'Fail-safe' Tape System Used in Conjunction with Cathodic Protection

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This article describes tests on a mesh-backed tape system that has "fail-safe" characteristics. A fail-safe coating system is defined as one that will allow cathodic protection (CP) current to pass through it to protect the substrate—not shield CP—should the coating bond fail and adequate CP is available. Certain types of high-dielectric coating systems shield CP current from providing protection to the substrate if the coating bond fails and water penetrates between the coating and the substrate.

Corrosion failures can occur under disbonded coatings that shield cathodic protection (CP) current and prevent it from protecting the pipe. There are certain coating systems, however, that are considered "fail-safe" under this condition. Fail-safe means that if a coating bond fails, the coating system will allow CP current to pass through it to the substrate and corrosion of the metal will not occur—or will be reduced—when adequate CP is available. The mechanisms by which fail-safe coatings provide this property are varied. The key consideration is: "Will the coating shield CP if the bond fails?"[1] This article discusses the testing and use of a so-called fail-safe tape-coating.

Coating Disbondment from Soil Stress

Soil stress and CP shielding problems of tape coatings are major concerns in the pipeline industry.[2] Tapes are not the only coating systems that can disbond and cause shielding problems; however, all coatings are permeable—they have micropores and fissures that eventually permit water vapor to reach the substrate.[3]

There also are many mechanisms by which a coating system can disbond and allow water to penetrate between the coating and the substrate.

Some companies simply avoid the use of certain types of tape coatings because of problems (or potential problems) with disbondment, CP shielding, and soil stress.[2] Tape coating systems do have some advantages, however, such as field application without sophisticated equipment, generally less stringent surface preparation requirements, ease of storage and transport, overall environmental safety, cost-effectiveness, and very little or no required cure time before backfilling. Even though these coating systems can provide very good protection when properly applied, the inherent problems with soil stress and CP shielding are present in many of these systems.

Fail-safe Tape System

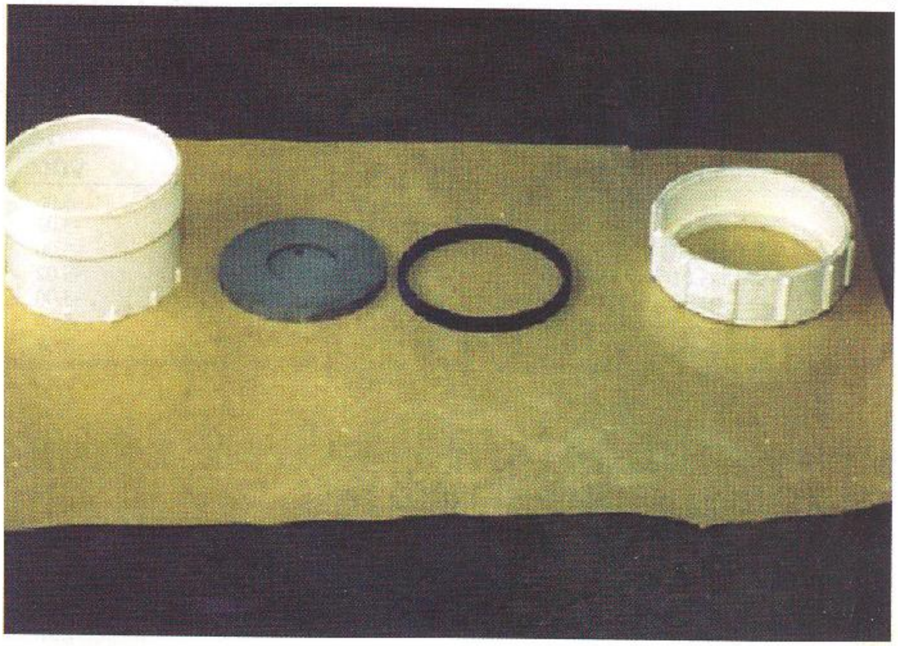
The geotextile mesh-backed (GTMB) tape system discussed in this article is designed to be fail-safe. The tape has very little stretch under soil stress conditions and will not shield CP current if there is damage to the compound.[3] Recent in-house and outside laboratory tests have confirmed that this particular GTMB tape coating system would be fail-safe if water were to penetrate between the coating and the substrate, with the water being in contact with the overlap assuming that adequate CP current were available. Because coatings used in conjunction with CP must have some dielectric strength, part of the testing was conducted to ensure that the GTMB coating system has a dielectric strength consistent with industry standards.

The intent of the testing was to show that CP can be achieved when there are no holidays in the coating, there is water between the coating and the substrate, and the water is in contact with the overlap area.

Testing

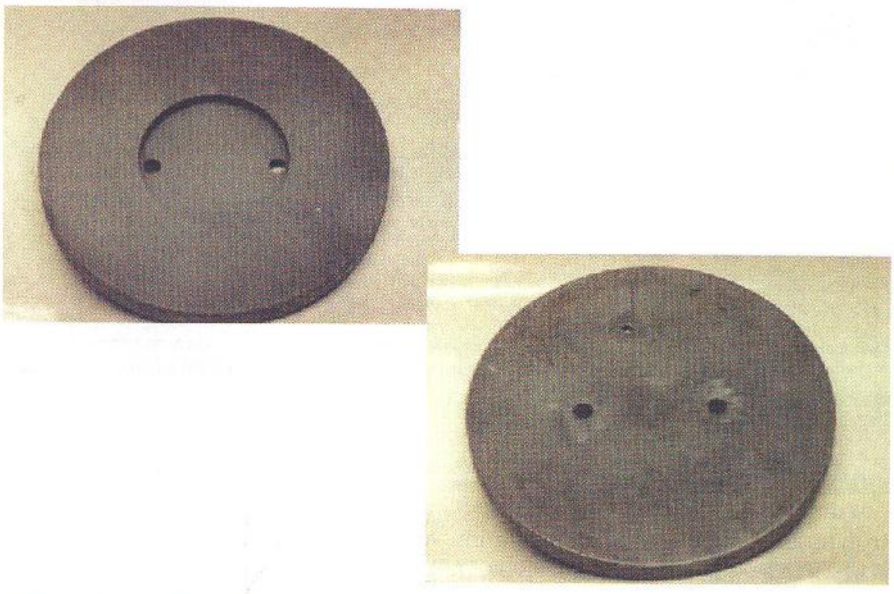
The process of testing whether a coating is fail-safe involves the use of a properly designed test apparatus. Figure 1 illustrates the apparatus, which was developed by the tape manufacturer. A 17.5-cm (7-in.) diameter by 1.25-cm (0.5-in.) thick steel disc was designed to allow water to be placed in a void between the coating and the substrate. The void was milled to a depth of 0.625 cm (0.25 in.) and a diameter of 7.5 cm (3 in.). The void will hold ~27.6 cm^3 (1.7 in.^{3}) of water. The steel discs (Figure 2) were cleaned with a solvent and grit-blasted to a near-white finish with an anchor profile of 2 to 3 mils (51 to 76 μm). Before the tape was applied, a 25-lb (1.1-kg) weight was placed on the tape overlap area for at least 24 h to simulate the tension to seal the overlap and helix areas during spiral wrapping. The primer was applied to all surfaces but the void. When the primer was properly cured, the tape was applied to the primed surface but suspended over the void area. Two-part epoxies were applied on a nonwoven fiber mesh to support the epoxy over the void while the epoxy cured.

FIGURE 1



Apparatus used for determining if a coating is fail-safe. Photo courtesy of Polyguard Products, Inc.

FIGURE 2



Discs used in fail-safe coating test jig. Photo courtesy of Polyguard Products, Inc.

Valves were installed in the void for inserting and removing water before and after the test. The disc was then placed in a holding jig that was sealed with silicon to prevent water and current leakage at the outside diameter of the disc. Salt water was placed above the coated surface so that CP could be applied and monitored. Unlike cathodic disbondment testing, no intentional holiday was made in the coating. Hence one could determine whether CP currents could provide protection to the substrate in a void filled with water.

Lab-quality "pure water" was introduced into the void through the valves to simulate an area under the coating where water had penetrated but was

TABLE 1(a)

FAIL-SAFE TESTING OF SOLID-BACKED TAPE SYSTEM VS GTMB TAPE SYSTEM

Days of Test	Cell No. 1 Solid-Backed Tape & Primer		Cell No. 2 GTMB Tape & Primer 1-in. Overlap		Cell No. 3 GTMB Tape & Primer 1-in. Overlap		Cell No. 4 GTMB Tape & Primer No Overlap	
	VDC	µA	VDC	µA	VDC	µA	VDC	µA
1	-3.00	0.1	-3.01	0.2	-3.06	40.2	-3.02	0.1
2	-3.01	0.1	-3.00	31.8	-3.02	43.0	-3.03	0.1
4	-3.00	0.1	-3.00	64.1	-3.00	53.3	-3.01	0.1
7	-3.01	0.1	-3.00	69.8	-3.02	61.8	-3.00	0.1
8	-3.00	0.1	-3.01	69.8	-3.00	62.0	-3.02	0.1
13	-3.00	0.1	-3.01	77.6	-3.00	68.3	-3.01	0.1
21	-3.00	0.1	-3.00	103.3	-3.08	106.9	-3.04	0.1

TABLE 1(b)

RESULTS OF pH FROM TEST 1(a)

	Cell No. 1 pH	Cell No. 2 pH	Cell No. 3 pH	Cell No. 4 pH
Void water pre-test	7.03	7.03	7.03	7.03
Void water post-test	7.10	8.82	9.01	7.04
Electrolyte pre-test	11.0	11.0	11.0	11.0
Electrolyte post-test	11.0	11.0	11.0	11.0

pH Instrument: Corning "pH-30"
Tests 1(a) and 1(b) were conducted by ITI Anti-Corrosion, Inc.

TABLE 2

RESULTS OF pH FROM TEST 2

	Cell No. A GTMB Tape—No Overlap pH	Cell No. B GTMB Tape—Overlap pH	Cell No. 3 GTMB Tape—Overlap pH	Cell No. 4 Solid Backed Tape—Overlap pH
Void water pre-test	6.9	6.9	6.9	6.9
Void water post-test	6.45	11.27	10.64	9.72[A]
Electrolyte pre-test	5.9	5.9	5.9	5.9
Electrolyte post-test	4.6	8.45	8.71	4.31

[A]This pH change is not typical for solid-backed tapes and may have resulted from a leaking cell or overlap.
Test 2 was performed by CC Technologies, Inc.

not directly exposed to the same electrolyte as the CP anode. A platinum wire anode was used. It was placed above the disc in the salt water and connected to the positive lead of the power source. The negative connection of the power source was connected to the steel plate. The potential was set at 3 V vs saturated calomel electrode (SCE) to accelerate the process. A 1.5 V (SCE) also was used to confirm the same type of results at a lower voltage. The apparatus must have a very good seal around the sample edges and at the tape overlap. An inadequate seal will allow the current to follow unintended paths.

Coating Systems Tested

Several coating systems were tested to confirm the differences between the GTMB tape and other types of coatings. Samples of the GTMB tape also were tested without an overlap over the void to prove that current will not penetrate the coating unless there is damage to the compound and water penetrates to the overlap fibers. Several solid film-backed tapes and one other mesh-backed tape were tested with overlaps. Two two-part epoxy systems also were tested.

Test Results

The GTMB tape allowed CP to protect the void area as indicated by the significant change in pH of the void water. The electrochemical reactions at the cathode surface cause the electrolyte to become more alkaline (higher pH) around the cathode. An alkaline (high) pH of 9 or above is protective to steel and will reduce or stop corrosion. Other coatings tested with this apparatus allowed only smaller changes in pH. Another mesh-backed tape did not show the same fail-safe characteristics as did the GTMB tape. Tables 1(a), 1(b), 2, and 3 show the test results.

Figure 3 shows hydrogen gas evolving through the GTMB tape over the void during one test. It supports the previous finding that the coating in question does allow CP to penetrate a void with water under the coating at the overlap. At lower voltages, the pH in void water also changed in the alkaline direction with the GTMB tape.

A wet 5-cm (2-in.) diameter by 7.2-cm (18-in.) length of pipe was wrapped without primer to simulate total disbondment in an area of the GTMB tape. The pipe was placed in a vat of salt water and CP was applied to the pipe to hold a 1.5-V (SCE) potential for 2 weeks. The entire wet surface under the GTMB tape had a pH of 10 to 12, indicating CP was being achieved.

TABLE 3

IN-HOUSE TESTING OF COATINGS TO DETERMINE FAIL-SAFE CHARACTERISTICS

Coating Type	Tape Overlap Yes	Tape Overlap No	Void Water pH Pre-test	Void Water pH Post-test	Voltage (V)	Number of Days
GTMB tape		X	6.1	6.03	3	14
GTMB tape		X	6.1	6.93	3	14
GTMB tape	X		6.1	11.68	3	14
GTMB tape	X		6.1	6.1	Control No CP	14
GTMB tape	X		6.1	11.96	3	14
GTMB tape	X		6.1	11.27	3	14
GTMB tape	X		6.1	10.4	1.5	14
GTMB tape	X		6.1	7	Control No CP	14
Solid-backed tape Type 1	X		6.1	5.7	3	14
Solid-backed tape Type 2	X		6.4	7.2	3	40
Solid-backed tape Type 3	X		6.4	6.6	3	30
Mesh-backed tape Type B	X		6.4	6.2	3	21
Two-part epoxy[A] Type A	—	—	6.4	6.8	3	21
Two-part epoxy[A] Type B	—	—	6.4	6.6	3	21

[A]Two part epoxy was applied on a mesh fiber over the void and allowed to cure before the void was filled with water.

pH taken with Orion Model 310.

Field Examination

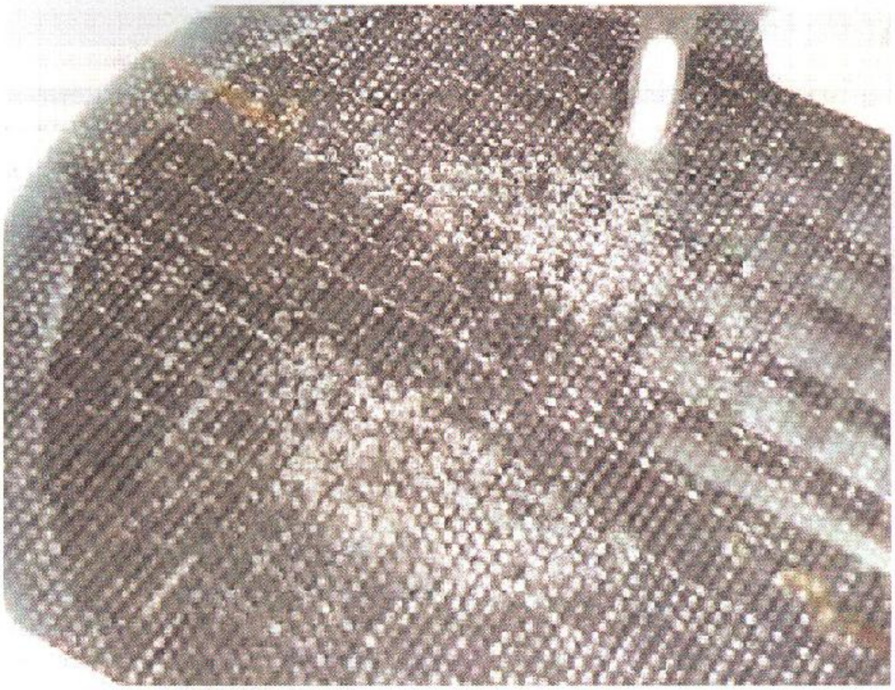
CASE HISTORY NO. 1

GTBF tape was applied in 1993 to a natural gas pipeline in southeast Texas. The pipe was sweating on the bottom half during the application. In 1996, the pipe was excavated to evaluate the coating. The GTBF tape showed no soil stress problems. The coating was well bonded on the top of the pipe, which had been dry during installation. Where the pipe was wet during coating application, the coating lost adhesion (approximately from the 3 to 9 o'clock positions). The condition of the tape overlap was good. The water under the coating was pH 11.

CASE HISTORY NO. 2

GTMB tape coating was applied in 1996 and 1997 to portions of a Canadian pipeline. Excavations in these areas in 2003 revealed two discoveries. First, cohesive failure of the tape occurred while trying to peel it off from where the tape was applied to the blasted pipe surface. Second, the tape at another site did not adhere as well to the polyolefin coating as it did at the first site, but it was found to adhere very well to the prepared steel. The polyolefin coating was not blasted to provide a profile to enhance adhesion. Removing the tape at the second location took two laborers more than a day and required ~200% of the blast media used at other locations to clean up. There was no soil stress damage and no water penetration under the coating (Figure 4).

FIGURE 3



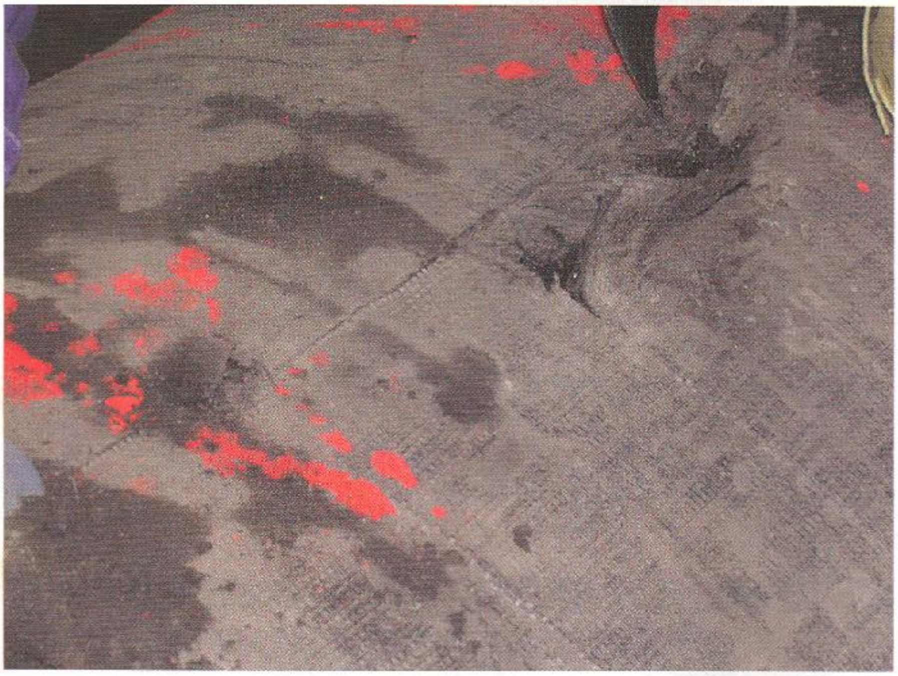
Hydrogen evolving through mesh-backed tape coating during fail-safe test. Photo courtesy of CC Technologies, Inc.

Advantages of Fail-safe Coatings

Fail-safe coating systems have several advantages:

- There is very little or no corrosion on the substrate if the coating disbonds, and water penetrates between the coating and substrate when adequate CP is available.
- Disbonded fail-safe coatings allow more CP current to penetrate to the substrate at a disbonded area than in areas that have not disbonded.

FIGURE 4



Peeling back GTMB tape after 7 years' exposure.

This characteristic should make it possible to locate disbonded areas by performing an over-the-pipeline direct current voltage gradient, wave form analysis, or close-interval survey. On pipelines having high-dielectric-strength coatings, surface potentials do not reflect the potential at the steel in a disbonded area—a fact documented by various researchers.[4-6]

Disadvantages of Fail-safe Coatings

- The major disadvantage of fail-safe coatings is that overall CP requirements are somewhat higher than those for high-dielectric-strength coatings.
- One must evaluate the additional current required to protect fail-safe coatings vs high-dielectric-strength coatings in terms of costs (coating plus CP), feasibility, susceptibility to soil stress, and the risk of corrosion under disbonded areas.

Conclusions

To protect underground pipelines adequately, a coating must conduct CP current when disbondment occurs.[7] GTMB tapes have been shown to be fail-safe through field observations and laboratory testing. Further testing programs and methods need to be developed to identify and understand coatings that have fail-safe characteristics.

The GTMB tape discussed in this article has been laboratory-tested to prove its fail-safe qualities. Field experience also reveals these characteristics, which provide the user with a coating that can transmit CP current to the steel substrate in an area of coating disbondment.

References

1. D.P. Moore, "Cathodic Shielding Can Be a Major Problem After a Coating Fails," MP 39, 4 (2000): p. 44.

2. R. Norsworthy, "Addressing Soil Stress and CP Shielding by Using a Woven Geotextile Fabric Backed Tape System With a Rubber Modified Bituminous Compound," CORROSION/2000, paper no. 769 (Houston, TX: NACE, 2000).

3. "Coatings Used in Conjunction with Cathodic Protection," Technical Committee Report, NACE International Publication 6A100, July 2000.

4. B. Luciani, X. Gutierrez, "External Corrosion Assessment in a LNG Pipeline," CORROSION/98, paper no. 614 (Houston, TX: NACE, 1998).

5. T. Svartdal, W.H. Thomason, "Qualitative Versus Quantitative Assessment of Coating Quality in CP/Coating Applications," CORROSION/93, paper no. 447 (Houston, TX: NACE, 1993).

6. J.A. Beavers, N.G. Thompson, "Corrosion Beneath Disbonded Coatings: A Review," CORROSION/96, paper no. 208 (Houston, TX: NACE, 1996).

7. E.W. Klechka, "Liquid Coatings for Pipeline Repair and Rehabilitation," CORROSION/2000, paper no. 760 (Houston, TX: NACE, 2000).

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