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Materials & Products – Coatings
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Examination of SINTAKOTE® in Service

SUMMARY

The performance of SINTAKOTE®, Steel Mains' fusion bonded polyethylene pipeline coating, has been assessed on three operating water pipelines at various time intervals. Pipelines were examined after 8, 14, 26, 35, and 40 years' service. All pipelines were buried, however a section of the pipeline examined at 26, 35, and 40 years was also installed above ground.

The condition of the coatings was assessed by visual assessment, testing the adhesion, hardness, impact resistance, oxidation/thermal degradation, and where possible the yield strength, elongation at break, environmental stress cracking resistance, and resistance to indentation.

All of the tests undertaken on the coatings passed the applicable requirements for SINTAKOTE that existed at the time that coating was applied. The examinations and test results allow us to conclude that after 40 years' service, there was no significant change in the properties of the SINTAKOTE.

These results give us further assurance that the coating will meet our expectations for a life well in excess of 100 years when buried, and for in excess of 50 years when exposed to continuous solar radiation above ground.

John Andreatta
QA & Technical Manager

INTRODUCTION

In order to obtain detailed information on the in-service performance of SINTAKOTE®, the following in-service examinations of operating pipelines have been performed:

1. **Site 1 -** A 724mm outside diameter (OD) buried SINTAKOTE steel pipeline installed in 1983 was examined in November 1991 in conjunction with the owner/operator, Horsham Water Board. See Figure 1.
2. **Site 2 -** A 724mm OD buried SINTAKOTE steel pipeline installed in 1977 was examined in November 1991 in conjunction with the owner/operator, Horsham Water Board. The pipeline inspected at Site 1 was an extension of this pipeline. See Figures 2, 3 & 4.
3. **Site 3 -** A 813mm OD above ground section of SINTAKOTE steel pipeline in Geelong was examined. It is part of the 15km mainly buried pipeline that conveys water from Montpellier to the Lovely Basins reservoirs. It was installed in 1978 and was examined in December 2004 in conjunction with the owner/operator, Barwon Water. Subsequent examinations were undertaken at this site, immediately adjacent to the previously tested sites, in December 2013 & September 2018. See Figures 5, 6, 7, 8, 9 & 10.
4. **Site 3 -** A 813mm OD buried SINTAKOTE steel pipeline in Geelong was examined. The pipeline is an extension of the above ground pipeline described in Site 3. It was examined in December 2004 in conjunction with the owner/operator Barwon Water. Subsequent examinations were undertaken at this site, immediately adjacent to the previously tested sites, in December 2013 & September 2018. See Figures 5, 6, 11, 12, 13 & 14.

EXPERIMENTAL

At each site the material around the pipe was removed for pipeline examination. Some or all of the following tests were then undertaken:

1. Description/assessment of the soil surround to determine its corrosivity.
2. Visual examination to determine if there were any surface defects, such as blisters, cracks, perforations, visual change in the coating's appearance, etc.
3. Bond testing to determine the bond/adhesion of the coating, and if it had changed during service.
4. Hardness testing. This is a general indicator of change in material properties. A large change in the hardness of the coating, with either softening or hardening, would indicate deterioration of the coating, leading to possible water permeation, damage from soil stress, or cracking due to embrittlement.
5. Impact testing to determine if the coating strength, ductility, and resistance to damage has changed significantly from when initially supplied. A change in impact resistance is another general indicator of coating deterioration.
6. Mechanical testing for yield stress, elongation to break, and indentation resistance, on coating samples removed from the pipeline and tested in the laboratory. These tests will indicate if there's been any embrittlement or deterioration.
7. Thermal testing for oxygen induction temperature/time to determine the amount of any thermal degradation / ageing that may have occurred in the coating during service. It is also an indicator of remaining life.
8. Chemical testing to determine whether or not the resistance to environmental stress cracking has changed.

It wasn't possible at Site 3 to successfully remove sufficient coating to undertake the mechanical tests due to the very high bond of the coating.

RESULTS & DISCUSSION

Above ground section – Site 3

Photographs of the site and related testing are shown in Figures 5 to 10.

Visual examination of all the coating when examined in 2004, 2013 and 2018 indicated it was in excellent condition, with no evidence of crazing, cracking, or any other surface defects, such as blisters, cracks, perforations, etc. Note that the first signs of thermal degradation/ageing can usually be identified by visual examination, and no such signs were evident.

High voltage continuity inspection was carried out on the coating at 15kV in 2013 and 2018. No coating deterioration holidays were found, however there was minor third-party damage at one point, which was thought to be related to grass cutting activities.

The results of the above ground coating tests are shown in Table 1. The results are compared with typical values from as-applied coating.

Details are as follows:

Bond/adhesion testing was performed in accordance with AS 2518, the most relevant standard for the low-density polyethylene coating that was applied in 1978, however note that the first edition of AS 2518 only came into being in 1982. AS 2518 requires a minimum bond strength of 2.5N/mm.

During all 2004, 2013 and the 2018 inspections the coating was tightly adherent, and this made it very difficult to undertake the test without the coating fracturing first. On all 3 occasions a definitive result could not be obtained, with every indication the bond was well above 2.5N/mm in all tests. The values recorded in Table 1 represent the load achieved just prior to coating fracture. The steel surface underneath the removed coating was bright, with no evidence of corrosion, indicating the coating has satisfactorily performed its primary function of providing a barrier oxygen and water permeation.

There has been a slight, minor increase in the average coating hardness over the testing period. This is not thought to be significant, especially when considering the uncertainty of measurement for such testing. Fig. 8 shows the hardness test being undertaken.

As there was no test method in AS 2518 for impact resistance, we undertook the quality control impact test specified in the German/European Standard DIN 30670 for fusion bonded polyethylene. DIN 30670 covers a range of bonded polyethylene coatings, including fusion bonded polyethylene.

DIN 30670 requires that fusion bonded polyethylene coatings withstand an impact energy of 5 times the specified minimum coating thickness, using a 25mm diameter tup.

At Site 1 and 2 the impact energy was set at 15J, as required for a 3mm minimum thickness coating.

The coating thickness was measured at 2.7mm at Site 3, indicating a specified minimum coating thickness of 2.5mm, and hence a required impact energy of 12.5J. One complication for above ground testing was the fact that the steel pipe was installed at an angle of approx. 20° to the horizontal (so the pipeline could transition from above ground to a considerable depth, as it had to go under the nearby road). This meant the impact could not be at 90° (as the drop tube had to be maintained vertical), thereby slightly diminishing the severity of the impact. To compensate for that the impact tests were done at 15J, representing a 20%

increase in impact loading on the minimum requirement. A 25mm diameter headed tup weighing 1kg was dropped from heights of 1.5m to achieve impact energy of 15J.

After the coating was impacted it was high voltage continuity tested at 15kV, and no holidays were found. This indicates a high level of coating ductility and indicates that there has been no measurable deterioration in the impact strength of the coating after 40 years in service. The oxygen induction temperature (OITemp) test provides a good measure of the thermal resistance of polyethylene and provides information on its remaining life. The OITemp is the temperature at which decomposition occurs in still air. This method was the specified method for polyethylene pipes in the 1980's and 1990's and required a result of ≥ 230°C on new as-produced pipe to pass.

Currently the oxidation/ageing resistance requirement for polyethylene pipes is given in AS/NZS 4130, which references the ISO test method - ISO 11357-6. OITime measures the time to commencement of degradation in oxygen at a constant temperature of 200°C. Polyethylene pipe supplied from 2009 has to meet a requirement of ≥ 20 minutes in this test. Both OITemp and OITime provide good measures of the oxidation/ageing resistance of polyethylene and provide information on its remaining life.

As testing for polyethylene oxidation resistance is generally now only conducted as OITime to ISO 11357-6, that method was exclusively used post 2004. The results show no deterioration from 2004 to 2018, and a pipe coating that still meets the current day requirement for polyethylene pipe. Taking into account comparisons with the below ground coating results and the results for as-applied coating it can be seen that there has been only slight deterioration in oxidation resistance during the 40-year exposure period. This indicates the coating is on track for a life well in excess of 50 years when fully exposed to outdoor sunlight.

In summary all the testing showed that the above ground coating, in continuous outdoor exposure, would still pass all the new as-applied coating tests after 40 years exposure. Together with the fact that there is no evidence of reduced adhesion, and only a minor reduction in oxidation / ageing resistance, these SINTAKOTE® results after 40 years service provide strong evidence to support the view that a service life well in excess of 50 years would be expected for above ground service.

Below ground sections – Sites 1, 2 & 3

Photographs of the sites and related testing are shown in Figures 1 to 6 and 11 to 14.

Soil testing results are shown in Tables 2 and 3. Different methods of soil assessment were used as indicated in the Tables. The soil from Site 1, Horsham was classed as corrosive.

No samples were taken from Site 2; however, it can be seen in Figures 2 and 3 that a sand backfill was placed around the pipe.

The soil surround at Site 3, in Geelong was classed as non-corrosive, with the native soil classified as moderate to very corrosive.

Visual examination of all the coatings examined indicated they were in excellent condition, with no evidence of crazing, cracking, or any other surface defects, such as blisters, cracks, perforations, etc. Note that the first signs of thermal degradation/ageing can usually be identified by visual examination.

The results of the below ground coating tests are shown in Table 1. The results are compared with typical values from new as-applied coating.

Details are as follows:

In all cases the adhesion was high, and easily met the factory bond test requirement at the time of coating application. In no case was there any evidence of corrosion under the removed coating, with bright steel evident. This indicates SINTAKOTE is continuing to perform its main function of providing a barrier oxygen and water permeation.

There has been a slight, minor increase in the average coating hardness over the testing period. This is not thought to be significant, especially when considering the uncertainty of measurement for such testing.

Impact testing was performed as detailed above in the above ground coating section. The results indicated there was no decrease in impact performance of the coating. In all cases the coating met the factory quality control requirement for newly applied coating, indicating no sign of deterioration.

OITemp and OITime testing was undertaken, as detailed in the above ground coating section. The results show virtually no change in oxidation/ageing resistance in all samples tested, after 8, 14, 26, 35 and 40 years service. This indicates that there has been no significant deterioration of the buried SINTAKOTE®, at any of the sites, which includes exposure up to 40 years. The results endorse the claim that SINTAKOTE will provide a service life well in excess of 100 years.

The yield strength and elongation at break data shows that after 14 years service the coating met the quality control requirements of newly applied coating. This was also the case for environmental stress cracking resistance (ESCR) and indentation testing. Unfortunately, the high level of coating adhesion prevented samples being taken from the pipe at Site 3.

In summary all the testing showed that the buried coatings examined would pass all the new as-applied coating tests when in service for up to 40 years. Together with no evidence of reduced bond/adhesion and no significant deterioration occurring this provides strong evidence to support the view that a service life well in excess of 100 years will be achieved for SINTAKOTE pipe coating.

CONCLUSIONS

A range of inspections and tests were undertaken on SINTAKOTE® (Steel Mains' fusion bonded polyethylene) after 8, 14, 26, 35 and 40 years exposure both above and below ground exposure.

As a result of these examinations and testing the following conclusions are made:

1. On both the above and below ground sections visual inspection showed the coating to be in excellent condition, with no evidence of crazing, cracking, or any other surface defects, such as blisters, cracks, or any perforations. In addition, no holidays due to deterioration were detected when the coating was subjected to a 15kV high voltage continuity test.
2. On both the above and below ground sections the coating was highly adherent, meeting the bond strength requirements of an as–applied coating, and with no evidence of any corrosion under the steel.
3. On both the above and below ground sections the coating hardness was similar to the original coating hardness.
4. Both the above and below ground coatings exhibited an impact resistance in excess of 15J after 40 years' service – in excess of the minimum requirement for an as–applied coating, indicating a high degree of ductility in the coating.
5. Both the above and below ground coatings demonstrated a high level of ongoing resistance to oxidation, with both areas demonstrating compliance with as-produced new polyethylene coated steel pipe.
6. The results indicate that a predicted service life of well in excess of 50 years will be achieved for the above ground SINTAKOTE coating.
7. The results indicate that the predicted service life of well in excess of 100 years will be achieved for the below ground buried SINTAKOTE coating.

ACKNOWLEGEMENTS

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REFERENCES

1. Standards Association of Australia, AS 2518:1992, “Fusion-bonded low-density polyethylene coating for pipes and fittings”.
2. Standards Association of Australia, AS 1463:1988, “Polyethylene pipe extrusion compounds". Appendix B, “Determination of thermal oxidative stability”.
3. German Standard DIN 30670:1980, “Polyethylene Coating of Steel Pipes & Fittings”.
4. Standards Association of Australia, AS/NZS 4130:2018, “Polyethylene (PE) pipes for pressure applications”.
5. International Standards Organisation, ISO 11357-6, “Plastics — Differential scanning calorimetry (DSC) — Part 6: Determination of oxidation induction time”.

Table 1 Coating Test Results

Property	Site 1 – Horsham, 8 years old	Site 2 – Horsham, 14 years old	Site 3 – Geelong, 26 years old	Site 3 – Geelong, 35 years old	Site 3 – Geelong, 40 years old	SINTAKOTE, as-applied to AS 2518	
						Requirements	Typical initial values
Bond Strength (N/mm)	Could not peel, ≥ 4	Could not peel, ≥ 6.5	Could not peel, > 6 N/mm above and below ground	Could not peel, > 2.2N/mm above ground, > 3.5N/mm below ground	Could not peel, > 2.2N/mm above ground, > 3.5N/mm below ground	≥ 2.5 (AS 2518)	4 – 8 N/mm
Hardness (Shore D)	46 – 52	50 – 52	52 Shore D above and below ground	52 – 56 Shore D both above and below ground	57 Shore D both above and below ground	None	50 – 52 Shore D
Impact DIN 30670 (J)	Passed at 15 J	Passed at 15 J	Passed at 15 J above and below ground	Passed at 15J both above and below ground	Passed at 15J both above and below ground	> 12.5 (DIN 30670)	> 12.5 J
Oxygen Induction Temperature - OITemp (°C)	Not done	259	256°C above ground, 253°C below ground	Not tested	Not tested	> 230°C (AS 1463)	256 – 264°C
Oxygen Induction Time - OITime (°C)	Not applicable	Not applicable	24 minutes below ground, above ground not tested	24 minutes above ground, 28 minutes below ground	24 minutes above ground, 28 minutes below ground	> 20 minutes (AS/NZS 4130 / ISO 11357-6)	30 – 40 minutes
Yield Strength	9.1	9.0	Could not remove coating for testing	Could not remove coating for testing	Could not remove coating for testing	≥ 8.5 MPa (AS 2518)	9.0 – 10.0 MPa
Elongation at break	320	310				≥ 300 % (AS 2518)	300 – 400 %
ESCR, F_{50}	5	5				≥ 3 hr (AS 2518)	3 – 5 hr
Indentation	0.12	0.11				< 0.3 mm (DIN 30670)	0.10 – 0.15 mm

Table 2 Soil Assessment Results from Site 1 (1991) and Site 3 (2004)

Property	Site 1, Horsham, 1991	Site 3, Geelong – pipe surround, 2004	Site 3, Geelong – adjacent native soil, 2004
Classification	Orange-brown clay	Brown loamy sand	Very dark brown loam
Saturated resistivity	860 ohm cm	14182 ohm cm	800 ohm cm
pH	9		
Sulphides	Trace		
Overall Assessment	Corrosive to very corrosive	Slightly corrosive	Moderately corrosive

Table 3 Soil LPR Assessment Results from Site 3 (2013)

Sample	Texture	Colour	Average Rp, ohm	Normalised pitting rate, mm/yr	Soil corrosivity
Imported material around pipe	Sandy loam	Brown	151	0.05	Non-corrosive
Native soil	Clay loam	Dark greyish brown	22	0.4	Very corrosive

Figure 1 - Site 1, Horsham, 1991, showing the 8-year-old 724mm OD SINTAKOTE® steel pipe and preparations for impact testing.

Figure 2 – Site 2, Horsham, 1991, showing the 14-year-old 724mm OD pipe with soil being removed.

Figure 3 - Site 2, Horsham, 1991, showing the 14-year-old pipe ready for examination (with 50c coin for perspective).

Figure 4 – Site 2, Horsham, 1991, undertaking the bond adhesion test on the 14-year-old pipe.

Above ground section

Below ground sites

Figure 5 – Site 3, Geelong 2004 & 2013, showing a general view of the test sites at Lovely Banks reservoir site (facing NNW).

Above ground inspection point, 2013

Above ground inspection point, 2004

Below ground inspection point, 2004.

Below ground inspection point, 2013

Figure 6 - Site 3, Geelong, 2004 & 2013. Detailed view of the test sites showing regions of examination (facing North).

Above ground inspection point, 2013

Above ground inspection point, 2004.

Figure 7 – Site 3, Geelong, 2004 & 2013. Close up view of the above ground pipeline section (taken facing West).

Figure 8 – Site 3, Geelong, 2013. Shore D hardness test on above ground pipe.

Figure 9 - Site 3, Geelong, 2013. Bond testing the above ground pipe.

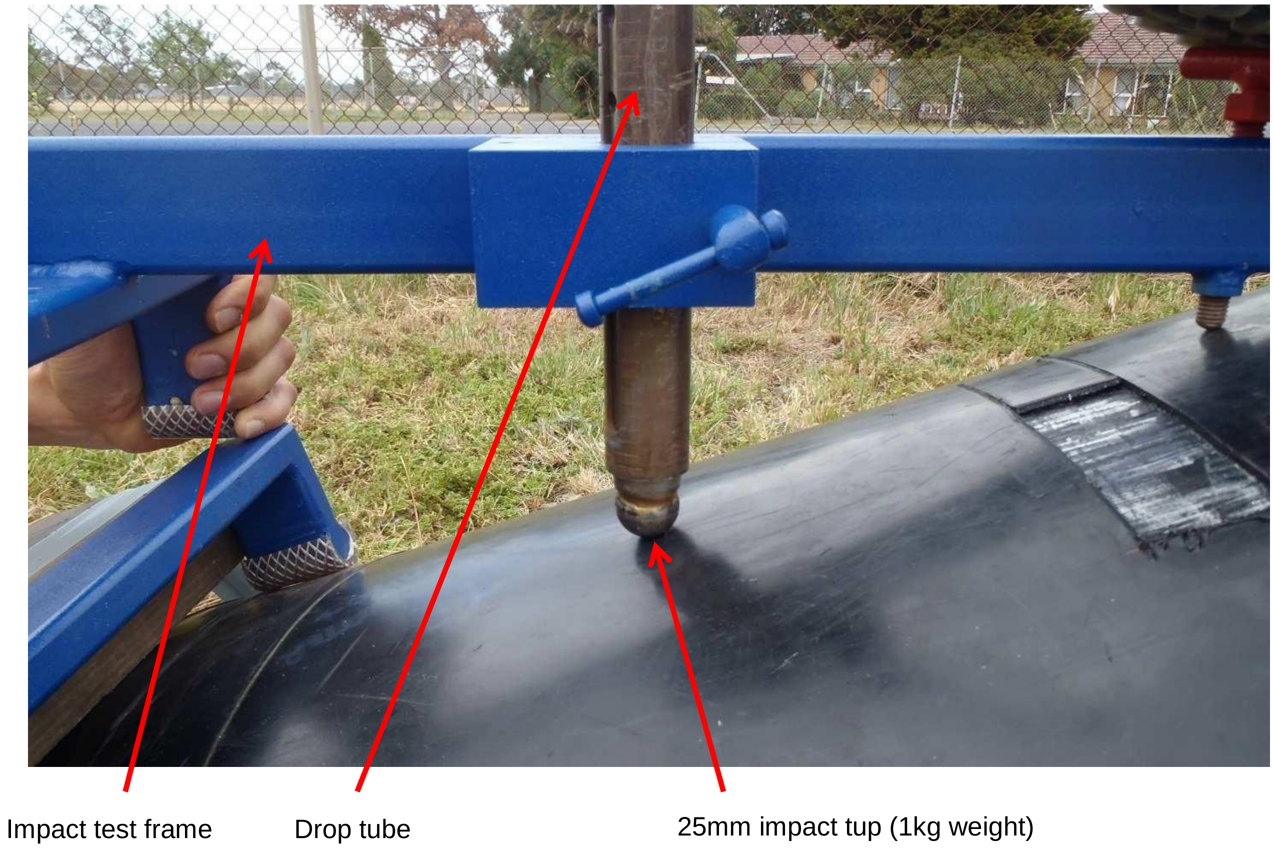

Figure 10 – Site 3, Geelong, 2013. Impact test set up on the above ground section. The left-hand side was elevated to ensure the drop tube was vertical.

Figure 11 – Site 3, Geelong, 2004. Close up view of buried pipe showing impact test indentation (LHS) and bond test (RHS)

Figure 12 – Site 3, Geelong, 2013. Bond testing the buried pipe.

Figure 13 – Site 3, Geelong, 2013. Buried pipe ready for examination (facing NW).

Figure 14 – Site 3, Geelong, 2013. High voltage 15kV continuity testing of impacted positions on buried pipe.