



JOINTEC

SZMF Experimental Testing

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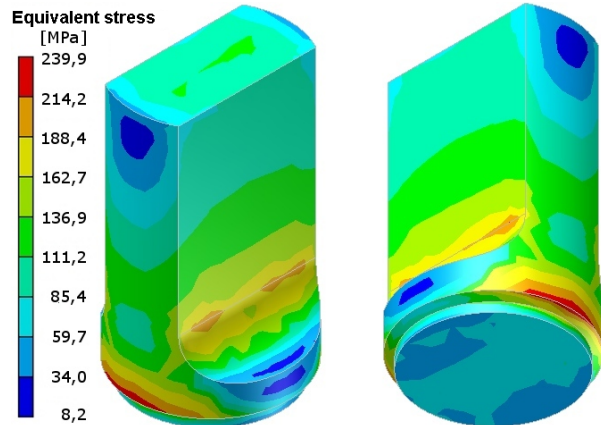
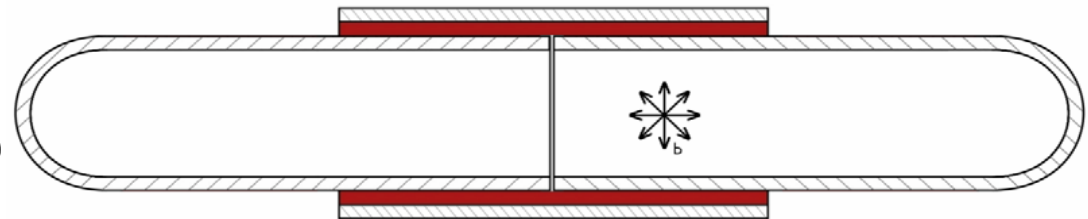
hydrostatic tests (simulation of operating)

summary

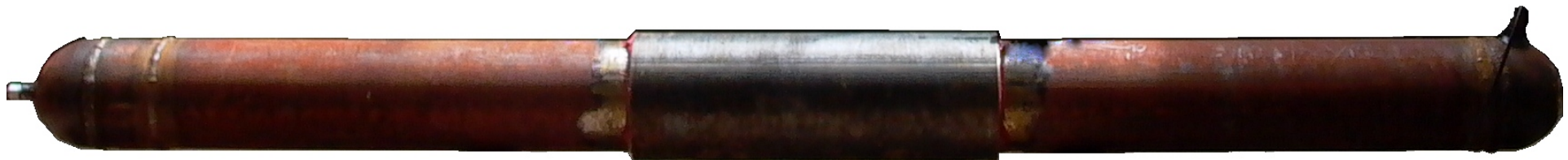
tensile test (simulation of laying)

conclusion

outlook

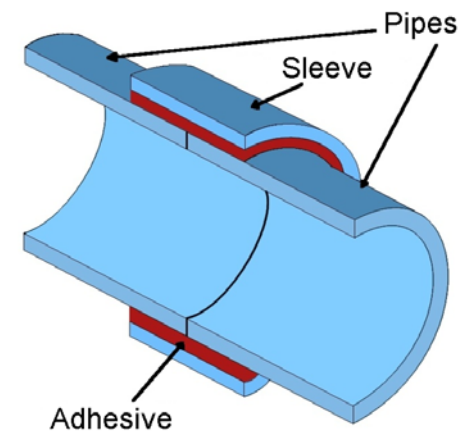
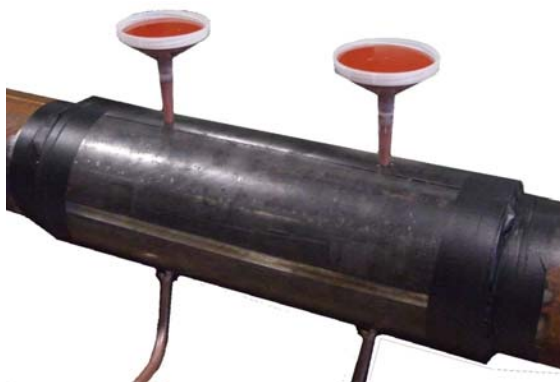


- ↻ Testing of the adhesive bond in the operating state
 - ▶ Hydrostatic internal pressure
 - ▶ Cyclic internal pressure
- ↻ Testing of the adhesive bond under construction
 - ▶ Tensile test
- ↻ Improvement of impermeability

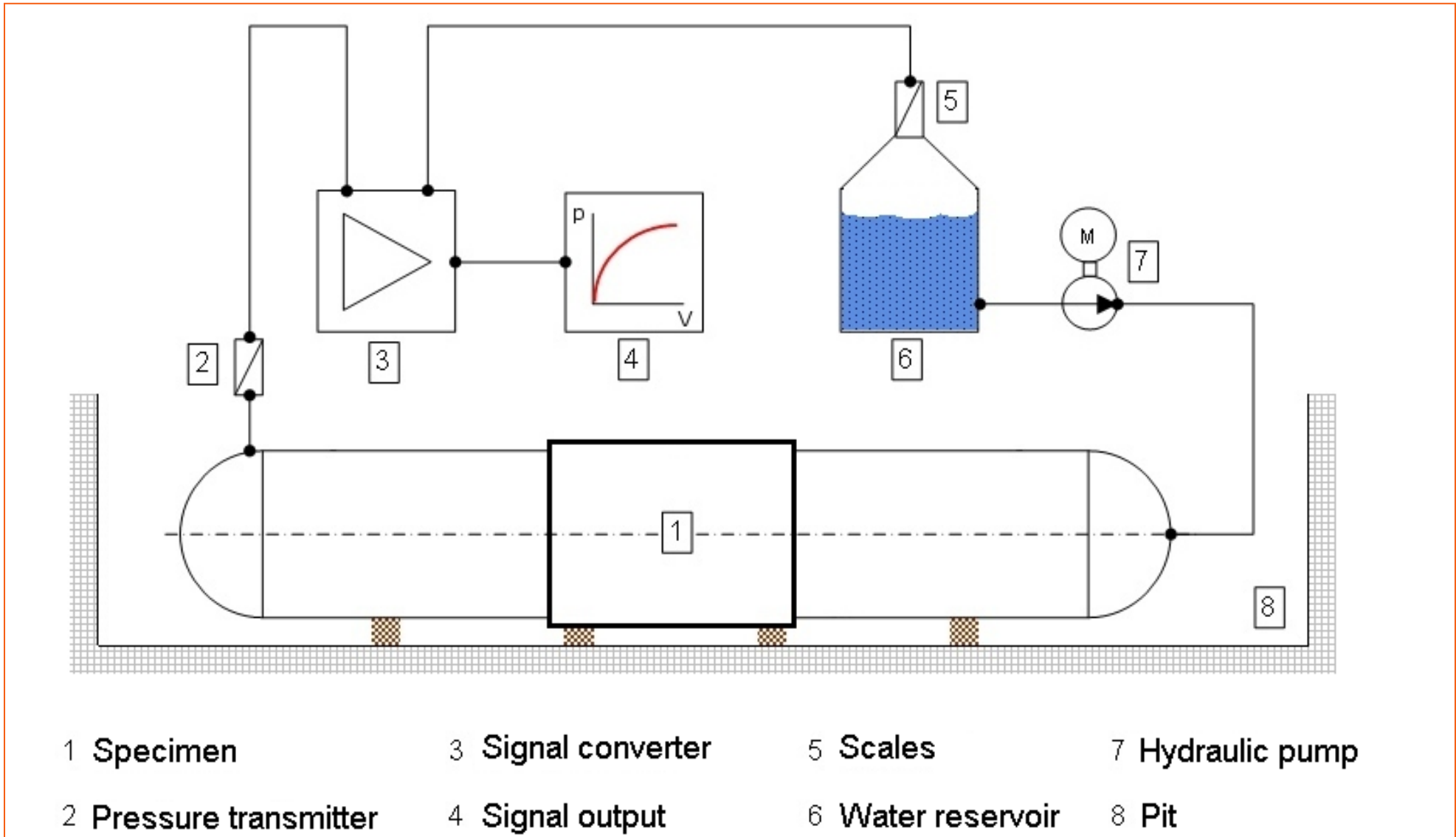


Test Programm SZMF

	No.	Pipe material		Material	Testing Procedure	sleeve length	Amount
		D_a [mm]	t [mm]				
Small-scale	A				Internal static pressure		6 ✓
	B	168	7	S355	Internal cyclic pressure	550	1 to do
	C				Tensile Test		3 ✓
Full-scale tests	D				Internal static pressure		2 } 2 } to do 0 }
	E	508	9	X60	Internal cyclic pressure	700	
	F				Tensile Test		



Internal Hydrostatic Pressure Tests



1st specimen

- Leakage within the adhesive layer
- max. pressure $p_{\max} = 87$ bar

2nd specimen

- Leakage through the borehole
- max. pressure $p_{\max} = 67$ Bar

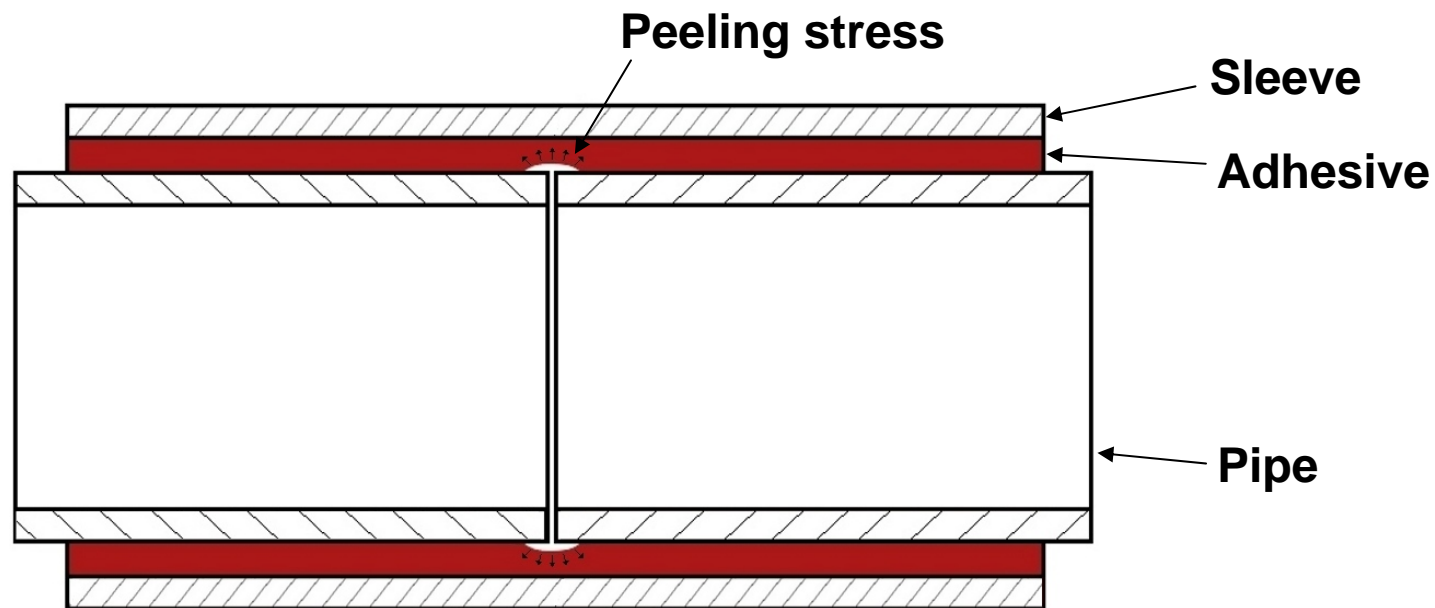
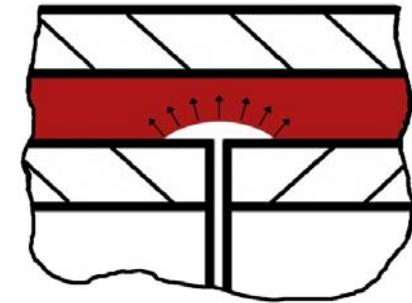
calculated burst pressure:

$$p_b = 383 \text{ bar}$$



Leakage

- partially liquid adhesive (not cured)
- unfavorable impact on the adhesive
- water creates a channel between the tube and adhesive



3rd specimen

- ↻ Leakage within the adhesive layer
- ↻ Max. pressure $p_{\max} = 109$ Bar



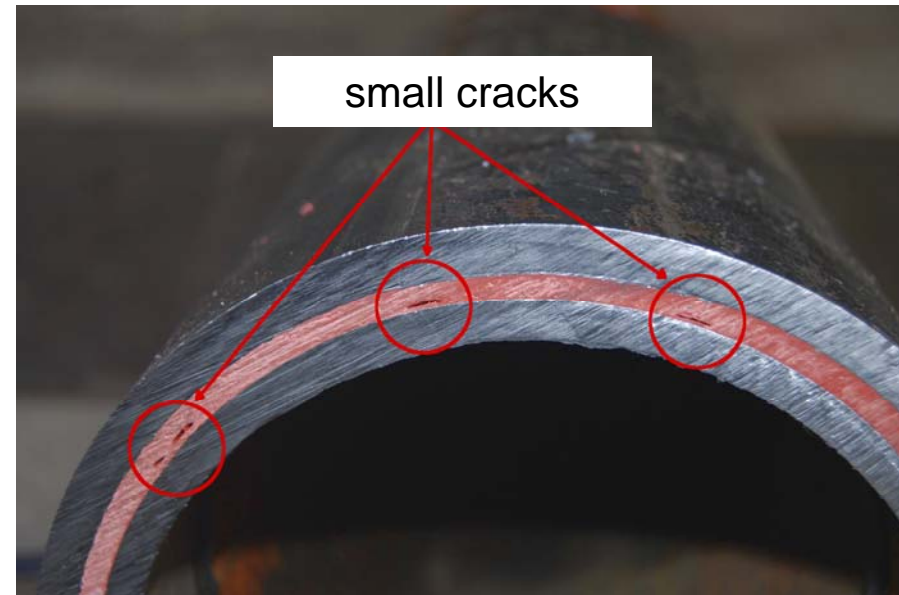
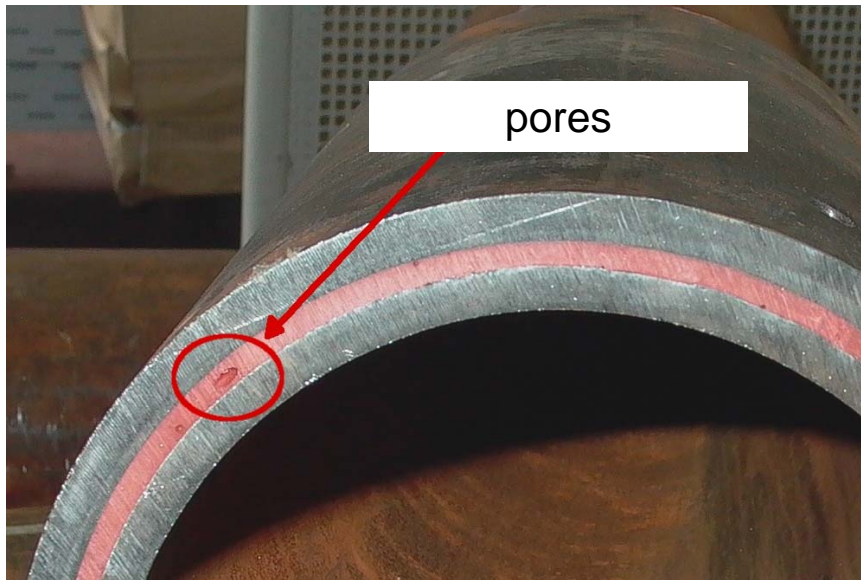
4th specimen

- ↻ Leakage within the adhesive layer
- ↻ Max. pressure $p_{\max} = 38$ Bar

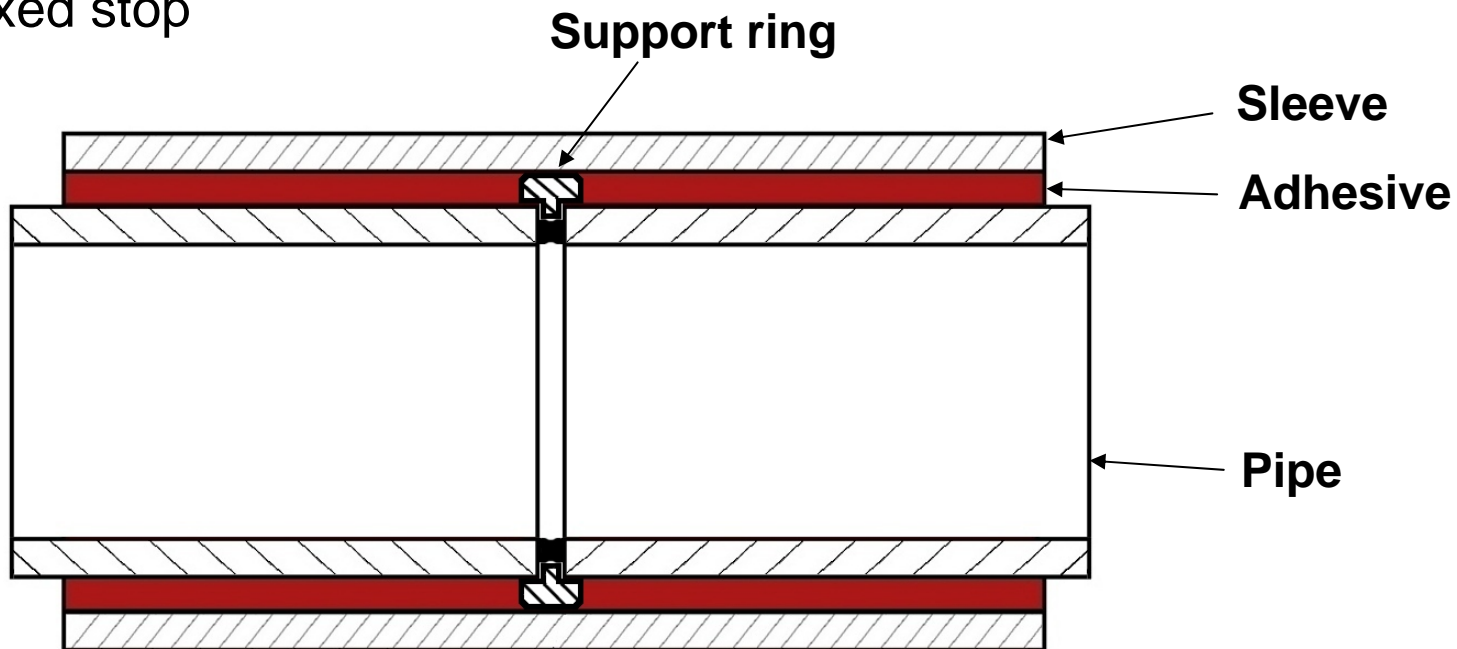
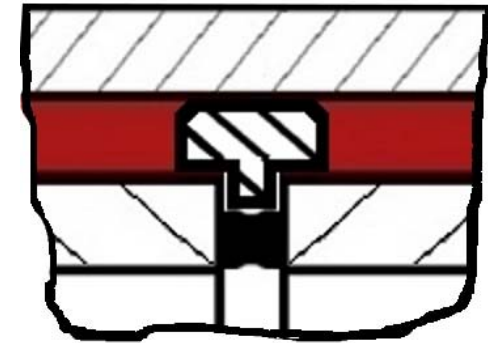


Analysis of experiments

- ↻ adhesive fully cured
- ↻ pores – no influence
- ↻ small cracks due to shrinkage?

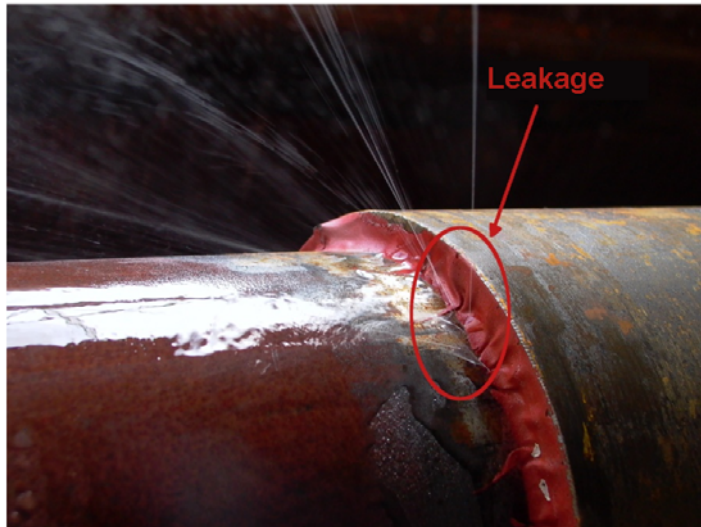


- ↻ **problem is hydrostatic pressure !**
- ↻ separation of the adhesive layer
- ↻ centering of the pipes
- ↻ standard seals
- ↻ fixed stop



5th specimen

- ↻ Leakage within the adhesive layer
- ↻ Max. pressure $p_{\max} = 133$ Bar



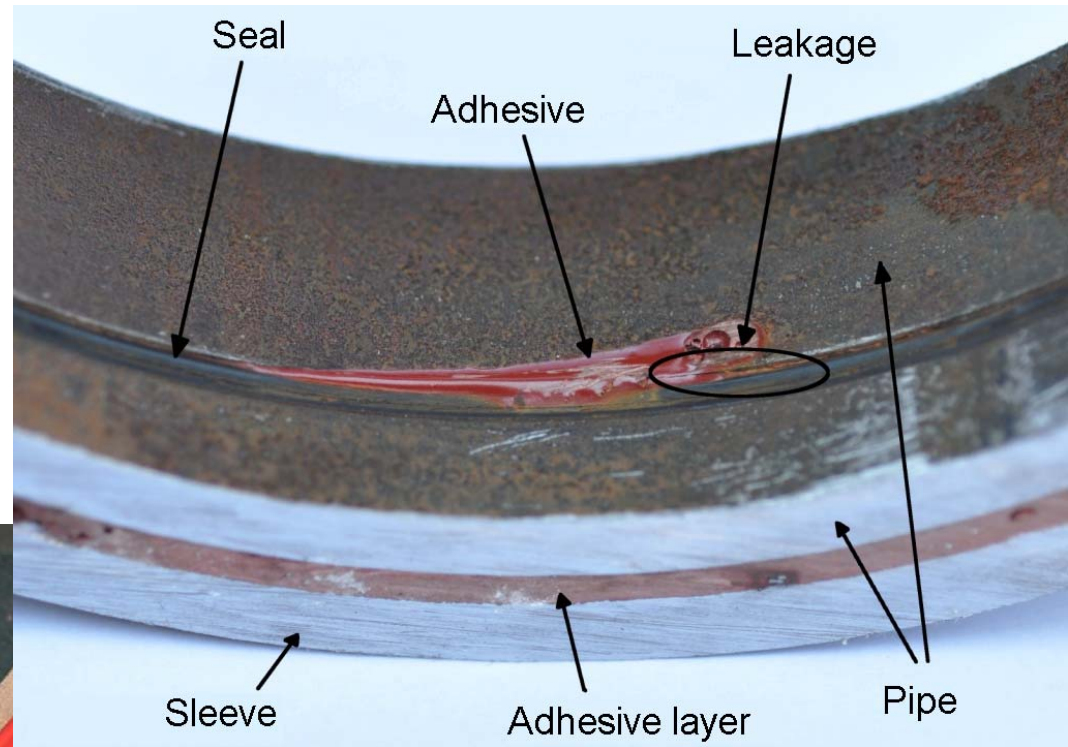
6th specimen

- ↻ Leakage within the adhesive layer
- ↻ Max. pressure $p_{\max} = 94$ Bar



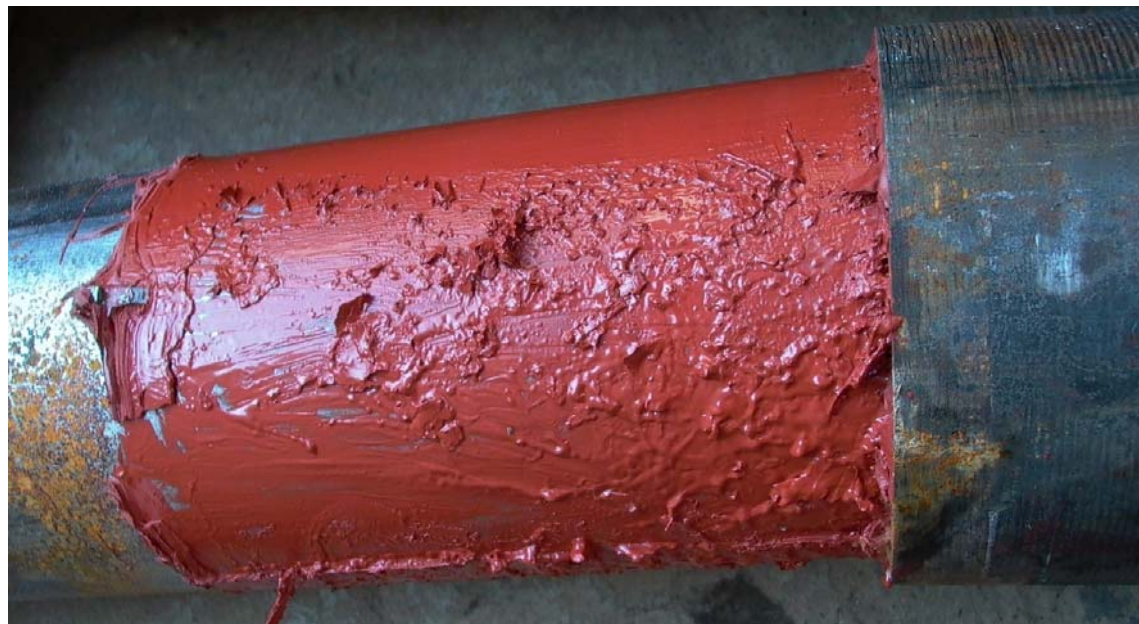
Seal

- ↻ adhesive constrains seal
- ↻ tight tolerances
- ↻ installation procedure not easy



Cyclic Internal Hydrostatic Test B

- ↻ cyclic pressure 2 – 24 bar intended
- ↻ failure at $p_i < 2$ bar at first pressure increase
- ↻ adhesive almost completely liquid
- ↻ adhesive mixture not correct
- ↻ not detectable in non-destructive testing



Summary of Internal Hydrostatic Tests

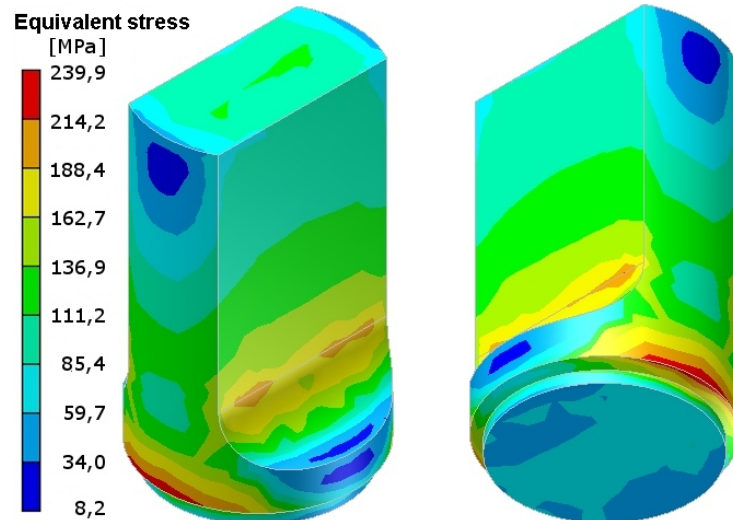
Specimen Number	Position of the Leakage	Maximal Pressure	Failure Cause
A – 1	between the pipe and adhesive layer, south	87 bar	uncured adhesive, unfavorable load case
A – 2	borehole in the sleeve	67 bar	see above
A – 3	between the pipe and adhesive layer, south	109 bar	unfavorable load case
A – 4	between the pipe and adhesive layer, both sides	38 bar	unfavorable load case, cracks due to shrinkage
A – 5	between the pipe and adhesive layer, north	133 bar	inaccurate sealing, unclean sealing surface
A – 6	between the pipe and adhesive layer, north	94 bar	inaccurate sealing, mixing problems
B – 1	Complete	< 2 bar	Completely liquid adhesive

} static

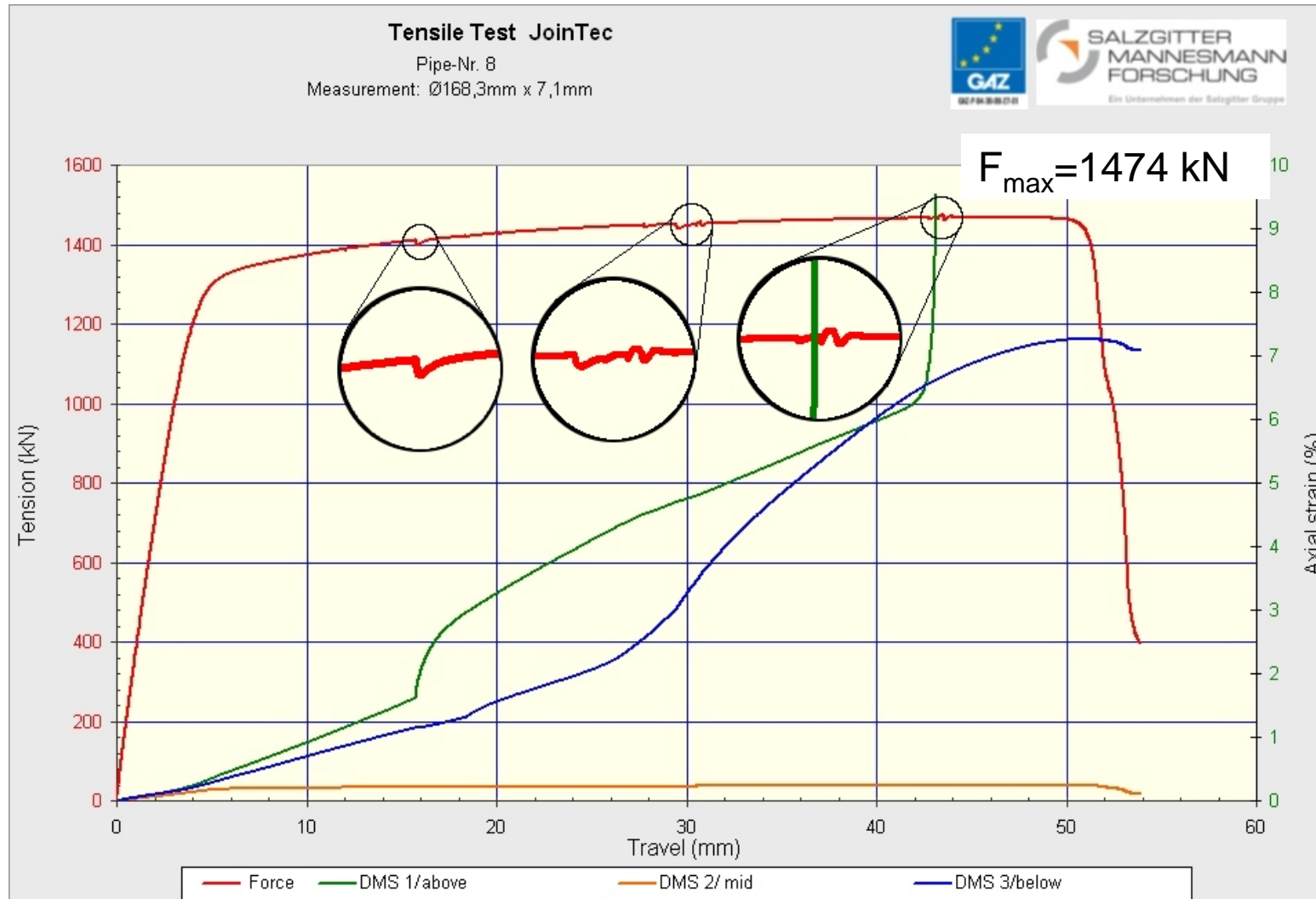
} „cyclic“

Tensile test

- ▶ maximum transferable force
- ▶ behavior of adhesive bond under tension



Tensile test



Resistance:

steel pipe:

$F_{max} = 1503 \text{ kN}$

adhesive:

$F_{max} = 2181 \text{ kN}$

Stresses

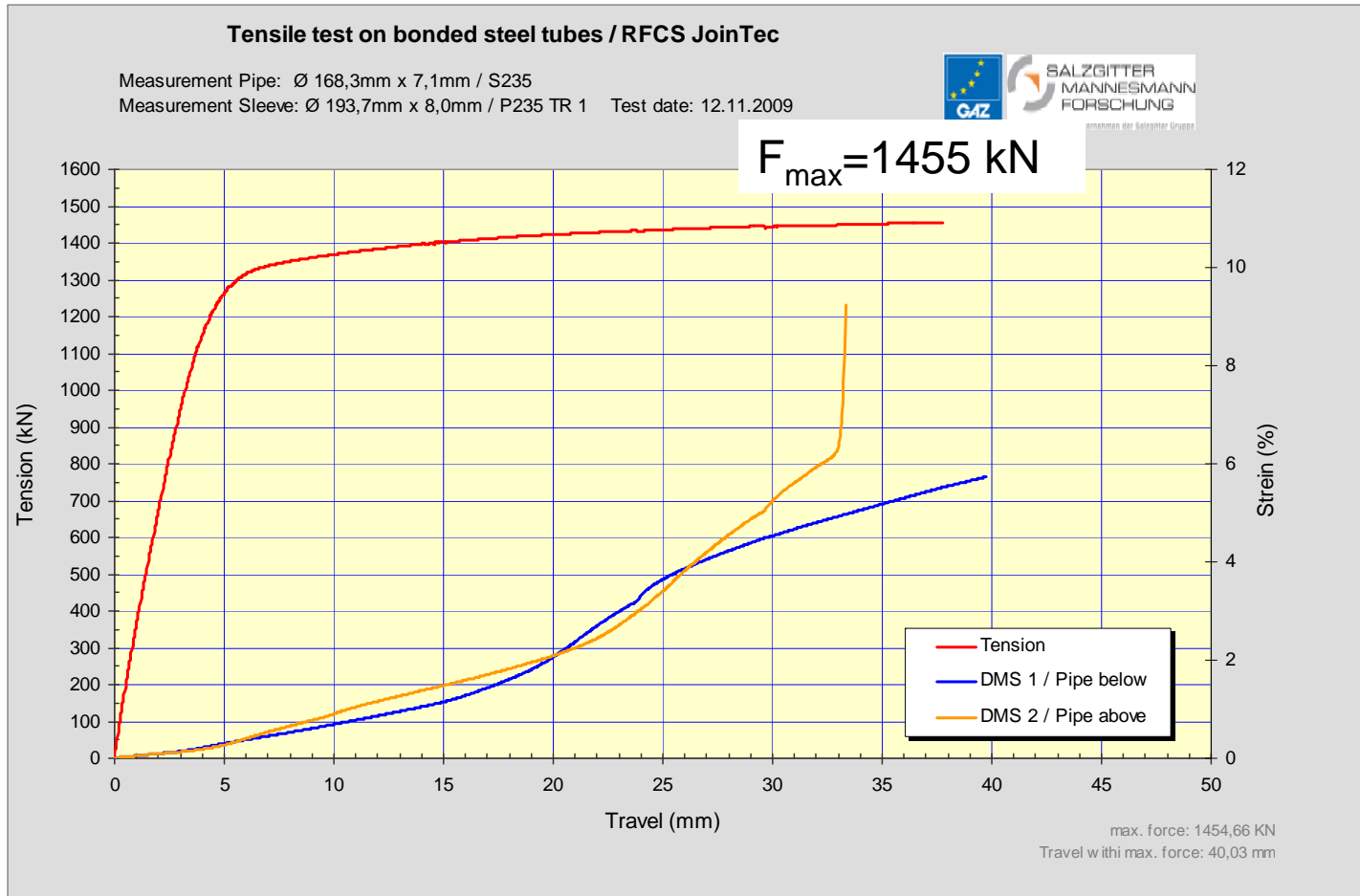
steel pipe:

$\sigma_{max} = 410 \text{ MPa}$

adhesive:

$\tau_{max} = 10 \text{ MPa}$

Tensile test



Resistance:

steel pipe:

$F_{max} = 1503 \text{ kN}$

adhesive:

$F_{max} = 2181 \text{ kN}$

Stresses

steel pipe:

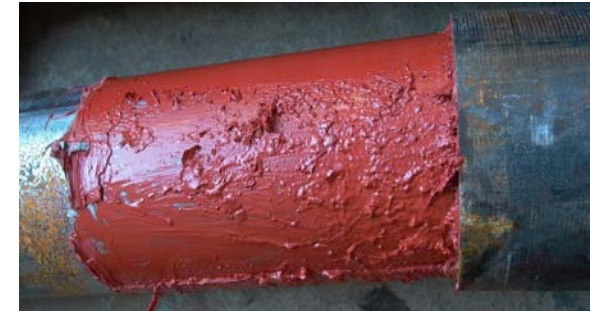
$\sigma_{max} = 404 \text{ MPa}$

adhesive:

$\tau_{max} = 9,9 \text{ MPa}$

Findings from internal hydrostatic pressure test

- ▶ mixing ratio is of utmost importance
- ▶ seal improves impermeability (needs to be developed)
- ▶ even under poor conditions at low pressures leak-proof
- ▶ behavior under cyclic load unknown



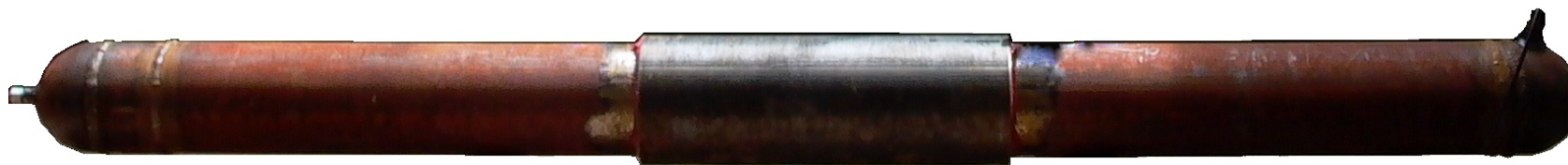
Findings from the tensile test

- ▶ laying a pipeline is possible due to axial force
- ▶ bond strength as high as strength of steel pipe



General knowledge

- ▶ for pressureless pipelines (water supply) already applicable ($p_{\min} > 38$ bar)



Further development

- development of the concept of sealing
- long-term internal pressure (cyclic)
- testing on larger diameters (OD 508 pipes)
- testing of further load cases (bending, CSM)

	No.	Pipe material D _a [mm]	t [mm]	Material	Testing Procedure [-]	sleeve length [mm]	Amount [-]	
Small-scale	A				Internal static pressure		6	✓
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	C				Tensile Test		3	✓
Full-scale tests	D				Internal static pressure		2	} to do
	E	508	9	X60	Internal cyclic pressure	700	2	
	F				Tensile Test		0	



Whatever you intend to do.

Thank you for your attention !

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