

CHAPTER 16.1

COATINGS FOR PIPELINES AND OTHER UNDERGROUND STRUCTURES

by

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This chapter on coatings covers the fundamentals for selection, application, and performance of pipe coatings used to prevent the deterioration of metals buried in earth or submerged in water.

Regulations from Department of Transportation, Occupational Safety and Health Act (OSHA), and Department of Environmental Resources (DER) have all had an impact on the pipe coatings industry. The energy shortage and the emphasis on energy conservation, along with other governmental regulations, will continue to influence the selection and use of pipe coatings.

And yet a twenty-six year old statement by Norman Peifer and Frank Costanzo is still the norm for corrosion protection on underground structures: "Effective coatings complemented with cathodic protection have been most successful in arresting and in preventing corrosion losses"¹.

Asphalt and coal tar enamel coatings are the most widely used external pipe coatings.²

I. PURPOSE OF PIPE COATING

Pipe coating on underground structures isolates metal from contact with surrounding environments. Since a perfect coating cannot be assured, cathodic protection is used in conjunction with the coating system to provide the first line of defense against corrosion. And since a properly selected and applied coating should provide 99% of the protection required, it is of utmost importance to know the advantages and disadvantages of available coatings. "The right coating material properly used will make all other aspects of corrosion control relatively easy".³

The number of coating systems available necessitates careful analysis of the many desired properties for an effective pipe coating. The National Association of Corrosion Engineers clearly defines the specific qualities that a pipe coating should possess in NACE Standard RP-01-69, Section 5: Coatings.⁴

II. DESIRABLE CHARACTERISTICS OF A PIPE COATING

A. EFFECTIVE ELECTRICAL INSULATOR

Since soil corrosion is an electrochemical process, a pipe coating has to stop the current by isolating the structure from the environment.

B. EASE OF APPLICATION

The coating material must be suitable and properly applied to be effective. Many excellent pipe coatings require exacting application procedures that are difficult to maintain. Consistent quality may be obtained with a coating system that is least affected by variables. Coating application specifications and good construction practices combined with proper inspection contribute to the quality of the finished coating system.

C. APPLICABLE TO PIPING WITH A MINIMUM OF DEFECTS

This characteristic correlates with ease of application. No coating is perfect, and that is why cathodic protection is required. Do not buy a pipe coating that has too many holidays (voids in coating) even before it leaves the mill.

D. ADHESION TO PIPE SURFACE

Coating adhesion is important to eliminate water migration between the metal substrate and the pipe coating. The coating adhesion assures permanence and ability to withstand handling during installation without losing effectiveness.

E. RESIST DEVELOPMENT OF HOLIDAYS

Once the coating is buried, two areas that may destroy or degrade coatings are soil stress and en-

environmental contaminants. Soil stress, brought about in certain soils that are alternately wet and dry, creates tremendous forces that may split or cause thin areas. Adhesion, cohesion, and tensile strength are important properties to evaluate in order to minimize this problem. The coating's resistance to chemicals, hydrocarbons, and acidic or alkaline conditions has to be known in order to evaluate performance in known contaminated soils.

F. HANDLING, STORAGE, AND INSTALLATION

The ability of a coating to withstand damage is a function of its impact, abrasion, and ductile properties. Pipe coatings are subjected to a great deal of handling from application to backfill. While precautionary measures of proper handling, shipping, and stockpiling are recommended, coatings vary in their ability to resist damage. Outside storage requires resistance to ultraviolet rays and temperature changes. These properties must be evaluated to assure proper performance.

G. CONSTANT ELECTRICAL RESISTIVITY

Since corrosion is an electrochemical reaction, a coating with a high electrical resistance over the life of the system is important. The percentage of initial resistance drop is not as indicative of the pipe coating quality as the overall level of electrical resistivity.

H. RESISTANT TO DISBONDING

Since most pipelines are eventually cathodically protected, it is necessary for the coating to withstand cathodic disbondment. The amount of cathodic protection is directly proportional to the quality and integrity of the coating. Considering interference and stray current problems, this becomes a most important requirement. Cathodic protection does two things. First, it drives water through a coating that would ordinarily resist penetration. It also may produce hydrogen at the metal surface where current reaches it, and the hydrogen breaks the bond between the coating and metal surface. No coating is completely resistant to damage by cathodic protection, but it is very important to choose a coating that minimizes these effects. The ASTM G8 test for Cathodic Disbonding of Pipeline Coatings, commonly known as the salt crock test, measure a coating's resistance to damage by cathodic protection. An intentional holiday is placed in the coating and the sample is immersed in a 3% salt solution (1% Sodium Carbonate, 1% Sodium Sulfate, and 1% Sodium Chloride). Then, when a negative electrical potential is applied through the aqueous salt solution by an anode or rectifier, an electrical current flows through the solution to the bare metal surface.

This test is run at ambient temperatures; the sample is maintained at a constant potential; and the current drain required to protect the sample is measured periodically. After 30 to 90 days the sample is removed and examined

for undercutting or any discontinuities. Discontinuities are identified by an accumulated calcite deposit around them. Relative resistance of the coating to cathodic protection is determined by the number of unintentional holidays, by the amount or increase in current, and by the amount of cathodic disbondment or undercutting that has occurred around the intentional holidays.

The difference in reactions to this test by various coatings is sometimes vivid. In some cases, such a quantity of water is driven through the coating that the coating develops large water blisters around the sample. In other cases the cathodic disbondment around the intentional holiday is so great that the entire sample is disbonded from the surface. Some samples experience very frequent unintentional holidays, little water being driven through the coating, and almost no cathodic disbondment around the unintentional holiday.⁵

I. EASE OF REPAIR

Recognizing that some damage may occur and that the weld area must be field coated, compatible field materials are required to make repairs and complete the coating after welding. Manufacturers' recommendations should be followed. Variables in conditions influence selection of materials.

All nine of these characteristics (A-I) are important when evaluating the selection of a pipe coating.

The following factors should also be considered when selecting a pipe coating:⁶

1. Type of Soil or Backfill

Soil conditions and backfill influence the coating system selected and thickness specified. USDA Soil Survey Manuals help determine soil types along the right-of-way. Soils are rated by their shrink-swell factor (soil stress). High shrink-swell soils can damage conventional coatings. Ideally, trenches should be free of projections and rocks, permitting the coating to bear on a smooth surface. When backfilling, rocks and debris should not strike the pipe coating. The following ASTM tests are recommended to measure resistance to penetration of the pipe coating if set on stones in the trench: ASTM D 785, "Method of Test for Rockwell Hardness of Plastics and Electrical Insulating Materials," ASTM D 5, "Method of Test for Penetration of Bituminous Materials," and ASTM D 2240, "Method of Test for Indentation Hardness of Rubber and Plastics by Means of a Durometer".

The following ASTM tests are recommended to measure the resistance against damage by rock in back fill: ASTM G 13, "Limestone Drop Test" and ASTM G 19, "Falling Weight Test". Soil stresses on pipe coatings may be evaluated by ASTM D 427, "Method of Test for Shrinkage Factors of Soils".

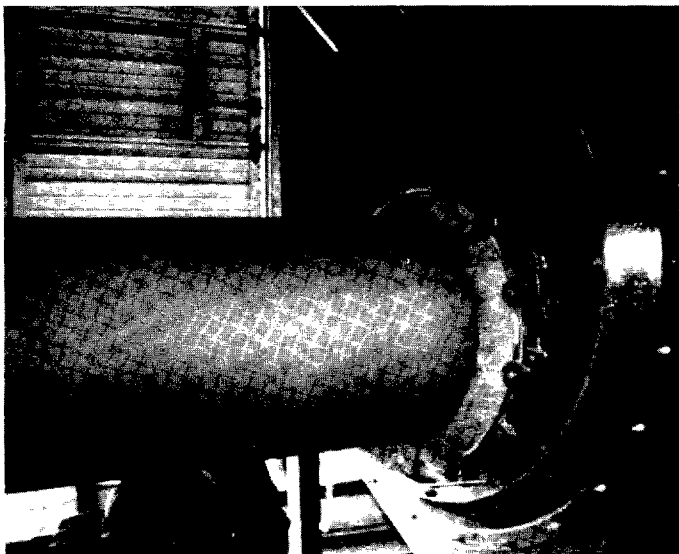


FIGURE 1

A good cleaning job coming out of the shot blast machine.
Courtesy: Irish Pipe Coating Co., Inc.

2. Accessibility of Pipeline

When a pipeline is inaccessible or in a marine environment, the best system should be selected with less emphasis on initial cost. Experience under similar conditions for at least five years or well-designed laboratory tests on new products are the best criteria for coating selection.

3. Operating Temperature of Piping

Surface temperature and environmental conditions must be considered, because, once buried, a coating experiences a wet heat condition, which is more detrimental than dry heat and harms coating effectiveness. A modified disbondment test, ASTM G 8 "Cathodic Disbonding of Pipeline Coatings", determines resistance to elevated temperatures.

4. Ambient Temperatures During Construction and Installation

Temperatures during construction and installation are often more critical than operating temperatures. For instance, some thermoplastic systems such as mastics, tapes, or enamels may become brittle in freezing temperatures. (Polyethylene coating systems, however, have been field bent at $-40^{\circ}\text{F}/-40^{\circ}\text{C}$). Above recommended operating temperatures, thermoplastic systems may cold flow. Extra care in handling, transport and storage is needed under extreme conditions.

5. Geographical and Physical Location

Pipe source and coating plant location often determine the coating or are a cost factor in selection. Severe environments, such as river crossings, pipe inside casings, exceptionally corrosive soils, high soil stress areas and rocky conditions

require special consideration. On large projects in remote areas, the economics may favor a railhead or field coating site.

6. Handling and Storage

Handling, shipping and stockpiling are important in the selection process. Some coatings require special handling and padding. All require careful handling.

Most underground coatings are not designed for above ground use and are affected by excessive above-ground storage. Coal tar asphalt enamel and mastic coatings are protected from ultraviolet deterioration by whitewash or kraft paper. In polyethylene, the addition of 2.5 percent carbon black is the most satisfactory deterrent. Stock should be rotated, first-in, first-out, to minimize the potential problem. Long-term storage requirements could determine coating selection.

7. Costs

Evaluation of pipe coating properties with the above considerations assists in selection. The most misunderstood factor is "costs". In pipe coating economics the end has to justify the means. The added cost of coatings and cathodic protection has to pay for itself through reduced operating costs and longer life. "True" protection costs include not only initial costs of coating and cathodic protection but also installation, joint coatings and repairs⁷. Field engineering and facilities to correct possible damage to other underground facilities may add costs, possibly outweighing initial costs of the pipe coating.⁸

III. DESCRIPTION OF COATING SYSTEMS

A. ENAMELS

Bituminous enamels are formulated from coal tar pitches or petroleum asphalts and have been widely used as protective coatings for over sixty-five years. Coal tar and asphalt enamels are available in summer or winter grades. These enamels are the corrosion coating, combined with glass and/or felt to obtain mechanical strength for handling. These materials should meet requirements of the National Association of Corrosion Engineers, National Association of Pipe Coating Applicators or The American Water Works Association. Enamel coatings have been the workhorse coatings of the industry and provide efficient, long-life corrosion protection.

Bituminous enamel systems may be used within a temperature range of 30°F to 180°F (-1.1°C to 82°C). When temperatures fall below 40°F (4.4°C), precautions should be taken to prevent cracking and disbonding during field installation. Enamels are affected by ultraviolet rays and should be protected by kraft paper or whitewash. Enamels also are affected by hydrocarbons. A barrier coat

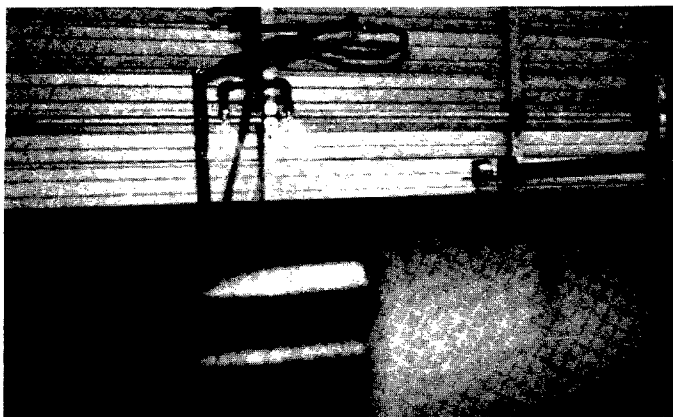


FIGURE 2

A 30-inch pipe, shot blast-cleaned, with the primer being sprayed on.

Courtesy: Irish Pipe Coating Co., Inc.

is recommended when contamination exists. This coating is available on all sizes of pipe. Recently, enamel use has declined for the following reasons:^{9,10}

- Reduced suppliers
- OSHA, EPA, and FDA environmental and health standards
- Increased acceptance of plastic coating
- Utilization of raw materials as a fuel.

Pipe should be bare and free of mill coatings for the best surface preparation. Prior to blast cleaning, the pipe is heated to drive off surface moisture and loosen mill scale. Blast cleaning uses sand, steel shot, or grit or a combination for the desired profile and cleaned surface. "Blasting operations remove all rust, scale and other impurities from the surface, exposing base metal over all, which presents a grayish matte appearance between Steel Structures Painting Council Standard SSPC-SP 6 and SSPC-SP 10." This is equivalent to NACE Standard TM-01, Visual Standards, between NACE No. 3 and NACE No. 2¹¹ (Figure 1).

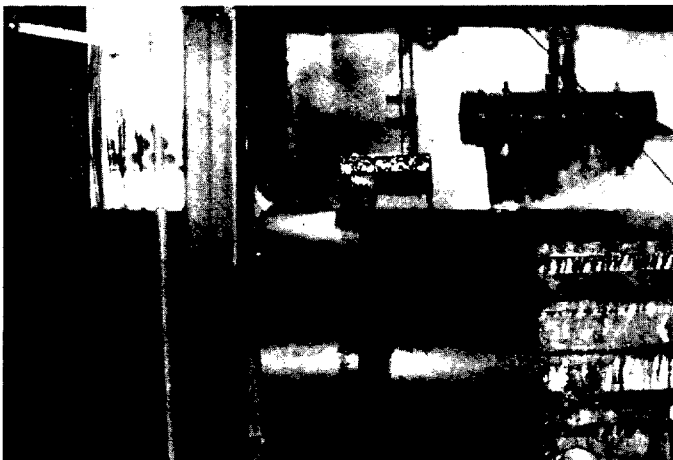


FIGURE 3

Pipe going through the coating machine with a "rabbit" to keep the enamel off the bevels. The "rabbit" travels through the machine at the same speed as the pipe.

The blast cleaned surface is primed (Figure 2), and when dry, coating and wrapping is performed by the hot application of a bituminous coating. The coating is pumped from the coating machine through a spreader, from which the coating flows in a flood coat onto the pipe surface. Be sure that the coating material is melted properly and brought to application temperature gradually. This is done in an agitated kettle.

Agitation maintains uniform heat and prevents mineral fillers (25 to 35 percent) from settling out. Settling fillers may develop hot spots, or carbon spots, on the kettle bottom. These small carbon spots break down and get into the coating and eventually cause jeeps or holidays in the line. Carbon spots are cathodic to the metal and cause pits. Thus, the melting operation and mechanical agitators are of extreme importance.¹²

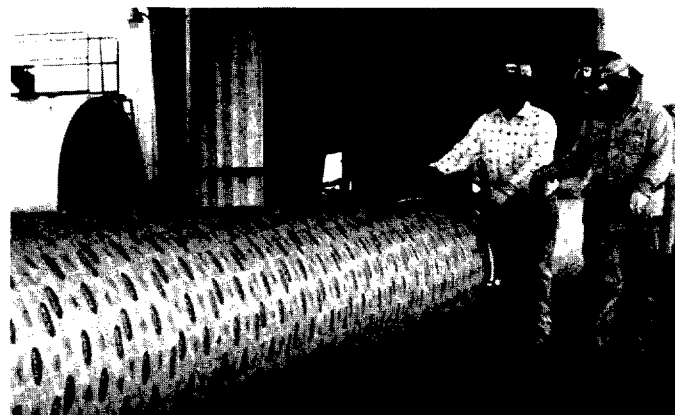


FIGURE 4

A pipe being holiday-detected.

Courtesy: Irish Pipe Coating Co., Inc.

Asbestos felt has generally been used as the outer wrap, but with restrictions on asbestos as a carcinogen, it is being replaced by an asbestos free glass wrapper. The glass wrap must be properly encapsulated with enamel to prevent a wicking action of moisture from the environment to the steel.

Mill wrapping with various specifications of bituminous coating materials is applied to a nominal $\frac{3}{32}$ " (.24 cm) thickness, followed by the glass or asbestos felt or combination. Multiple enamel coatings are often applied to build up thickness where greater protection is required (Figure 3). An electrical inspection of completed coatings is made in accordance with procedures established by NACE Standard RP-02, Recommended Practice for "High Voltage Electrical Inspection of Pipeline Coatings" (Figure 4). For a more detailed treatment of this subject, the ANSI/AWWA C203 American National Standard for Coal-Tar Protective Coatings is recommended (Figures 5 and 6).

B. ASPHALT MASTIC

Asphalt-Mastic pipe coating is a dense mixture of sand, crushed limestone, and fiber bound with a select, air-

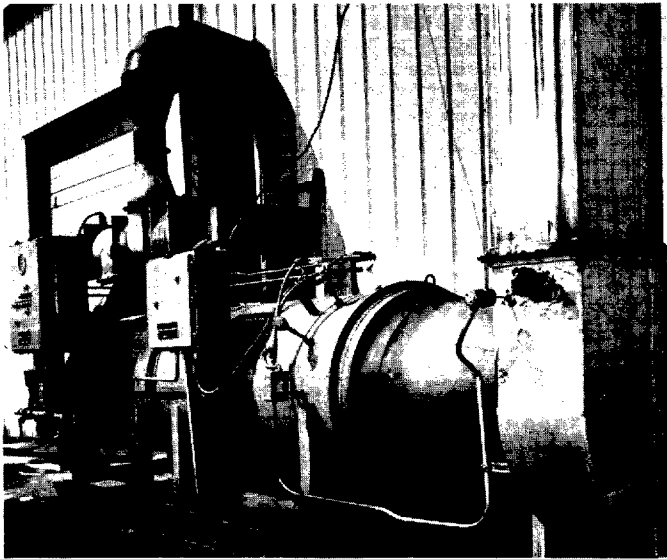


FIGURE 5

Thermal oxidizer for air pollution.

Courtesy: Irish Pipe Coating Co., Inc.

blown asphalt. These materials are proportioned to secure maximum density of approximately 132 pounds per cubic foot. This mastic material is available with various types of asphalt. Selection is based on operating temperature and climatic conditions to obtain maximum flexibility and operating characteristics. This coating is a thick, $\frac{1}{2}$ " to $\frac{5}{8}$ " (1.27 cm to 1.6 cm), extruded mastic resulting in a seamless corrosion coating. Extruded asphalt mastic pipe coating has been in use for over fifty years. It is the thickest of the corrosion coatings and is cost effective for offshore installations. Its ability to dissipate heat while providing a relatively holiday-free coating has made it the most used pipe coating for pipe-type cable installations.¹³

Asphalt mastic systems may be designed for installation and use within an operating temperature range of 40°F to 190°F (4.4°C to 88°C). Precautions should be taken when handling in freezing temperatures. Whitewash protects it from ultraviolet rays, and this should be maintained when in storage. This system is not for aboveground or in hydrocarbon-contaminated soils. This coating is available on 4½" to 48" O.D. (11.4 cm to 122 cm) pipe.

The application procedure¹⁴ is as follows. Prior to

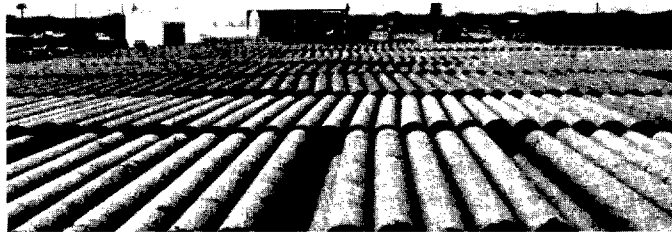


FIGURE 6

Pipe in storage at plant.

Courtesy: Irish Pipe Coating Co., Inc.

blast cleaning, the pipe is heated to drive off surface moisture and loosen mill scale. A combination of shot and grit removes all rust, scale and other impurities, exposing base metal, which presents a grayish matte appearance between Steel Structures Painting Council Standard SSPC-SP 6 and SSPC-SP 10 (NACE 2 — NACE 3). Pipe is then spray coated with an asphalt primer prior to extrusion of the hot mastic mix to the circumference of the pipe. The extrusion forms a seamless coating bonded to the pipe. Whitewash is applied to reflect the sun's rays and to facilitate stockpiling (Figure 7). An electrical inspection of the completed coating should be made in accordance with the procedures established by NACE Standard RP-02, Recommended Practice for "High Voltage Electrical Inspection of Pipeline Coatings". Holidays are patched and retested. Patching is relatively easy because the mastic is thermoplastic and can be heated and worked with a trowel to reseal.

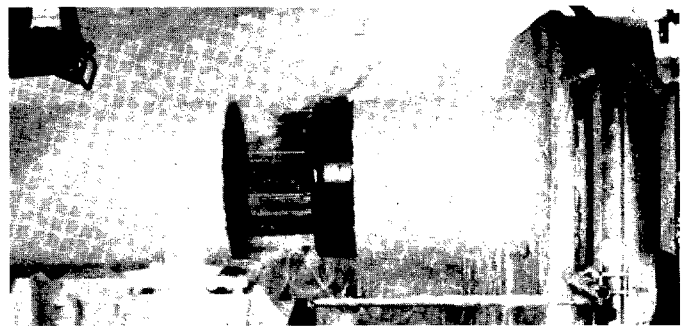


FIGURE 7

Pipe exiting from extrusion process, forming a seamless coating. Whitewash is applied to reflect sun and facilitate stockpiling.

Courtesy: Bredero Price Co.

C. EXTRUDED PLASTICS — POLYETHYLENE AND POLYPROPYLENE

Extruded plastic coatings have been available since 1956. Their growth and acceptance have been remarkable. Initial problems of stress cracking and shrinkage have been minimized by better quality and grade of high molecular weight polyethylene resins.

There are two systems available in the United States. One is an extruded polyethylene sleeve, shrunk over a 10-mil asphalt mastic. The other is a dual extrusion where a butyl adhesive is extruded onto the blast-cleaned pipe followed by multiple fused layers of polyethylene (Figure 8). The latter utilizes multiple extruders in a proprietary method, which obtains maximum bond with minimum stress.

The sleeve type is available on ½" through 24" O.D. (1.3 cm through 61 cm) pipe, while the dual extrusion is presently available on 2½" through 103" (6.35 cm through 262 cm) pipe. The operating temperature range for polyethylene systems is from -40°F to 180°F (-40°C to 82°C), and for polypropylene it is -5°F to 190°F (-21°C to 88°C). Polyethylene systems have been successfully