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DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON

Letter
Circular
LC-435

(January 5, 1935)

PROTECTIVE COATINGS FOR UNDERGROUND PIPING SYSTEMS

The following abstracts and summaries have been prepared from articles and reports relating to protective coatings for underground piping systems and are intended to give a fairly complete outline of recent investigations and developments in this field. Where more detailed information is desired the unabridged articles should be consulted.

1. Scott, G.N., The use and behavior of protective coatings on underground pipes, Oil and Gas J., 27, 195 (1928), and Bul. Am. Pet. Inst., 10, 78 (1929).

Scott discusses a few of the important aspects of care in the application of protective coatings, the types of failure which have been found to occur in service, and the manner in which false conclusions may be drawn from tests on specimens buried in selected soils. One of the objections to mill-coated pipe is the ease of rupture of the coating by rough handling before use. Continuity of the coating is essential so as to prevent localized corrosion; hence patch work, unless done very carefully, should be avoided. Since oil-soaked earth will readily dissolve the coating, it is necessary that all collars be properly caulked to prevent leaks. Air entrapped in the coating will cause rupture of the fabric. The added life that may be realized from the application of a particular coating is a function of the conditions of service to which the coating will be subjected.

Generally, the destruction of a protective coating in service may be either chemical or physical or a combination. A soil which expands or contracts with a change of moisture content and which has the ability to adhere to the coating causes considerable damage to certain classes of protective coatings; this may be called the "soil stress effect." Chemical changes may involve oxidation, loss of volatile constituents, and solution of bitumens in oil. Physical changes may be due to loss of bond between asphalt and metal, softening and flowing of the coating, distortion of the coating by movement of the earth caused by uneven trench bottoms and settling of the backfill earth. Temperature changes cause considerable distortion, cracking, and checking of coatings. Laboratory tests show that soils which give surface or subsurface checking may be expected to have a distorting effect upon coatings. Such soils are usually high colloidal. No direct relation between soils which are corrosive to bare pipe and those which are highly destructive to coatings was noted.

2. Fitzgerald, C., The Pure Oil Pipe Line Co. of Texas, Corrosion and pipe line coatings, Am. Pet. Inst. Production Bul. no.204 126, (January 2, 1930).

Only a small part of any Mid-Continent pipe line system traverses what may be termed highly corrosive soil or hot spots. At present these spots cannot be located accurately or economically until the pipe within their limits approaches destruction. When such spots are located and the pipe replaced, or additional lines laid, it then becomes advisable to apply the very best type of protection available, almost regardless of cost, as such places are usually of very short length. When the expense of replacing a few joints in an isolated spot and the probable loss of oil are considered, it would be cheap to spend one dollar per foot or even more on protection of this type; but it manifestly would be folly to put such a covering on an entire line before locating points of trouble.

There appears to be little doubt that simple coatings are in the development state, and, therefore, the application of such a coating at the present time must be considered an experiment. It is suggested in the interest of economy that such experiments be limited to short lengths of line, and as a further economy that the application be made on a new line whenever possible rather than later as a reconditioning job, in which case the experiment becomes about three times as expensive. During construction of a line, it is a good precaution to place the very best type of protection on short lengths of line through very deep ditches, and in places where gypsum or some other known corrosive substance is apparent in the soil. The proposed three-cornered tests provide an economical means for obtaining information on new or improved materials and methods.

It is apparent that many of the simple coatings in common use are practically immune to the chemical attack of the corrosive agents in the soil, but they do not remain on the line to provide the protection which, from a chemical viewpoint, they possess.

The damage caused to simple coatings by soil stress effect may be reduced materially by the use of one or more layers of a protective covering, chosen more for resistance to mechanical penetration than for chemical inactivity. It is indicated that the useful life of a simple coating is materially increased by an added protection of this type, which may consist of pipe line felt, wood veneer, thin sheet iron, aluminum foil, or other similar substance (fig. 6). The extent to which the life of a coating is lengthened depends upon the nature of the soil and the quality and quantity of the wrapping. However, it should not be inferred that an indefinite life of coating is thus obtained, as there have been many cases of direct penetration through wrapped coatings, in from two to five years, under severe corrosive conditions.

It seems logical to decide, without the necessity of much computation, that no coating should be used where the soil is non-corrosive; and it is equally apparent that no mathematics is required to demonstrate the futility of applying, at any price, a coating that is not likely to provide protection for more than a few months.

3. Scott, G.N., Field inspection of protective coatings applied to oil and gas lines, Am. Pet. Inst. Production Bul., no. 204 p.136 (January 2, 1930); also the Oil and Gas J., 28, 96 (December 12, 1929).

The causes of failure of coatings are numerous, but most important are soil action, faulty application and careless handling, and such miscellaneous factors as loss of bond between the coating and the pipe, material disintegrations, etc. By far the greater percentage of the inspections where the coating was unable to maintain the pipe corrosion-free showed some form of mechanical disruption of the coating.

So far as the data presented are concerned, the coating types may be considered in two large divisions. Division I, - which includes all coatings composed of paints, primers, bituminous materials applied hot, cutback bituminous materials, greases, enamels, emulsions with and without cement, and some of the above wrapped with thin woven fabrics-- is less able, as a whole to prevent corrosion from occurring on the pipe than division II, which includes coatings employing one or more plies of saturated fabrics of the roofing felt type, cemented together with hot or cold-applied bituminous materials or greases.

Coatings in division I break down so quickly to a point where corrosion starts that their use cannot be expected to eliminate repairs and replacements in highly corrosive soils. The use of these coatings may postpone the time and extent of repairs and replacements more than sufficiently to justify economically the application of the coating, but prolonged freedom from trouble on the line cannot be anticipated.

The combined experience of operating companies has shown that a very small portion of all pipe lines lies in highly corrosive soil.

It is not feasible to determine from field inspections what prolongation of pipe life may be expected from any particular treatment.

4. Logan, K.H., Why not call for quotations on pipe line protection, Western Gas, 7, 37 (Oct., 1931).

The purpose of this paper is to point out the distinction between good protective coating materials and pipe line protection.

Materials suitable for some soil conditions may be unsatisfactory in other soils. A large percentage of failures of coatings is attributable to improper application of inherently good materials. Since the failure of a coating may result from poor or unsuitable materials or from improper application or handling of the coating, the pipe line owner is seldom able to fix the responsibility for the failure. Since the pipe line operator is not a specialist in the identification of corrosive soils and is usually not versed in the details of combatting corrosion it would be to his advantage to purchase protection for his line rather than to purchase materials the effectiveness of which is not guaranteed.

If an operator received a quotation for the protection of a line for a specified period he could calculate from the cost of this protection the monetary advantage if any which he would receive by accepting the bid.

The necessary steps in securing bids for the guaranteed protection of a pipe line are outlined and the advantages and disadvantages of purchasing protection as distinguished from pipe coatings or coating materials are discussed.

5. Scott, G.N., A.P.I. coating tests. Progress report to the Am. Pet. Inst. committee on corrosion of oil field equipment, Production Bul. no. 208, 55 (Nov., 1931).

In the following paragraphs are summarized the more important results, deductions and conclusions of the first inspection of the A.P.I. line pipe coating tests. The statements are tentative only and subject to revision after subsequent inspections of like coating samples. Four more inspections of each coating in each locality are planned.

(1) Two practicable tests for the field examination of protective coatings for underground pipe lines have been developed and described in detail.

(2) Conductance measurements have been shown to be of considerable value in the study of protective coatings in the field.

Note: As a guide for operators desiring to apply conductance measurements on coatings in service the following interpretation is suggested. If the conductance of a coating under investigation is less than ten micromhos per square foot the coating may be considered to be giving perfect protection. If the coating has a conductance of ten micromhos per square foot or over but less than forty micromhos per square foot the coating may be described as possibly faulty, but need not be removed for further inspection. If the conductance is greater than forty micromhos per square foot the coating should be removed and the underlying pipe inspected for corrosion.

(3) The pattern test which consists of obtaining a pattern of pinholes by the use of a potassium ferricyanide indicator has been shown to be a useful tool for the examination of protective coatings. At the present stage of development of the test the patterns should be considered as a tool only, a) to record the condition of the coating, b) to show the quantity distribution of the breakdown, and c) to locate the actual points of rupture on the coating.

(4) The conductance and pattern tests are not completely applicable to all types of coatings, but when applied with intelligence one or the other, or both, will give satisfactory results for all types of coatings under test in this investigation.

(5) It is not particularly difficult to select from any given series of coatings tested those which are of little value and those which are quite effective, but it is an extremely difficult problem to determine what actual added pipe life is afforded in any particular case. This fact itself is of the greatest moment since the data are absolutely essential for the application of any economic rule of coating selection.

(6) The measurement and visual inspection of the pipe underlying protective coatings constitute the most satisfactory method of studying all types of coatings. The visual inspection is less certain for short service periods and for mildly corrosive environments, but when supported by the conductance and pattern tests becomes much more definite and reliable.

(7) The presence of pits on a coated pipe constitutes the most satisfactory criterion for judgment upon the protective value of coatings. The presence of rust (no development of pits) may have different significances depending upon the type of coating under consideration. The pitting criterion may be too liberal with respect to the coating for short periods of service or for mildly corrosive environments.

(8) The importance of knowing the corrosive environment of a coating inspected is emphasized.

(9) To take account of the corrosive environment of the coating, minimize the injustice of the percent-pitted figure in mildly corrosive environments and to assign a value to the various coatings whereby they may be compared quantitatively, a "degree of effectiveness" has been calculated for each coating. A justification for the use of this criterion lies in the agreement of the results with those obtained from the pitting criterion.

(10) The percentage of coated pipe showing pits is related to the thickness of the coating. The data indicate that the effectiveness of the coating increases very rapidly with the thickness up to about 0.20 inch.

(11) The data indicate that the rate of development of the deeper pit on a pipe beneath a ruptured coating as compared with a similar unprotected pipe is not related to the exposed area of the coated pipe.

(12) Only the heaviest coatings showed the development of no pits.

(13) For the period of test covered by this report the calculated degrees of effectiveness indicate that the soft coatings are of no value in preventing pits. These coatings are entirely too soft to resist soil stresses.

(14) Enamel coatings without shields or reinforcements reduce the anticipated average pitting by roughly fifty percent or less.

(15) All of the fabric-reinforced treatments, excepting the reinforced grease coating, reduce the anticipated average pitting by eighty percent or more.

(16) Shields are effective in general but wood veneer is less effective than strip steel or pipe line felts.

(17) The problem of perfect protection is still largely one of minimizing the effect of soil stress.

6. Davidson, J.H. et al, Study of protective coatings for interior of steel tanks and underground pipe lines, Am. Rway Eng. Assn. Proc., 30, 143 (1929); Rwy. Eng. and Maintenance 25, 244 (1929).

A coating of portland cement grout, preparation of a petroleum base into which rust-inhibiting chemicals have been compounded, or asphaltic liquid paints appear to have given better results for protection on the interior of steel water tanks than red lead and linseed oil customarily used. In underground pipe lines, records indicate that portland cement is much the best, bituminous coatings wrapped are next and paint coatings give the lowest increase in life.

7. Stokes, Albert, et al., First report of the corrosion of pipes sub-committee, Inst. Gas. Eng., Communication no. 20, (1930).

The effects of various coatings on wrought iron and steel were determined in two types of tests. (a) The coated metal was placed in soil and made the anode of a closed electrical system. The source of current was a 6-volt battery. The current was measured at different intervals of time and the resistance of the coating calculated. (b) The voltage differences between a coated and uncoated specimen were measured at various times. The resistance of the coating decreased with increasing water content while the voltage measurements showed increasing values. Painted pipes showed much greater resistance to the flow of current than bare pipe. Pipes covered with paper wrappings and paints were about 50 times as resistant to the flow of current as paint coatings. Deep pits occurred in the metal surfaces where the coatings were broken. Cement coatings were found temporarily resistant to stray current electrolysis.

Also in Gas J., 192, 725 (1930).

8. Shepard, E.R., Bureau of Standards, Measurement of the electrical conductance of non-metallic pipe coatings, Am. Gas J. 136, 22 (June, 1932).

The electrical conductance of pipe coatings is recognized as an important factor in the study of protective coatings. Because of the very wide range in conductances encountered, it is difficult to find a simple and universally applicable method of test suitable for field use. Resistances of the order of megohms are frequently encountered, which precludes the use of the a-c bridge with induction coil and telephone receiver. On thin coatings, capacity effects are noticeable when using a periodically reversed current, and where the resistance is very high, the error introduced by this effect may be large.

Errors involved in the measurement of conductance by the use of direct-current apparatus include: (1) polarization; (2) galvanic potentials between the pipe and the auxiliary electrode, called the saddle; and (3) endosmose, or the movement of moisture within the capillary pores of the coating. Polarization errors are found to be relatively small if the pipe is made anodic during the measurement. Galvanic potentials between the pipe and the saddle may be as high as 0.3 volt, even though an iron saddle is used. Errors from this effect may be kept within limits considered satisfactory for this class of work, if a potential difference of at least 3 volts is applied across the coating under test. A potential difference of 30 volts is sometimes found to give variable and erratic results when testing coating conductances. This is attributed to endosmose or the movement of the liquid in the direction of current flow, within the pores of the coating.

With these various difficulties in mind, a simple and portable direct-current test-set has been assembled which measures coating conductances with an accuracy considered satisfactory for that class of work. It includes two current indicating instruments in series with a 3-volt dry battery. A number of ranges corresponding to currents of 4.5 microamperes to 0.45 ampere are obtained by a combination of shunts. For the lower resistances a Weston milliammeter is used which can be read immediately after closing the circuit and before polarization appreciably diminishes the deflection. For the higher resistances a microammeter is employed, the relatively long period of which is not objectionable, as polarization effects are not serious at low current densities. For extremely high resistances, a 30-volt battery is provided.

Comparative tests on a large number of sample pipe coatings in soil boxes indicate that this d-c test-set, when properly used, can be relied upon to give results within about 15 percent of those obtained with an a-c bridge. Because of the variable and unstable character of coating resistances, this accuracy is considered satisfactory.

Summary of Test Procedure.

The following procedure should be employed in measuring pipe coating conductances in the field with direct-current apparatus:

(1) Make measurement soon after uncovering pipe.

(2) Provide a suitable conducting medium between the coating and the metal saddle, which makes intimate contact with the coating at all points.

(3) Prevent surface leakage along the coating by either cutting the coating away on both sides of the saddle or by thoroughly drying the coating surface. Only on very high-resistance coatings will the surface leakage introduce a serious error.

(4) Use a voltage of not less than three volts and not more than six volts, except for coatings of very high resistance. Avoid the application of sustained high voltages when making tests.

(5) Connect the positive terminal of the test set to the pipe and the negative terminal to the saddle to insure a flow of current through the pad from the pipe to the saddle.

(6) Read the indicating meter as quickly as possible after closing the circuit to eliminate, as far as possible, the effects of polarization and endosmose.

9. Rogers, W.F., Influence of oil in soil corrosion, Proc. Am. Pet. Inst. 13, 131 (1932).

The paper describes the results of the examinations of oil lines in various parts of Texas, carrying widely different crude oils. The findings have been so consistently the same that it is now regarded that the presence of oil can accelerate soil corrosion. It seems that regardless of the type of oil, as long as a sufficient quantity is present, accelerated corrosion will occur. The soil texture does not play a direct part in promoting the rate of corrosion in the presence of oil. Soil texture is important only when it controls the rate at which oil may be washed away. The type of pitting which has been discussed is that of sharp-featured direct pits filled with black-green and white corrosive products. It has been found that this type is almost universally confined to oil bearing soils.

The corrosion appears to be the result of a difference of potential originating in the exclusion of oxygen from a limited area on the pipe surface by the oil.

10. Gill, Stanley, Pipe line protection, Ind. Eng. Chem. 25, 49 (1933).

This paper describes briefly the different types of pipe line protection now in use pointing out the virtues and weaknesses of each. The following are excerpts: "Generally speaking this class (bituminous cutbacks) are of little or no value for the protection of pipe which is exposed to destructive soil corrosion. The asphalt emulsion coatings have not been at all successful on buried pipe lines. The greases possess in comparison with bituminous materials, the advantage of a far greater inherent impermeability. This advantage is more than overbalanced by the fact that the greases possess no mechanical strength and are consequently punctured by the slightest soil pressure. In combination with suitable wrapping materials grease coatings will give good protection but it is essential that the wrapping material shall itself be quite impervious as otherwise the grease may be absorbed by the soil. There have been no extensive field tests of pipe line coatings of the lacquer type. In general by properly selecting asphalt and wrapper and by exercising proper care in application, coatings of good protective value can be obtained. Certain petroleum asphalts are entirely unsuitable for pipe line protection, being subject to rapid deterioration. Others have been found to be exceedingly stable when exposed to soil action. Asphalts should never be used without the protection of a wrapper.

Coal tar enamel coatings will afford protection under some conditions without the use of wrappers. The wrapped enamel coatings which probably possess greater protective value than any currently available coatings of comparable cost fall into two classes depending upon whether the wrapper is applied while the bitumen is still molten or whether the wrapper is applied loosely for a chilled enamel layer. The most widely used, and at present the most satisfactory, wrapping materials are bitumen-saturated felts similar in general character to those which are used for roofing. Generally speaking, the asbestos felts are most satisfactory for the purpose, since rag felts have been found to deteriorate when exposed to certain soils.

Experience has shown that a properly applied cement mortar coating will afford lasting protection against soil action under almost any conditions. The objections to cement coatings are the relatively high cost of application and the fact that pipe so coated cannot be economically recovered for re-use if the pipe line is abandoned.

Pipe coated with vitreous enamels has been marketed during the past few years in Germany, and a large American manufacturer of pipe is now equipped to supply a similar coated pipe. Since there have been no lines laid with this pipe and since no data on its performance in actual lines are available, no conclusion as to its merit can be drawn.

11. <u>Peper, J.H., Use of cement in protecting underground pipe lines against corrosive action of soils, Oil and Gas J., 32, 9 (1934).</u>

The value of cement as a protective coating for metals subjected to the corrosive action of soils can hardly be questioned. It is today considered a most durable and reliable material for all structures in contact with either soils or atmosphere.

The protective value of cement in cases of electrolysis due to stray currents is questionable. Boxing and cementing lines to protect them against stray currents was tried by our companies many years ago and proved a failure. The pipe was destroyed in a short time.

As compared with coatings of bitumen, the chief objection to the general use of cement coatings has been the heavy cost.

Lately there have been developments in the application of cement coatings which bring the cost of these coatings down to a basis comparing favorably with the well-designed bituminous coatings.

As a rule, a plain sand-cement mortar will not have the high qualities that a good concrete has. The mortar costs more and ordinarily a much higher water ratio has to be used, because where a thin coating - say one-fourth inch to one-half inch - is to be applied, it is impossible to use anything but a thin mortar. The thin mortar coating, however, is sufficient in most cases to thoroughly protect the metal against soil corrosion.

Combinations of asphalt emulsion with cement and concrete have been developed and claims are made that under certain conditions the asphalt is helpful in preventing disintegration of the concrete. The combination should be effective as a protective coating, but the cost and method of application have to be such as to make it practicable.

In 1914 a cement coating was applied to 2 miles of 6-inch pipe by means of a gun. After several trials as to the best way of applying this coating the following method was developed: the pipe was laid in the bottom of the ditch on a 6-inch board and supported above the board by 1-inch concrete blocks. The mixture was shot under the pipe and prevented from getting away by holding boards against the pipe and edge of board, thus forming a dam. After the bottom was filled up, the nozzle was applied to the top and sides until about three-fourths inch of coating was built up. The job of coating cost about 31 cents per foot and has never to this date given any trouble.

At the present time our companies are using a method involving a form which applies a 1:3 cement mortar one-half inch to five-eighths inch thick. This method consists of an 8-foot hinged metal form suspended from the pipe by hangers which give the proper clearance all around. Slaters felt is used inside the forms to prevent the mortar from sticking to the forms and at the same time prevent leakage at the joints. The felt also sticks to the mortar and prevents rapid drying out of the mixture. The form can be removed the next day following the application. The pipe is supported on skids over the ditch while coating is applied and lowered into the ditch a day or so after forms are removed. This method is now in use for reconditioning jobs at the rate of approximately 20 miles per year and the average cost is not in excess of 15 cents per foot. Details as to the construction and use of the forms are given in the Oil and Gas J., Feb. 1, 1934.

Information in regard to the making and using of the forms has been given several different companies. Patents have been applied for on the form, largely as a measure of protection to ourselves, and we are glad to allow other companies to use them when they express a desire to do so.

There are several distinct advantages in using cement:

(1) There is no time lost in its application while waiting for proper weather conditions. This applies most generally to field applications, which in the majority of cases, call for careful cleaning of the pipe, application of primer, followed by the main coating. When using cement, the work can be done at any time that it is possible to do pipe work, except in freezing weather. It is not necessary to have the pipe warm and dry, as is the case with the hot applications. The saving in time is a cost factor of considerable importance.

(2) Reconditioning with cement can be done without taking the line out of service; in fact, with oil in the line, quick drying out of the coating is prevented and is an advantage. Combined with the use of the electric welder for spot welding, the application of a cement coating can be accomplished with a minimum loss of use of line.

(3) While it is necessary to clean a line in order to observe its condition, it is not necessary to clean as thoroughly when using cement coating as when a primer is to be applied.

(4) Cement has high corrosive inhibitive qualities and acts toward the arresting of corrosive action. A close observation of the depth of pits in a line to be reconditioned will show that a majority of the pits are not deep enough to weaken the pipe materially, provided corrosion goes no further in them. Cement will stop the action and thereby make it possible to cut down the amount of welding.

(5) There is less danger of injury to men when using cement than when using hot bitumens. It is also easier to get men to work with cement than to work with hot tars.

(6) The corrosive effect of oil-soaked soils on pipe has been clearly demonstrated. Under such conditions it is unsafe to apply any coating which is affected by crude oil. Cement coatings will be found effective under these conditions.

12. <u>Scott, G.N., A.P.I. coating tests, Progress report No.4, Proc. Am. Pet. Inst., 15, (1934).</u>

This is a report on the conditions of 19 kinds of bituminous pipe coatings applied to working lines in approximately ten widely separated localities and 46 coatings applied to short lengths of pipe exposed in 15 locations. The time of exposure was approximately four years. The tests were conducted jointly by coating manufacturers, the American Petroleum Institute, and the National Bureau of Standards. Tables are given showing the structure and performance of each coating.

The following conclusions are based upon the results of 1934 and previous inspections and are subject to revision after a final inspection which is planned.

(1) While complete prevention of corrosion by any of the coatings in this test has not been realized, pitting has been reduced by most coatings. A practical view of the problem is taken and suggestions offered in the choice of coating. Shielding or reinforcing is considered minimum and necessary practice in pipe protection for average conditions. Special measures depending upon circumstances will be required in severely corrosive environments.

(2) In general, soil stress is progressive and is the most important factor in coating design. Methods of eliminating soil stress are discussed.

(3) The next most important progressive factor is the absorption of moisture by the coating. Suggestions for the improvement of coatings in this respect are given.

(4) Inspection Methods. Neither of the electrical tests are entirely satisfactory for arranging all coatings in any order of preference. In a particular case the conductance may measure the amount of water absorbed and/or the area of pipe surface exposed. The amount of dissolved substance in the water will determine the particular value of conductance determined. The pattern test is efficient only when there is an actual exposed area of pipe. However, both of these tests are of value in eliminating the less desirable coatings. The best criterion for judging the behavior of a coating is the condition of the pipe.

(5) For the purpose of arranging a variety of coatings in order of relative merit, tests on short pipe sections of small diameter do not agree closely with tests on large operating lines. Reasons for this disagreement are discussed.

13. Rolfe, E.C., Reconditioning of pipe lines is fast becoming of primary importance, Oil & Gas J. 33, 97 (Oct. 25, 1934).

This is a descriptive paper covering briefly recent trends in pipe line protection including the use of thicker coatings and new apparatus for locating lines, cleaning pipe, applying and testing coatings and handling the coated pipe. Soil stress is said to be appreciable in a large portion of the midcontinent and western states. For such soils an asbestos felt should be incorporated in the coating to prevent its distortion and puncture.