THE DURABILITY OF A LOW-PRESSURE GAS DISTRIBUTION SYSTEM OF DUCTILE PVC

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ABSTRACT

One of the options for a low-pressure gas distribution system is the use of ductile PVC pipes and joints. The long-term performance of ductile PVC pipes has been reported in a number of previous studies. In this paper the long-term performance of the socket joints, in which elastomeric (NBR) sealing rings are used, is evaluated. The long-term quality of socket joints in ductile PVC pipeline systems has been determined by various tests on a number of excavated joints, which have been in operation for more than 20 years. Leak tightness determined according to the present specifications did fulfil all requirements. The quality of the rubberrings , established by e.g. tensile testing and hardness tests, was also still at the level of new rubberrings. The socket joints started only to leak at deflections of the pipes far exceeding the deflection levels met in field practice. The compression set of the excavated samples was also rather low and extrapolated to long times will not exceed a maximum required value of 70 % before 50 years. These results once again show that ductile PVC pipe systems for low-pressure gas distribution exhibit an excellent (long-term) performance.

INTRODUCTION

A variety of pipeline materials are available for low-pressure gas distribution systems, like steel, ductile iron, PE and ductile (high-impact) PVC. Nowadays, PE and ductile PVC are the most widely used materials. In the Netherlands , ductile PVC is the preferred plastic pipe material, whereas almost all other countries haven chosen for PE.Yet, ductile PVC has some very strong technical and economic advantages, like a complete and sophisticated system, simple and reliable jointing and branching techniques, and low overall costs. The ductile PVC system and its properties have extensively been described in a number of publications (ref. 1 – 5).

Ductile PVC systems have shown to be very reliable. These systems are in operation now for more than 25 years. The numbers of leaks is almost neglible and spontaneous failures do not occur. Stress cracking caused by certain gas constituents is not an issue, as proven by a lot of

investigations (ref. 3). Materials taken from the grid after extended times in operation have shown that the material still fulfils all requirements of the relevant specifications and not any notice of degradation of the material is met.
The ductile PVC pipes are jointed by means of separate fittings containing elastic sealing rings made of NBR (nitrile butadiene rubber) . To guarantee a safe and reliable pipeline system over the full lifetime , the joints should be tight over this lifetime. In this paper it will be reported about a number of recent studies into the long-term performance of these rubberring joints. For this study old ductile PVC pipes and joints have been excavated and the quality of these joints was determined by various laboratory experiments.

USED ELASTOMER

Up to 1978 an SBR based elastomer has been used for the sealing rings. In 1978 a study has been carried out on the performance of these sealing rings in comparison with a new elastomer grade, a nitril butadiene rubber (NBR). The conclusion of this investigation was that the used SBR rings still performed very well after more than 12 years use in field practice (ref . 6). But the new NBR grade even showed a better performance and was more resistant to gas constituents. Therefore it was decided to apply only NBR rubber rings in joints in ductile PVC gas distribution systems from 1978 on. The performance of these NBR rings in joints is now studied here after more than 20 years in operation. A comparison with old SBR rings still in use in old gas grids is also made.

TEST METHODS

The laboratory testing has been divided into 4 parts :

- Leakage testing according to the specifications
- Leakage testing under extreme deflection of the pipes
- Determination of the dimensions of the pipe, socket joint and elastomeric seal
- Quality determination of the used elastomeric seals and estimation of the residual lifetime

More information on the various tests will be given below.

Leakage testing according to the specifications

In order to qualify the elastomeric sealed socket joints of 22 years old ductile PVC gas distribution systems, a comparison of the leak tightness with new ductile PVC joints was made. The old socket couplers including the pipes were tested in accordance with the Dutch (NEN 7231) and International ISO 6993-2 (Draft) standard. Due to the fact that the pipes taken out of the gas grid did not fulfill the requirements of a length of 10 x $d_{n,}$ the angular deflection as mentioned in the standard was not performed. Another reason of not executing this angular deflection is that these socket couplers had to be used for the extreme deflection test .
The tests according to the standard performed are given in Table 1.
This Table 1 is equal to the first part of table B.1– Test scheme tightness of joints with internal air pressure of annex B of both the Dutch standard and the ISO standard.

Step	Time (min)	Procedure
1	0	Apply smoothly, in 30 sec, a pressure of (2,5 ± 0,5) kPa. Check on leakage
2	10	Increase smoothly, in 30 sec, the pressure to (100 ± 2) kPa. Check on leakage
3	20	Reduce the pressure to atmospheric pressure. Apply a diametrical deflection of (10 ± 2) % at a distance of (d_n ± 2) in mm of the socket-end.
4	25	Apply smoothly, in 30 sec, a pressure of (2,5 ± 0,5) kPa. Check on leakage
5	35	Increase smoothly, in 30 sec, the pressure to (100 ± 2) kPa. Check on leakage
6	45	Reduce the pressure to atmospheric pressure and take the piece out of the test rig..

Table 1. Test scheme for testing tightness of joints with internal air pressure

After this test the assembly of pipe and coupler are tested according to the so-called vacuum test according to appendix C of the standards mentioned before. The test scheme used is given in Table 2.

Step	Procedure
1	Apply on both sides of the test piece on a distance of (d_n ± 2) mm of the socket-end a diametrical deflection of (10 ± 2) %
2	Place the test pieces in the water bath at 23 °C, completely submersed
3	Apply a negative pressure of – (80 ± 2) kPa on the test piece {+ (20 ± 2) kPa absolute}
4	Maintain this negative pressure for (120 ± 5) min.
5	After this time, bring back the pressure to atmospheric pressure
6	Take the test piece out of the water bath
7	Check the inside of the test piece on leakage by incoming water on the socket-ends

Table 2. Test scheme for testing tightness of fittings under negative pressure and mechanical loading.

Leakage testing under extreme deflection of the pipes

In this test the horizontal deflection (just beside the joint) of the pipe at which leakage starts is measured. A picture of the test rig is shown in fig. 1.

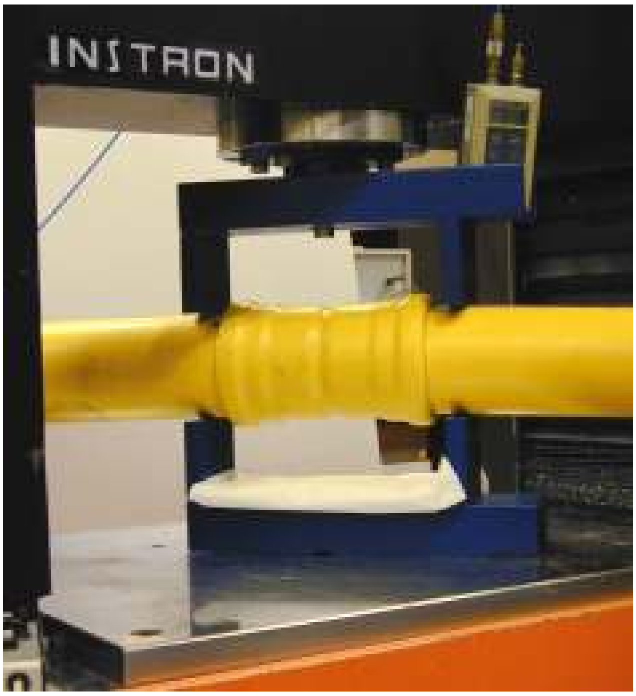

Fig. 1 Test rig for extreme deflection tests

Dimensions

In order to decide if leakage is to be expected due to the change in dimensions, the most important dimensions are measured
In Figure 2 the different spots measured are indicated.

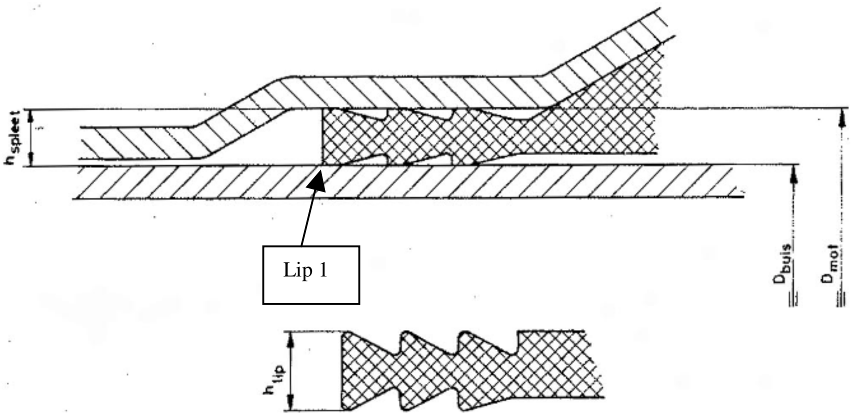

Figure 2. Detail of socket joint

Quality of the used elastomeric seals and estimation of residual lifetime

At first the outside diameter of the pipe samples was measured as close to the socket as possible. Also the outside diameter of the socket was measured at the location of the rubber seal. After that the combinations were demounted by pulling the pipe out of the socket by the

use of a tensile testing machine. Thirty minutes after demounting the dimensions of the lips on the seals, the outside diameter of the pipe at the location of the seal and the wall thickness of the socket were determined.
From four samples the following properties were determined as well:

- hardness according to ISO 7619
- density according to ISO 2791
- tensile strength according to ISO 37
- elongation at break according to ISO 37
- modulus according to ISO 37

The necessary test pieces were obtained by cutting and buffing from the seal.

RESULTS

All tests have been performed on 110 mm SDR 41 pipes.

Leakage testing according to the specifications
All tested samples passed the requirements.

Leakage testing under extreme deflection of the pipes
In ref .6 results on SBR and NBR based elastomeric seals in sockets couplers are given. These results will be used here for reference and are reproduced in Table 3.

Code	Year of installation	Year of excavation	Age	Type of elastomer	Flattening of the pipe (mm) at which leakage starts
11	1966	1978	12	SBR	55
12	1966	1978	12	SBR	56
1	1969	1978	9	SBR	35
3	1969	1978	9	SBR	32
5	1972	1978	6	SBR	56
7	1972	1978	6	SBR	31
13	1975	1978	3	SBR	56
16	1975	1978	3	SBR	50
New	1978	1978	0	NBR	56
New	1978	1978	0	NBR	50

Table 3. Results of Van Schagen and Broere.(ref 6, measured on original samples)

The results of the tests on the recently excavated pipe samples are given in Table 4.

Code	Year of installation	Year of excavation	Age	Type of elastomer	Deflection of the pipe (mm) at which leakage starts
1	1970	2000	30	SBR	48.5

4		2000	30?	SBR	89.2
7	1983	2000	17	NBR	81
W1	1978	2001	23	NBR	55.1
W4	1979	2001	22	NBR	40
W5	1978	2001	23	NBR	70

Table 4. Maximum deflection at which leakage occurred

When comparing the previous results with the new results, it is observed that the scatter in the results is now somewhat bigger. A possible explanation is that the elastomeric seals stick to the socket and the pipe. This sticking might also result in time-dependent behaviour and a higher deflection value before leakage occurs. From the recently obtained results a minimum deflection value of about 36 % before leakage occurs can be concluded.

Dimensions
From the dimensions the compression set of the rubber rings has been calculated. These compression set values range between 15 and 40 %, with some extreme values up to 50 %

Quality of the used elastomeric seals and estimation of the residual lifetime
A summary of the results obtained are given in Table 5.

Code	Hardness Shore A]	Density mg/m^3]	Tensile strength MPa]	Elongation at break %]	Modulus at .. elongation MPa]		
					100 %	200 %	300%
3-1	49	1.11	10.5	410	1.3	3.0	6.3
8-1	56	1.30	12.9	470	1.8	4.2	7.3
W2-1	57	1.30	15.7	470	2.2	5.0	8.6
W7-1	56	1.23	14.7	545	2.1	4.8	7.2

Table 5. Summary of some properties (median values)

DISCUSSION

It has been shown that the joints start to leak when the deflection of the pipes exceeds a value of 36 %. During the last decades the deflection of ductile PVC pipes under various operational conditions have been measured. Using these values, the probability that a joint will start to leak in field practice can be calculated. Some results of these calculations are given in Table 6.

code	Deflection at which leakage starts	Approximation of the chance that deflection in practice is exceeded
	in %	[-]
1	44	6.10^{-36}
4	81	2.10^{-139}
7	74	1.10^{-114}
W1	50	5.10^{-48}
W4	36	1.10^{-22}
W5	64	2.10^{-83}

Table 6. Calculation of the probability of exceeding the measured deflection at which leakage starts.

These calculations show a neglible chance of leakage to occur under practical conditions.

As leakage testing according to the specifications showed no failure of any test specimen, it can be concluded that the excavated socket joints, which have been in operation for years, show a mechanical behaviour in accordance with the standards for new socket joints.

Although difficult to measure, the dimensions give a good impression of the compression set of the different sealing rings. Assuming that the original height of the profile on the seals was 6 mm , it is useful to estimate the remaining lifetime. This is useful because the properties obtained on the used seals are still at a good level and fulfilling the requirements for new seals. Plotting the highest values for the compression set versus the logarithm of the time it is possible to predict what might be expected for the following years. The compression set will increase linearly over a long period of time when plotted versus the logarithm of time. These results are given in fig. 3.

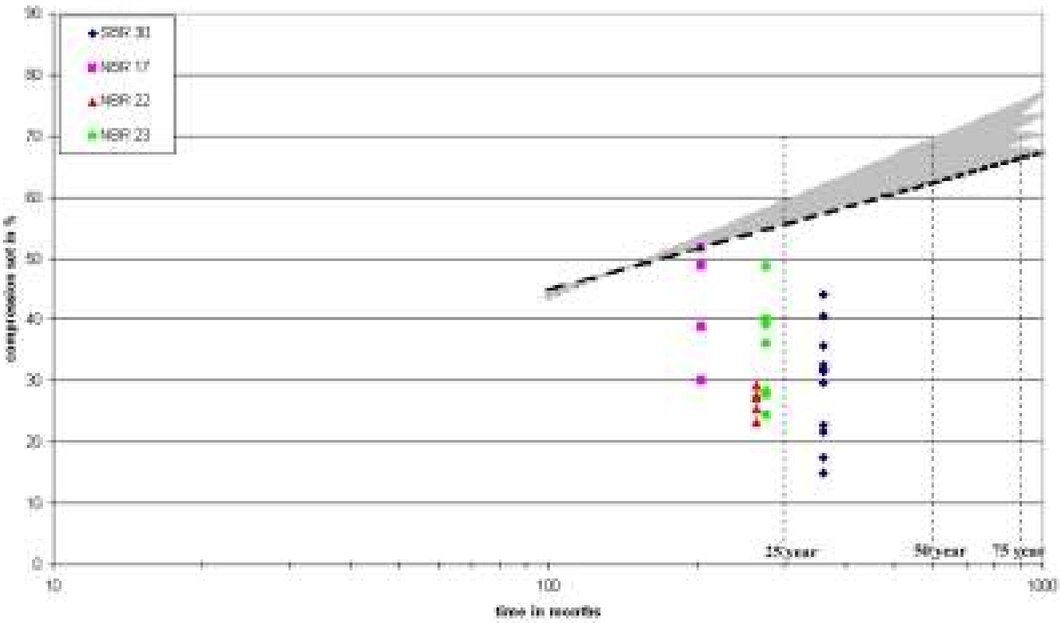

Fig.3 Extrapolation of compression set data

From the extrapolation of results it can be seen that it will take about 50 years before the compression set will be above 70 %. Based on experience it is known that leakage will only occur when the compression set exceeds a value of 70 %. The probability that the compression set under practical conditions will indeed exceed this value is therefore very low.

CONCLUSIONS

All excavated, old socket joints (between 20 and 30 years in operation) tested fulfilled the requirements for leaktightness according to the specifications. The minimum deflection of pipes at which leakage in laboratory tests occurs is 36 %, which is far above the deflections observed in field practice.
All seals investigated are still of a good quality and there are no signs of deterioration.
Based on the compression set determined for the excavated seals a lifetime of at least 50 years can be established.
So, after tens of years in use the socket joints, including the sealing rings, are in a very good shape. These results confirm once again that ductile PVC systems have an excellent quality and will perform safely and reliably for at least 50 years.

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