REPORT

issued by an Accredited Testing Laboratory

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Testing

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Compilation of results from pipe testing reports issued by RISE Pipe Centre, Spring 2018

This report is a compilation of the reports in table 1.

Table 1 Detailed information about the products can be found in the following reports.

Object number	Report number	Report date
1	7P08784-1-rev	2018-04-12
2	7P08784-2	2018-05-04
3	7P08784-4-rev	2018-04-12
4	7P08784-5	2018-05-04
5	7P08784-7	2018-05-04
6	7P08784-8	2018-05-04
7	7P08784-9	2018-05-04
8	7P08784-10-rev	2018-04-12

1 Objects

Seven pipes made from cross-linked polyethylene, PEX. One pipe made from PE-RT, see table 2. All of the pipes were delivered with a protective pipe. Full marking and detailed information of the pipes can be found in the reports referred to in table 1.

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Table 2 The following pipes were bought by RISE from the open market and were delivered to RISE Pipe Centre in Gothenburg.

Object number	Supplier	Date of delivery	Brand name	Nominal dimension [mm]	Pipe material	Oxygen barrier	Production date according to marking
1	Ahlsell	2017-12-08	LK-pex Universal pipe	16x2.2	PEX-a	Yes	2017-11-19
2	Ahlsell	2017-12-14	Roth Multipex	15x2.5	PEX-c	Yes	2017-10-24
3	Meltex	2017-12-29	Meltex PEXGOL	15x2.5	PEX-a	No	2017-12-14
4	Brødrene Dahl	2018-01-04	Dahl/Altech X-flex Universal	15x2.5	PE-RT	Yes	2017-10-03
5	Onninen	2018-02-14	JRG Sanipex (Sweden)	16x2.2	PEX-a	No	2017-11-19
6	eBay, Germany	2018-02-09	JRG Sanipex (Italy)	16x2.2	PEX-a	No	2017-11-16
7	VVSoch Bad.se	2018-02-02	Wavin TIGRIS PexOne	15x2.5	PEX-c	Yes	2017-11-16
8	Onninen	2018-02-14	Uponor aqua pipe	16x2.2	PEX-a	No	2017-12-06

2 TEST PROCEDURES

The following mechanical and hygienic testing has been performed. The tests have been performed in the time period December 2017 – May 2018.

2.1 Mechanical testing

All of the mechanical tests except the exchangeability has been performed by RISE Pipe Centre in Gothenburg. The exchangeability test has been performed by RISE in Borås.

Characteristics	Method standard	Accreditation EN ISO 17025
Geometrical characteristics and ovality	EN ISO 3126	Yes
Hydrostatic pressure test	ISO 1167	Yes
Elongation at break	ISO 6259-1, ISO 6259-3	Yes
Longitudinal reversion	EN ISO 2505	Yes
Cross-linking level	EN 579	Yes
Flexibility*	Measuring of force required to bend the pipe	No
Necking at tensile*	Measuring of necking force CSTB 3597, version 2007	No
Burst testing*	ASTM D1599	No
Exchangeability	Nordtest NT VVS 129 (6.4.13 and 6.4.14)	Yes

* Detailed test description below.

2.2 Hygienic testing

RISE has anonymized the pipes and sent samples to *Hygiene-Institut des Ruhrgebiets* in Germany for accredited Hygien tests according to the table below and the KTW Guideline, issue date 2016-03-07.

Evaluated property	Standards and guidelines	Comment
Colour	SOP 14.5, 2008-11	Tests were performed at both 23 and 60 °C for 31 days.
Turbidity	SOP 14.5, 2008-11	
Tendency to foam formation	SOP 14.5, 2008-11	
Threshold odour number (TON)	EN 1622, 2006-10	
Threshold flavour number (TFC)	EN 1622, 2006-10	
Total organic carbon (TOC)	EN 1484, 1997-08	
2,5-Dimethyl-3-hexyne-2,5-diol CAS 142-30-3	Hygiene institute In-house method (GC-MS)*	

*These tests are not accredited.

2.3 Flexibility

The main steps in the procedure were as following and the purpose was to evaluate the force needed to bend the pipe during pipe installation:

1. Cutting out a sample of pipe having a length of 1570 ± 3 mm.
2. Condition at ambient temperature 23± 2 °C.
3. Bending the pipe into a ring along the pre-curvature.
4. Insertion of the pipe ring into a tensile tester.
5. Pre-testing, compress the pipe ring to force 5 N at speed 50 mm/minute.
6. Reset load and position measurement.
7. Testing, compress the pipe 100 mm at 200 mm/minute and record the final force.

Figure 1 Generic picture of flexibility testing.

2.4 Necking at tensile

The test pieces for this tests are whole pipes approximately 10-12 cm long.
The testing speed is chosen according to test procedure according to CSTB 3597 Version 2007 clause 8. The main steps in the test procedure are as following:

1. Mount one test piece in a tensile testing machine.
2. Measure the force while the pipe is elongated, 100 mm/min.
3. Record the force at necking of the pipe, i.e the yield point of the material.

2.5 Burst testing

The burst testing are performed at 81 ± 1 °C in a water bath. The pressure was ramped during 60 seconds according to the table below. The aim was to find in which test case the pipe failed and record the pressure at failure. What constitutes a failure are described in ASTM D1599-99 clause 5. Five samples were used for each test case.

Test case	Nominal outside diameter mm	Nominal minimum wall thickness mm	Hoop stress at 60 seconds MPa	Pressure at 60 seconds bar	Rate of loading bar/s
1	15	2.4	5.25	20.00	0.33
	16	2.2	5.25	16.74	0.28
2	15	2.4	7.88	30.00	0.50
	16	2.2	7.88	25.11	0.42
3	15	2.4	10.5	40.00	0.67
	16	2.2	10.5	33.48	0.56

3 TEST RESULTS

The results apply only to the tested objects.

3.1 Geometrical characteristics

The diffusion barrier was measured by microscope.

Test no	Mean outside diameter mm	Out of roundness mm	Wall thickness min. mm	Wall thickness max. mm	Diffusion barrier mm
Object number 1					
1	16.1	0.7	2.10	2.25	0.09
2	16.1	0.7	2.10	2.25	
3	16.1	0.7	2.10	2.25	
Object number 2					
1	15.1	0.4	2.55	2.60	0.11
2	15.1	0.4	2.55	2.60	
3	15.1	0.4	2.55	2.60	
Object number 3					
1	15.2	0.2	2.55	2.65	-
2	15.2	0.2	2.55	2.60	
3	15.2	0.2	2.55	2.65	
Object number 4					
1	15.0	0.2	2.50	2.70	0.17
2	15.0	0.2	2.50	2.70	
3	15.0	0.2	2.50	2.70	
Object number 5					
1	16.1	0.5	2.35	2.50	-
2	16.1	0.5	2.35	2.50	
3	16.1	0.5	2.35	2.50	
Object number 6					
1	16.3	0.2	2.30	2.40	-
2	16.3	0.2	2.30	2.40	
3	16.3	0.2	2.30	2.40	
Object number 7					
1	15.1	0.2	2.50	2.65	0.18
2	15.1	0.2	2.50	2.60	
3	15.1	0.2	2.50	2.60	
Object number 8					
1	16.1	0.5	2.30	2.40	-
2	16.1	0.5	2.30	2.40	
3	16.1	0.5	2.30	2.40	

Test method: *EN ISO 3126:2005*
The measurements were performed at 23 ± 2 °C with equipment with the following accuracy:
Wall thickness: *0.01 mm*
Diameter: *0.1 mm*
Length: *0.1 mm*

3.2 Resistance to internal pressure

The results from hydrostatic pressure testing are associated with a big uncertainty of the method. The actual temperature, pressure and wall thickness have a very significant effect on the rupture time. The uncertainty originating from the geometrical measurement is especially big for pipes with a small wall thickness. To decrease the statistical uncertainty of the time to rupture at the specified hoop stress, a wider testing with several more samples needs to be performed. The test pressures are calculated after subtraction of the diffusion barrier from the geometrical dimensions. The requirement for the PEX-pipes are determined by EN ISO 15875-2:2003 table 7.

Object number	Test no	Hoop stress MPa	Test temp. °C	Test pressure MPa	Time to rupture h	Requirement h
1	1	4.7	95	1.360	337	>22
	2	4.7	95	1.360	204	>22
	3	4.7	95	1.360	168	>22
2	1	4.7	95	1.832	>400	>22
	2	4.7	95	1.832	>400	>22
	3	4.7	95	1.832	>400	>22
3	1	4.7	95	1.893	>400	>22
	2	4.7	95	1.893	>400	>22
	3	4.7	95	1.893	>400	>22
4	1	4.7	95	1.773	<1	-
	2	4.7	95	1.773	<1	-
	3	4.7	95	1.773	<1	-
5	1	4.7	95	1.612	>400	>22
	2	4.7	95	1.612	>400	>22
	3	4.7	95	1.612	>400	>22
6	1	4.7	95	1.557	95	>22
	2	4.7	95	1.557	>400	>22
	3	4.7	95	1.557	62	>22
7	1	4.7	95	1.756	>400	>22
	2	4.7	95	1.756	>400	>22
	3	4.7	95	1.756	>400	>22
8	1	4.7	95	1.588	>400	>22
	2	4.7	95	1.588	>400	>22
	3	4.7	95	1.588	>400	>22

The observed ruptures were ductile. The tests were interrupted after 400 hours.

Pressure test method: *EN ISO 1167-1:2006, End caps of type A*
Dimension measurement method: *EN ISO 3126:2005*
The test condition parameters were as following
Free length between the end caps: *400 mm*
Conditioning time: *1 h*
Internal/External medium: *Water/water*
Time to achieve the pressure: *<5 minutes*
Test temperature: *± 0.3 °C*
Test pressure: *± 0.7 %*

3.3 Elongation at break

The mean values from the elongation at break tests are presented in figure 2.

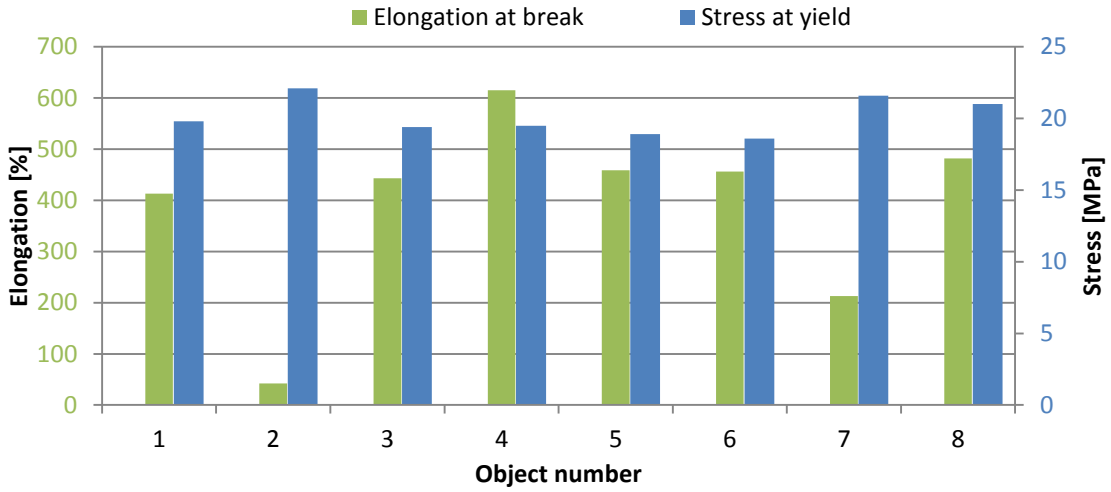

Figure 2 Mean values for stress at yield and elongation at break.

Test method: *ISO 6259-1:2015*
Test piece chosen according to: *ISO 6259-3:1997 and ISO 6259-3:2015*
Test temperature: *23 ± 2 °C*

3.4 Longitudinal reversion

The tests were performed in air and in two points, due to the curvature of the pipe. The mean values from the longitudinal reversion tests are presented in figure 3.

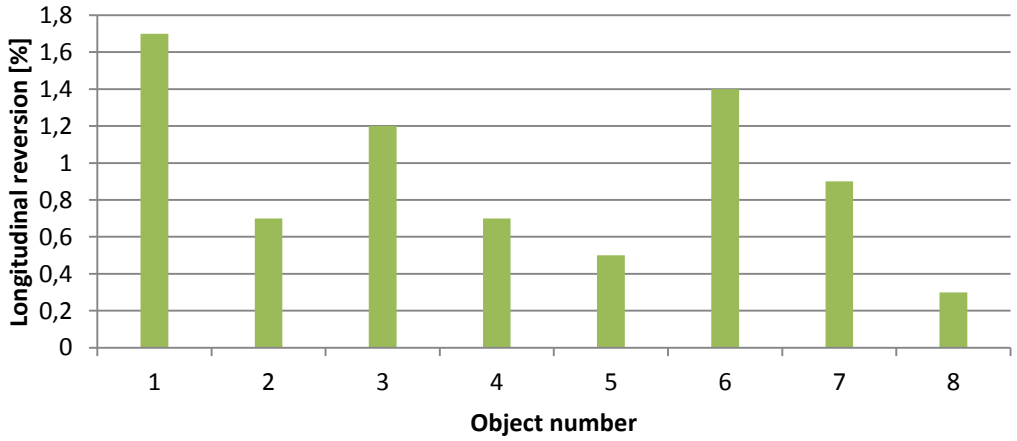

Figure 3 Mean values for the longitudinal reversion measurements.

No bubbles or cracks were observed after the tests.

Test method: *EN ISO 2505:2005*
Test temperature: *120 ± 1 °C*

3.5 Degree of crosslinking

The mean values from the degree of crosslinking tests are presented in figure 4. PE-RT is not a cross-linked material and no test were therefore performed on object number 4.

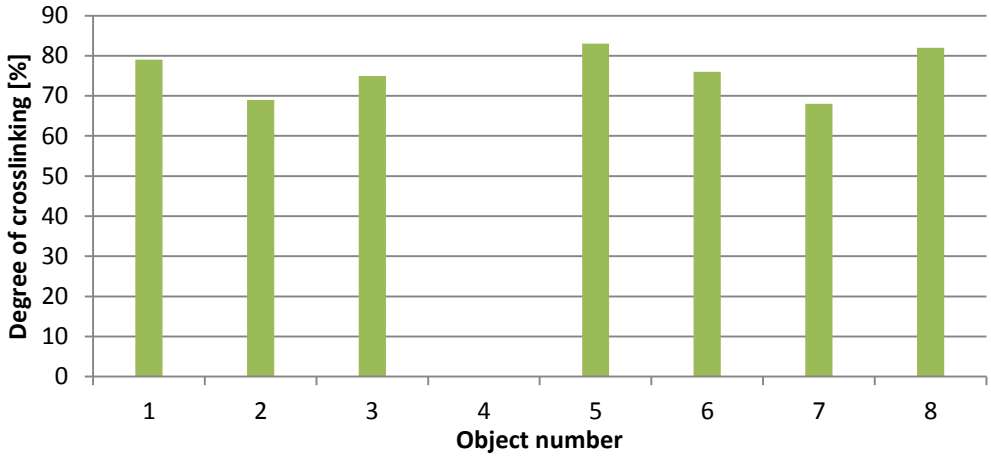

Figure 4 Mean values from the measurements of degree of crosslinking

Test method: *EN 579:1993*
Weighting uncertainty: *± 0.1 mg*

3.6 Flexibility

The mean values of the force at the end of the tests are presented in figure 5.

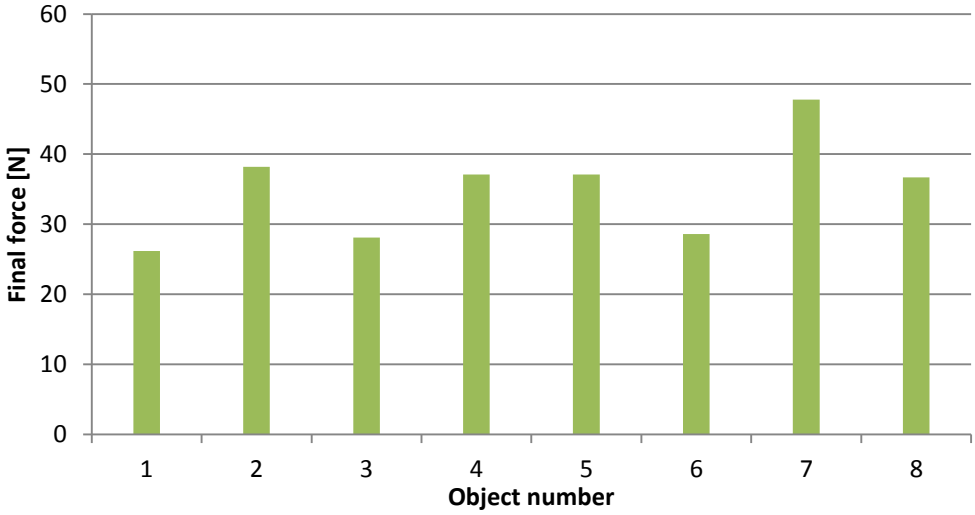

Figure 5 Mean values from the flexibility tests.

Test method: *See test procedures, page 4*
Test temperature: *23 ± 2 °C*
The calculated uncertainty for the force measurement is <1%

3.7 Necking at tensile

The mean values of the force at necking are presented in figure 6.

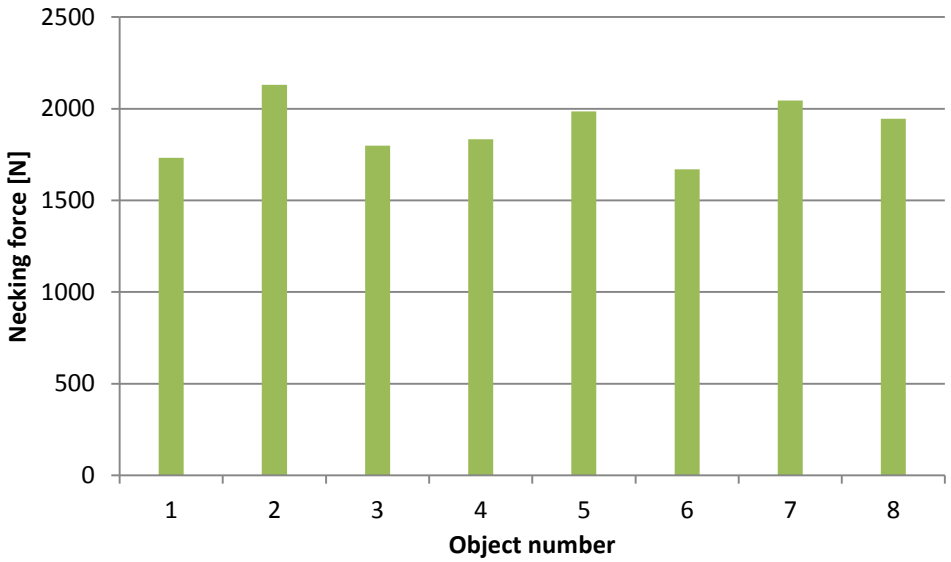

Figure 6 The mean values of the force from the necking tests.

Test method: *See test procedures, page 4*
Test temperature: *23 ± 2 °C*
The calculated uncertainty for the force measurement is <1%

3.8 Burst testing

The mean values for the burst hoop stresses from case 3 testing are presented in figure 7. The stresses are calculated from nominal pipe dimensions.

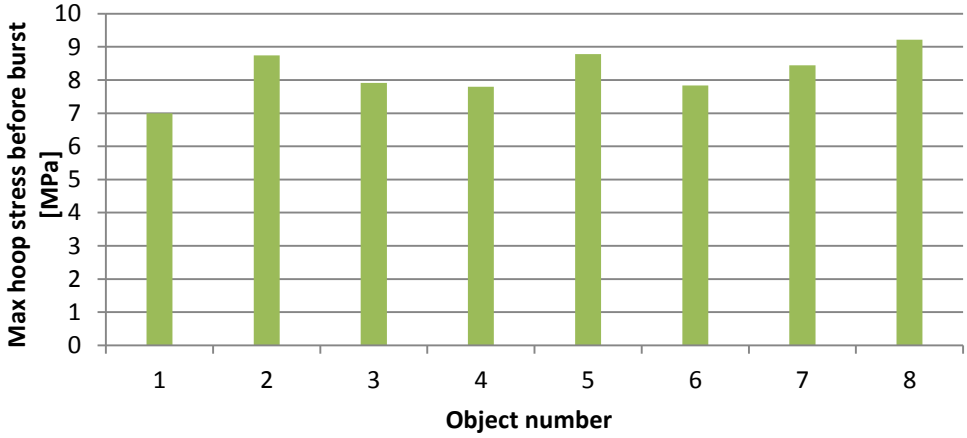

Figure 7 Mean maximum hoop stress values from the pipes, when tested in accordance with case 3.

Test method: *ASTM D1599-99, see test procedures, page 5*
Test temperature: *81 ± 1 °C*
Conditioning time: *1 h*
Internal/External medium: *Water/water*

3.9 Exchangeability

Wall bend fixtures and exchange nipples were used according to the manufacturers instruction. Some of the pipes did not have a specified instruction and the exchange were then made in accordance with: *Byggforsk Vannskadekontoret Rör-i-rör-systemer Lommehåndbok, utgåva 2, daterad 2006.* Details about the used methods and products can be found in the respective testing report in table 1.

Object number	Installation method	Fulfilled the test with no leakage	Comment
1	Lommehåndbok	No	Leakage in the bend in the wall bending fixture.
2	Manufacturer's instructions	No	The exchange nipple came of the new pipe in the wall bending fixture. Leakage in the bend in the wall bending fixture.
3	Lommehåndbok	Yes	No leakage in the subsequent leakage test.
4	Lommehåndbok	No	The ring that is intended to keep the protection pipe in place during the test came off and the protection pipe moved a small distance. Leakage in the bend in the wall bending fixture.
5	Manufacturer's instructions	No	Leakage in the wall box, which consists of two parts. Separate leakage test of the protection pipe showed no signs of leakage.
6	Manufacturer's instructions	No	Leakage in the wall box, which consists of two parts. Separate leakage test of the protection pipe showed no signs of leakage.
7	Lommehåndbok	Yes	No leakage in the subsequent leakage test.
8	Manufacturer's instructions	Yes	No leakage in the subsequent leakage test.

Test method: *Nordtest NT VVS 129 clause 6.4.13 and 6.4.14*
Test set up: *Figure 6 in NT VVS 129*
Test temperature: *23 ± 2 °C*
Date of test *January-March 2018*

3.10 Hygienic testing

The following results were reported to RISE by *Hygiene-Institut des Ruhrgebiets* in the reports:

K-296510-18-Ä-Ko, report date: 2018-03-28, and *K-296561-18-Ä-Ko*, report date: 2018-03-29.

Values below the possible measurement threshold are presented as 0.1 in the following diagrams. Some of the objects, where the odour tests showed high results, do not have results for flavour. The results from the diol-measurements are not presented in this report due to the absence of hygienic migration limits for this substance. The measured diol is a result from the crosslinking process and from the polymer or any other starting substance. The diol is not verified to be hazardous to human health or not.

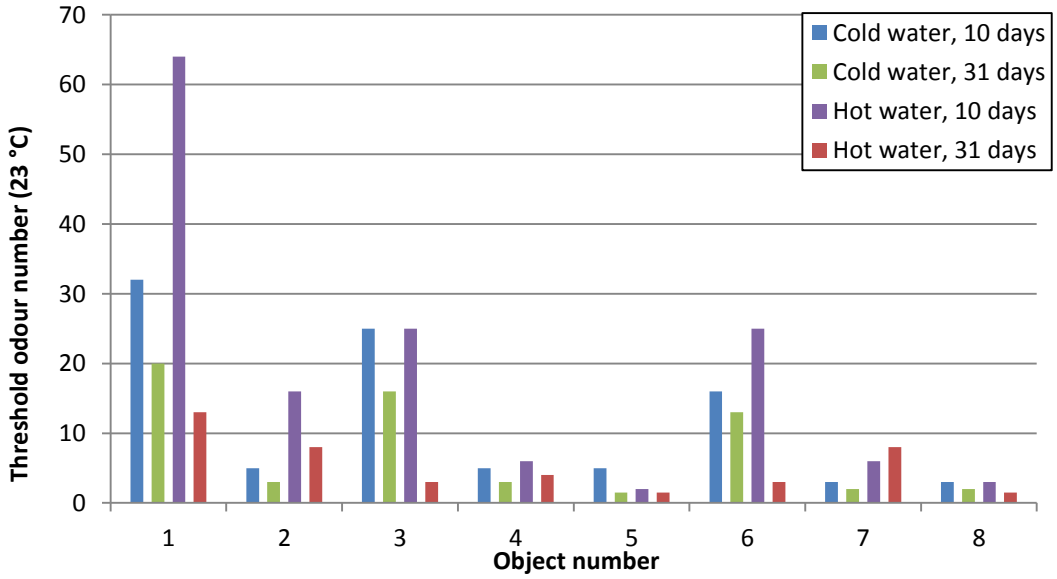

Figure 8 Testing of odour (TON) according to DIN EN 1622, 2006-10.

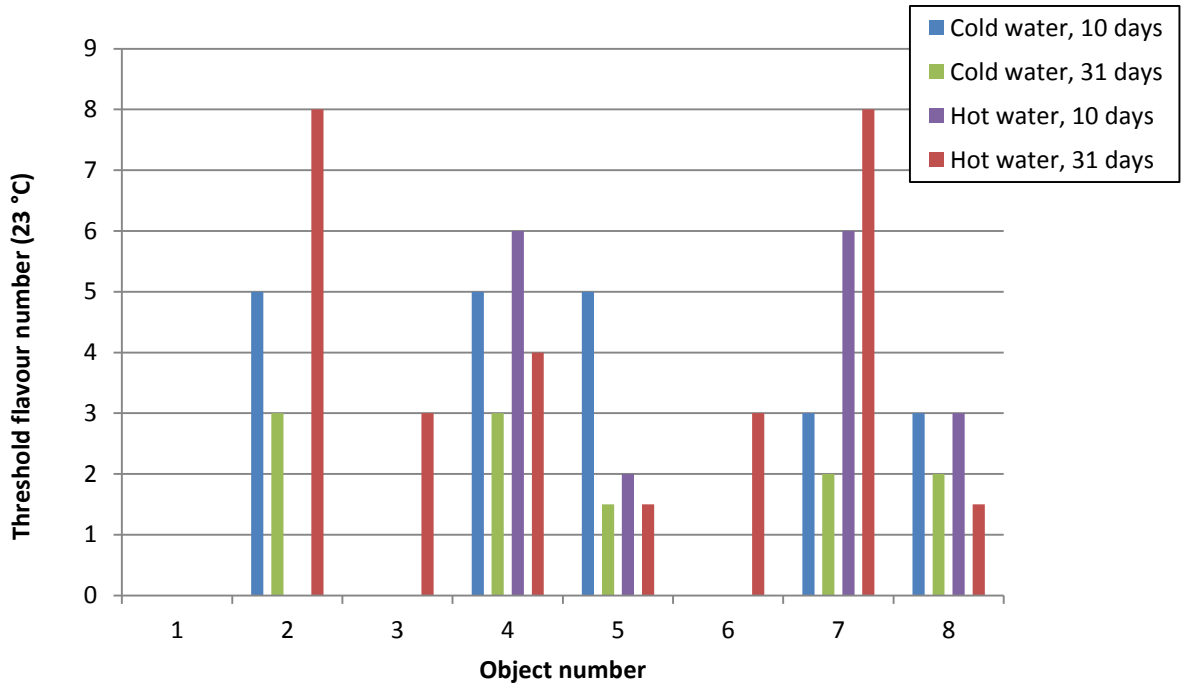

Figure 9 Testing of flavour (TFC) according to DIN EN 1622, 2006-10.

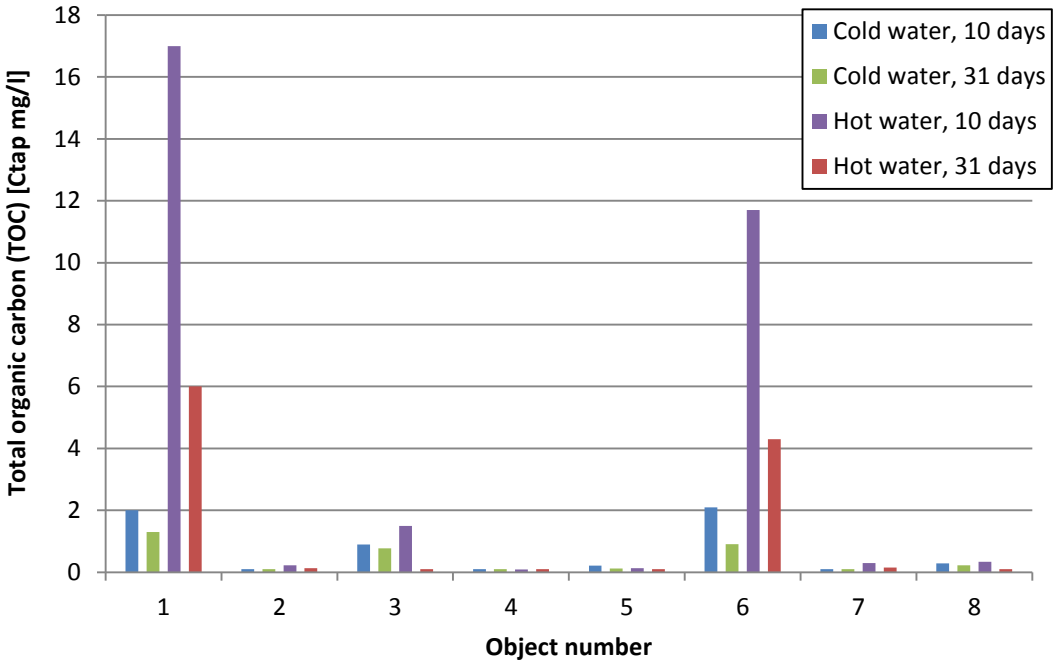

Figure 10 Total organic carbon measurements, (TOC)

All the tested pipes showed similar results for colour and turbidity of the water, i.e colourless and clear. The results are presented in the following table:

Test object	Parameter	Cold water test (23 °C)		Warm water test (60 °C)	
		10 days	31 days	10 days	31 days
All objects	Colour	Colourless	Colourless	Colourless	Colourless
All objects	Turbidity	Clear	Clear	Clear	Clear
Test object 1	Tendency to foam formation	Slightly	Slightly	Significant	Slightly
Test object 7	Tendency to foam formation	None	None	Slightly	None
Object 2,3,4,5,6,8	Tendency to foam formation	None	None	None	None

4 DISCUSSION

The following discussion is to conclude RISE thoughts about the tests and present which pipes performed different than others in some of the tests.

4.1 Geometrical characteristics

The results from the measurements shows that some of the pipes with diffusion barrier do not meet the requirement for wall thickness. The minimum wall thickness requirement for the 15x2.5 mm pipes is 2.4 mm according to table 3 in EN ISO 15875-2: 2003. Subtraction of the barrier thickness yields that object number 7 do not fulfil the requirement but object number 2 does. Object number 4 is made from PE-RT and the requirement for this pipe is also 2.4 mm, according to table 4 in EN ISO 22391-2:2009, which means that the measured pipes of object 4 is not fulfilling the requirements.

The requirement for a 16 mm PEX-pipe is the same as the nominal dimension, 2.2 mm, according to table 3 in EN ISO 15875-2: 2003. Meaning that object number 1 fails to fulfil the wall thickness requirements in this standard, EN ISO 15875-2 is however not mentioned in the marking of object number 1.

4.2 Resistance to internal pressure

As already written in the results-section 3.2, there are big uncertainties associated with hydrostatic pressure tests. The approach with only using three test objects are the general procedure for quality testing of a pipe and checking that it conforms with the requirements in the product standard. All of the PEX-pipes fulfils the requirement of at least 22 hours to rupture at 4.7 MPa calculated hoop stress. It is also obvious that test object number 4, made from PE-RT-material, is much less durable at high temperatures compared to the PEX-pipes.

4.3 Elongation at break

The elongation at break according to ISO 6259 are standard tests for polymer pipes. The test piece preparation for pipes as small as 15 and 16 mm pipes are quite important. Test object number 2 and 7 have significantly lower results than the other objects, especially number object number 2. These pipes have in common that they are PEX-c pipes, and not PEX-a pipes as the other PEX-pipes. All of the measured yield stresses are in the same region around 20 MPa.

4.4 Longitudinal reversion

The requirement for longitudinal reversion in ISO 15875-2:2003 is less than 3 %. All of the pipes fulfil this requirement.

4.5 Degree of crosslinking

The measurement of degree of crosslinking according to EN 579 are standard tests for pipes made from cross-linked polyethylene. Test object 2 and 7 which are the PEX-c pipes, which are crosslinked with the electron-beam method, have a lower degree of cross-linking according to the measurements. The requirement for PEX-c pipes are $\geq$ 60 % crosslinking, both pipes fulfil this requirement. The requirement for PEX-a (peroxide) pipes are $\geq$ 70 % crosslinking. All of the PEX-a pipes fulfils this requirement and test object 5 and 8 exceed 80 % crosslinking according to the measurements.

4.6 Flexibility

The flexibility test is measuring how stiff the pipe is. In practice this property for example affects how difficult it is to bend the pipe around a corner or how much force you need to drag the pipe through a protective pipe. On the other hand, a more stiff pipe means a higher stability during installation, fewer fixing points may be required. There are no standard requirements for this test.

4.7 Necking at tensile

This test is designed to measure the maximum force the pipe can handle in the axial direction without permanent deformation. All of the tested pipes have a measured maximum force of more than 1500 N. There are no standard requirements for this test.

4.8 Burst testing

The burst test is showing the robustness of the pipe. Pressures of more than 20 bar combined with temperature 81 °C is not supposed to happen to these pipes during normal installation. One important factor for this test is how the wall thickness is varying along the pipe and in the circumferential direction. The pipe will most probably break on its weakest point and the wall thickness variations is therefore crucial for the result. Note that the presented values for maximum hoop stress in clause 3.8 are calculated from nominal pipe dimensions and maximum pressure before burst.

4.9 Exchangeability

The exchangeability test is a quite high demanding test, especially for the protective pipes. Only three of the tested pipes did pass the test without any remarks. The wall box used for object 5 and 6 according to the manufacturer’s instructions did not have the expected leak tightness. The use of lubrication is something that differs in the instructions from the manufacturers, lubrication reduces the friction between the pipe and protective pipe which makes it easier to pass the test.

4.10 Hygienic testing

The most obvious results from the hygienic testing is that object 1 and 6 has high amounts of organic carbon released into the water compared to the other pipes. These two pipes, together with pipe number 3, are showing the worst results in the odour test as well. The two manufacturers of pipe 1 and 6 has a different manufacturing process than the other tested PEX-a producers.

5 CONCLUSIONS

There are some conclusions that can be made from the tests performed. It is though important to note that the tests are only spot checks of random pipes purchased from the open market. All manufacturers may have a problematic production batch at some time, the most important thing is to ensure that the internal quality routines prevents this bad batch of pipes from reaching the market.

The compiled reports consisted of 7 PEX pipes and one PE-RT pipe. The hydrostatic strength test at high temperature shows clearly that the PE-RT pipe is not as durable as the PEX-pipes. This fact is important to be aware about when choosing pipes for a system where high temperatures may occur.

The results from the hygienic testing shows quite significant differences between the pipes, especially regarding the total amount of organic carbon.

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