The Rising Acceptance of Plastic Pipeline Coatings Applied Internally, In Place

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INTRODUCTION

The internal protection of pipe through the use of plastic coatings applied by "in place" methods has enjoyed a rising acceptance in the oil and gas industry during the past four years. This growth was witnessed in 1958 as compared to all preceding years, not only by a larger dollar value of sales, but also by a larger average job contract; a wider variety of reasons which lead the individual user to select "in place" methods; and by an actual greater number of users.

This rising acceptance of "in place" work has been predicated upon the contractor's ability to improve his cleaning and coating techniques.

The present day "in place" cleaning method, which relies not only upon mechanical scraping but also upon chemical reagents and solvents, results in a surface comparable to any surface cleaned industrially, as in automotive or appliance plants.

CONTAMINANTS

A qualitative determination of the contaminants in new steel pipe (not yet in service) furnishes us with three general categories:

1. Mill scales.
2. Mill Lacquers.
3. Corrosion products resulting from atmospheric exposure.

Similarly, a qualitative determination of the contaminants in an old pipeline which has been in either crude oil, petroleum products, natural gas, potable or salt-water service furnishes us with five categories of contaminants. All of these contaminants may not be present in any specific line, but some of the following will be present, in varying combinations, in any pipeline:

1. Paraffinic and asphaltic deposits, oil residues.
2. Hydrogen sulfide.
3. Oxides of iron.
4. Mineral scales such as the sulfates, carbonates, and chlorides.
5. Corrosion stimulators.

These contaminants may be combined into loose, bulky scale or tight, compact scales; both types may be either poorly or tightly bonded to the pipe wall.

PROBLEM OF CLEANING

The particular problem of cleaning was finally resolved through the development of a family of special detergents, embodying emulsifying and wetting agents, which were usable in petroleum solvents and potable water. This particular system reduces the crude residues to a water-soluble condition. The contaminants can readily be removed from the line by water flushes, and their removal leaves no oily or caustic film.

These crude residues provide much of the binder material which builds the mineral scales into a tight layer of nonhomogenous contaminants. A great deal of the mineral scale will be removed by the mechanical abrasion used in conjunction with the crude residue removal procedures. The remaining scales can then be attacked more effectively by further strenuous mechanical scraping.

After the removal of the mineral scales, the line will be clean and completely water wet. It is then dried by batching through the line, by means of dehydrated air, various alcohols, acetones, and ketones. The clean and dry line is then ready for the application of a plastic coating.

Our engineering staff felt that although the surface so far discussed was clean to the eye and had given an excellent account of itself in actual service, it lacked two qualities essential to optimum coating life. First, it was doubtful that the corrosion stimulators (invisible particles of the salts of mineral and some organic acids) had been removed; and second, the pipe surface did not have the quality known as "tooth."

Both these much sought-after conditions are obtained in the factory by acid etching baths, while only tooth is obtained by sandblasting. Therefore, our engineers investigated the various acids available for this work in industry. Over many years, industry had developed various phosphoric acid formulations which destroyed the corrosion stimulators and etched a tooth into the metal surface. Here, however, their use in a pipeline was more difficult, as the acids could not be used hot and their time of contact with the pipe wall was limited.

Repeated laboratory and field experiments have developed special techniques and a formulation using phosphoric acid as a base. Incorporated into the acid were certain wetting and special agents which overcame the two principal difficulties to the use of acid in "in place" work. A supplementary benefit to the use of a phosphoric acid is that the acid will also remove light corrosion products.

Thus, by the use of the above described methods, it is possible to obtain a chemically clean, neutral metal surface with an adequate tooth; in short, the optimum conditions are obtained inside the pipeline that are also obtained in the closely controlled environment of the modern factory.

In a few old lines, thick mineral scales are particularly hard and dense, well bonded to the pipe wall, and held together not by petroleum residues but by other mineral scales. In such cases, even the hardest mechanical scraping, combined with detergents and phosphating acids, could not produce a clean line at anything like an economically acceptable price. Other quicker, cheaper methods had to be developed for these lines if the benefits of cleaning and coating were to be realized.

Various sections of pipe containing different types of these hard, dense scales were submitted to extensive laboratory examination, and then subjected to various feasible reagents. From these tests, it was determined that it would be too expensive to attempt to dissolve these deposits in toto, but that it might be possible to break down a chemically weak link in the deposit. This would loosen the deposit's bond to the pipe and its cohesion to itself and thus make these scales more vulnerable to mechanical abrasion.

As a result of further intensive laboratory and field tests, a muriatic acid containing wetting, sequestering, and inhibiting agents, plus some special solvents, was developed. When used in conjunction with mechanical abrasion, it destroyed the scale-binder material, loosened its bonds, and allowed the mechanical action to scrape it from the pipe wall.

RESIN COATINGS

After satisfactorily cleaning an internal pipe surface, a resin coating must then be selected which is suitable to the proposed service.

In the selection of suitable resins to withstand oil country service, we placed great reliance upon the historic records of field applications of the different resins which were made available to us by various major oil companies. These historic records have been generously supplemented by a wealth of test data developed in the laboratories of these same companies.

We have also consulted extensively with several reputable resin and coating manufacturers. All of these interviews and reviews of past work looked only to the resolution of our first problem; that is, has the proposed resin given a satisfactory account of itself as a component of the coatings used in normal oil field applications and in the laboratory under accelerated test conditions. If the answer was "yes", the coating had proved its chemical resistance and a coating manufacturer could then proceed to a formulation of an actual coating for "in place" work.

The early "in place" work used spray and brush coatings because no other composition was available; and no other could be made until the specific properties required to facilitate "in place" application had been defined. We began our development of suitable coatings, at this particular point in time, largely by empirical means. However, with the passage of time, it became possible to define the broad mechanical characteristics necessary. Some of the most important are:

1. Total solid concentration.
2. Percentage of actual resin.
3. Viscosity of the coating.
4. Relation between viscosity and temperature.
5. Degree of thixotropy.
6. Volatility of the solvent system.

The coatings formulator, now knowing the efficacy of the resin to the proposed chemical exposure and also the physical properties required for the most efficient "in place" application, could then proceed to an accurate formulation of a specific material embodying these known qualities.

Thus, with the coating in hand, field application by "in place" procedures was possible. Over the years, it has become evident in which services each resin has given a good account of itself. A tabulation of these results appears below:

Resin	No. Manufacturers Formulating Coating	Crude Oil	Lo Pr. Gas	Hi Pr. Gas	Salt Water	Potable Water	Products
Air Dry Phenolic	1	X	X	X			
Polyviny Chloride	2			X	X		
Amine Cured Epoxy	4	X	X		X	X	X
Chlorinated Rubber	1				X		
Coal Tar Epoxy	1				X		

The actual operation of applying any of these resins is similar and accomplished as follows:

Specially designed rubber plugs are used to apply the coating. Two of these plugs are placed in the loading joint at the upstream end of the line. The desired amount of coating material is then pumped between the two plugs, forcing the lead plug down the line. After all the coating is in the line, air pressure is applied to the line and a calculated back pressure is maintained. The construction of the plugs makes it possible to hold the coating material under compression, forcing it into any crevices or imperfections on the pipe wall.

When the coating train reaches the downstream end, the excess coating is removed from the line. This excess is measured and if the proper amount has been left in the line, the deposited film is ready to be dried.

The plug method of application adapts the basic advantages of the dip or roller system of coating application, and has actually enhanced the basic wettability of the surface. Wetting and flowing properties of the coating are minimized since the coating is forced into intimate contact with the metal surface. Since the plugs are propelled down the line by differential positive pressures, the column of liquid coating material between the coating plugs is under a positive pressure. This pressure forces the coating into the most minute crevices and pits in the pipe wall and will displace any contaminants which would have been trapped under the film, if the coating had been applied by spray gun.

In the pressure controlled plug application, the coating is laid down in a continuous film with no possibility of inferior coverage of the joints. Since it does not depend upon the wetting or flowing properties of the coating material itself, it is possible to apply the full thickness required in one coat and still be assured of a continuous film.

What was one of the major problems encountered in the "in place" application has turned out to be one of the major advantages. This is the drying of the wet coating in the confined atmosphere which makes it possible to carefully control the drying rate, keeping the surface of the coating wet and letting the drying proceed from the inside out. In this way, solvent bubles are not trapped by the surface filming over and a pinhole free coating is assured.

So much for present day techniques of the internal, "in place", coating contractor; let us now examine where in the oil field these techniques are gaining the rising acceptance previously mentioned.

HISTORIC RECORD

Historically, the first "in place" work was accomplished in the winter of 1947-1948 in sour crude and sour gas gathering lines. A few of these early lines are inspected in West Texas biannually by the NACE and are still giving satisfactory service. Based upon history alone, the use of "in place" applied plastic linings in these two services is accepted almost universally in the oil industry.

In conjunction with the work in sour crude lines, it was observed that paraffin buildups were greatly reduced; and it was but a short time later that the first "in place" lining was installed in flow lines solely to mitigate paraffin deposits.

Many of the production companies have, over the past several years, conducted extensive field tests on the ability of "in place" linings to reduce paraffin buildups to manageable proportions and they have approved these linings as economically feasible. We feel that the historic record is complete on this aspect of "in place" work.

Recently, the Carlon Products Corporation sponsored a research project at the University of Texas which was conduted by F. W. Jessen and James N. Howell, seeking "to compare the relative effectiveness of several plastic materials to aid in the reduction of paraffin accumulations in surface flow lines." These tests concluded: "The rate of deposition on plastic pipe or plastic lined pipe is substantially lower than on steel or aluminum pipe."

At the present time, considerable work, both test and actual field jobs, is being conducted in the use of plastic applied "in place" in water floods, water disposal systems, and in potable water lines.

The first "in place" work in water injection and salt water disposal lines was completed in 1953, while it was in 1954 that the first potable water lines were coated. Consequently, the historic records are not as complete as in the case of sour crude and gas lines.

At the present time, the most interest in the application of "in place" linings in water piping is centered in the use of these linings to protect extremely light weight pipe, 12-gauge and 10-gauge, handling salt water; and as a means of increasing liquid throughput in both old and new pipe.

The surface roughness of average pipe as it comes from the steel mill is approximately 575 microinches. The average surface roughness of a coated line is only 160 microinches. By using these values in the appropriate components of the Hazen Williams formula, it is possible to calculate the "C" factor of a coated line. The "C" factor of a new coated line computed from the Hazen Williams is 160.

Actually, as a result of several extensive field tests, a coated new pipe line should have a "C" factor in excess of 155, while an old line should have a factor well in excess of 140; and of course, these factors should be maintained for years. The benefits are then either more throughput or the same throughput at less pumping cost.

PRESENT AND FUTURE PLANS

With the development of satisfactory chemical cleaning methods and coating plugs which can negotiate tube turns, it has become practical to coat plant lines handling such chemicals as stearic acid, sodium hydroxide, etc. Here, the internally coated steel pipe is substituted for stainless and other alloy piping at a great saving of money.

Extensive tests and field jobs have been completed during 1958, attempting to determine the economic practicability of "in place" applied plastic linings to improve throughput in natural gas lines, to protect aviation gasoline and jet fuel from contamination during its transport through a pipe and as a means of mitigating paraffin and eliminating corrosion in offshore lines.

The same theory which led to investigation of internal, "in place" applied linings as a means of improving water line throughput has been used to justify the "in place" coating of 5 miles of 24-inch natural gas transmission line. Here, although the computations are not final, an improvement in throughput of from 8 to 12 per cent over the throughput of a thoroughly pigged line is indicated.

With the rapidly rising aviation gasoline and jet fuel markets at the more important air ports, it has become more economical in some instances to pipe the fuels to the air port rather than transporting them by truck. These fuels must arrive at their destination absolutely uncontaminated; one step in this direction has been to protect these fuels from contamination in the pipe line by lining the pipe. The first significant job for this purpose was begun in 1958.

The offshore work accomplished in 1958 was performed to determine if "in place" procedures used on land were equally applicable to offshore lines and if the protection afforded the pipe from corrosive attack and the mitigation of paraffin buildups were similar to onshore results. At the present time, the methods and results have proved to be equal.