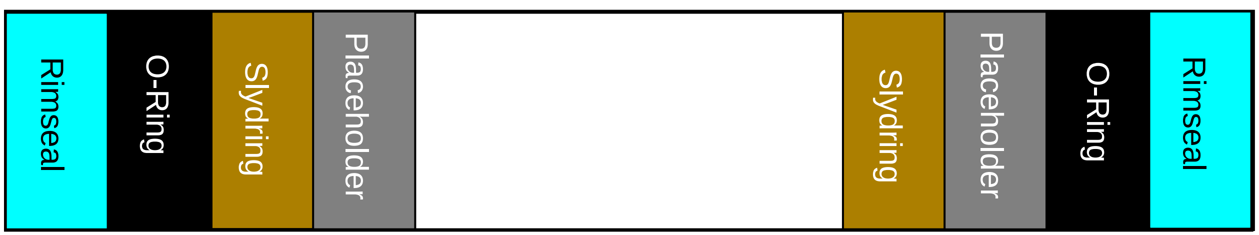
Influences such as the position of elements to be considered

Schematic:



Seals:





WP II; fluid mechanical analysis 4th RP

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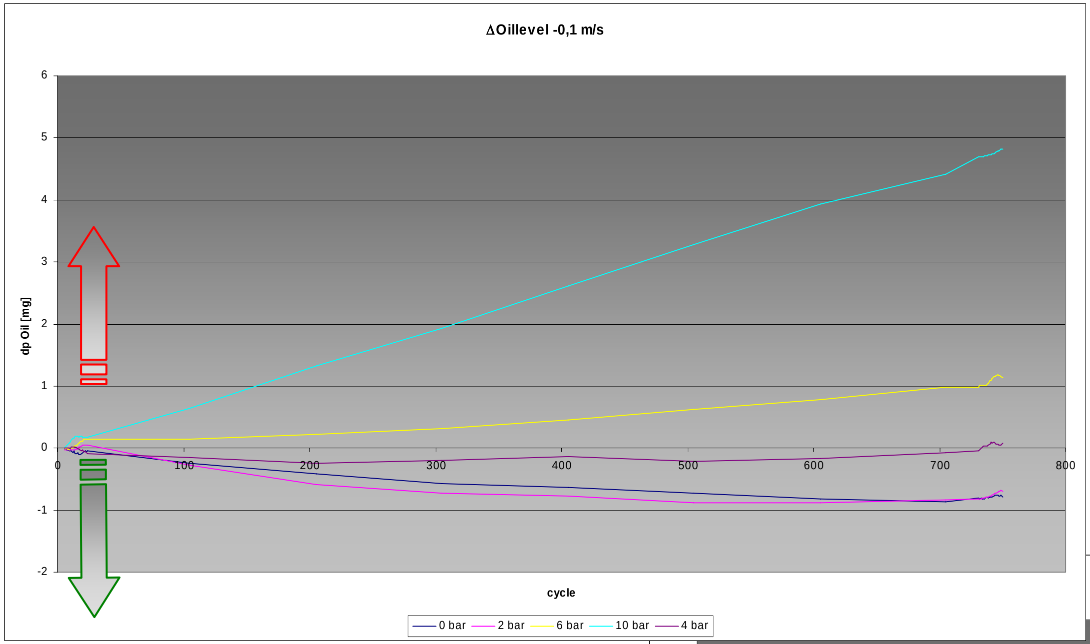
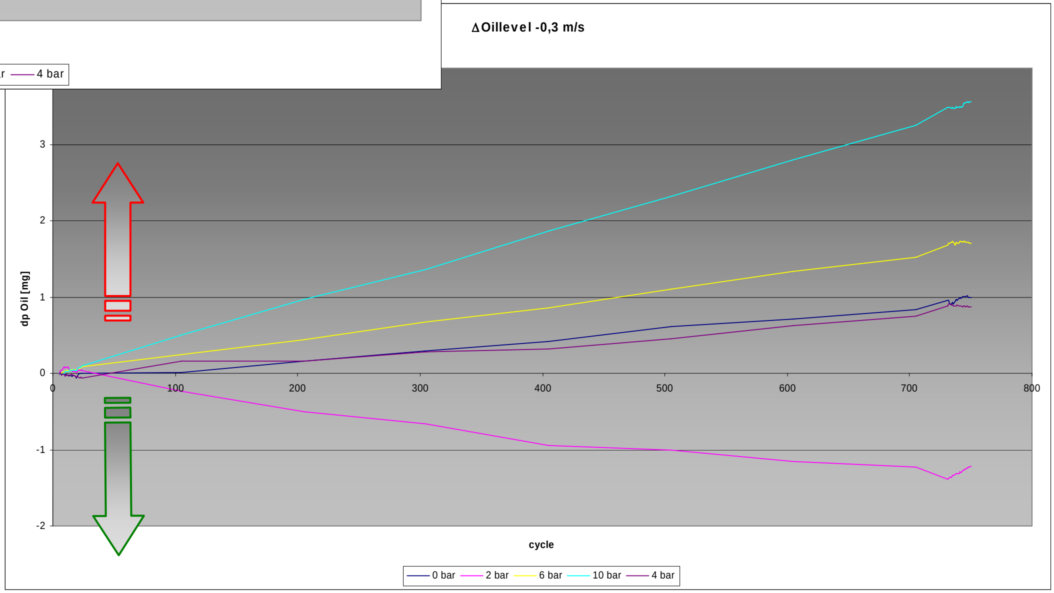
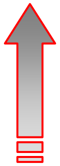


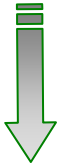
Dependency on speed

(on instroke)



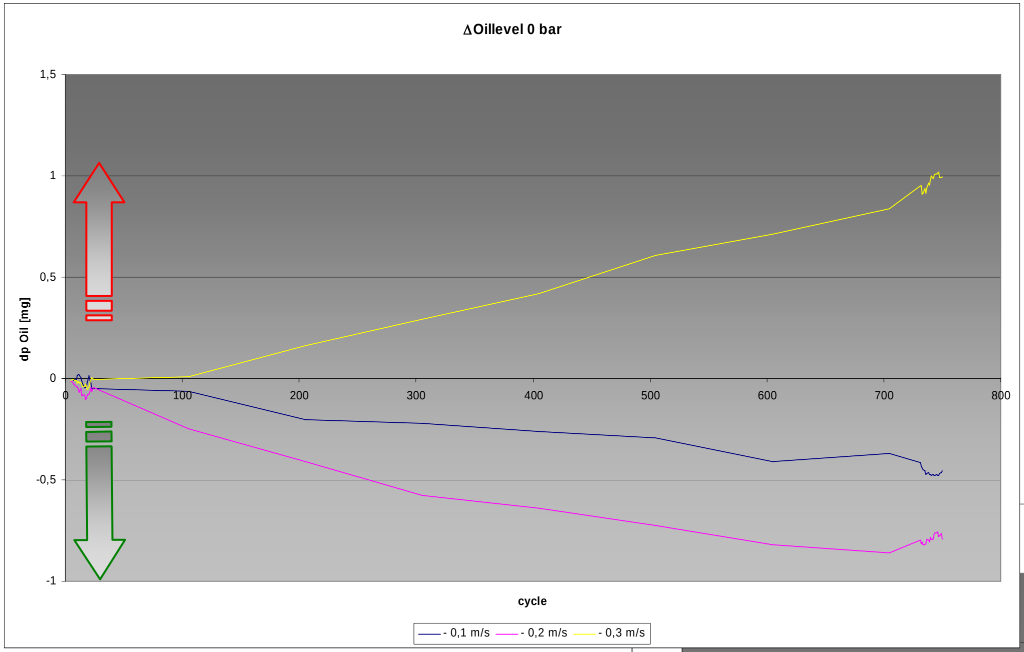


Leakage



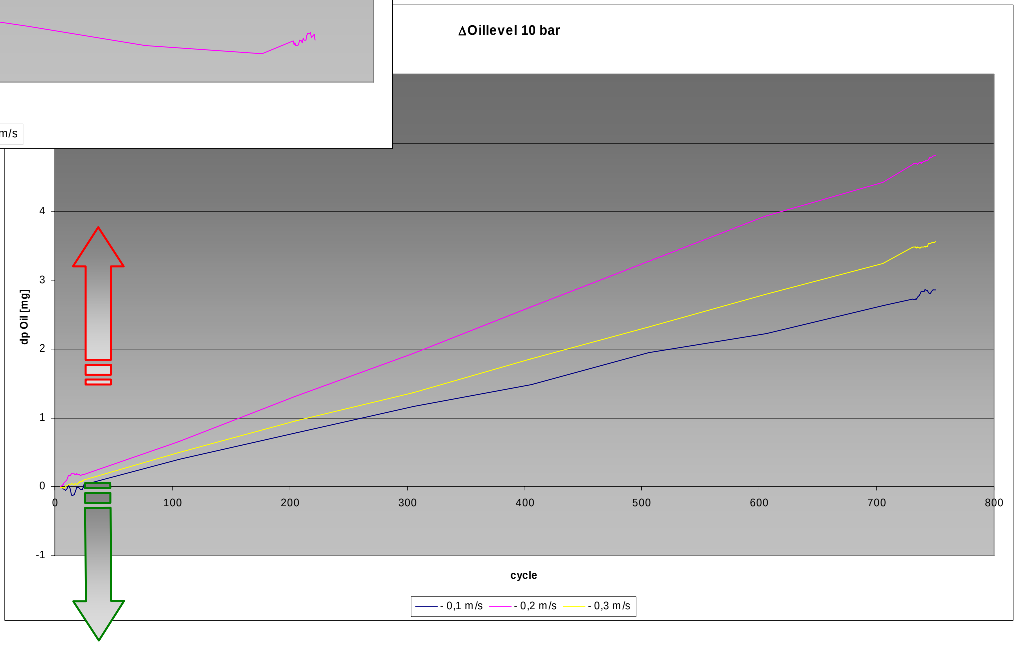
Back-Pumping

WP II; fluid mechanical analysis 4th RP



Dependency on pressure

(on instroke)



Leakage

Back-Pumping

WP III; Elastomeric + Thermoplastics

T3.2 Elastomeric + Thermoplastic Materials (co-operation with HEF, BCE, Roquet, Honingtec)

Objective:

Focus on the development of elastomeric and thermoplastic materials. Divided in subtasks of:

- Surface texture analyse
- study of new materials and geometries
- study of tribological properties

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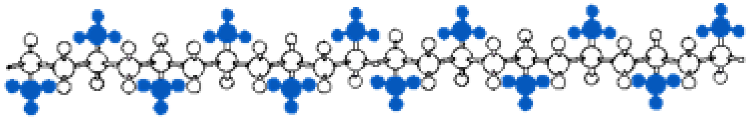
WP III; Elastomeric + Thermoplastics

Focus of TSS on:

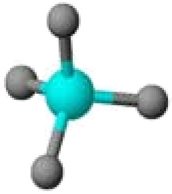
- Development of new seals / compounds resp. improvement of existing PU
    - In terms of temperature behaviour for rod seals
    - considering plateau-honed surfaces for piston seals
- Determination of Life time Curves

WP III: Modification of PU

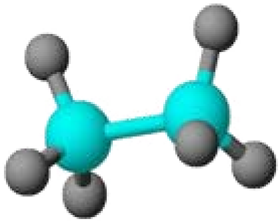
Sealing Materials:



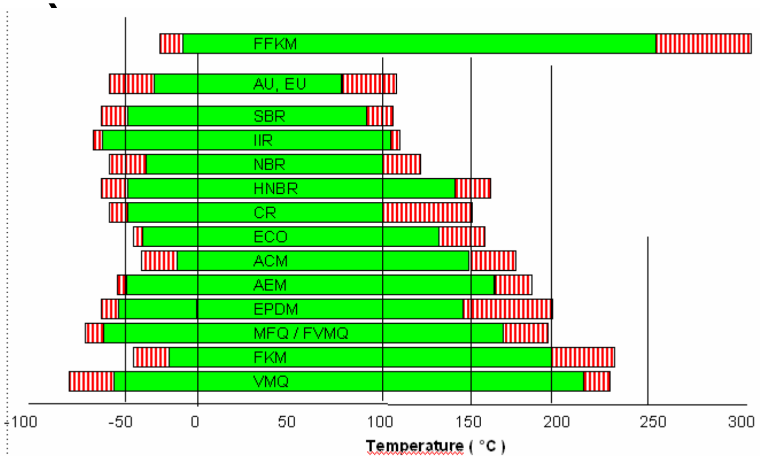
- high-molecular composition
  = Polymer
  (Contrary to metals with atomic build-up)



- Consisting of linear or complex chains of molecules (= *Macromolecules)*



- Macromolecules consist of single molecules (= *Monome*



WP III: Modification of PU

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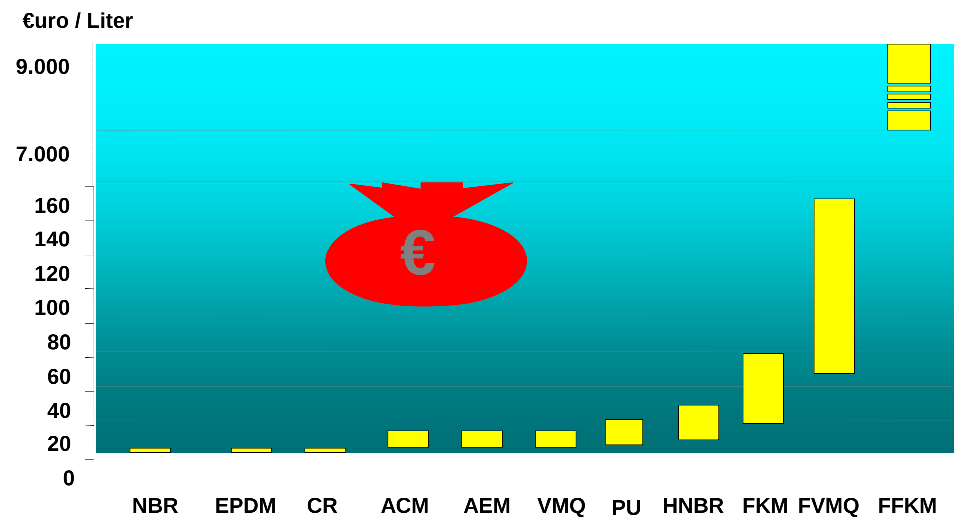
Sealing Materials

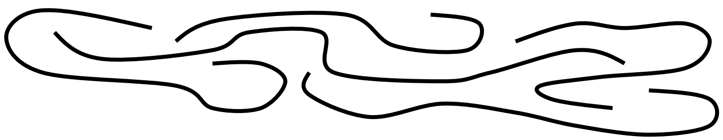
Thermoplastics	Elastomers	Thermoplastic Elastomers	Duroplastics
PVC	Natural rubber (NR)	TPU	Phenolresin
PE		Polyetherester	Epoxidresin
PP	Synthetic Rubber	Polyetheramid	Melaminresin
PA	• ACM	...	...
PS	• AEM		
ABS	• EPDM		
SAN	• NBR		
PS	• HNBR		
PTFE	• FKM		
...	• VMQ		
	• CR		



WP III: Modification of PU

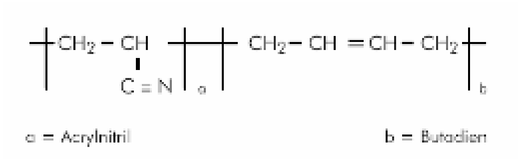
Thermoplastics:

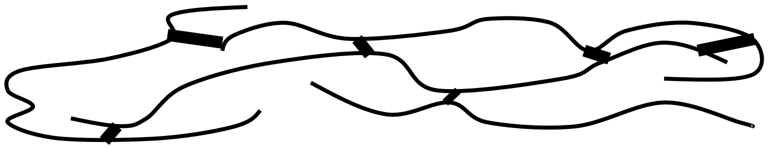
- consist of long chains of molecules; don´t have any cross links.
- are easy to be deformed at higher temperatures and also do get plasticly deformed when effected by forces
- at moulding process the material is getting softened plasticly by the intake of temperature and / or melted and is getting solidified again into the cooled down mold.



Elastomers:

- are widely meshed high-polymer compounds
- behave elastically at lower temperatures and don´t flow viscously at high temperatures but behave rubber-elastic at ambient or lower temperature up to the temperature of pyrolysis..





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WP III: Modification of PU

General Characteristics

- Temperature range - 30°C up to 100 - 110°C (short term 120°C)

Target 1: improve to 120 - 130°C

- Min. swelling in mineral oil / Good hydrolysis resistance
- High tensile strength (use without back-up rings)
- Synthetic and natural ester HEES, HETG up to +60 °C
- Flame-retardant hydraulic fluids HFA and HFB up to + 40 °C
- Good abrasion and high extrusion resistance
- Low compression set

Target 2: improve for piston seals

WP III: Modification of PU

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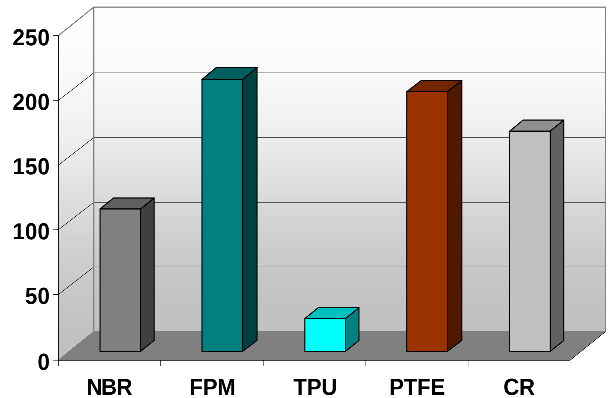
PU is made out of 3 basic materials

- Polyol* — HO-R_1-OH (long chain)
- Diisocyanate** — OCN-R_2-NCO
- Chain extender / curing agent*** — HO-R_3-OH (short chain)

* forms the soft segment, influence to compatibility and low temp. properties

** to form macromolecules

*** forms the hard segment / physical network, influence to hardness of compound



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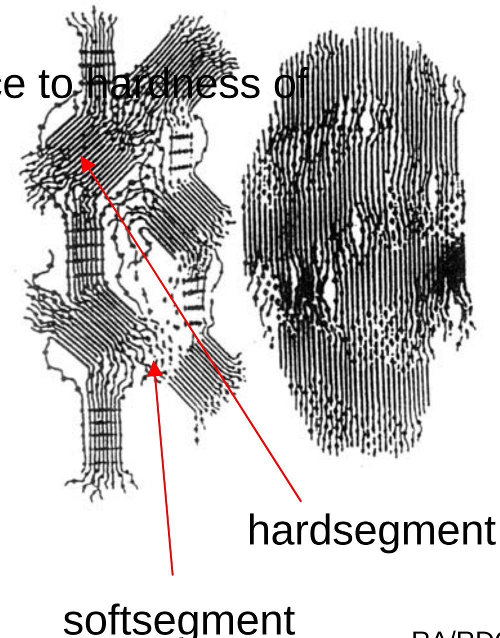

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WP III; Modification of PU

VPU03/001-5

VPU 12/010

...

VPU03/001-6

VPU 12/013

VPU03/009

VPU 12/011

...

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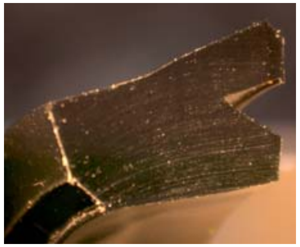
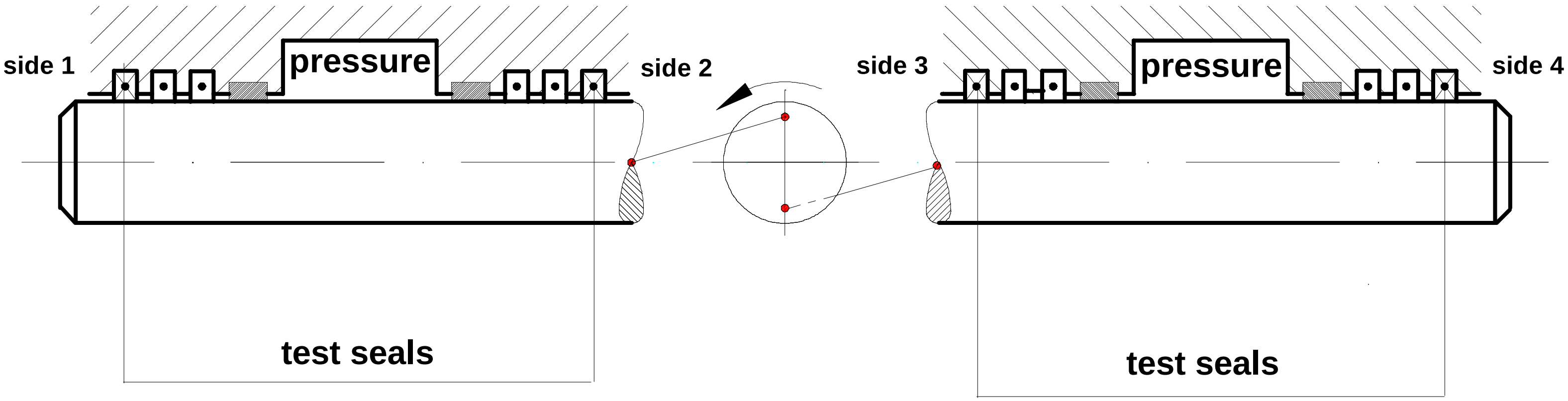
WP III; Modification of PU (rod seals)

Pressure (cycling):	0/30 MPa
Velocity (sinus):	0.2 m/s
Stroke:	300 mm
Duration:	250.000 cycles
Öltemp.:	120 °C (130 °C)
Type of oil:	HLP46





WP III; Modification of PU (piston seals)

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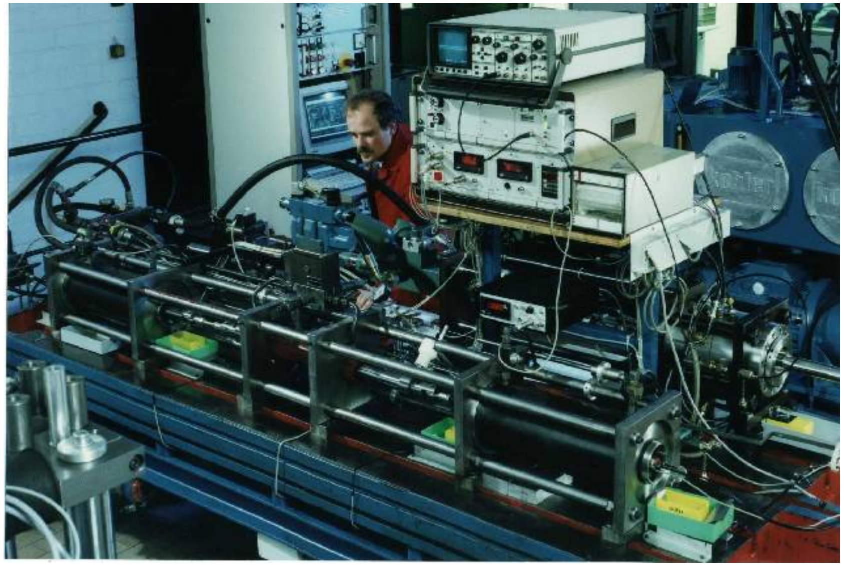
Testing* Conditions:

Dimension:	80 x 64,5 x 6,3
Pressure	max. 30 MPa
Speed:	0,2 m/s
Oil:	Shell Tellus HLP 46
Temp.:	60°C
Duration:	250.000 dbl. strokes (endurance test)

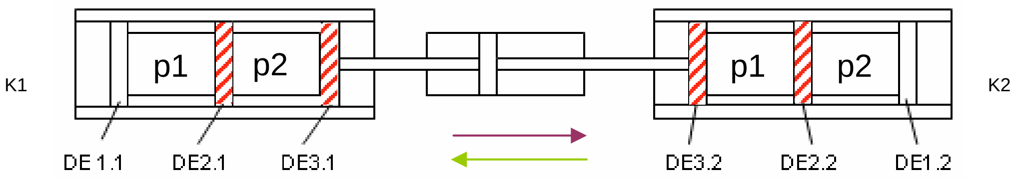


Pic 1: Piston Seal test rig

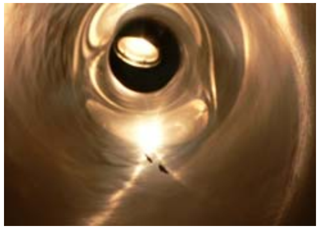
Test does consist from out 5 single tests:

- Static leak test (1h at 2, 5, 10, 15, 20, 25, 30 MPa)
- Dynamic leak test (1000 cycles at above mentioned steps)
- Endurance test (p1=30 ÷ p2=2 MPa while motion towards right side; p1=2 ÷ p2=30 MPa while motion towards left side)
- Dynamic leak test (1000 cycles as above)
- Static leak test (1h as above)

Schematic (leak tests just with 2 seals per tube):



WP III; modification of PU (piston seals (∅ 80))



Tubes (Dinacil): - PH- … - PH-M-50;

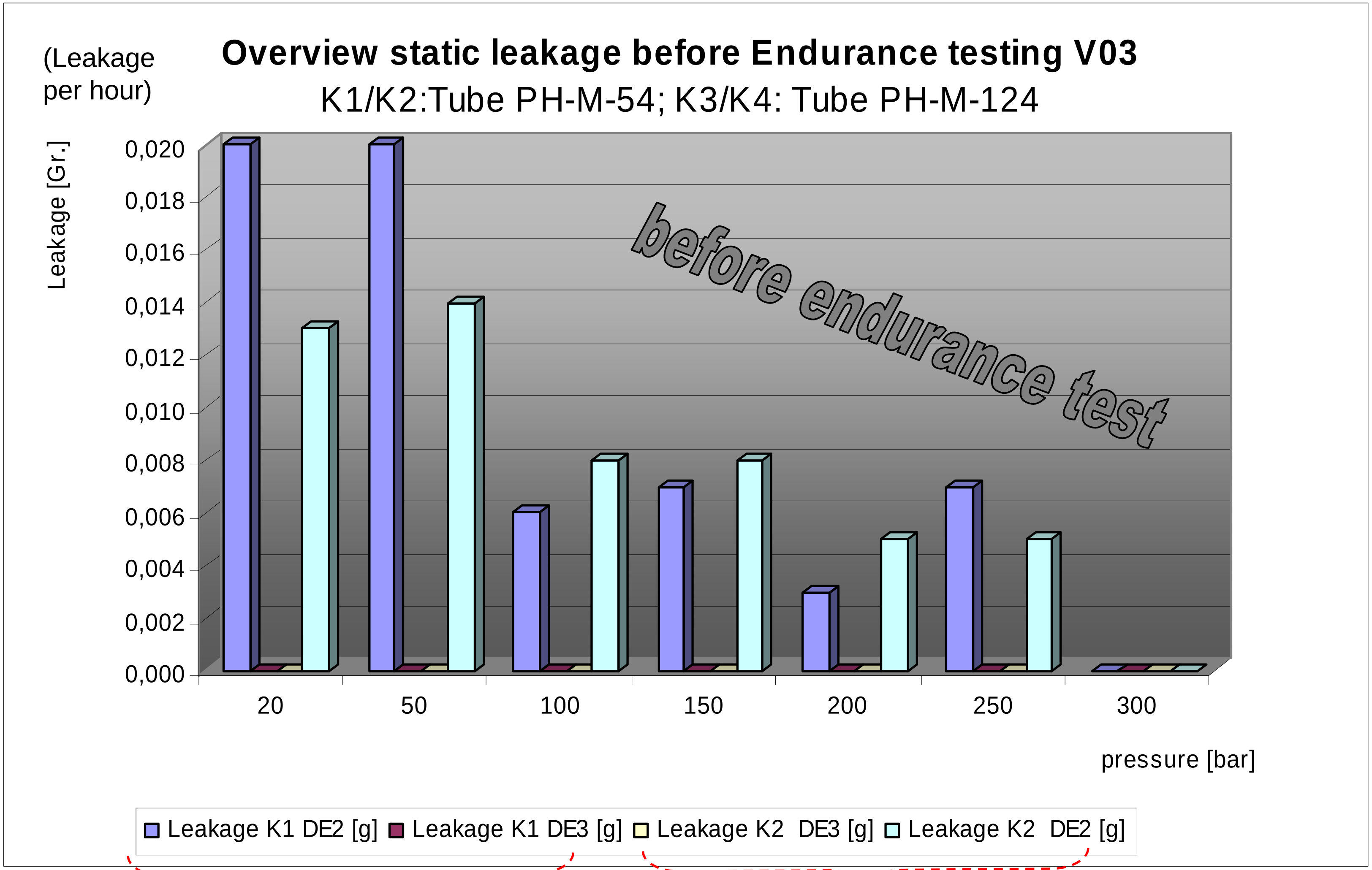
- PH-M-51; - PH-M-52; - PH-M-53; - PH-M-54;
- PH-M-55; - PH-M-56; - PH-M-57; - PH-M-….;

Tubes (Honingtec): PH-M-119 (B181+B20 ; 5 strokes);

- PH - M -123 (B91+B20; 4 strokes); - PH-M-124 (B91+B20 ; 6 strokes);
- PH -M - 128 (B64+B20; 4 strokes); - PH-M-130 (B64+B20 ; 6 strokes)*****;
- PH -M - 135 (B181+B20; 9 strokes); - PH -….

Tube	before testing			after testing		
	R_a	R_z	R_{max}	R_a	R_z	R_{max}
PH-M-...	...	...	...			
PH-M-54	0,02 ÷ 0,04 µm	0,38 ÷ 0,73 µm	0,96 ÷ 1,87 µm	0,01 ÷ 0,04 µm	0,12 ÷ 0,42 µm	0,13 ÷ 1,42 µm
PH-M-56	0,07 ÷ 0,14 µm	1,08 ÷ 2,57 µm	3,66 ÷ 4,92 µm	0,05 ÷ 0,13 µm	0,97 ÷ 2,13 µm	3,01 ÷ 4,23 µm
PH-M-57	0,01 ÷ 0,03 µm	0,13 ÷ 0,45 µm	0,16 ÷ 1,50 µm	0,01 ÷ 0,02 µm	0,11÷ 0,32 µm	0,11 ÷ 0,92 µm
PH-M-123	0,46 ÷ 0,72 µm	3,68 ÷ 5,11 µm	5,13 ÷ 8,21 µm	0,35 ÷ 0,61µm	3,12 ÷ 4,79 µm	0,02 ÷ 0,04 µm
PH-M-124	0,30 ÷ 0,96 µm	2,57 ÷ 5,67 µm	3,36 ÷ 7,02 µm	0,26 ÷ 0,81 µm	4,68÷ 7,01 µm	3,22 ÷ 6,97 µm
PH-M-...	...	...	...	...		

WP III; modification of PU (piston seals)



VPU03/009

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VPU12/012

RA/RDCS
26.05.2087

WP III; modification of PU (piston seals)

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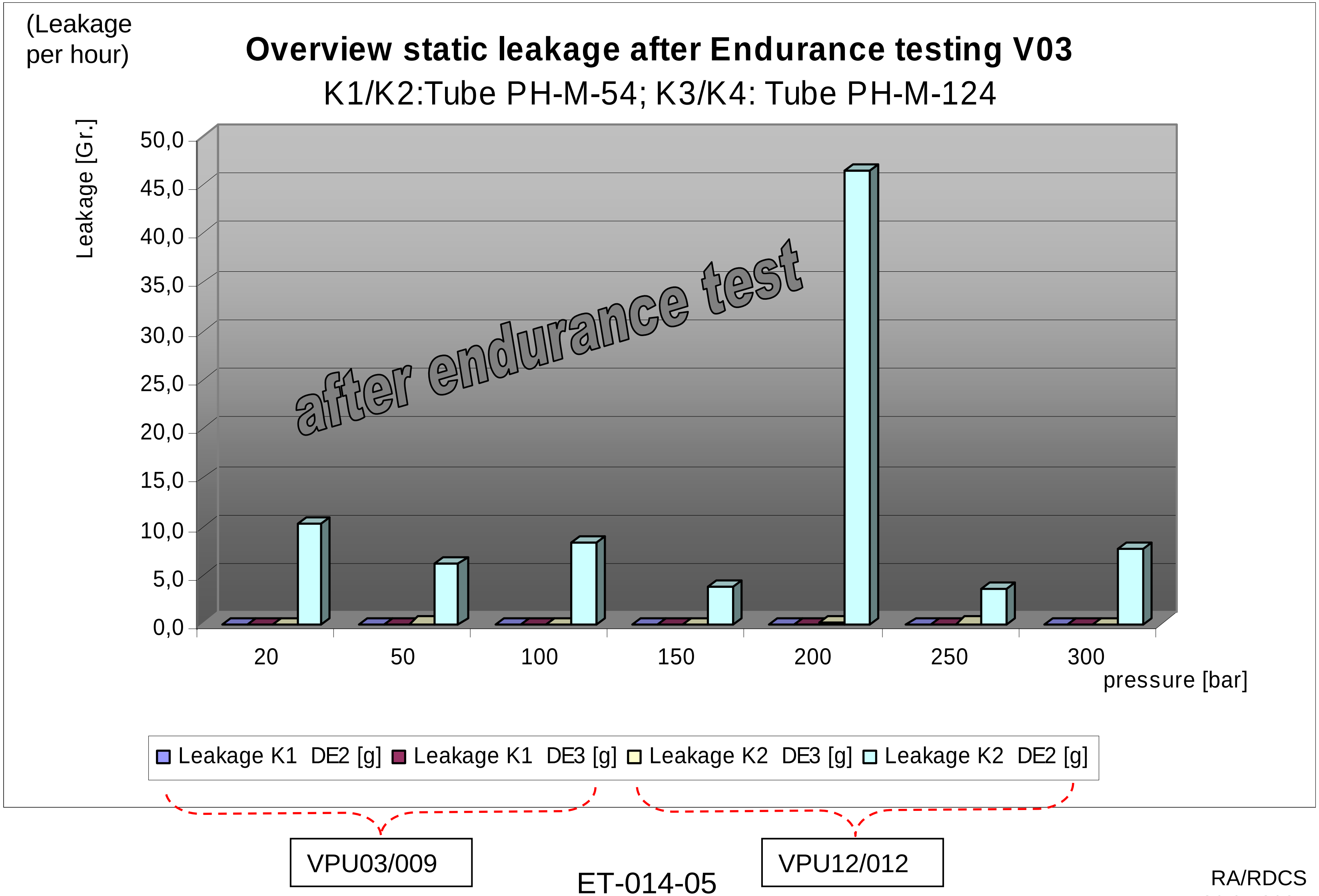

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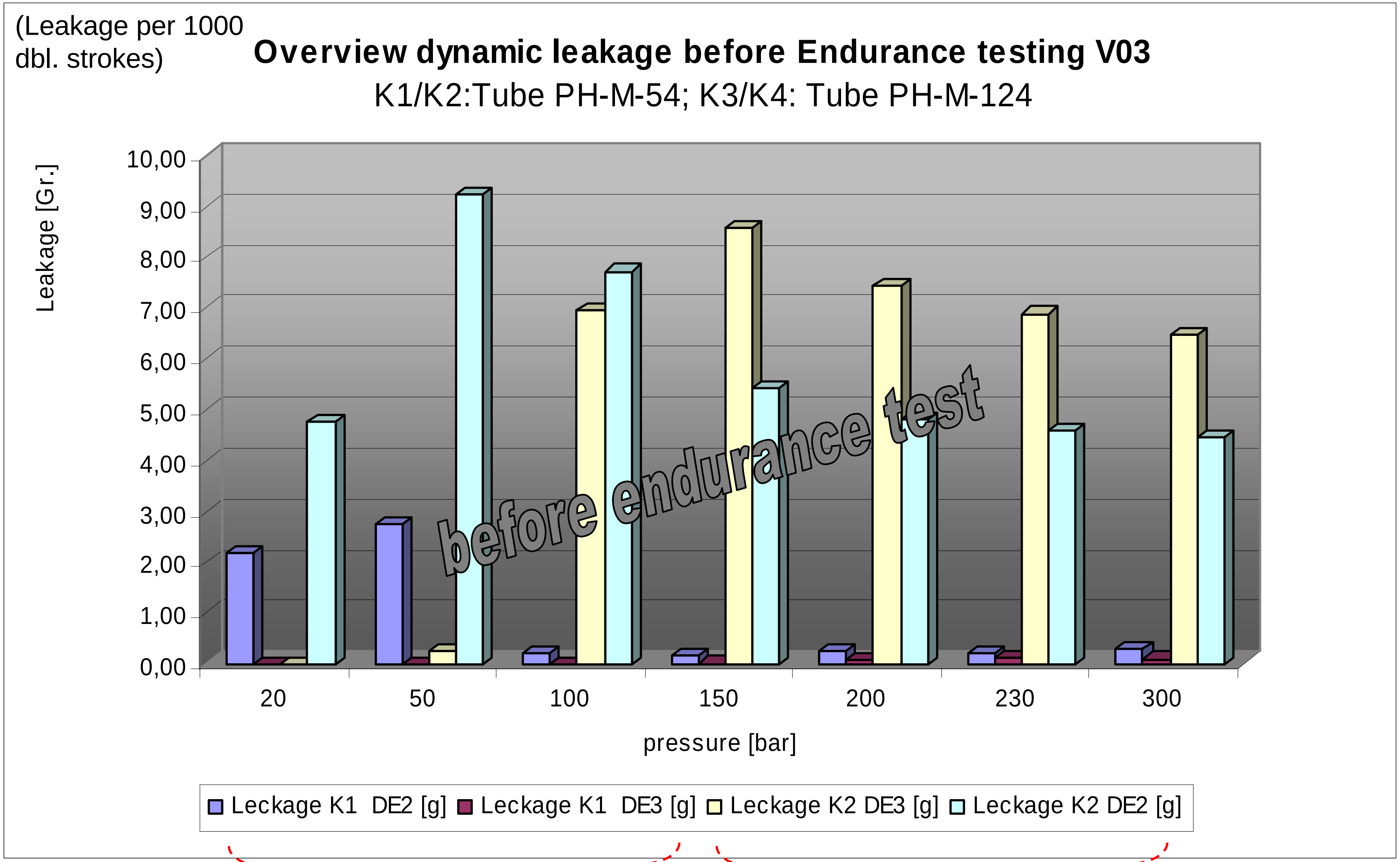
WP III; modification of PU (piston seals)



VPU03/009

VPU12/012

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WP III; modification of PU (piston seals)

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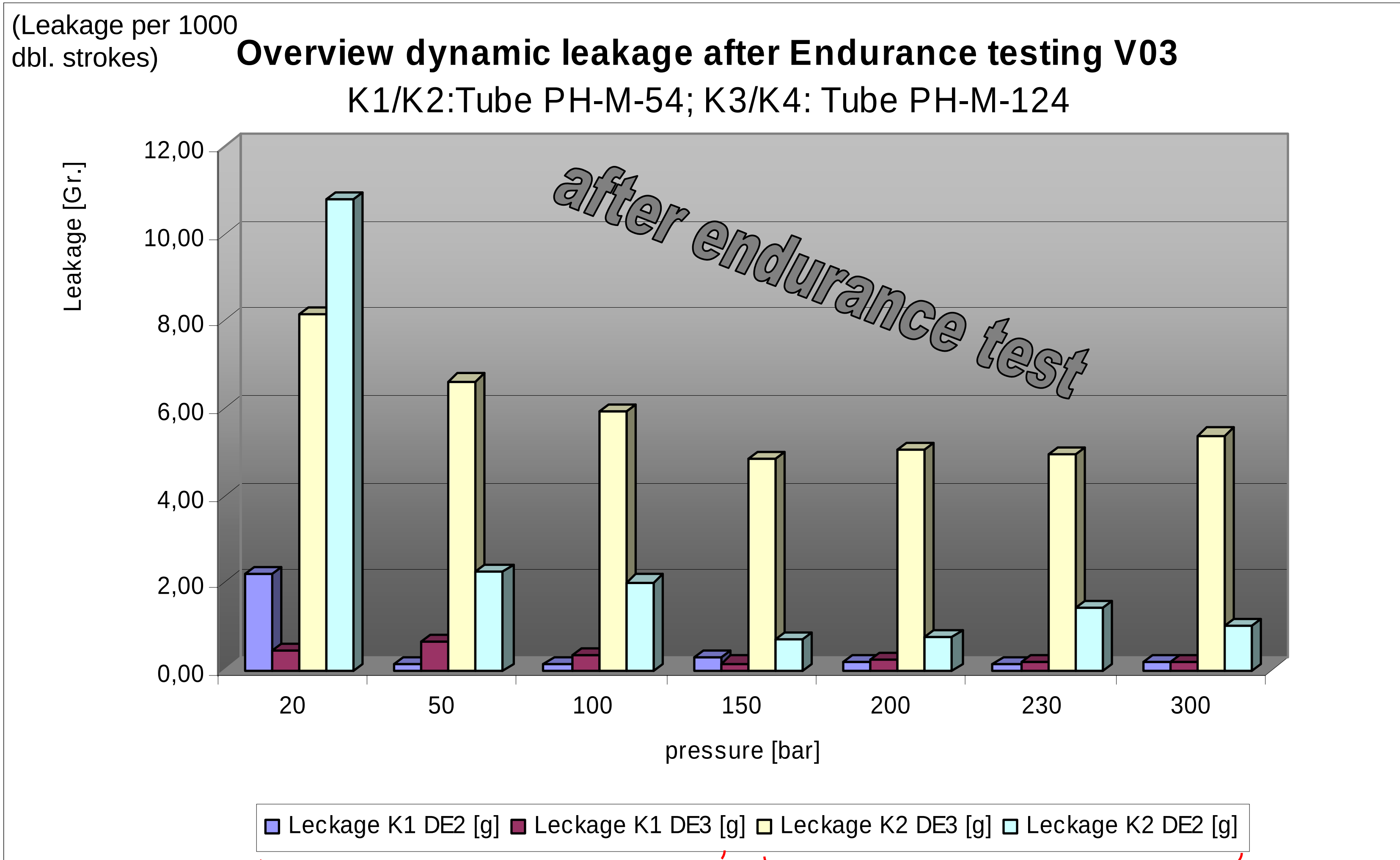

VPU03/009

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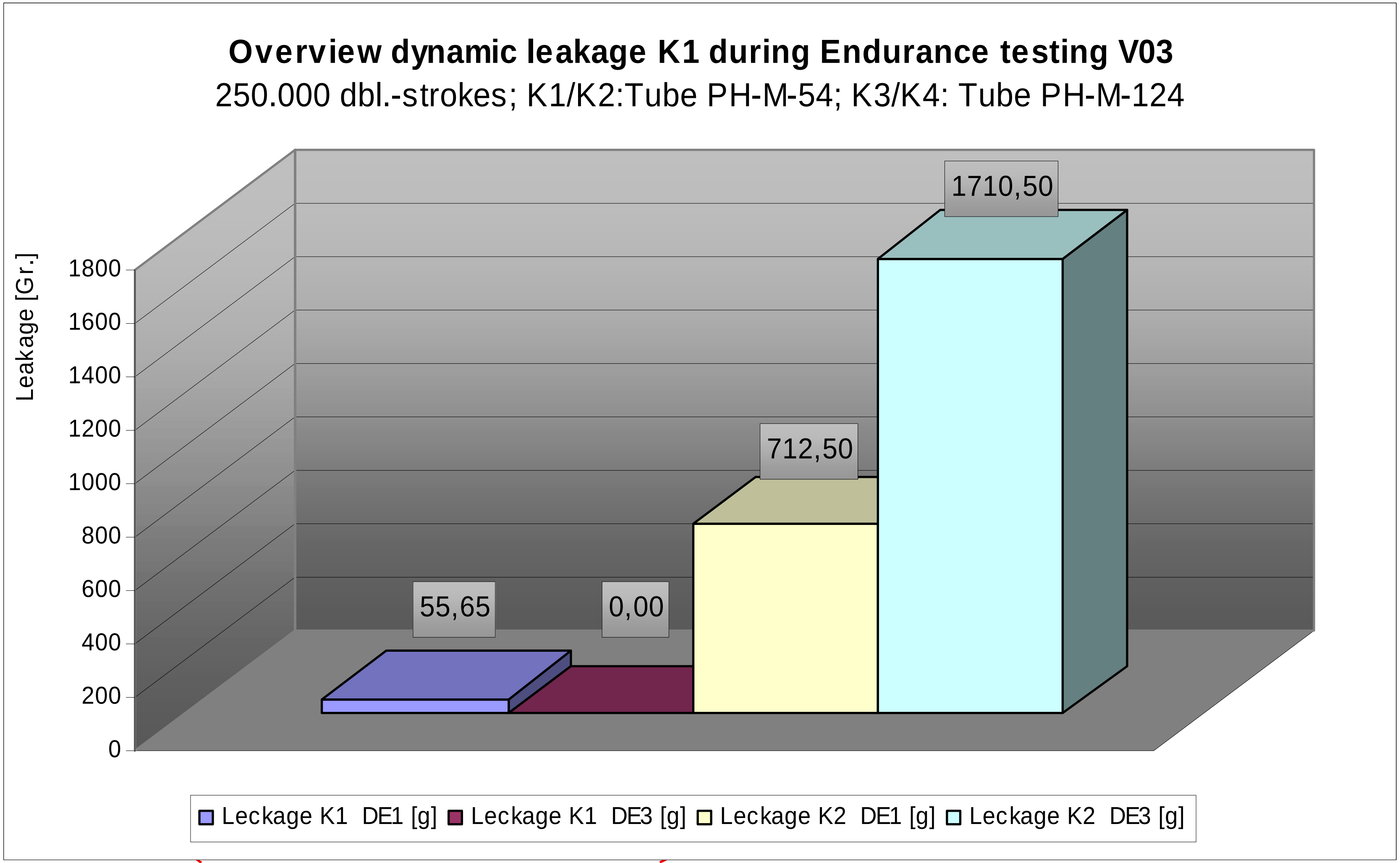
VPU12/012

WP III; modification of PU piston seals)



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WP III; Life time Curves

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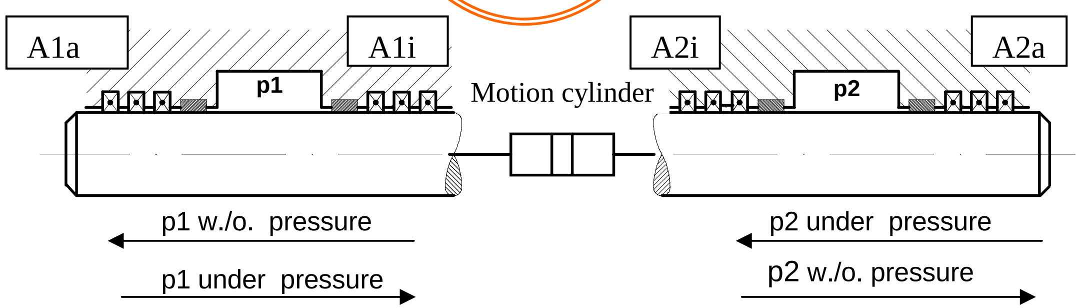
Endurance Tests

High Pressure Tests

Lab test



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WP III; Life Time Curves

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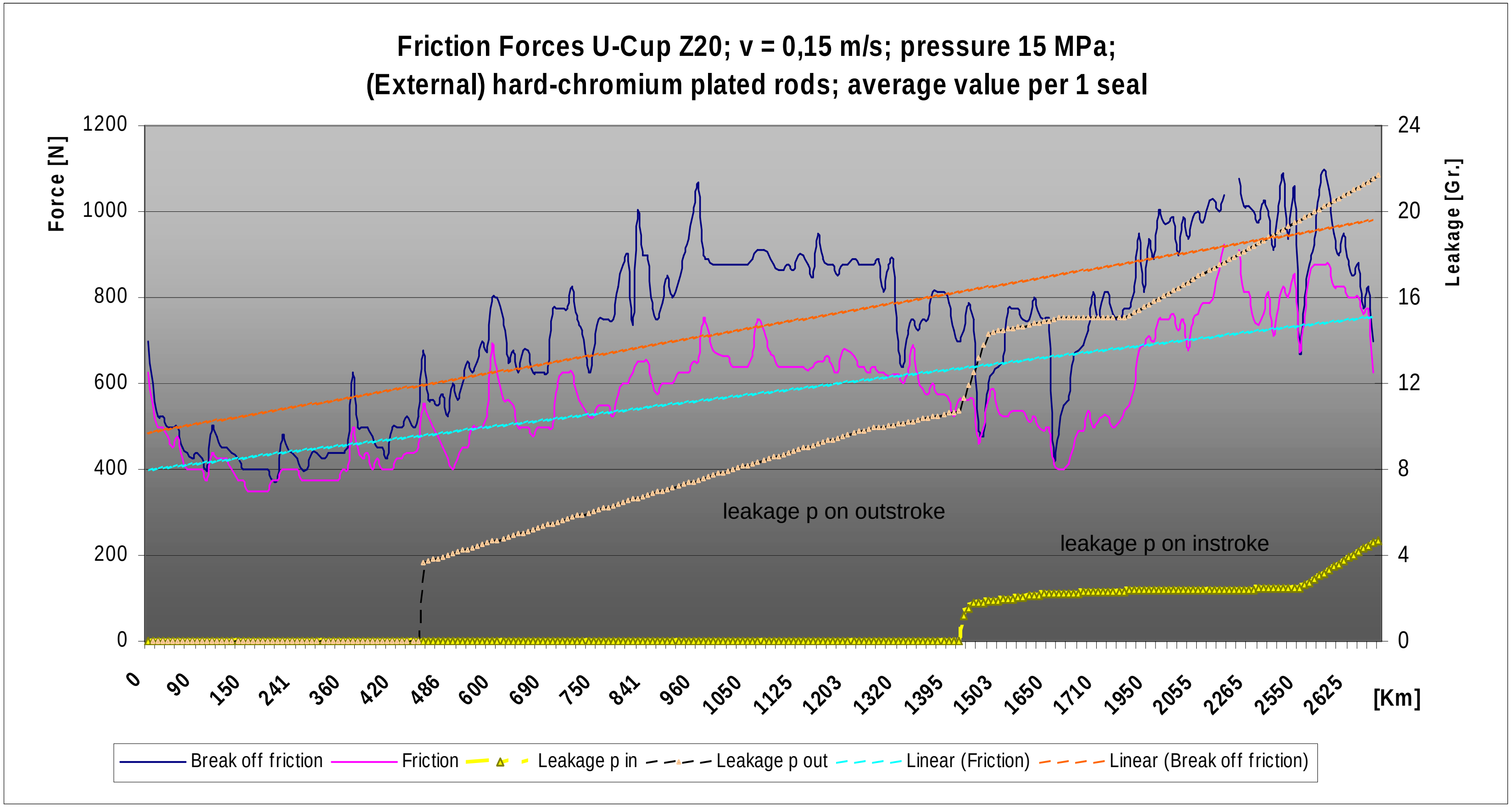
4. Determination of Long time behaviour



WP III; Life Time Curves

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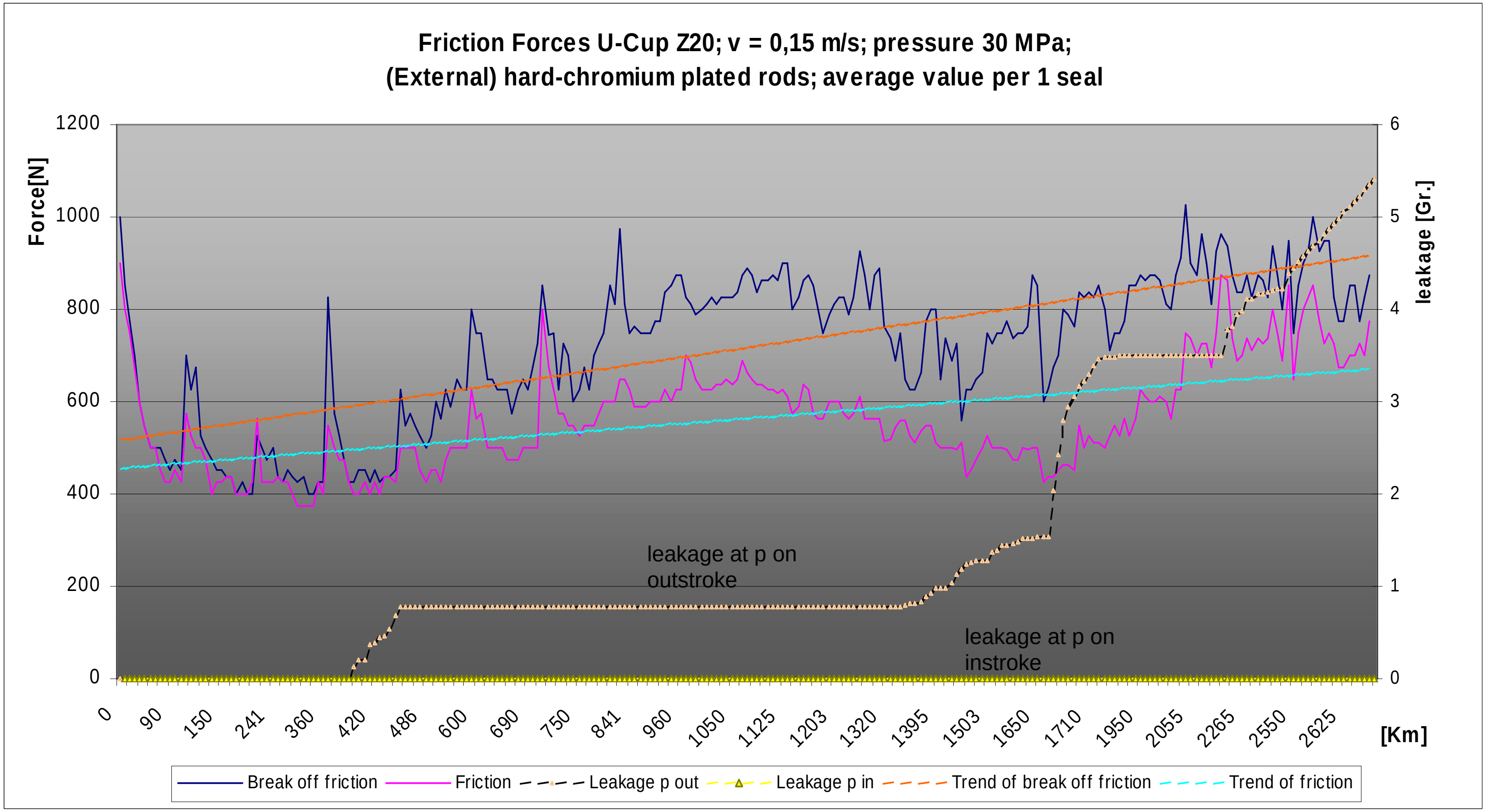
4. Determination of Long time behaviour



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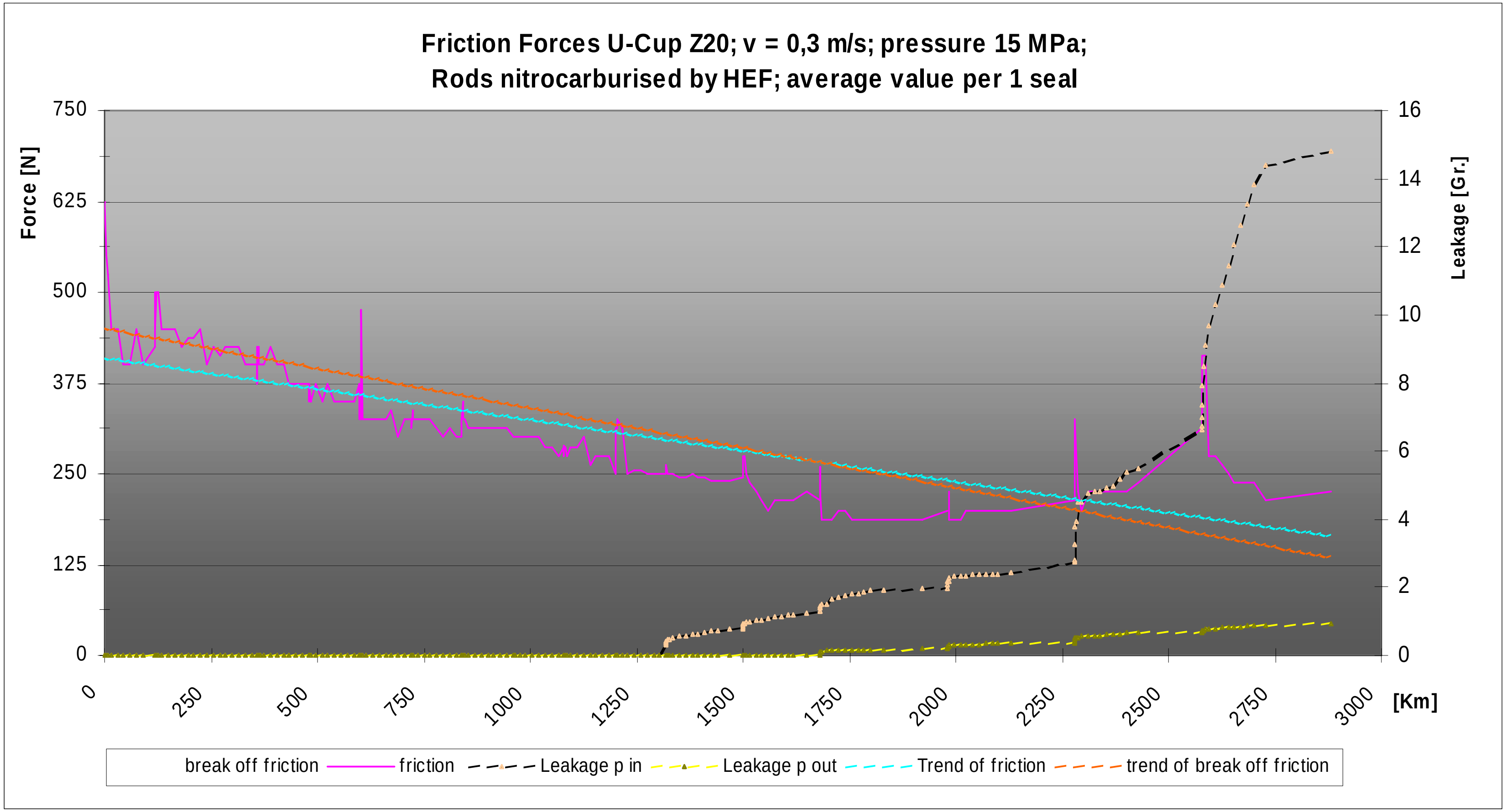
WP III; Life Time Curves

Pro Hipp

4. Determination of Long time behaviour



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WP III; Life Time Curves

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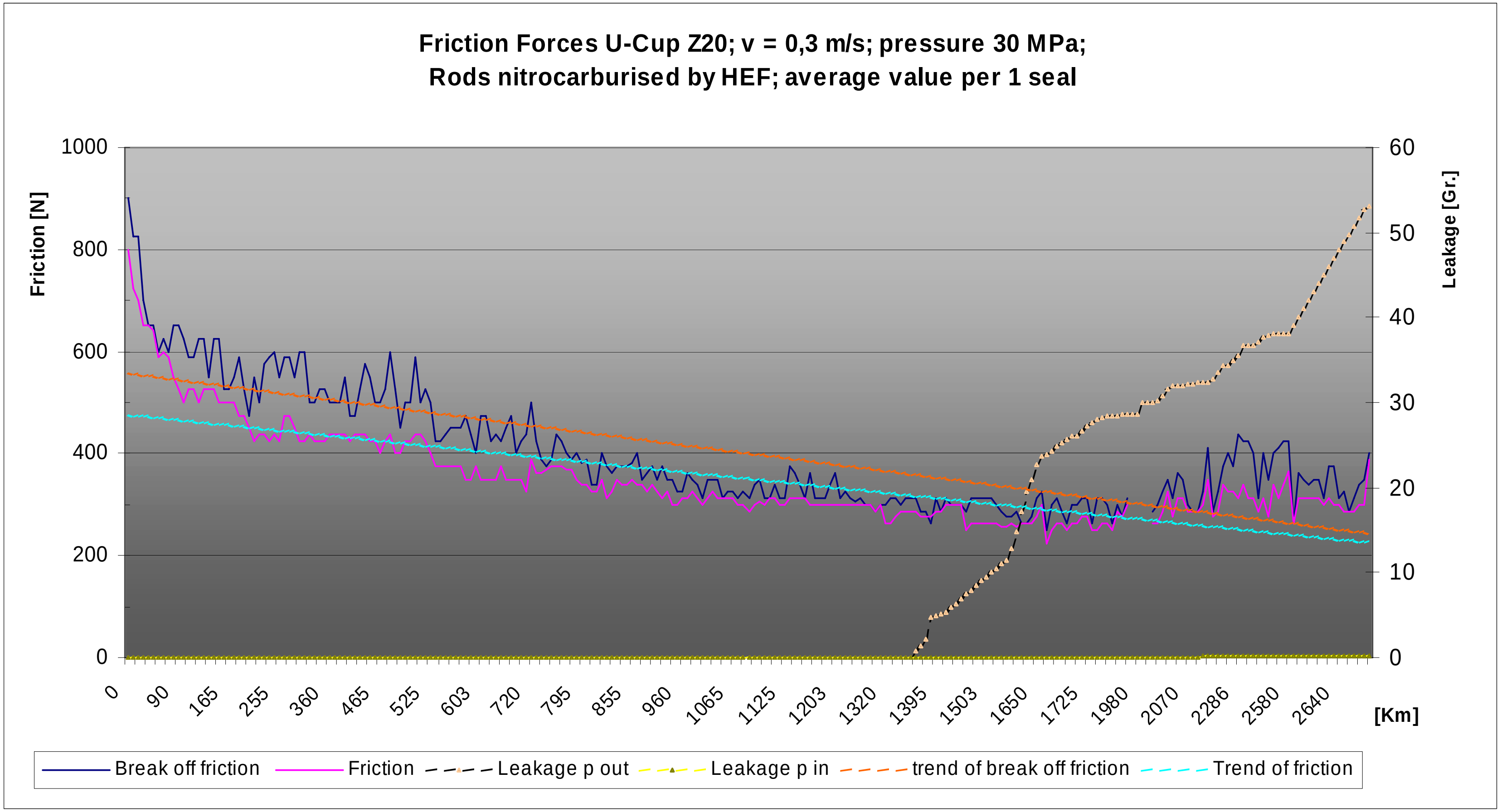
4. Determination of Long time behaviour



Administration issues 4th RP

▸ Activities WP II:	- No deviation; ongoing testing of alternative profiles
▸ Activities WP III:	- awaiting tubes ∅60 for final verification testing honed vs. plateau honed; - high pressure tests ongoing - clarification of commercial and series production aspects
▸ Men months spent:	16,66
▸ Over all costs spent:	€ 244.834

Achievements PROHIPP Project

- Target I: Introduction / Investigation of Plateau Honing
- Target II: Develop new PU piston seal and compound (improve cost-benefit-ratio, considering plateau-honing)
- Target III: Improvement of PU characteristics for rod seals (increase operating temperature performance)
- Target IV: Determination of Life Time Curves

Target I: Plateau Honing

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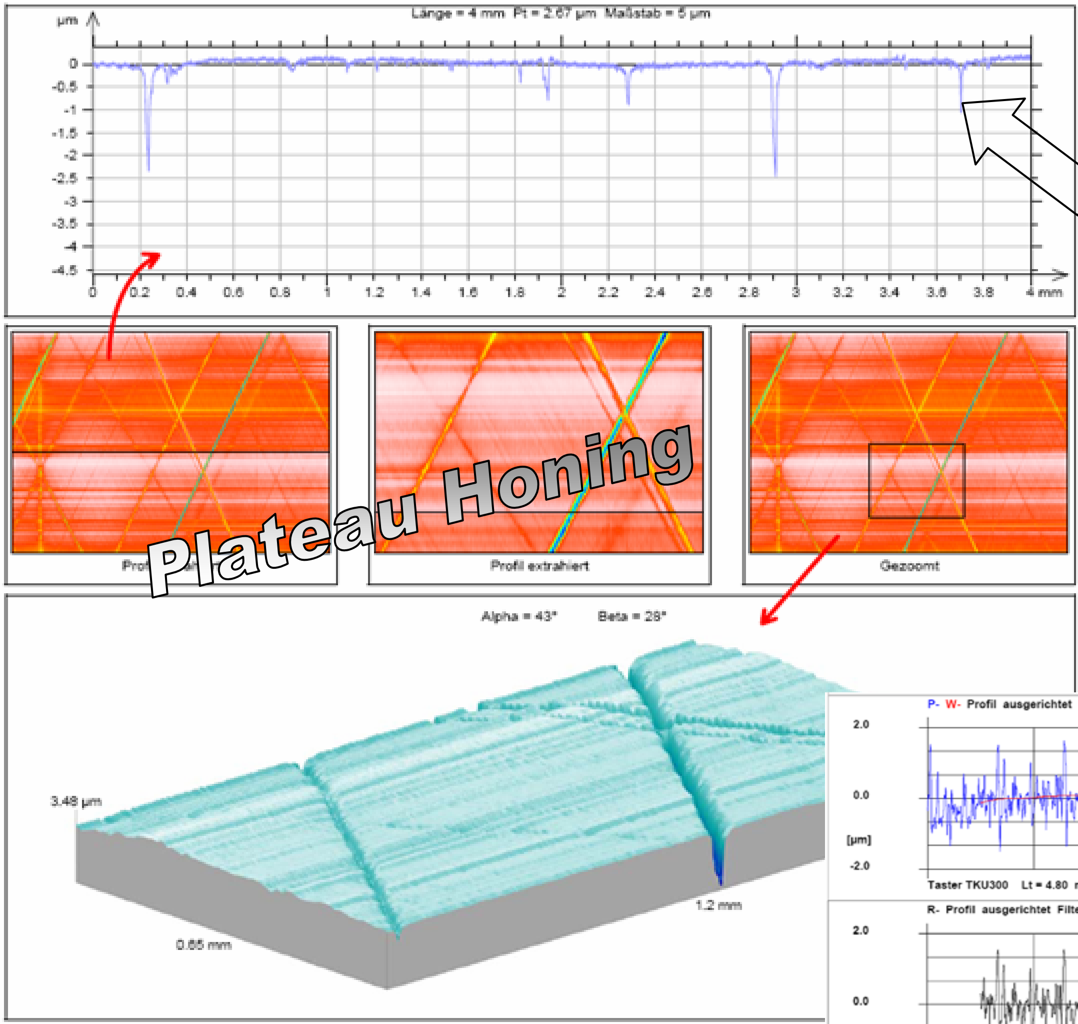
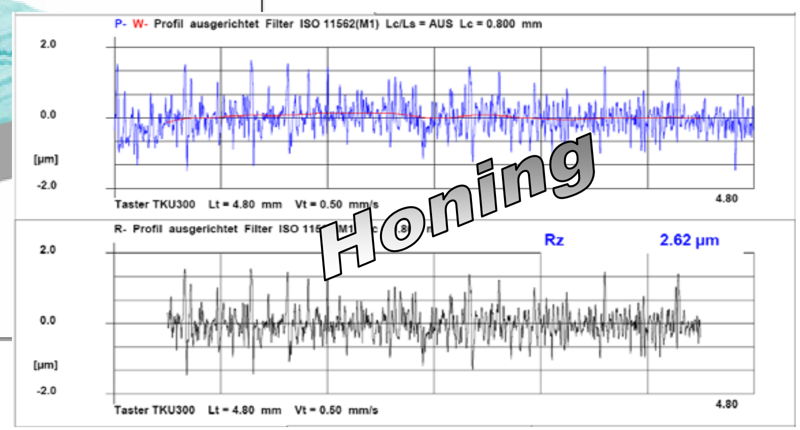


Diminished abrasivity due to flattened surface texture



Target I: Plateau Honing

ProHipp

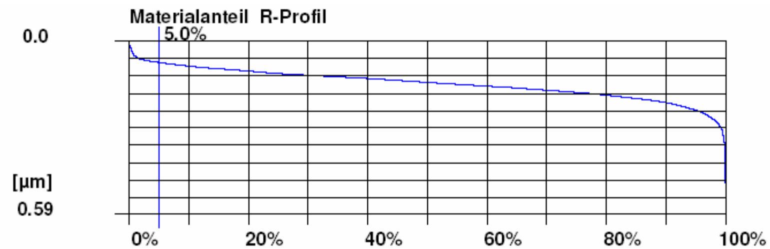
Definition of Surface (Recommendation)

Trelleborg:

Value for Surface Roughness			
Parameter	Mating Surface		Groove Surface
	Turcon	**Zurcon**	
R_{max}	0,63 - 2,50 µm	1,00 - 4,00 µm	≤ 16,0 µm
R_z	0,40 - 1,60 µm	0,63 - 2,50 µm	≤ 10,0 µm
R_a	0,05 - 0,20 µm	0,10 - 0,40 µm	≤ 1,6 µm

The material contact area R_{mr} should be approx. 50 – 70 %, determined at a cut depth c = 0,25 x R_z, relative to a reference line of c_{ref} 5%.

Rmr0	0.07 µm
Rmr01(5.0 %)	0.00 µm
Rmr02(10.0 %)	0.01 µm
Rmr03(15.0 %)	0.02 µm
Rmr04(20.0 %)	0.03 µm
Rmr05(25.0 %)	0.04 µm
Rmr06(30.0 %)	0.04 µm
Rmr07(35.0 %)	0.05 µm
Rmr08(40.0 %)	0.05 µm
Rmr09(45.0 %)	0.06 µm
Rmr10(50.0 %)	0.07 µm
Rmr11(55.0 %)	0.07 µm
Rmr12(60.0 %)	0.08 µm
Rmr13(65.0 %)	0.09 µm
Rmr14(70.0 %)	0.09 µm
Rmr15(75.0 %)	0.10 µm
Rmr16(80.0 %)	0.11 µm
Rmr17(85.0 %)	0.12 µm
Rmr18(90.0 %)	0.14 µm
Rmr19(95.0 %)	0.16 µm
Rmr20(100.0 %)	0.51 µm



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SEALING SOLUTIONS

Target I: Plateau Honing

Quality

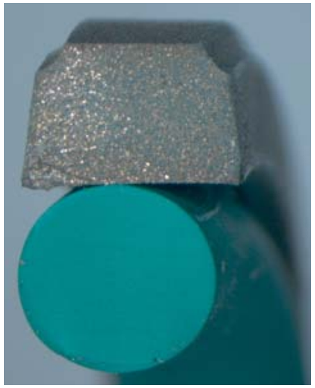
Tool

Recommendation

ID	Fecha inicio / Data start	Fecha final / Data end	Ø pistó / pist[illegible]	e[illegible]/ r[illegible]	C[illegible]er[illegible]	Ra	Rt	Rz	% T[illegible]	Proceso de bruñido / Honing process	ID tapon guia / ID Cylinder gland	ID piston
PH-M-136	25-6-2006	6-6[illegible]	5[illegible]	[illegible]	[illegible]	[illegible],25	2,42	3,23	67,9	STANDARD DINACIL	PH-M-136/T	PH-M-136/P
PH-M-137	25-6-2006	6-[illegible]20[illegible]	5[illegible]	[illegible]	[illegible]	[illegible],352	4,04	3,04	57,4	STANDARD DINACIL	PH-M-137/T	PH-M-137/P
PH-M-138	15-6-2006	21[illegible]6	4[illegible]	[illegible]	[illegible]	0,07	0,99	1,59	83,5	B5 + B5 ESPECIAL (AMB [illegible]NCRUSTRACIONS DE B46	PH-M-138/T	PH-M-138/P
PH-M-65	15-6-2006	21[illegible]2006	[illegible]	30	0,27	0,07	1,744	1,123	84	HONINTEC rough B-64 + [illegible] min.) B20 ACABAT	PH-M-65/T	PH-M-65/P
PH-M-73	28-4-2006	12-7-2006	[illegible]	30	0,27	0,357	5,012	3,349	81	HONINGTEC rough:B181 fini[illegible]9strokes B2[illegible]	PH-M-73/T	PH-M-73/P
PH-M-80	28-4-2006	12-7-2006	[illegible]0	30	0,27	0,449	6,007	3,756	79	HONINGTEC rough:B181 fini[illegible]strokes B[illegible]	PH-M-80/T	PH-M-80/P
PH-M-96	28-4-2006	12-7-2006	50	30	0,27	0,307	3,568	2,65	83	HONINGTEC rough:B64 finis[illegible]rokes[illegible]	PH-M-96/T	PH-M-96/P
PH-M-87	28-4-2006	12-7-200[illegible]	50	30	0,27	0,311	3,605	2,628	82	HONINGTEC rough:B64 fi[illegible]rokes B20	PH-M-87/T	PH-M-87/P
PH-M-63	28-4-2006	12-7-20[illegible]	50	30	0,27	0,748	6,217	4,666	76	HONINGTEC rough:B181 [illegible]n: 3 strokes [illegible]	[illegible]	[illegible]M-63/P
PH-M-79	28-4-2006	12-7-2[illegible]06	50	30	0,27	0,834	6,947	5,155	80	HONINGTEC rough:B181 finish:3strokes B20	[illegible]	[illegible]H-M-79/P
PH-M-95	28-4-2006	12-7-[illegible]006	50	30	0,27	0,187	3,061	2,016	84	HONINGTEC rough:B64 finish:6strokes B20	PH-M-9[illegible]	PH-M-95/P
PH-M-90	28-4-2006	12-7[illegible]2006	50	30	0,27	0,235	3,224	2,241	81	HONINGTEC rough:B64 finish:4strokes B20	PH-M-90/T	PH-M-90/P
PH-M-110	20-7-2006	28-[illegible]-2006	50	30	0,27	0,05	0,55	0,96	45,5	ESPECIAL DINACIL B5 (NO PRODUCCIÓ)	PH-M-73/T	PH-M-110/P
PH-M-111	20-7-2006	28[illegible]8-2006	50	30	0,27	0,08	0,79	0,98	62,3	ESPECIAL DINACIL B5 (NO PRODUCCIÓ)	PH-M-80/T	PH-M-111/P
PH-M-108	20-7-2006	2[illegible]-8-2006	50	30	0,27	0,05	0,75	1,22	92,2	ESPECIAL DINACIL B5 (NO PRODUCCIÓ)	PH-M-96/T	PH-M-108/P
PH-M-109	20-7-2006	[illegible]8-8-2006	50	30	0,27	0,07	0,91	1,4	76,1	ESPECIAL DINACIL B5 (NO PRODUCCIÓ)	PH-M-87/T	PH-M-109/P
PH-M-106	20-7-2006	[illegible]8-8-2006	50	30	0,27	0,05	0,67	1,16	94,2	ESPECIAL DINACIL B5 (NO PRODUCCIÓ)	PH-M-63/T	PH-M-106/P
PH-M-107	20-7-2006	[illegible]8-8-2006	50	30	0,27	0,07	0,71	0,85	66,9	ESPECIAL DINACIL B5 (NO PRODUCCIÓ)	PH-M-79/T	PH-M-107/P
PH-M-112			50	30		0,07	1,05	1,63	95,9	ESPECIAL DINACIL B5 (NO PRODUCCIÓ)	PH-M-95/T	PH-M-112/P
PH-M-113			50	30		0,[illegible]5	0,73	1,1	93,6	ESPECIAL DINACIL B5 (NO PRODUCCIÓ)	PH-M-90/T	PH-M-113/P
PH-M-114	26-07-06	29-07-06	50	30	0,275	0,0[illegible]	0,66	0,83	89,9	ESPECIAL DINACIL B5 (NO PRODUCCIÓ)		
PH-M-139	26-07-06	29-07-0[illegible]	50	30	0,275	0,08	1,12	1,72	[illegible]93	B5 + B5 ESPECIAL (AMB INCRUSTRACIONS DE B46)		
PH-M-91	20-11-06	15-03-[illegible]7	50	30	0,27	0,154	2,799	1,704	65,4	HONINGTEC B64 + B20 (6 Strokes)	PH-M-73/T	PH-M-91/P
PH-M-92	20-11-06	15-03[illegible]7	50	30	0,27	0,26	3,173	[illegible]	[illegible]	HONINGTEC B64 + B20 (2 Strokes)	PH-M-80/T	PH-M-92/P
PH-M-93	20-11-06	15-0[illegible]7	50	30	0,27	0,214	[illegible]	[illegible]	[illegible]	HONINGTEC B64 + B20 (4 Strokes)	PH-M-96/T	PH-M-93/P
PH-M-94	20-11-0[illegible]	[illegible]5-[illegible]07	50	30	0,27	0,197	[illegible]	[illegible]	[illegible]	HONINGTEC B64 + B20 (4 Strokes)	PH-M-87/T	PH-M-94/P
PH-M-100	20-11-0[illegible]	[illegible]07	50	30	0,27	[illegible]	[illegible]	[illegible]	94,3	HONINGTEC B64 + B20 (6 Strokes) - Tap guia 30.10	PH-M-100/T	PH-M-100/P
PH-M-101	20-11-0[illegible]	[illegible]07	50	30	0,27	[illegible]	[illegible]	1,628	63,1	HONINGTEC B64 + B20 (6 Strokes) -Tap guia 30.15	PH-M-101/T	PH-M-101/P
PH-M-78	13-04-07	[illegible]	50	30	[illegible]	[illegible]	[illegible]	3,269	81	HONINGTEC B91 + B20 (2 Strokes)	PH-M-91/T	PH-M-78/P
PH-M-82	13-04-07	[illegible]-08	50	[illegible]	[illegible]	[illegible]153	2,597	1,696	94,7	HONINGTEC B64 + B20 (6 Strokes) (W)	PH-M-92/T	PH-M-82/P
PH-M-98	13-04-07	[illegible]-07	[illegible]	[illegible]	[illegible]	0,449	4,198	3,239	83	HONINGTEC B91 + B20 (2 Strokes) (G)	PH-M-94/T	PH-M-98/P
PH-M-99	13-04-07	[illegible]08	[illegible]	[illegible]	0,27	0,303	3,911	2,763	86	HONINGTEC B91 + B20 (4 Strokes) (W)	PH-M-93/T	PH-M-99/P

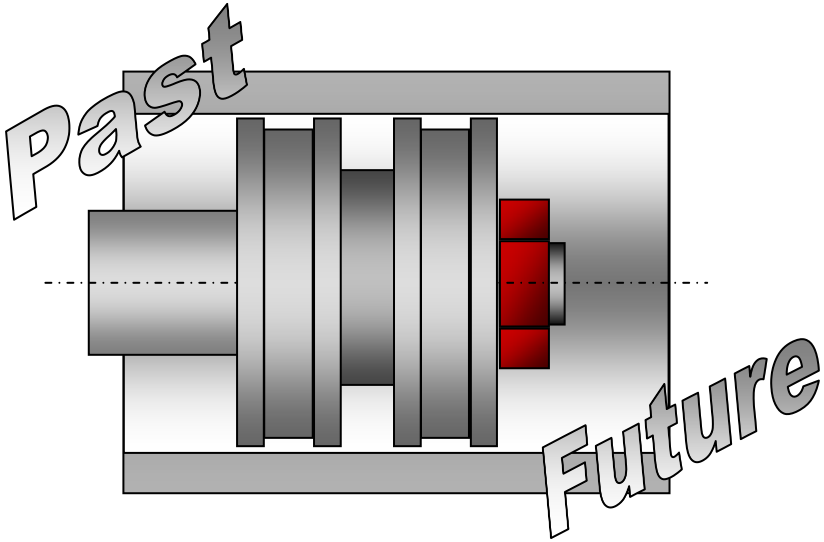
Value for Surface Roughness			
Parameter	Mating Surface		Groove Surface
	Turcon	Zurcon	
R_{max}	0,63 - 2,50 μm	1,00 - 4,00 μm	≤ 16,0 μm
R_z	0,40 - 1,60 μm	0,63 - 2,50 μm	≤ 10,0 μm
R_a	0,05 - 0,20 μm	0,10 - 0,40 μm	≤ 1,6 μm

Target II: New piston seal / compound

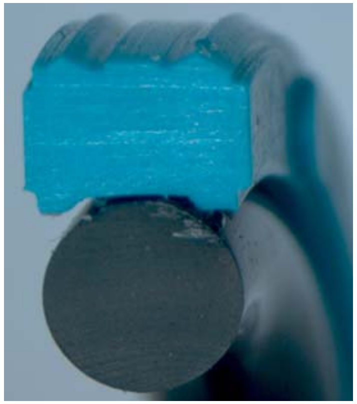


PTFE Glydringl

Benefit: proved state of the art; cost intensive solution



PU Wynseal



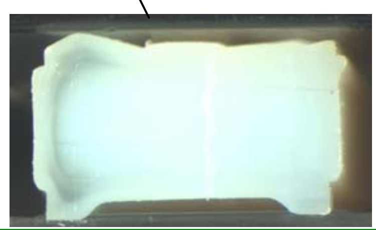
Benefit: Less abrasivity ; improved cost-benefit-ratio

Versus plateau-honing adapted profile / compound

TRELLEBORG

Target II: New piston seal / compound

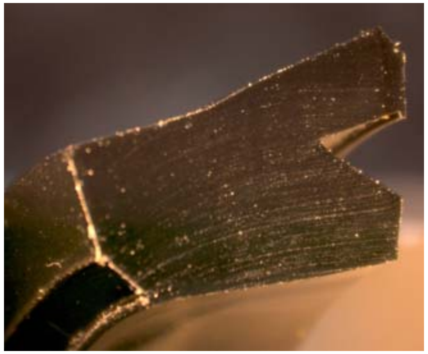
SEALING SOLUTIONS

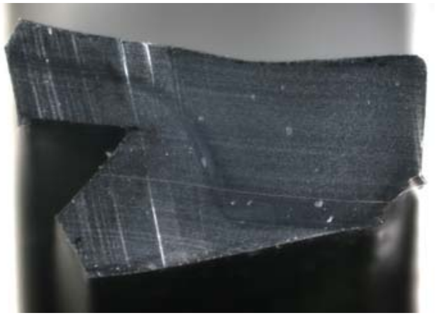


Commercial and production issues about to be clarified

Target III: Improve PU for rod seals

	Code	Hardness	Application features
Hydraulic	Z 20	93 Sh A	Hydraulic Standard Material
	Z 22	93 Sh A	Low temperature, < -45°C
	Z 23	96 Sh A	Reduced friction
	Z 24	93 Sh A	Hydrolysis resistant
	Z?	54 Sh D	high temperature resistance up to 120-130°C
Pneumatic	Z 30	83 Sh A	Pneumatic Standard Material
	Z 32	83 Sh A	Pneumatic low temperature + hydrolysis resistant





Compound proved to withstand 120 ÷ 130°C permanent operating temperature; to be introduced into series production; commercial and production issues about to be clarified

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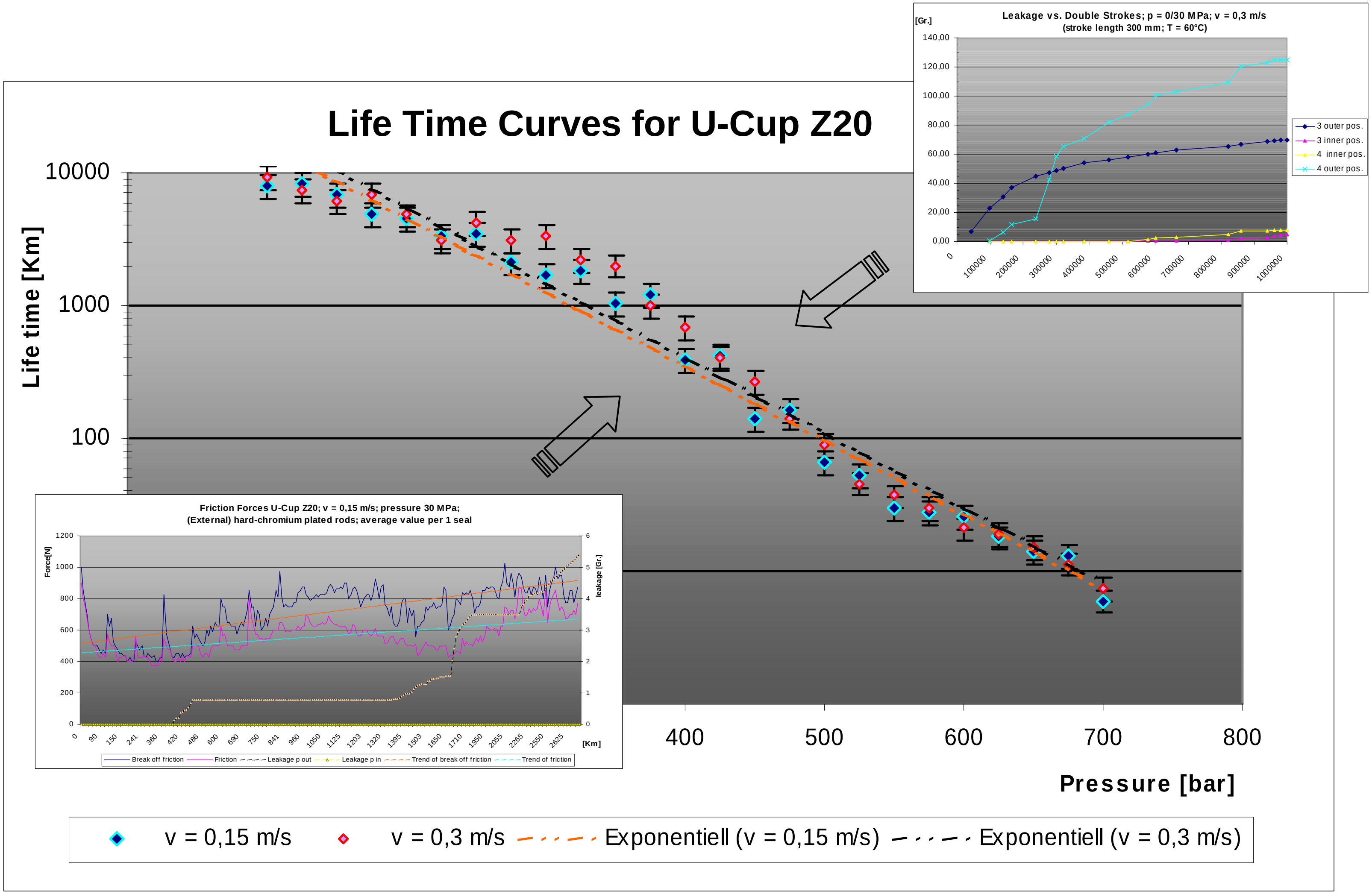
Target IV: Life Time Curves



ET-014-05

RA/RDCS
26.05.2087

WP VII: Demonstration