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Testing of the GRP casing "Kebudur GRP system" for continuous operating temperature 80°C Final report

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Order Letter dated 06.06.08

This expert opinion contains:

1 Cover
22 pages of text, of which
19 tables

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1 Introduction

Kebulin-Gesellschaft Kettler GmbH & Co. KG commissioned me to test a glass fibre reinforced plastic (GRP) coating**, the "Kebudur GRP System",** for coating steel pipes, steel fittings and welded joints for a continuous operating temperature of 80°C.

The tests were carried out in accordance with ISO/DIS 21809-3 (draft December 2007). In addition, tests were carried out on bendability in accordance with DIN EN 10290 and on shear resistance on PE factory cladding in accordance with DVGW worksheet GW 340.

The "Kebudur GRP system" consists of:

- Wound layers of polyester fleece and roving fabric and vinyl ester resin as a binding agent

The following test specimens were provided for testing:

- GRP-coated steel pipes DN 100, DN 150
  GRP/PE-coated steel pipes DN 100
- GRP/PP-coated steel pipes DN 100 GRP
  plates (50 • 50) mm
- GRP-coated flat steel samples (300 • 50 • 5.6) mm

2 Test

Tables 1 and 4 summarise the test conditions and requirements, and the test results are listed in the "Actual values" column. The corresponding individual values can be found in the tables.

3 Result

The tested GRP coating "Kebudur GRP System" essentially meets the requirements of ISO/DIS 21809-3. In addition, the shear strength meets the requirements of DVGW worksheet GW 340.

Deviations were found in the adhesion strength test on steel and on PE and PP factory coatings. Some of the values determined are significantly below the specified requirements.

Since the level of adhesion values is not significantly altered by hot water storage, this can be considered an indication of a durable coating.

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4 **Normative** references

DIN EN 10290	Steel pipes and fittings for onshore and offshore pipelines - Coatings (external coatings) with polyurethane and polyurethane-modified materials
DIN EN ISO 868	Plastics and hard rubber - Determination of indentation hardness with a durometer (Shore hardness)
DIN EN ISO 4624	Painting materials - Pull-off test for assessing adhesion (ISO 4624: 2002) German version EN ISO 4624: 2003
pr ISO/DIS 21809-3	Petroleum and natural gas industries - Coatings for pipelines laid in earth and water transport systems - Part 3: Coatings for welded joints
DVGW Worksheet 340	FZM coating for the mechanical protection of steel pipes and fittings with polyolefin coatings

Table 1

"Kebudur GRP system"

Tests	Test method	Test conditions		Requirements	lst value
Dry layer thickness	ISO 21809-3 Appendix A	Non-destructive testing, 12 measurements per part	(23 2)°C	›3.7 mm	(6.5 0.3) mm (6.4 0.2) mm (6.7 z 0.3) mm (6.6 0.3)mm (6.6 0.3) mm (6.4 z 0.2)mm Table 5
Pore test	ISO 21809-3 Appendix B	5kV / pm; max 25kV		Pore-free	Pore-free
Impact resistance	ISO 21809-3 Appendix G	Ball diameter: 25 mm; Drop height: 1 m Minimum distance between impact points: 50 mm; Impacts: 10 each; Pore test ISO 21809-3, Appendix B		5 • mm layer thickness	10 J/mm
			(-5 3)°C	› 1.5 J • mm layer thickness	s ? mm
Indentation resistance	ISO 21809-3 Appendix H	Stamp diameter: 1.8 mm; Stamp surface: 2.5 mm^2 Mass: 2.5 kg Load duration: 24 hours	(80 + 2)°C	s 10% of the initial layer thickness	(1.3 to 0.2)% Table 6
Flexibility	DIN EN 10290 Annex K	Test specimen: (50 • 300 • 6')min; v: 25 mm/min; Diameter of test stamp: 194 mm and 294 mm; Pore test ISO 21809-3. Annex B	(23 + 2)°C	e:294 without failure: (no cracks, delamination or defects) Pore-free at 25 kV	without defects
			(0 + 2)°C		

* actual thickness = 5.6 mm

Table 2

"Kebudur GRP system"

Tests	Test method	**Test conditions**		**Requirements**	Actual value
Cathodic underpinning	ISO 21809-3 Appendix F	3% NaCl; a= 6 mm; Ug: -1.26V Underpinning depth: 1 2 measurements	2d; (60 2)°C	Average values 8	(2.6 z 0.2)mm Table 7
			28d; (80 to 2)°C	Average values 15 mm	(11.1 ± 0.9) mm Table 7
Hardness: Shore "D"	DIN EN ISO 868	**Measurement without stand;** Distance between edges 9 mm, distance between measuring points: z 4 mm; placement without impact	(23 + 2)°C	Manufacturer's specificatio n: z60 without tripod	76 = 2 Table 8
Hate resistance on steel	ISO 4624	Test duration <90 sec; test stamp diameter: 20 mm	(23 2)°C	10.0 MPa	(5.9 to 1.2) MPa Table 9
Adhesion strength on factory packaging	ISO 4624			PE z3.5 MPa	(1s3 0.3) MPa Table 10
				pp	(2.3 z 0.9) MPa Table 11

Table 3

"I€ebudzzr-Gfl'X-Systeza"

Prüfungen	Prüfmethode	Prüfbedingung		Requirements		Actual value
f-laflIesügkeit zuoi stable ascb 28 d, hot water storage at Tg= 80°C	ISO 21809-3 *Anhangl+* ISO 4624	Test duration: 7 days, 14 days, 21 days and 28 days **Test solution: drinking water,** cut edges are outside the **solution or covered;** **After storage:** Adhesion test; test duration 90 sec; Test stamp diameter: 20 mm	(23 ± 2)°C	z7.0 MPa		7 days: (4.5 to 1.5) MPa 14d: (5.2 ± 1.5) MPa 21d: (6.5 ± 1.1) MPa 28 days: (6.0 1.3) MPa Table 12
Adhesion strength to the work envelope after 28 d, hot water la8‹xung at Tg= 80e C				z2.0 MPa	PE	7d: (1.6 0.8) MPa 14d: (1.6 -F 0.8) MPa 21d: (1.2 to 0.1) MPa 28d: (1.1 -s 0.3) MPa Tables 13 and 14
					PP	7d: (1.1 -s 0.2) MPa 14d: (1.1 + 0.2) MPa 21d: (1.1 0.2) MPa 28d: (1.3 a 0.3) MPa J'abeI1en 15 and 16
Specific electrical volume resistance	ISO 21809-3 Appendix K	*fct-'* 0.1mOhm; test voltage z50 V; sample area z0.03 m' Measure every week	(23 +2)°C; 100 d	10"f2 m² o = 0.8		(5.0 z 1.3) 10*' flm' a = 0.8 Table 17
			(80+2)e *' 30 d"	io•n n›*		(7.9 + 7.5) 10** f7m² Table 18

*Personal information

Table 4

"Kebudur GRP system"

Tests	Test method	Test condition	**Anforderungen**	Actual value
Shear resistance	GW 340 Section 6.5.4	Sample preparation: A 3-layer PE-coated steel pipe was with a GRP coating (thickness 3.5 mm to 4.0 mm) and a length of 50 mm) provided (23 + 2) °C (60 + 10) r.F. Test press: 5000 kN according to DIN EN l 2390-4 Test frequency: (80 to 10) N/s	50 N/cm^2	(1421 11) N/cm' Table 19

Table 5

Dry layer thickness

No	Dry layer thickness in pm										
1	6.1	6.9	6.3	6.5	6.7	6.9	6.5	b,8	6.8	6.5	5.6
	7.0	6.6	6.1	6.4	6.3	6.3	6.2	6.6	6.3	6.5	6.5
	6.7	6.2									
	Arithmetic mean and standard deviation 6.5 = 06										
2	6.7	6.4	6.6	6.7	6.7	6.4	6.5	6.3	6.5	6.3	6.4
	5.9	5.9	6.4	6.6	6.2	6.2	6.2	6.4	6.5	6.8	6.5
	6.3	6.7									
	Arithmetic mean and standard deviation 6.4 + 0.2										
3	6,8	6,6	6,8	6,4	6,9	6,3	6,9	6,4	6,8	6,5	6,7
	6,5	6,8	6,3	6,4	6,8	6,6	6,8	6,5	7,2	6,3	7,2
	6,5	7,3	6,6	7,2	6,9	6,9	6,7	6,8	6,8	6,8	
	Arithmetic mean and standard deviation 6 7 0										
4	6.9	6.7	7.1	6.1	6.4	6.3	6.7	6.5	6.5	7.0	6.9
	6.8	6.6	6.9	6.3	6.6	6.5	6.7	6.5	6.9	6.2	6.5
	6.4	6.7	6.3	5.9	6.8	6.5	6.8	6.6	7.0	6.2	
	Arithmetic mean and standard deviation 6.6 + 0.3										
5	6,5	7,1	7,0	7,0	6,9	7,1	6,6	6,7	6,5	7,0	6,7
	6,3	6,8	6,6	6,5	6,6	6,2	6,4	6,4	6,4	6,4	6,1
	6,3	6,5	6,5	5,8	6,7	6,9	6,3	6,6	7,0	6,8	6,9
	Arithmetic mean and standard deviation 6 6 + 0 3										
6	5,7	6,5	6,1	6,5	6,3	6,3	6,3	6,4	6,2	6,3	6,4
	6,4	6,4	6,1	6,3	6,2	6,7	6,3	6,6	6,4	6,5	6,3
	6,4	6,5	6,7	6,6	6,6	6,4	6,1	6,6	6,5	6,5	
	Arithmetic mean and standard deviation 6.4 + 0.2										

Table 6

Impression resistance			
No	Temperature ¡p ^{o}C	Initial layer thickness	
		Individual values	Arithmetic mean and standard deviation in mm
			in
1	(80 2)	1.0	1.3 + 0.2
3		1,3	
4		1,5	
5		1.0	
6		1.7	
7		1.3	

Table 7

Cathodic infiltration								
Test conditions	No.	Creepage depth in mm						
		Individual values				Arithmetic mean value and **standard deviation**		Maximum
2d, (60 + 2)°C	1	3.0	3.0	3.0	3	3.0 + 0.0	2.6 0.2	3.0
		3.0	3.0	3.0	3.0			
		3.0	3.0	3.0	3.0			
	2	2.5	2.5	2.5	2.5	2.5 0.0		2.5
		2.5	2.5	2.5	2.5			
		2.5	2.5	2.5	2.5			
	3	2.5	2.5	2.5	2.5	2.5 0.0		2.5
		2.5	2.5	2.5	2.5			
		2.5	2.5	2.5	2.5			
	4	2.5	2.5	2.5	2.5	2.5 0.0		2.5
		2.5	2.5	2.5	2.5			
		2.5	2.5	2.5	2.5			
28d, (80 + 2)•c	1	10.0	11s0	11.0	13.0	12.2 + 1.0	11.1 + 0.9	13.0
		13.0	13.0	13.0	13.0			
		13.0	12.0	12.0	12.0			
	2	12.0	11.0	9.0	10.0	10.8 1.0		12.0
		12.0	12.0	12.0	10.0			
		10.0	10.0	11.0	11.0			
	3	9.0	9.0	10.0	10.0	9.8 0.4		10.0
		10.0	10.0	10.0	10.0			
		10.0	10.0	10.0	10.0			
	4	12.0	12.0	13.0	12.0	11.4 z 1.7		13.0
		13.0	13.0	10.0	8.0			
		8.0	12.0	12.0	12.0			

Table 8

Shore hardness "D"

No	Target: z 60 single value	Arithmetic mean and standard deviation
1	78	76 = 2
2	72	
3	73	
4	78	
5	76	
6	78	
7	79	
8	78	
9	76	
10	73	

Table 9

Adhesion strength on steel				
No	force	Arithmetic mean value uad Standard deviation Deviation	separation	
	in MPa or in (N / mm°)		Adhesive	kohäsiv
1	6.7	5.9 + 1.2		100% GRP
2	6.4		80% GRP / steel tube	20% GRP
3	6.9		100% GRP / steel tube	
4	5.5		100% GRP / steel tube	-
5	4.7		90% GRP / steel tube	10% GRP
6	6.9		40% GRP / steel tube	60% GRP
Y	3.0			100% GRP
8	7.1		100% GRP / steel tube	
9	5.2		100% GRP / steel tube	-
J0	6.4		100% GRP / steel tube	-

Table 10

Tensile strength on factory packaging

Nr.	Force	arithmetic mean value and standard deviation abweichung	separation	
	in MPa or in (N / mm')		adhesive	cohesive
	Factory packaging: F		; (storage: 0h)	
1	2.0	s 1.3 + 0.8	100% GRP / PE	-
2	3.3		90% stamp / GRP	10% GRP
3	2.1		-	100% GRP
4	<0.8		100% stamp / GRP	-
5	<0.8		100% stamp / GRP	-
6	<0.8		100% GRP/PE	-
7	<0.8		100% GRP / PE	
8	1.3		100% GRP / PE	
9	<0.7		100% GRP / PE	
10	0.8		100% GRP / PE	-
		Factory packaging: F	; (storage: 0h)	
1	2.0	2.3 0.9	100 % stamp / GRP	-
2	1.7		100% stamp / GRP	-
3	3.1		100% stamp / GRP	-
4	2.5		100% moulded / GRP	-
5	2.1		100% stamp / GRP	
6	2.3		100% stamp / GRP	-
7	3.9		90% stamp / GRP	10% GRP
8	0.5		1 00% GRP/PP	-
9	2.6		100% GRP / PP	-
10	1.8		100% GRP / PP	-

Table 11 Adhesion

strength on steel after hot water storage

No.	Force Arithmetic mean and standard deviation in MPa or in (N / mi ^{2})		separation	
			B£ÏÏ¥ÏtSfiV	kOÏtÏiSlV
	Storage		Time: 7 days	
1	5.0	4.5 1.5	100% GRP / steel tube	-
2	6.2		100% GRP / steel tube	-
3	3.3		100% GRP / steel tube	-
4	3.4		100% GRP / steel tube	
5	5.1		100% stamp / GRP	-
6	5.2		100% stamp / GRP	-
7	1,1			100% GRP
8	4.5			100% GRP
9	5		100% stamp / GRP	-
10	6.6		100% stamp / GRP	-
		Storage	Time: 14 days	
1	4.4	5.2 1.5	95% GRP / steel pipe	5% GRP
2	7.3		95% GRP / steel tube	5% GRP
3	4.2		95% GRP / steel tube	5% GRP
4	6.4		80% GRP / steel tube	20% GRP
5	6.4		100% GRP / steel pipe	-
6	2.6		80% GRP / steel tube	20% GRP
7	5.6		80% GRP / steel tube	20% GRP
8	5.2		95% GRP / steel tube	5% GRP
9	6.5		70% GRP / steel tube	30% GRP
10	2.9			100% GRP

Table 12 Adhesion

strength on steel after immersion in water

No	Force Arithmetic mean and standard deviation in MPa bmv. io (N / ww2)		separation	
			adhesive	cohesive
		Outsourcing	Time: 21 days	
1	5.2	6.5 + 1.1	90% GRP / steel tube	10% GRP
2	6.4		100% GRP / steel tube	-
3	7.3		95% GRP / steel tube	5% GRP
4	6.4		90% GRP / steel tube	10% GRP
5	7.7		70% GRP / steel tube	30% GRP
6	6.2		70% GRP / steel tube	30% GRP
7	8.2		70% GRP / steel tube	30% GRP
8	7.3		-	100% GRP
9	4.4		100% GRP / steel tube	
10	5.5		100% GRP / steel tube	
		Storage	Time: 28 days	
1	6.6	6.0 1.3	70% GRP / steel tube	30% GRP
2	3.7		95% GRP / steel tube	5% GRP
3	4.7		98% GRP / steel tube	2% GRP
4	5.4		98% GRP / steel tube	2% GRP
5	7.7		98% GRP / steel tube	2% GRP
6	4.9		90% GRP / steel tube	10% GRP
7	5.6		-	100% GRP
8	7.0		70% GRP / steel tube	30% GRP
9	8.1		70% GRP / steel tube	30% GRP
10	6.4		70% GRP / steel tube	30% GRP

Table 13

Adhesive strength on factory coating

Nz.	force	Arithmetic mean and Standard deviation in MPa orin(N/mm°)	separation	
			adhesive	cohesive
Factory packaging: PE; (storage: 7 days)				
1	1.3	1.6 + 0.8	100% GRP / PE	
2	1.2		100% GRP / PE	
3	l,l		100% GRP / PE	
4	4.1		100% GRP / PE	
5	1.4		100% GRP / PE	
6	1.5		100% GRP / PE	
7	1.6		100% GRP/PE	
8	1.3		100% GRP / PE	
9	1.3		100% GRP / PE	
10	1.6		100% GRP / PE	-
		Factory wrapping: **PE;** (storage: **14 days)**		
1	l,l	1.2 0.1	100% GRP / PE	-
2	1.1		100% GRP / PE	
3	1.0		100% GRP / PE	-
4	1.3		100% GRP / PE	-
5	1.3		100% GRP / PE	
6	t,2		100% GRP / PE	-
7	1.0		100% GRP / PE	-
8	1.2		100% GRP/PE	
9	i,i		100% GRP / PE	-
10	1.2		100% GRP / PE	

Table 14

Adhesive strength on factory coating

No. Nr.	Kraft force arithmetischer Mittelwert und Standardabweichung in MPa bzw. in (N / mm²) or in (N / mm²)		separation	
			Adhesive	cohesive
Factory packaging: PE;			(storage: 21 days)	
1	0.7	1.2+0.3	100% GRP / PE	-
2	1.2		100% GRP / PE	
3	1.2		100% GRP / PE	
4	1.6		100% GRP / PE	
s	*I,s*		100% GRP / PE	
6	1.1		100% GRP / PE	
7	1.2		100% GRP / PE	
8	1.4		100% GRP / PE	
9	0.7		100% GRP / PE	
10	1.2		100% GRP / PE	-
		Factory wrapping: PE;	(Storage: 28 days)	
1	0.8	1.1 0.3	100% GRP / PE	
2	0.9		100% GRP / PE	
3	1.0		100% GRP / PE	
4	1.1		100% GRP / PE	
5	0.8		100% GRP / PE	
6	1.3		100% GRP / PE	
7	1.0		100% GRP/PE	
8	1.7		100% GRP / PE	
9	1.3		100% GRP / PE	
10	1.2		100% GRP / PE	-

Table 15

Adhesive strength on factory packaging

No	Force	Arithmetic mean and standard deviation in MPa or in (N / mm°)	Adhesive	
			separation	cohesive
	Werhsuinbüllung: PP; (outsourcing: 7d)			
1	0.8	1.1 0.2	100% GRP / PP	
2	1.3		100% GRP / PP	
3	1.0		100% GRP / PP	
4	1.4		100% GRP / PP	
5	1.2		100% GRP / PP	
6	1.1		100% GRP / PP	
7	1.4		100% GRP / PP	
8	1.4		100% GRP / PP	
9	1.1		100% GRP / PP	
10	0.8		100% GRP / PP	
				-
	Factory wrapping: **PP;** (storage: **14 days)**			
1	0.7		100% GRP / PP	
2	1.3	1.2 + 0.2	100% GRP / PP	
3	1.3		100% GRP / PP	
4	1.0		100% €iFK / PP	
5	1.1		100% GRP/PP	
6	1.0		100% GRP / PP	
7	1.2		100% GRP / PP	
8	1.5		100% GRP / PP	
9	0.9		100% GRP / PP	
10	1.2		100% GRP / PP	
				-

Table 16

Adhesive strength on factory packaging

No	Kraft Force bzw. in MPa or in (N / mm²)	Arithmetic mean and standard deviation arithmetischer Mittelwert und Standardabweichung in MPa	separation	
			adhesive	cohesive
Factory packaging: PP;			(Storage: 21d)	
i	1.0	1,1 + 0.2	100% GRP / PP	
2	1.2		100% €iFK / PP	
3	1.2		100% GRP/PP	
4	1.2		100% GRP / PP	
5	0.8		100% GRP / PP	
6	1.5		100% GRP / PP	
7	1.2		100% GRP / PP	
8	t,3		100% GRP / PP	
9	0.9		100% GRP / PP	
10	0.8		100% GRP / PP	-
		Factory coating: PP;	(Storage: 28 days)	
1	0.9	1.3 0.3	100% GRP / PP	
2	1.7		100% GRP / PP	
3	1.4		100% GRP / PP	
4	1.6		100% GRP / PP	
5	1.2		100% GRP/PP	
6	1.5		100% GRP / PP	
7	1.2		100% GRP / PP	
8	1.7		100% GRP / PP	
9	1.2		100% GRP / PP	
10	1.0		100% GRP / PP	-

Table 17

Specific electrical volume resistivity

No	Specific electrical envelope resistance in II m² at (23 2)° C				$a \cdot \frac{R_{s100}}{c70} > 0.8$
	Individual values			Arithmetic mean and standard deviation after 100 d	
	Acceleration time in d				
	3	7	14		
	21	28	35		
	42	49	56		
	63	70	77		
	84	91	100		
1	55.0 10"	36.7 10"	19.1 10"		1.3
	12.3 10+	9.4 10+'	7.9 10°		
	6.6 l0+'	9.0 10	9.0 10°		
	6.3 10+'	5.2 10+'	6.0 10+'		
	9.2 10+	4.9 10+	6.8 10		
2	7.3 10°	6.1 10°	4.2 10"		1.2
	3.1 10°'	2.2 10°'	2.2 10°'		
	2.1 10+	2.3 10+'	2.8 10"	(5.0 + 1.3) 10"	
	2.6 10"	3.3 10°'	3.8 10+'		
	5.4 10°	4.9 10°'	4.1 l0+'		
3	17.6 10+'	13.3 10+'	5.2 10°'		1.3
	4.1 10+'	3.9 10°	3.2 10°		
	2.8 10"	3.3 10"	3.2 10°		
	2.7 10"	3.1 10°'	3.5 10°'		
	4.9 10°'	4.9 10+'	4.0 10°'		

Table 18

Specific electrical envelope resistance

No	Specific electrical sheath resistance ›,n*' at (80 6 2)° C		
	Individual values		Arithmetic mean and standard deviation after 30 days
	Test duration in days		
	3	7	
	14	21	
	30		
1	>19.6 10"	>19.6 10°	(7.9 + 7.5) 10+'
	11.5 10	7.5 10"	
	1.8 10	-	
2	7.0 10	6.5 10+	
	6.1 10"	1.7 10"	
	0.56 10	-	
3	3.3 10"	1.4 10"	
	(1.53 II"	Ö Ö 1(l"	
	0.68 10"	-	

Table 19

"z" DVGW worksheet GW 340

Shear resistance			
No	Temperature in °	Shear resistance in N/cm'	
		Individual values	Arithmetic mean and standard deviation
1	(23 2)^0	130	142 11
2		156	
3		139	