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FUSION BONDED POLYETHYLENE COATINGS – 40 YEARS ON

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SUMMARY:

The introduction of Fusion Bonded Polyethylene (FBPE) coatings in the 1970's superseded the earlier hot applied bitumen and coal tar enamel coatings previously used to protect steel water mains. These bitumen and coal tar coatings were adequate, but had a number of issues in buried applications including soil stress and moisture absorption.

FBPE coatings, now available in all practical sizes used in the water industry are now the default coating system for all steel water pipelines. This brief review looks at the performance and evolution of FBPE coatings with reference to both buried and above-ground applications.

The essential issues of coating performance have been reviewed with emphasis on actual field performance of the pipeline as a whole. As such, the effects of installation, joint coating, cathodic protection and coating degradation are assessed.

The conclusions are that FBPE performance has been excellent over its 40 year history, which was largely expected in buried applications, but surprising in above ground situations, for which the coating was not originally designed. This good performance is largely determined by the coating properties themselves coupled with excellent adhesion achieved through hot fusion application over a Class 2 ½ surface preparation in controlled factory conditions. Nevertheless, close field control of pipe joint reinstatement is important to ensure pipeline integrity as is the correct application of cathodic protection (where specified) to maximise the required long-term performance of FBPE coated water mains.

Keywords: Steel, Pipe, Coating, Polyethylene, Buried, Life

1. INTRODUCTION

When steel pipes were first used for water pipelines in the last quarter of the 19th century, either in riveted or locking bar format, hot applied Trinidad asphaltic bitumen was the standard corrosion protection both internally and externally [1]. In the early 1920's the external coating was reinforced with hessian as an early recognition of soil stress issues.

Hot applied coal tar enamel, as its name suggests is a coal derivative. and with generally reduced water absorption, became an alternative coating in the 1920's. These were also reinforced with hessian and then progressively asbestos fibre matting until glass reinforced fibres became available in the 1960's. The latter coating often had an outer asbestos felt wrap to assist in resisting soil stress effects. By the early 1970's this coating system remained the default protection for all buried steel pipelines, both oil & gas and water. Nonetheless the coating system had a low strain tolerance and was susceptible to soil stresses, especially on larger diameter pipelines. Experiences of coal tar coating failures on water pipelines in 1971 (see photos of soil stress failures Figures 1 and 2) led the State Rivers & Water Supply Commission (SR & WSC - Victoria) to explore alternative coating systems. Concurrently a local steel pipe manufacturer began applying a fusion bonded polyethylene (FBPE) coating. That coating system was first used in 1972 and so began the use of a new pipeline coating system that has now been in use for over 40 years.

2. HISTORY OF USE

2.1 Australia

The first use of the emerging technology FBPE coatings in Australia was by the SR & WSC in early 1972. The coating system was applied at a minimum thickness of 1mm, was yellow in colour and contained a patented blowing agent which produced a porous region in the coating at the steel surface with the intention of “aiding” adhesion [2, 3]. After several months in storage it became apparent that the coating had insufficient ultraviolet ray stabilisation and poor adhesion, as evidenced by cracking of the coating and delamination at pipe ends. Information was sought from European steel pipe and coating companies that had been applying FBPE coatings for over 10 years [2]. The European technology was transferred to Australia in 1973 and the non-patented FBPE coating that was then applied was a black (containing at least 2% of carbon black) low density polyethylene applied at thicknesses from 1.8 to 3.0mm with the thickness increasing with pipe diameter [3].

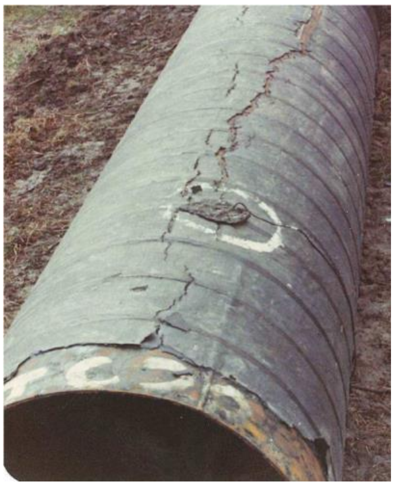


Figure 1: Coal tar enamel coating showing crown cracking 914mm pipeline - 1971

Figure 2: Coal tar enamel coating showing coating on deformation on 914mm pipeline - 1971

The application process involves grit blasting the outside of the pipe, then heating it to approx. 300°C (typically by direct gas flame impingement), dipping in a bath of fluidised polyethylene powder whilst the pipe is rotated, then allowing the molten polyethylene to solidify. During application the first particles of polyethylene are transformed and the functional groups formed provide the adhesion to the steel. The coating thickness is built up by a simple melting process as the pipe is rotated in the bath. When removed the coating continues to melt-through until a smooth outer surface is formed.

In the 1970’s there were steel pipe manufacturing plants in every state, and because the only FBPE coating facilities were in Melbourne, supply of FBPE coated pipe was confined to Victoria until 1984. In the first 10 years of supply over 400km of steel pipe was coated with FBPE in sizes from 114mm to 1752mm in diameter. Of interest was the application of the coating system to 33km of 114mm diameter x 12.5mm wall thickness oil pipe (in 1978) that was welded into a continuous “string”, reeled onto a 4m diameter drum and unreeled into Bass Strait. The pipeline conveyed hot oil at 100°C. A photograph of the reeling operation is shown in Figure 3.

The application of the coating was initially governed by a SR & WSC specification. With that as a starting point, and considering other standards such as the German standard DIN 30670 [4], an Australian standard for FBPE coatings was published in 1982 [5].

In the mid 1980’s FBPE coated pipes became readily available in NSW, Queensland, South Australia and Tasmania, with the final steel water pipe plant in Western Australia being converted in 1989. During this period most pipes coated were for the water industry with some oil and gas pipelines being coated, particularly for offshore applications. In 1985 the coating system was first applied to the ends of elastomeric jointed pipes, together with the water industry's preferred cement mortar lining, this meant that no field joint coating was required – see Figures 4 and 5.

In 1991 the FBPE system was extended to line steel pipes, either solely as a lining or in combination with the FBPE external coating [6]. The coating formulation remained constant throughout this period until the development of new stronger and tougher polyethylenes in the 1980's that led to a development program to explore their suitability as FBPE coatings. In 1993/4 a new medium density FBPE coating became available with higher strength, higher toughness / impact resistance and higher resistance to temperature [7]. The new coating was applied at thicknesses in the range 1.6 to 2.3mm with the thickness increasing with pipe diameter. Despite the decrease in applied thickness the impact resistance of the new medium density FBPE delivered improved adhesion, increased resistance to penetration and an average 10% increase in impact resistance [7]. A new Australian Standard was developed to cover medium density FBPE in 1995 [8]. The "new" MDPE formulation has remained the same since 1993.

The other development over the past 20 years has been the increased capability in coating fittings. In addition to RRJ fittings, a large range of fittings, including large diameter fittings with compensating rings, can be coated.

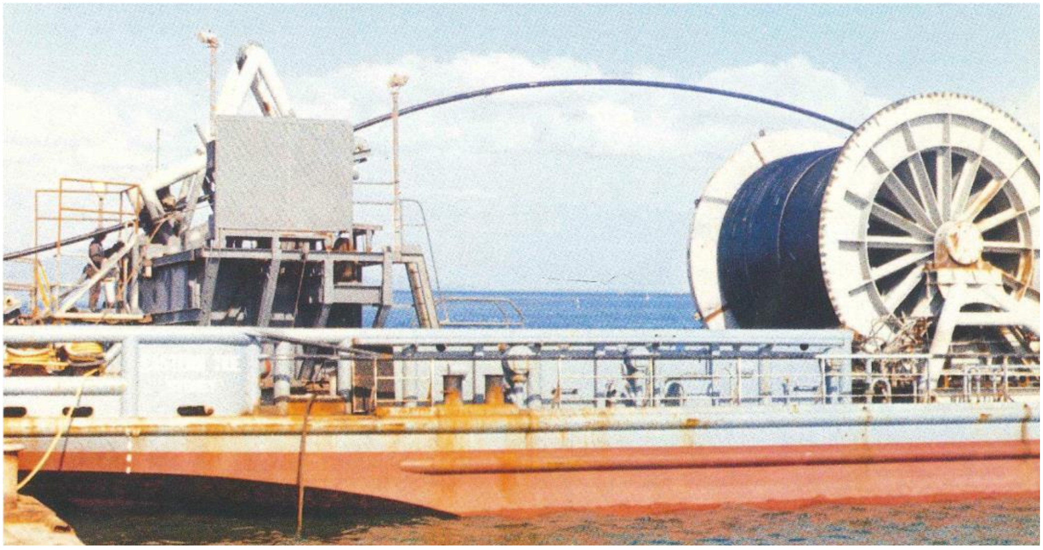


Figure 3: 114mm diameter steel pipe coated with FBPE being reeled onto a large barge – circa 1979

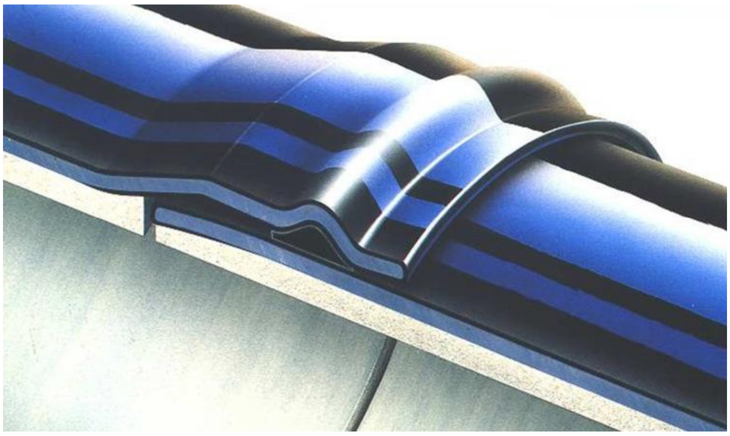


Figure 4: Schematic view of FBPE applied to elastomeric joints – as used in the water industry

Figure 5: Photo of elastomeric socket coated with FBPE – as used in the water industry

2.2 South Africa

In 1993 the capability to apply FBPE coatings with elastomeric joints was established in South Africa to compete with hot bitumen applied coatings. A South African Standard was developed to cover the coating system in 1995 [9]. Pipes continue to be coated with FBPE in South Africa with the MDPE material having been introduced in 1997.

2.3 Other Countries

Over the years of coating application notable steel water pipeline projects coated with FBPE have been supplied to places such as Singapore (for the NeWater project) and Abu Dhabi.

In the USA a FBPE coating standard has been developed based on medium density polyethylene [10], as a precursor to supply of FBPE coatings.

In Europe FBPE coatings have been applied since the 1960's. From the 1980's production has been confined to a small number of applicators as most production was converted to extruded polyethylene coatings which are more cost effective for long production runs and smaller diameter pipe. Extruded polyethylene was also used for oil and gas pipelines in Australia as most pipe diameters were less than 500mm. FBPE is more cost effective for short production runs and larger diameters.

3. SERVICE PERFORMANCE

3.1 In Service Inspections

A number of in service inspections have been performed in conjunction with end users over the 40 years FBPE coatings have been used. The focus has been on the older pipelines as detailed below.

Site 1 - A 724mm diameter buried steel water pipeline installed in 1983 was examined in November 1991 in conjunction with the owner/operator, GWMWater (formerly Horsham Water Board) and an industry expert who had worked at SR & WSC.

Site 2 - A 724mm diameter buried steel water pipeline installed in 1977 was examined in November 1991 in conjunction with the owner/operator, GWMWater and the industry expert. The pipeline inspected at Site 1 was an extension of this pipeline.

Site 3a - A 813mm diameter above ground section of steel water pipeline in Geelong was examined. It was installed in 1978, and was examined in December 2004 in conjunction with the owner/operator, Barwon Water. A second examination was undertaken at this site, immediately adjacent to the original site, in December, 2013 with Barwon Water and a Research Engineer from CSIRO.

Site 3b - A 813mm diameter buried steel water pipeline in Geelong was examined. The pipeline is an extension of the above ground pipeline discussed above in Section 3a. It was examined in December 2004 in conjunction with the owner/operator Barwon Water. A second examination was undertaken at this site, immediately adjacent to the original site, in December, 2013 with Barwon Water and the CSIRO researcher.

Soil samples were taken to access the corrosivity of any imported surround material as well as the native soil. The results showing saturated soil resistivity and linear polarisation resistance are shown in Table 1 together with an overall soil corrosivity classification. At Site 1 the soil was waterlogged and was classified as being corrosive. No samples were taken from Site 2, which had a sand surround. Site 3 also had a sand surround classified as non-corrosive, however the surrounding soil was corrosive.

Table 1 Soil Assessment Results

Sample	Texture/colour	Saturated resistivity	Rp (average)	Normalised pitting rate	Estimated Soil corrosivity
Site 1, native soil	Orange brown clay	860 ohm.cm	Not done	Not estimated	Corrosive
Site 3, pipe surround material	Sandy brown loam	14,182 ohm.cm	151 ohm	0.05 mm/yr	Non-corrosive
Site 3, native soil	Dark greyish brown clay loam	800 ohm.cm	22 ohm	0.4 mm/yr	Corrosive

A range of tests were undertaken on the coated pipes both in-situ and on samples tested in the laboratory. The site tests undertaken were visual inspection, bond (adhesion) testing, hardness testing, and impact testing. Other laboratory tests undertaken were oxygen induction temperature, oxygen induction time, yield strength, elongation, environmental stress cracking resistance (ESCR) and indentation. A summary of the test results is shown in Table 2 and photographs taken during the inspections are shown in Figures 6 to 11.

Visual inspection during all examinations showed the coating was in excellent condition, with no signs of cracking, blisters, etc at any of the sites.

Bond testing at all sites showed that the minimum requirement of 2.5N/mm was easily met except where the bond was so high that the coating broke before peeling occurred. The high bond strength meant that only two samples of sufficient coating size could be removed for the yield strength, elongation and ESCR tests.

Hardness testing indicated no significant change in coating performance. Note the changes in hardness recorded are relatively small in relation to the uncertainty of measurement of the test.

Impact testing was done in accordance with the German standard DIN 30670 as this was the most relevant standard that contained requirements for impact testing of low density FBPE coated pipe. The coating easily withstood the required impact when high voltage continuity tested at 15kV. At site 3 the pipe was on a slope so the impact (which had to be done vertically) was a slightly glancing blow. To account for this geometrical restraint, a higher impact energy of 18J (44% above the minimum requirement) was employed. The coating passed this test exhibiting compression of the coating, with no cracking evident, as would be expected from newly applied coating.

The oxygen induction test provides a good measure of the thermal resistance of polyethylene, and provides information on its remaining life. The oxygen induction temperature, determined in accordance with AS 1463 [11] is the temperature at which decomposition occurs in still air whilst the temperature is raised at a fixed rate. 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 for oxygen induction time. This test measures the time to commencement of degradation in oxygen at a constant temperature of 200°C. Polyethylene pipe supplied in 2014 has to meet a requirement of ≥ 20 minutes in this test. Both methods 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 to ISO 11357-6, that method was exclusively used post 2004. The results show no deterioration at test Site 3 from 2004 to 2013. The results also show that for all samples tested the material would meet the requirements for newly applied polyethylene, even after 35 years service above ground (the most onerous exposure).

As discussed above the very high adhesion of the FBPE coating at Site 3 meant that only sufficient coating for mechanical testing could be obtained from Sites 1 and 2. Such testing is also made more difficult as imperfections in the coating can lead to premature fracture. Nonetheless the yield strength, elongation at break, ESCR and indentation test results all met the requirements specified for newly applied coating.

Table 2 Summary of 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	FBPE applied to AS 2518	
					Requirements	Typical initial values
Bond (adhesion) Strength	Could not peel, > 4 N/mm	Could not peel, > 6.5 N/mm	Could not peel, > 6 N/mm above and below ground	Could not peel, > 2.2N/mm above ground, > 3.5N/mm below ground	≥ 2.5 N/mm (AS 2518)	4 – 8 N/mm
Hardness (Shore D)	46 – 52	50 – 52	52 above and below ground	52 – 56 both above and below ground	None	50 - 52
Impact DIN 30670 – 25mm tup	Passed at 15 J	Passed at 15 J	Passed at 15 J above and below ground	Passed at 15J and 18 J both above and below ground	> 12.5 J (DIN 30670)	> 12.5 J

Oxygen Induction Temperature	Not done	259°C	256°C above ground, 253°C below ground	Not tested	> 230°C (AS 1463)	256 – 264°C
Oxygen Induction Time	Not applicable	Not applicable	24 minutes below ground, above ground not tested	24 minutes above ground, 28 minutes below ground	> 20 minutes (AS/NZS 4130)	30 – 40 minutes
Yield Strength	9.1 MPa	9.0 MPa	Could not remove coating for testing	Could not remove coating for testing	≥ 9.0 MPa (AS 2518)	9.0 – 10.0 MPa
Elongation at break	320%	310%			≥ 300 % (AS 2518)	300 – 400 %
ESCR, F_{50}	5 hr	5 hr			≥ 3 hr (AS 2518)	3 – 5 hr
Indentation	0.12 mm	0.11 mm			< 0.3 mm (DIN 30670)	0.10 – 0.15 mm

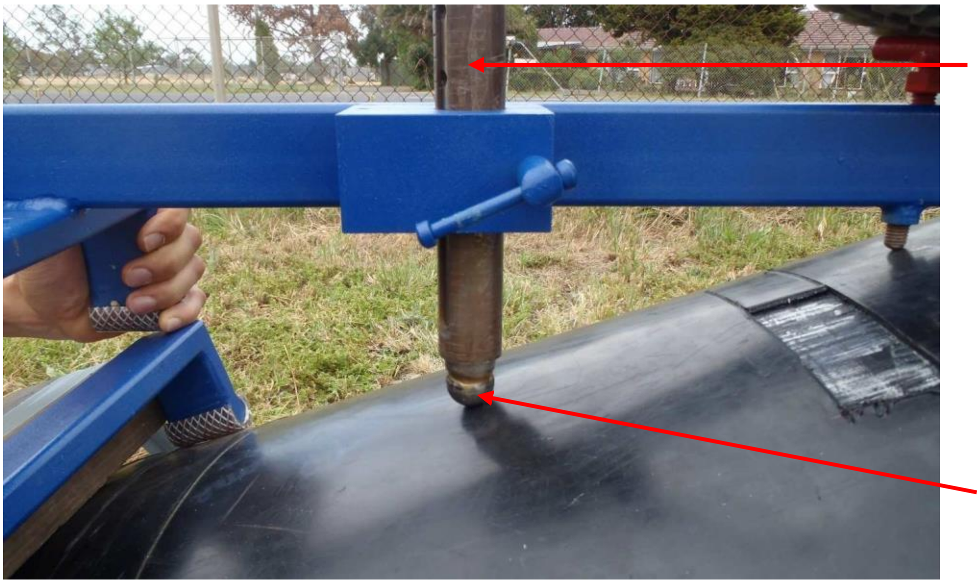
In summary the in service inspections have shown that there has been no significant deterioration of the FBPE coating after service for up to 35 years in both above and below ground service conditions. Based on these results the FBPE coating would be expected to provide a service life well in excess of 100 years where buried and 50 years above ground.

Figure 6: Site 1, Horsham, 1991, showing the 8 year service 724mm pipe, and preparations for impact testing

Figure 7: Site 2, Horsham, 1991, undertaking the bond adhesion test on the 724mm diameter, 14 year service pipe

2004 inspection position   2013 inspection position

Figure 8: Site 3, Geelong, 2004 & 2013. Above ground pipeline section



Drop tube

25mm tup (1kg)

Figure 9: Site 3, Geelong, 2013. Impact test set up on the above ground section.

Figure 10: Site 3, Geelong, 2004. Buried pipe showing impact test indentation and bond test.

Figure 11: Site 3, Geelong, 2013. Bond testing the buried pipe.

3.2 Long Term Testing

Long term testing has been undertaken on medium density FBPE coatings in chemical resistance testing for up to 12 months in a range of "contaminated" waters and on small plates subjected to a range of environments for up to 10 years.

3.2.1 Chemical Resistance Testing

Inorganic chemicals normally found in soils and waters have no significant effect on FBPE, but there was less information on the performance in contact with potentially aggressive petroleum products. CSIRO was commissioned to undertake testing on steel panels (100mm x 50mm x 8mm) coated with medium density FBPE exposed to a range of petroleum products spanning the C6 to C30 fractions. The panels were subjected to various concentrations of unleaded petrol, diesel, kerosene, toluene, xylene, and lubricating oil in aqueous solutions and in sand. The panels were then visually inspected for corrosion, change in material appearance, weight change and hardness change. The work was done to better predict the performance of FBPE coatings when buried in contaminated soils. The results are shown in Table 3.

The results show that for most contaminated soils, with concentrations of petroleum products up to 2,000ppm, that there is no significant change in the properties of medium density FBPE coatings.

Table 3 FBPE Coated panel Results after Exposure to a Range of Petroleum products for 12 Months

Immersion fluid	**Medium density FBPE coated steel** (starting hardness 57)			
	Average %wt change (2 samples)	Shore D hardness sample 1	Shore D hardness sample 2	Visual observations
Unleaded petrol				
100%	10.3	53	50	Slight dulling of surface only
500ppm	0.1	58	57	No change
2000ppm	0.3	59	58	No change
2000ppm in sand	0.3	56	55	No change
Diesel				
100%	6.7	53	52	Slight dulling of surface only
500ppm	0.4	58	57	No change
2000ppm	2.2	56	55	No change
2000ppm in sand	2.9	56	57	No change
Kerosene				

100%	8.1	53	53	Slight dulling of surface only
500ppm	0.2	55	60	No change
2000ppm	1.2	53	56	No change
2000ppm in sand	2.0	56	58	No change
Toluene				
100%	10.8	50	53	Slight dulling of surface only
500ppm	0.0	55	56	No change
2000ppm	0.3	60	60	No change
2000ppm in sand	0.1	63	55	No change
Xylene				
100%	11.0	50	52	Slight dulling of surface only
500ppm	0.2	53	53	No change
2000ppm	0.5	53	54	No change
2000ppm in sand	0.3	59	57	No change
Lubricating oil				
100%	1.0	53	50	No change
500ppm	0.2	56	56	No change
2000ppm	0.6	55	57	No change
2000ppm in sand	0.3	55	57	No change

3.2.2 Exposure to a Range of Environments for up to 10 Years

Soon after the introduction of medium density FBPE coatings in 1993 SA Water undertook testing on a number of FBPE coated steel panels. Panels of size 150mm x 100mm x 3 mm, with an average coating thickness of 1mm, were exposed to raw sewage and sewer gas. Panels of size 600mm x 150mm x 6 mm, with coating thicknesses above 1.3mm, were exposed to full and half immersion in fresh water and to a rural atmospheric environment. Photographs taken at the test sites are shown in Figures 12 to 15.

Small test panels were supported vertically and half immersed in flowing raw sewage at the Bolivar Waste Water Treatment Plant which is located north of Adelaide (see Figures 12 and 13). The vapour space is supplemented with the addition of chemically pure hydrogen sulphide gas and maintained at approximately 40 to 50 ppm. Panels were removed, cleaned and assessed at 6 monthly intervals. One panel had been under test for 7 ½ years and the other for 8 ½ years. No rusting, blistering or other changes have been observed during this time exposed to raw sewage and sewage gas. It is of interest to note that most high performance protective coatings fail or show signs of failure in this test in less than 2 years.

Large panels were supported vertically in timber frames which were supported by a floating pontoon moored in the River Murray at Morgan in South Australia (see Figure 14). The upper panel was half immersed in water with its upper half exposed to shaded rural atmospheric exposure and a narrow zone of splashing. A fully immersed panel was fixed directly below the half immersed panel. The panels were assessed after 10 years exposure when no rusting, blistering or other changes were observed after these river exposures.

Large panels were fixed to test racks which face a northerly direction at an inclination of 45˚. The site is located on the cliffs above the River Murray at Morgan where high UV and summer temperatures in excess of 40˚C are experienced. The FBPE coated panels were last assessed after 10 years exposure, when minor chalking (Rating 9 to AS/NZS 1580 Method 481.1.11) was observed. No other changes were evident.

In summary this testing reinforces the expected high longevity of FBPE coatings in a range of severe environments.

Figure 12: Sewage test chamber

Figure 13: Sewage test rack

Figure 14: Murray River Pontoon for immersion exposure

Figure 15: Atmospheric test racks at Morgan

3.3 Cathodic Protection

Cathodic protection (CP) is often applied as a secondary protection for water pipelines, and is mandatory for oil and gas pipelines. As a result of long-line corrosion effects, including telluric currents it is prudent to cathodically protect electrically conductive steel pipelines that are either critical, or of significant length. With the advent of FBPE coatings on elastomeric jointed pipe in 1985 the question was posed: is it prudent / cost effective to cathodically protect such nonelectrically conductive pipelines? Different Water Agencies took different approaches with some opting for elastomeric jointed pipelines without the application of CP, whilst others used either applied CP on elastomeric jointed pipelines or on welded pipelines (or a combination of both). One study involved a prominent cathodic practitioning expert, one of the authors and a major water authority in the mid 1990's. The outcome was the flow chart shown in Figure 16. The water authority adopted a more extensive version of that shown in Figure 16.

Cathodic protection selection chart

Should CP be used?

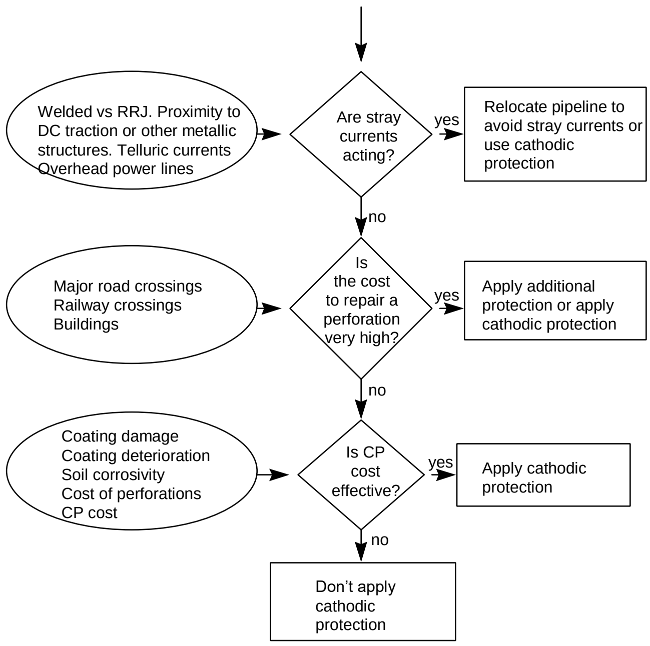


Figure 16. Selection chart to determine the desirability or not for CP

Where elastomeric jointed pipes are used, and CP is specified, the use of joint bonding cables are needed to electrically connect the pipes. The only major detrimental aspect of applying CP to any bonded pipeline is the possibility of breakage of the bonding cables, which must then be located through continuity surveys. To minimise the risks of this the installation of CP lugs has evolved over the years to that in predominate use today. CP lugs are normally attached to pipes prior to the application of the FBPE coating so that the only attachment required in the field is to attach a copper cable, via crimping, followed by a heat shrink sleeve over the cable junction. A typical assembled joint cable is shown in Figure 17.

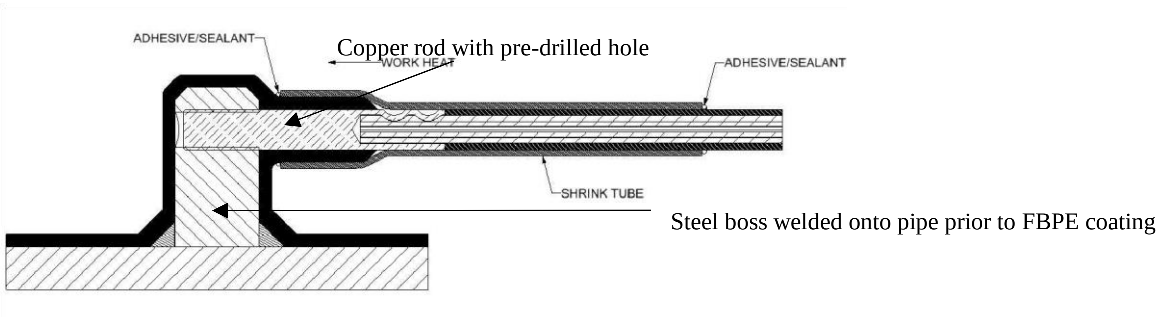


Figure 17: Schematic view of cathodic protection lugs attachment

Where CP is applied the determination and monitoring of CP current demand is an indicator of possible coating deterioration, though other factors also need to be considered. Verbal information provided by a number of CP practitioners indicates that the current demand of FBPE coated pipelines is typically in the range 5 – 10 μA/m^2 initially, with little increase during service. CP current demand data also necessarily includes the demand from field joint coatings which typically draw higher currents and are more susceptible to deterioration. Nonetheless details of CP current demand were sought from a large number of water agencies and consultants, but to date only data from 8 pipelines has been received and 7 of those were only in the as-commissioned state. The results of the 7 as-commissioned pipelines are shown in Table 4. It can be seen that initial current demand of the order of 5 – 10 μA/m^2 can readily be achieved. The reasons for the high demand on two of the pipelines (excluding the one subjected to stray currents) has not been determined, and include a range of possible causes including coating damage, over – protection, leakage to other structures, poor joint coatings, stray currents, etc.

Some data was also provided on a 35 year old 559mm diameter 5,100m long pipeline in Bacchus Marsh, Victoria. The current demand was 96 μA/m^2 after 35 years, which included 25m of bare pipe, which would be expected to account for most of the current demand.

Table 4 FBPE Cathodic Protection Current Demand Data

Location	Year installed	Pipe Diameter (mm)	Pipeline length (m)	Current demand ($\mu A/m^2$)	Comment
Melbourne metropolitan area	2006	900	3000	77	Stray current affected
Melbourne metropolitan area	2010	1200	3000	7	
Melbourne metropolitan area	2012	660	1660	10	
Melbourne metropolitan area	2013	660	1600	4	
Regional Victoria	2012	520	500	9	
Sydney area	1992	914	1006	48	Tape joint coating
Regional NSW	1996	1062	1573	57	Tape joint coating

4. JOINT COATINGS

Tape wrap field joint coatings were the traditional field joint coating applied to FBPE coated pipes. In the 1970's bitumen tapes were most prevalent though today the butyl tape systems, with improved adhesion and strength are preferred.

In the 1980's water agencies started using heat shrink sleeves (HSS). Advantages included better adhesion, elimination of the gap/void that is unavoidable at every overlap in tape coatings, and a significant reduction in the number of coating "steps" at overlaps. The main negative of HSS coatings is the need for pre-heat, which can be difficult to achieve on large diameter water pipelines, and hard to assure the minimum requirement has been met.

The water industry took notice of what was done with HSS application on gas pipelines that were in service. As it's not possible to significantly raise the temperature of such pipes, a primer was applied. Based on that, it is now common to specify a primer for use with HSS in the water industry. Using a butyl primer gives the best adhesion results and when applied immediately prior to HSS application, the minimum required pipe temperature is only 3°C above the dew point. Using a primer not only eliminates the need for pre-heat, it also eliminates the major risk in applying HSS, that of assurance that the minimum temperature has been obtained at all places on the surfaces to be coated. It also means the required preheat is the same as that for tape coatings.

5. CONCLUSIONS

This review aimed to examine the performance of Fusion Bonded Polyethylene (FBPE) coatings, which have now been in service for 40 years. The use of FBPE coatings has been documented for the past 40 years. Service performance has been reviewed by providing details of coating inspections on operating pipelines up to 35 years old. Data on the performance of FBPE subjected to a range of possible petroleum soil contaminants for a 12 month period has been detailed. Water Agency exposure testing for 10 years in a range of environments has been reported. The use of FBPE with cathodic protection has been reviewed and the changes in field joint coatings used on FBPE water industry pipelines are covered.

Taking into account all the information obtained it is concluded that FBPE coatings have lived up to the expectations of 40 years ago and today continue to provide excellent corrosion protection for steel pipelines where a long service life is required.

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P Fernandez, L Tuazon & R Franklin (Western Water)

Horsham Water Board

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