Under pressure: An IKT tester determines flexural strength at the point when a liner sample ruptures.

IKT-LinerReport 2017

CIPP Liner Quality: The Need to Pass all Four Tests

Too many liners still do not meet all four of the test criteria. They may pass individual criteria, but only those samples that pass all four can be considered really good.

by Roland W. Waniek, Dieter Homann and Barbara Grunewald

For the fourteenth year running, IKT - Institute for Underground Infrastructure is pleased to present its annual LinerReport. This sets out the results from over 2,100 liner samples taken from rehabilitation sites for quality control purposes in 2017 and tested by the IKT CIPP Liner Test Centre. Details of the contractors, lining systems and sample numbers are shown in Table 1.

Determining target performance for samples

As in previous years, the modulus of elasticity, flexural strength, wall thickness and water-tightness have been determined for each sample submitted (for details, see box titled 'Overview of liner test and inspection criteria'). Pass/fail was assessed for each

Data used in the 2017 IKT LinerReport

- Number of liner samples: 2,152
- Of those: 1,898 were GRP liners and 254 needle felt liners
- Minimum sample number requirement for each rehabilitation contractor: 25 samples of one type of liner taken from at least five different rehabilitation sites
- Sample submission: 67% by sewer owners, 33% by rehabilitation contractors
- Countries of origin: Germany, UK, Netherlands, Austria, Switzerland, Czech Republic

sample by comparison of results against its target performance, derived either from the liner's DIBt (German Institute for Building Technology) approval specification (Netherlands: KOMO Certificate; Switzerland: QUICK Guidelines) or as specified by the client (e.g. structural-analysis calculations).

Modulus of elasticity test – 2017 results slightly weaker

On average, 97.4% of the liners reached their required modulus of elasticity (Table 2). This result was 1.5% lower than 2016 and 1.7% lower than 2015, the year when the highest score was achieved in any of the previous IKT LinerReports. However, this does not necessarily indicate a trend. Fifteen out of the 25 rehabilitation companies in this year's survey achieved 100% for this test, one of them for two different liner systems.

Flexural strength test – 2017 results also weaker

The flexural strength test results (Table 3) were similar to the Modulus of Elasticity, with the average result lower than in both previous years (-0.8% and -1.7%, respectively). Fourteen rehabilitation companies achieved a score of 100%, but the results were much more broadly distributed. The lowest-scoring company passed only 70% of the tests.

Wall thickness test – wide variation in results

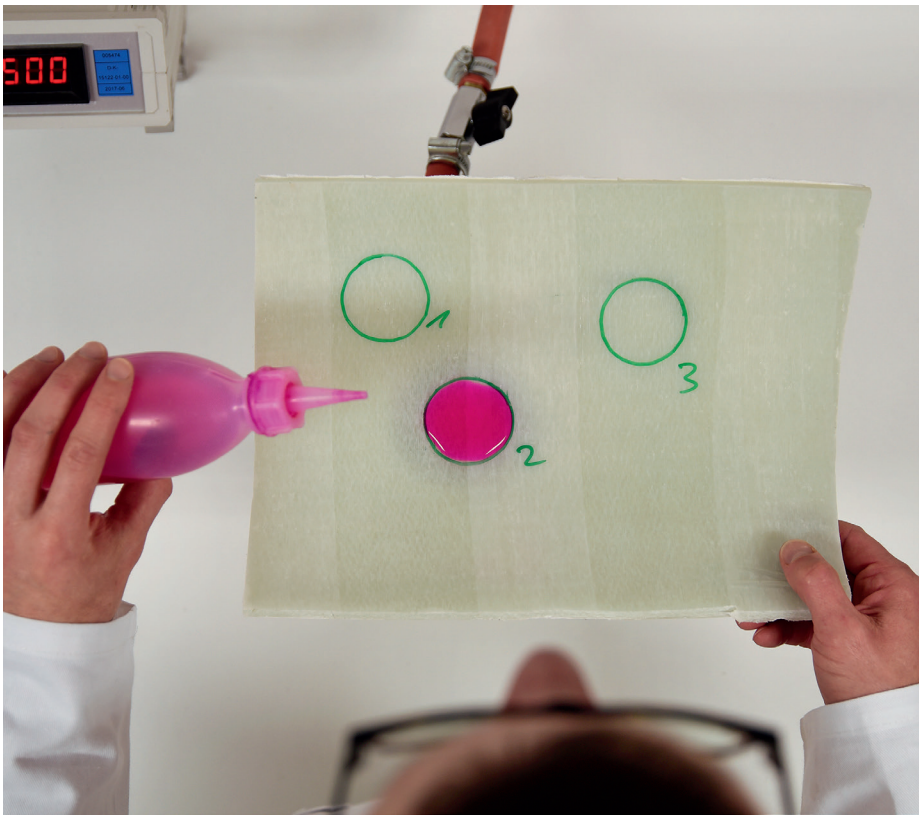
On average, the results of the wall thickness test (Table 4) were lower than for the two previous years: -1.7% compared to 2016 and -0.9% compared to 2015. The distribution of results for wall thickness was much greater than for the modulus of elasticity and flexural strength, with the lowest-scoring company passing 60% of the tests.

Water-tightness test – similar high results to last year

The water-tightness results (Table 5) remained at the same high average level as the previous year, with 99.1% of samples passing. This was the highest average score of all four test criteria. Seventeen rehabilitation companies passed all of the water-tightness tests.

Overall quality performance in 2017

Individually, the results for each test in 2017 were at a high level, with the average "pass" results for each test consistently above 95%. Numerous rehabilitation companies were able to achieve a score of 100% on one or more of the tests. However, the average values for the modulus of elasticity, flexural strength and wall thickness were lower than both previous years. Only the water-tightness test remained at the same high level as 2016 (Table 7).



Under vacuum pressure: the test fluid leaked through the laminate in very few samples.

Greater variability in test results

One concern is that the results for the four individual test criteria are much more broadly distributed around the average values than in previous years. The lowest scores in 2017 for the modulus of elasticity (80%), flexural strength (70%) and wall thickness (60%) were much worse than in previous years and are not acceptable results.

Importance of passing all four tests

Ideally, each liner sample should meet all four test criteria (modulus of elasticity, flexural strength, wall thickness and water-tightness). It is not sufficient for a sample to pass less than four criteria. This is especially important because the DWA-M 144-3 (ZTV rehabilitation – Supplementary Technical Contractual Conditions) explicitly uses these criteria for quality assessment. This ZTV is now a widely accepted stan-

Liner samples that met all four test criteria

– percentage of total number of liner samples –

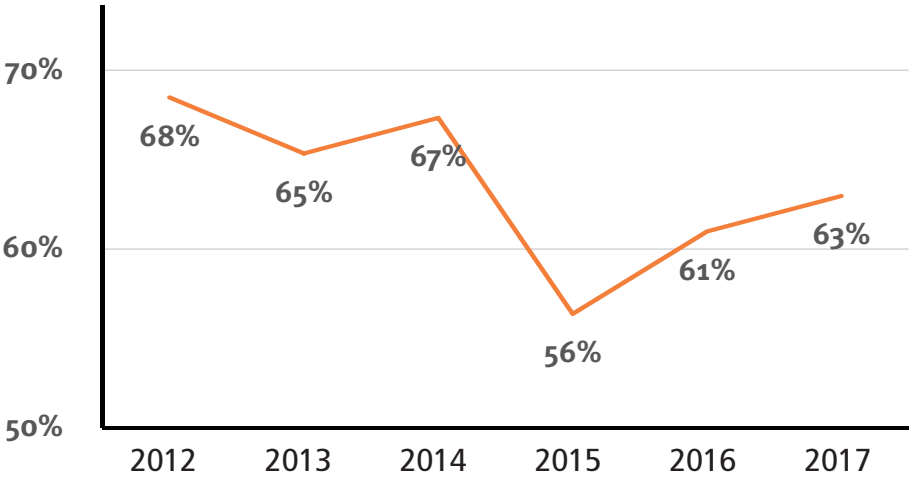


Diagram 1: Proportion (%) of liner samples passing all four test criteria each year

Of those that failed, most fulfilled three criteria and only a very small minority met fewer than three (see Diagram 2).

Liner samples by number of test criteria met

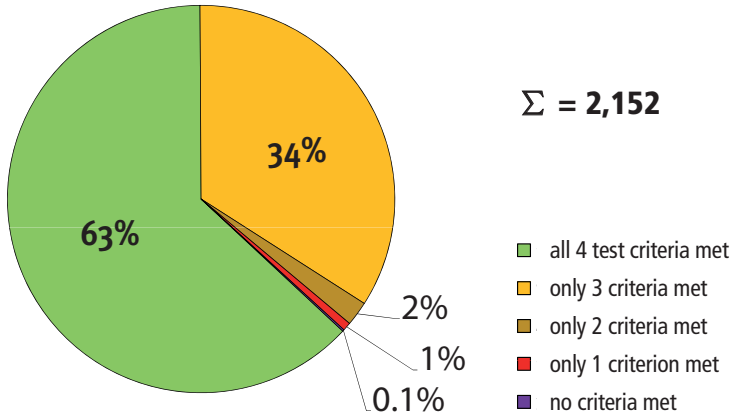


Diagram 2: Proportions (%) of liner samples passing test criteria in 2017

dard, and is used as the basis for most rehabilitation contracts.

The proportion of the liner samples tested in 2017 that actually met all four test criteria was 63% (previous year: 61%; see Diagram 1). While it is good that this rate has slightly improved on last year, it must be noted that more than one-third of the liner samples failed to meet one or more test criteria. Thus they do not meet the standards for high-quality sewer rehabilitation.

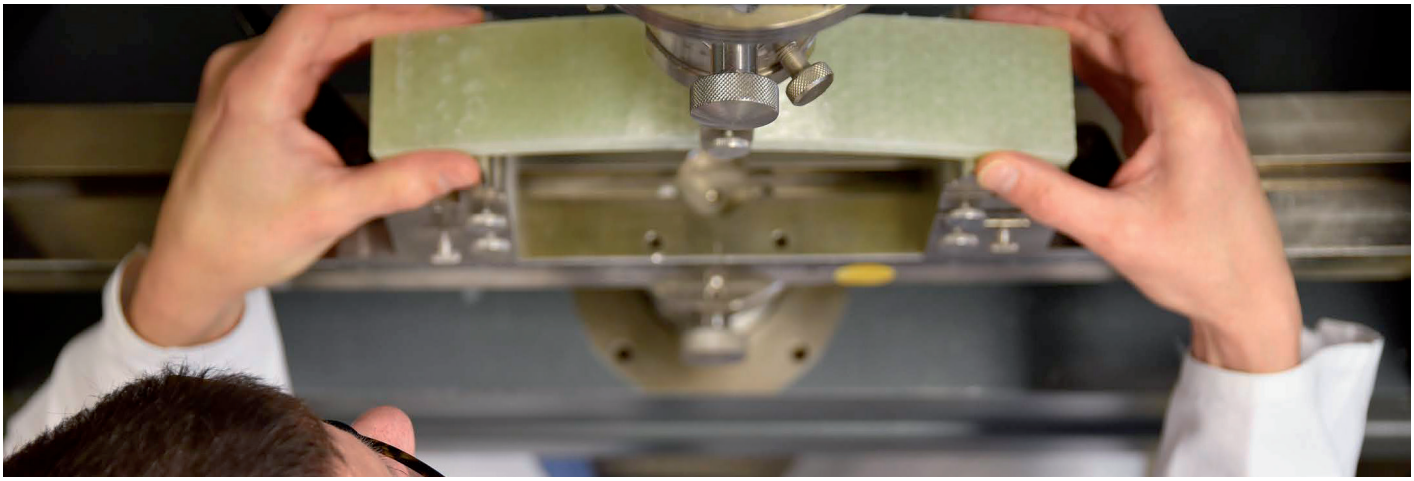
The top performing contractors in the 100% Club

The quality standards for liners are only met if samples pass all four test criteria. In 2017, 9 out of 25 rehabilitation companies achieved this goal (previous year: 5 out of 22), scoring 100% for all their samples. One company even achieved this top result for two different liner systems.

The nine rehabilitation companies made it into the 2017 '100% Club' are:

- Diringer & Scheidel Rohrsanierung, using the RS CityLiner
- Geiger Kanaltechnik, using the Alphaliner
- Hamers Leidingtechniek, using the Alphaliner
- Jeschke Umwelttechnik, using the Alphaliner **and** Brandenburger Liner
- Kanaltechnik Agricola, using the iMPREG Liner
- Koßmann Kanal- und Umwelttechnik, using the SAERTEX Liner
- KTF Kanal-Technik-Friess, using the iMPREG Liner
- LTS - Lilie Tief- und Straßenbau, using the SAERTEX Liner
- Max Bögl Stiftung, using the Brandenburger Liner

It is also important for clients to know whether a rehabilitation company delivered these top re-



sults for just one year, or whether it has done so consistently over several years. The "100% Club" graphic shows the companies that passed all of the tests for all four criteria over the last five years. Companies earn a star for each year between 2013 and 2017 in which they made it to the "100% Club." The more stars a company has, the more consistently it delivers the necessary top-quality rehabilitation results.

In summary: there is still room for improvement

The goal of the material tests on liners is for a sample to meet all four test criteria – modulus of elasticity, flexural strength, wall thickness and watertightness. Only 63% of the 2,152 liner samples tested by IKT in 2017 met that goal, while 37% failed one or more tests. The worst results were for wall thickness, which is especially important for structural stability.

This means a significant proportion of the liner samples did not achieve all of the target performance values established for them by certifications, structural calculations or the clients' stated requirements. In those cases, the goal of the lining process – to rehabilitate old pipes in such a way that they will last for decades – was only partially achieved.

The fact that this goal is achievable is shown by the nine rehabilitation companies that managed to meet all four criteria for all of their samples. Three of them have been able to consistently achieve this top result five years in a row. So it is not impossible.

What does that mean for the other rehabilitation companies? It means that there is still room for improvement. And for the clients? It means continuing to focus on quality assurance and to insist that all four test criteria are fulfilled, otherwise the permanence of the rehabilitation measures undertaken is questionable.

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Table 1: Rehabilitation contractors and liner systems, 2017

Contractor and countries (Germany unless indicated in brackets)	Liner systems	Liner-type	No. of samples	IKT testing commissioned by	
				Contractor %	Client %
Aarsleff Rohrsanierung GmbH	iMPREG liner	GRP	63	0.0	100.0
Aarsleff Rohrsanierung GmbH	PAA SF liner	NF	160	6.9	93.1
Arkil Inpipe GmbH	SAERTEX liner	GRP	57	0.0	100.0
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	Alphaliner	GRP	27	0.0	100.0
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	RS CityLiner	NF	30	76.7	23.3
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	SAERTEX Liner	GRP	61	0.0	100.0
Geiger Kanaltechnik GmbH & Co.KG	Alphaliner	GRP	84	17.9	82.1
GMB Rioleringstechnieken B.V. (NL)	SAERTEX liner	GRP	184	31.0	69.0
Hamers Leidingtechniek B.V. (NL)	Alphaliner	GRP	105	1.0	99.0
HF-Rohrtechnik GmbH (A)	Berolina liner	GRP	35	0.0	100.0
Insituform Rioolrenovatietechnieken B.V. (NL)	Brandenburger liner	GRP	25	8.0	92.0
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform CIPP liner (NL)	NF	64	26.6	73.4
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform iPlus Glass (NL)	GRP	30	0.0	100.0
ISS Kanal Services AG (CH)	Alphaliner	GRP	64	85.9	14.1
Jeschke Umwelttechnik GmbH	Alphaliner	GRP	128	75.0	25.0
Jeschke Umwelttechnik GmbH	Brandenburger liner	GRP	31	61.3	38.7
Kanaltec AG (CH)	Brandenburger liner	GRP	29	44.8	55.2
Kanaltechnik Agricola GmbH	iMPREG liner	GRP	46	34.8	65.2
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	GRP	74	9.5	90.5
Koßmann Kanal- und Umwelttechnik GmbH	SAERTEX liner	GRP	26	0.0	100.0
KTF GmbH	iMPREG liner	GRP	61	100.0	0.0
LTS - Lilie Tief- und Straßenbau GmbH	SAERTEX liner	GRP	47	76.6	23.4
Max Bögl Stiftung & Co. KG	Brandenburger liner	GRP	46*	0.0	100.0
OnSite Central Ltd (GB)	iMPREG liner	GRP	29	100.0	0.0
Rainer Kiel Kanalsanierung GmbH	SAERTEX liner	GRP	35	0.0	100.0
SKS-Servicecenter für Kanalsanierung GmbH	Alphaliner	GRP	33	60.6	39.4
Swietelsky-Faber Kanalsanierung GmbH	Brandenburger liner	GRP	41	14.6	85.4
Swietelsky-Faber Nederland Relining B.V. (NL)	Berolina liner	GRP	139	0.0	100.0
TKT GmbH &Co.KG	Alphaliner	GRP	118	52.5	47.5
Trasko a.s. (CZ)	Alphaliner	GRP	86	100.0	0.0
Umwelttechnik und Wasserbau GmbH	Alphaliner	GRP	163	27.0	73.0
Umwelttechnik und Wasserbau GmbH	Brandenburger liner	GRP	31	87.1	12.9
Total			**2,152**	**32.7**	**67.3**

GRP: Glass-fiber-reinforced backing material
NF: Needle-felt backing material
* from four rehabilitation projects

Table 2: Test results for modulus of elasticity, 2017 (short-term flexural modulus)

Contractors and countries (Germany unless indicated in brackets)	Liner systems	2017		2016	Trend
		No. of samples	Target* achieved in % of tests	Target* achieved in % of tests	
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	RS CityLiner	30	100	-	-
Geiger Kanaltechnik GmbH & Co.KG	Alphaliner	84		-	-
Hamers Leidingtechniek B.V.(NL)	Alphaliner	105		100	↔
HF-Rohrtechnik GmbH (A)	Berolina liner	35		-	-
ISS Kanal Services AG (CH)	Alphaliner	64		100	↔
Jeschke Umwelttechnik GmbH	Alphaliner	128		-	-
Jeschke Umwelttechnik GmbH	Brandenburger liner	31		100	↔
Kanaltechnik Agricola GmbH	iMPREG liner	45		100	↔
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	74		98.1	↑
Koßmann Kanal- und Umwelttechnik GmbH	SAERTEX liner	26		-	-
KTF GmbH	iMPREG liner	61		100	↔
LTS - Lilie Tief- und Straßenbau GmbH	SAERTEX liner	47		-	-
Max Bögl Stiftung & Co. KG	Brandenburger liner	44		97.8	↑
OnSite Central Ltd (GB)	iMPREG liner	29		-	-
SKS-Servicecenter für Kanalsanierung GmbH	Alphaliner	33		-	-
TKT GmbH &Co.KG	Alphaliner	118		99.4	↑
Aarsleff Rohrsanierung GmbH	PAA SF liner	160	99.4	96.7	↑
Aarsleff Rohrsanierung GmbH	iMPREG liner	63	98.4	100	↓
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	SAERTEX liner	61	98.4	-	-
Arkil Inpipe GmbH	SAERTEX liner	57	98.2	100	↓
Umwelttechnik und Wasserbau GmbH	Alphaliner	163	98.2	98.9	↓
Average			**97.4**	**98.9**	↓
Swietelsky-Faber Nederland Relining B.V. (NL)	Berolina liner	139	97.1	-	-
GMB Rioleringstechnieken B.V. (NL)	SAERTEX liner	183	96.7	97.0	↓
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	Alphaliner	27	96.3	-	-
Insituform Rioolrenovatietechnieken B.V. (NL)	Brandenburger liner	25	96.0	-	-
Rainer Kiel Kanalsanierung GmbH	SAERTEX liner	35	94.3	-	-
Trasko a.s. (CZ)	Alphaliner	86	94.2	100	↓
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform iPlus Glass (NL)	30	93.3	-	-
Swietelsky-Faber Kanalsanierung GmbH	Brandenburger liner	41	85.4	-	-
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform CIPP liner (NL)	64	84.4	96.6	↓
Kanaltec AG (CH)	Brandenburger liner	29	82.8	-	-
Umwelttechnik und Wasserbau GmbH	Brandenburger liner	30	80.0	-	-

* Target values in accordance with DIBt certification (or KOMO Certificate and QUIK Guidelines) or client's data (structural analysis/sample data record)
- Not evaluated, too few liner samples

Table 3: Test results for flexural strength, 2017 (short-term σ_{fb})

Contractors and countries (Germany unless indicated in brackets)	Liner systems	2017		2016	Trend
		No. of samples	Target* achieved in % of tests	Target* achieved in % of tests	
Arkil Inpipe GmbH	SAERTEX liner	57		96.3	↑
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	Alphaliner	27		-	-
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	RS CityLiner	30		-	-
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	SAERTEX liner	61		-	-
Geiger Kanaltechnik GmbH & Co.KG	Alphaliner	84		-	-
Hamers Leidingtechniek B.V.(NL)	Alphaliner	105		100	↔
HF-Rohrtechnik GmbH (A)	Berolina liner	35		-	-
ISS Kanal Services AG (CH)	Alphaliner	64		100	↔
Jeschke Umwelttechnik GmbH	Alphaliner	128	100	-	-
Jeschke Umwelttechnik GmbH	Brandenburger liner	31		100	↔
Kanaltechnik Agricola GmbH	iMPREG liner	45		100	↔
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	74		100	↔
Koßmann Kanal- und Umwelttechnik GmbH	SAERTEX liner	26		-	-
KTF GmbH	iMPREG liner	61		100	↔
LTS - Lilie Tief- und Straßenbau GmbH	SAERTEX liner	47		-	-
Max Bögl Stiftung & Co. KG	Brandenburger liner	44		100	↔
SKS-Servicecenter für Kanalsanierung GmbH	Alphaliner	33		-	-
Aarsleff Rohrsanierung GmbH	PAA SF liner	160	99.4	97.8	↑
TKT GmbH &Co.KG	Alphaliner	118	99.2	100	↓
Umwelttechnik und Wasserbau GmbH	Alphaliner	163	98.8	95.0	↑
Average			**97.6**	**98.4**	↓
Rainer Kiel Kanalsanierung GmbH	SAERTEX liner	35	97.1	-	-
Swietelsky-Faber Nederland Relining B.V. (NL)	Berolina liner	139	97.1	-	-
GMB Rioleringstechnieken B.V. (NL)	SAERTEX liner	183	96.7	96.3	↑
OnSite Central Ltd (GB)	iMPREG liner	29	96.6	-	-
Trasko a.s. (CZ)	Alphaliner	86	96.5	100	↓
Aarsleff Rohrsanierung GmbH	iMPREG liner	63	93.7	97.5	↓
Kanaltec AG (CH)	Brandenburger liner	29	93.1	-	-
Insituform Rioolrenovatietechnieken B.V. (NL)	Brandenburger liner	25	92.0	-	-
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform CIPP liner (NL)	64	90.6	98.0	↓
Umwelttechnik und Wasserbau GmbH	Brandenburger liner	30	90.0	-	-
Swietelsky-Faber Kanalsanierung GmbH	Brandenburger liner	41	85.4	-	-
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform iPlus Glass (NL)	30	70.0	-	-

* Target values in accordance with DIBt certification (or KOMO Certificate and QUIK Guidelines) or client's data (structural analysis/sample data record)
- Not evaluated, too few liner samples

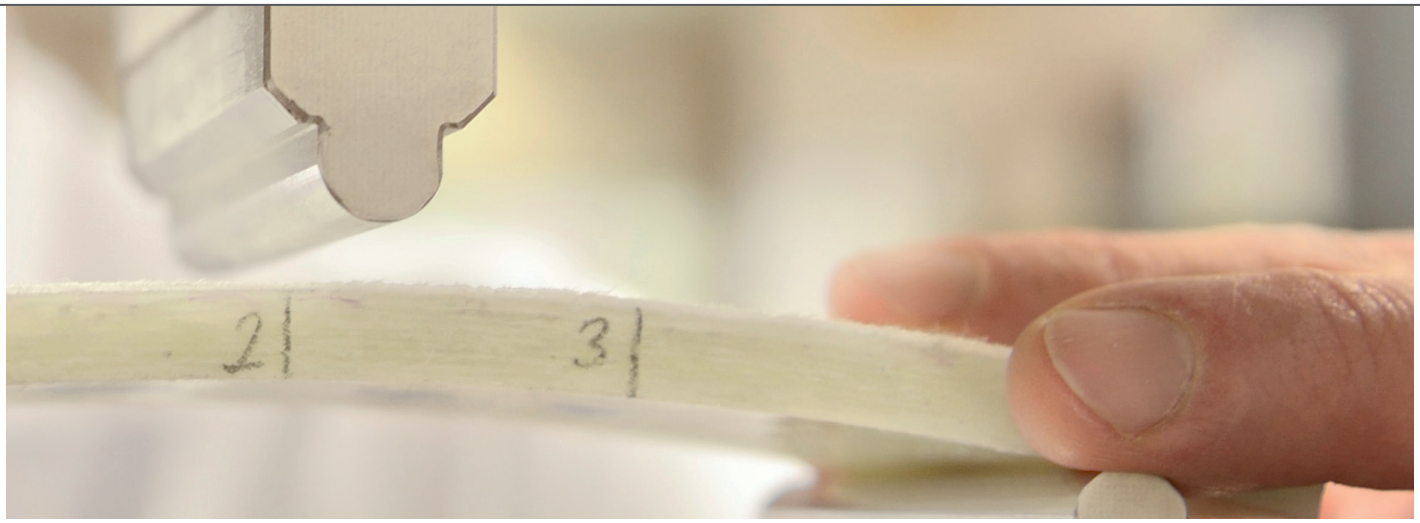

Table 4: Test results for wall thickness, 2017 (average combined thickness in acc. with DIN EN ISO 11296, Part 4)

Contractors and countries (Germany unless indicated in brackets)	Liner systems	2017		2016	Trend
		No. of samples	Target* achieved in % of tests	Target* achieved in % of tests	
Aarsleff Rohrsanierung GmbH	iMPREG liner	40	100	93.5	↑
Aarsleff Rohrsanierung GmbH	PAA SF liner	90		96.9	↑
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	RS CityLiner	28		-	-
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	SAERTEX liner	39		-	-
Geiger Kanaltechnik GmbH & Co.KG	Alphaliner	54		-	-
Hamers Leidingtechniek B.V.(NL)	Alphaliner	105		100	↔
Jeschke Umwelttechnik GmbH	Alphaliner	106		-	-
Jeschke Umwelttechnik GmbH	Brandenburger liner	31		100	↔
Kanaltechnik Agricola GmbH	iMPREG liner	46		100	↔
Koßmann Kanal- und Umwelttechnik GmbH	SAERTEX liner	11		-	-
KTF GmbH	iMPREG liner	61		100	↔
LTS - Lilie Tief- und Straßenbau GmbH	SAERTEX liner	22		-	-
Max Bögl Stiftung & Co. KG	Brandenburger liner	12		100	↔
Rainer Kiel Kanalsanierung GmbH	SAERTEX liner	23		-	-
ISS Kanal Services AG (CH)	Alphaliner	62	98.4	97.5	↑
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	64	98.4	93.5	↑
GMB Rioleringstechnieken B.V. (NL)	SAERTEX liner	183	97.8	99.3	↓
Umwelttechnik und Wasserbau GmbH	Alphaliner	70	97.1	98.6	↓
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform CIPP liner (NL)	64	96.9	98.5	↓
SKS-Servicecenter für Kanalsanierung GmbH	Alphaliner	22	95.5	-	-
Average			**94.5**	**96.2**	↓
Trasko a.s. (CZ)	Alphaliner	86	94.2	87.5	↑
Insituform Rioolrenovatietechnieken B.V. (NL)	Brandenburger liner	25	92.0	-	-
Umwelttechnik und Wasserbau GmbH	Brandenburger liner	23	91.3	-	-
Swietelsky-Faber Kanalsanierung GmbH	Brandenburger liner	11	90.9	-	-
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	Alphaliner	20	90.0	-	-
TKT GmbH &Co.KG	Alphaliner	41	82.9	91.7	↓
Kanaltec AG (CH)	Brandenburger liner	14	78.6	-	-
Swietelsky-Faber Nederland Relining B.V. (NL)	Berolina liner	133	70.7	-	-
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform iPlus Glass (NL)	30	60.0	-	-
Arkil Inpipe GmbH	SAERTEX liner	-	-	-	-
HF-Rohrtechnik GmbH (A)	Berolina liner	-	-	-	-
OnSite Central Ltd (GB)	iMPREG liner	-	-	-	-

* Target values in accordance with DIBt certification (or KOMO Certificate and QUIK Guidelines) or client's data (structural analysis/sample data record)
- Not evaluated, too few liner samples

Table 5: Test results for water-tightness, 2017

Contractors and countries (Germany unless indicated in brackets)	Liner systems	2017		2016	Trend
		No. of samples	Watertight in % of tests	Watertight in % of tests	
Aarsleff Rohrsanierung GmbH	iMPREG liner	63	100	94.4	↑
Aarsleff Rohrsanierung GmbH	PAA SF liner *	160		98.8	↑
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	Alphaliner	27		-	-
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	RS CityLiner**	30		-	-
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	SAERTEX liner	61		-	-
Geiger Kanaltechnik GmbH & Co.KG	Alphaliner	80		-	-
Hamers Leidingtechniek B.V.(NL)	Alphaliner	105		100	↔
HF-Rohrtechnik GmbH (A)	Berolina liner	35		-	-
Insituform Rioolrenovatietechnieken B.V. (NL)	Brandenburger liner	25		-	-
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform CIPP liner (NL) *	54		100	↔
Jeschke Umwelttechnik GmbH	Alphaliner	128		-	-
Jeschke Umwelttechnik GmbH	Brandenburger liner	31		100	↔
Kanaltec AG (CH)	Brandenburger liner	29		-	-
Kanaltechnik Agricola GmbH	iMPREG liner	46		100	↔
KATEC Kanaltechnik Müller und Wahl GmbH	Alphaliner	74		96.2	↑
Koßmann Kanal- und Umwelttechnik GmbH	SAERTEX liner	26		-	-
KTF GmbH	iMPREG liner	54		100	↔
LTS - Lilie Tief- und Straßenbau GmbH	SAERTEX liner	47		-	-
Max Bögl Stiftung & Co. KG	Brandenburger liner	46		100	↔
Rainer Kiel Kanalsanierung GmbH	SAERTEX liner	35		-	-
Swietelsky-Faber Kanalsanierung GmbH	Brandenburger liner	41		-	-
Umwelttechnik und Wasserbau GmbH	Brandenburger liner	28		-	-
GMB Rioleringstechnieken B.V. (NL)	SAERTEX liner	184	99.5	98.4	↑
Average			**99.1**	**99.1**	↔
Trasko a.s. (CZ)	Alphaliner	86	98.8	100	↓
Swietelsky-Faber Nederland Relining B.V. (NL)	Berolina liner	139	98.6	-	-
TKT GmbH &Co.KG	Alphaliner	118	98.3	99.4	↓
Arkil Inpipe GmbH	SAERTEX liner	57	98.2	100	↓
ISS Kanal Services AG (CH)	Alphaliner	56	98.2	100	↓
Umwelttechnik und Wasserbau GmbH	Alphaliner	161	98.1	99.4	↓
SKS-Servicecenter für Kanalsanierung GmbH	Alphaliner	32	96.9	-	-
Insituform Rioolrenovatietechnieken B.V. (NL)	Insituform iPlus Glass (NL)	30	90.0	-	-
OnSite Central Ltd (GB)	iMPREG liner	29	86.2	-	-

* No cutting of integrated inner film
** No cutting of integrated outer film
- Not evaluated, too few liner samples

Overview of test and inspection criteria	
Modulus of elasticity (short-term flexural modulus) • CIPP-liners must withstand loads such as those caused by groundwater, road traffic and soil pressure • The modulus of elasticity is an indicator of load-bearing capability • Stability may be endangered if modulus of elasticity is too low • Test method: Three-point bending test in acc. with DIN EN ISO 178 and DIN EN ISO 11296-4 > Results: see Table 2	**Wall thickness** (average combined thickness) • Excessively low wall thickness can endanger stability • Minimum values are specified in the structural-analysis calculation • Wall thickness and modulus of elasticity jointly determine the stiffness of the liner • Test method: Average combined thickness is measured in acc. with DIN EN ISO 11296-4 > Results: see Table 4
Flexural strength (flexural stress at rupture = short-term σ_{fb}) • This denotes the point at which the liner fails as a result of excessively high stress • The liner may rupture before the permissible deformation is reached if flexural strength is too low • Test method: Increase of load up to failure in the three-point bending test in acc. with DIN EN ISO 178 and DIN EN ISO 11296-4 > Results: see Table 3	**Water tightness** • The inner film is cut if it is not an integral component of the liner • Any outer film is cut or removed if it is not an integral component of the liner • Water containing a red dye is applied internally • A 0.5 bar partial pressure is applied externally • The liner is "Not tight" if water penetrates through • Test period: 30 min. > Results: see Table 5
A detailed description of these tests can be found on the IKT website: **www.ikt-online.org/cipp-liner**	

Table 6: Test results by liner types, 2017

Liner system		Water-tightness		Modulus of elasticity		Flexural strength		Wall thickness	
		No. of samples	Watertight in % of tests	No. of samples	Target* achieved in % of tests	No. of samples	Target* achieved in % of tests	No. of samples	Target* achieved in % of tests
RS CityLiner	NF	30	100.0**	30	100.0	30	100.0	28	100.0
PAA SF liner	NF	160	100.0**	160	99.4	160	99.4	90	100.0
Alphaliner	GRP	867	99.1	882	99.0	882	99.3	630	97.0
SAERTEX liner	GRP	410	99.5	409	97.6	409	98.3	281	98.6
Insituform CIPP liner (NL)	NF	54	100.0**	64	84.4	64	90.6	64	96.9
iMPREG liner	GRP	192	97.9	198	99.5	198	97.5	147	100.0
Berolina liner	GRP	174	98.9	174	97.7	174	97.7	133	70.7
Brandenburger liner	GRP	200	100.0	200	91.0	200	93.5	116	93.1
Insituform iPlus Glass (NL)	GRP	30	90.0	30	93.3	30	70.0	30	60.0
Average			**99.1**		**97.4**		**97.6**		**94.5**

average or above average
below average

* Target values in accordance with DIBt certification (or KOMO Certificate and QUIK Guidelines) or client's data (structural analysis/sample data record)
** Without cutting of integrated inner film
GRP: Glass-fiber-reinforced backing material
NF: Needle-felt backing material

Table 7: Test results compared to previous year

Liner type	Water-tightness watertight in % of tests			Modulus of elasticity Target* achieved in % of tests			Flexural strength Target* achieved in % of tests			Wall thickness Target* achieved in % of tests		
	2017	2016	+/–	2017	2016	+/–	2017	2016	+/–	2017	2016	+/–
Average												
– All samples	99.1	99.1	0.0 ←→	97.4	98.9	- 1.5 ↓	97.6	98.4	- 0.8 ↓	94.5	96.2	- 1.7 ↓
– GRP	99.0	99.1	- 0.1 ↓	97.7	99.3	- 1.6 ↓	97.7	98.4	- 0.7 ↓	93.9	95.9	- 2.0 ↓
– NF	100.0	99.5	+ 0.5 ↑	95.7	96.7	- 1.0 ↓	97.2	97.9	- 0.7 ↓	98.9	98.2	+ 0.7 ↑

GRP: Glass-fiber-reinforced backing material
NF: Needle-felt backing material
* Target values in accordance with DIBt certification (or KOMO Certificate and QUIK Guidelines) or client's data (structural analysis/sample data record)