CEMENT LINING OF PIPE AND TUBING FOR OILFIELD SERVICE

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ABSTRACT

In the search for new technology in materials to protect steel line pipe and tubing from internal corrosion, production and facility engineers sometimes overlook cement lining, the oldest and frequently the best system available for internal corrosion control. The purpose of this paper is to re-introduce cement lining to a new generation of engineers.

INTRODUCTION

The selection of coatings and linings for the protection of steel tubulars is an ongoing task for production company personnel, and with the many systems available, it can be difficult. However, when the selection is based on the principal consideration of cost and performance, i. e., maximizing cost effectiveness, cement lining provides a well established choice.

Cement lining for protection of steel pipe from corrosive water was first introduced into the United States well over a hundred years ago and became an accepted oilfield corrosion control system over fifty years ago. It's acceptance resulted from it's economy, durability, and outstanding corrosion resistance. In the past forty years, millions of feet of cement lined injection tubing and line pipe have been installed in oilfield applications across the producing areas of the United States.

In recent years, the cement lining industry has produced technical developments in application equipment and technique and in materials which have resulted in a vastly improved product. Modern cement linings, in corrosive environments, can provide a life expectancy of fifteen to twenty years for injection tubing, and twenty to thrity years for line pipe. There are many installations, put in service during the past thirty plus years, which substantiate these expections. Such outstanding performance, considered with a cost savings of 40% to 50% over most other linings, makes this an ideal product for internal corrosion control. Significantly greater savings may be realized by cement lining used tubing for injection tubing and for line pipe applications.

CHARACTERISTICS OF CEMENT LINING

The unique way in which cement lining protects steel pipe from corrosion sets it apart from other linings and coatings, and makes it more forgiving and in many cases a better system for corrosion control. Other linings and coatings attempt to eliminate corrosion by preventing contact of the corrosive liquids with the wall of the pipe. Thus, any thin spot, crack or damage due to improper application, handling, hauling and/or installation will result in a corrosion failure. Cement lining, on the other hand, is permeable (.01 millidarcy permeability) and corrosive water will migrate through the lining, wetting the entire internal pipe surface. As the migration occurs, the water absorbs calcium hydroxide (a product of the hydration process), a highly basic compound which raises the liquid pH from a corrosive level to 12 to 14 and passivates the steel surface, inhibiting corrosion.

Another unique characteristic of cement lining is it's inherent ability to self repair through a process known as autogenous healing.(Ref 1) This healing process is important because hairline cracks may well be created in the pipe during installation and will certainly occur in down-hole tubing applications. As tubing is installed in an injection well, the tubing stretch exceeds the tensile strength of the cement lining. The tensile stress imposed is relieved by the formation of circumferential cracks which occur as frequently as each 3/4 in., throughout the length of the tubing string. Calculations and field tests show that in properly designed tubing strings, set at less than 13,000 ft depth, these cracks will not exceed 2 mils in width. Calculations show that at these crack dimensions, passivation will be effective because water migration through the crack will be capillary, precluding turbulence which might inhibit passivation. (Ref 2) Furthermore, these cracks will heal in two to three weeks, as long as the tubing is kept wet, because continuing hydration forms new cementitious material which fills the cracks. This healing process is augmented by the reaction of fly ash which contributes to the production of cementitious products in the lining system. This same self healing characteristic allows for practical handling procedures in the installation of cement lined line pipe without fear of damage to the lining.

The bonding of cement linings in steel pipe is extremely effective and is a result of spinning the cement into the pipe at high speeds. The most significant bonding takes place due to the tremendous hoop strength produced in the lining through the centrifugal forces developed in the spinning process. These forces also drive the cement slurry into all of the non-uniformities in the steel surface, forming a mechanical bond between the lining and the pipe. (Ref 2)

A characteristic of cement lining, frequently unanticipated, is it's surprisingly smooth surface. The high rotational speed in the lining process and the extremely fine materials used in the slurry, result in a very smooth, low friction surface with a Hazen-Williams factor of 140.(Ref 3)

MATERIAL SPECIFICATIONS FOR CEMENT LINING

Cement lining mortors and slurries vary between applicators, but the most successful composition for oil field applications has been a cement/fly ash (artificial pozzolan) slurry. This mixture consists of 60% API Class C cement, a high early strength, highly sulfate resistant cement containing zero tricalcium aluminate: and 40% fly ash (API Class F) conforming to ASTM C-350. Alternate cement linings produced from sand mortors are available, but in order to avoid segregation of the sand and cement which have much different specific gravities and grain size, these linings must be spun at approximately one third the rotational speed of a cement/fly ash slurry. The resulting lining is inferior to the cement/fly ash lining in smoothness, bonding strength, and density. A mortor lining typically follows AWWA specifications and is not sulfate resistant. This, along with the inferior bonding of a mortor lining, have created many of the problems experienced in the utilization of cement lined pipe.

TECHNIQUES FOR CEMENT LINING PIPE

The first step in preparing pipe for lining is to inspect for straightness, roundness and the presence of flat spots and dents. Flat spots and dents may be cut out, leaving shorter lengths for lining, or the pipe must otherwise be rejected and replaced by the pipe supplier. In general, pipe with a camber less than 3/8 in. in 40 ft is acceptable. Minimum pipe specifications are reported in "API RP-10E"(4), and it is recommended that the pipe supplier always be notified when the pipe is ordered that it should be "suitable for cement lining."

In most cases "brush blast" sandblasting is adequate for cleaning the interior of new pipe, however, used pipe and some new pipe may require additional cleaning. Tight rust need not be removed as it will contribute to a better chemical bonding, and a "white metal" blast is never required.(4)

After pipe is ready for lining, it is moved into the lining area where the cement slurry is introduced into the pipe. The pipe is capped on one end and a lance is inserted the length of the pipe from the opposite end. The lance is withdrawn at a fixed rate while cement slurry is pumped into the pipe at a predetermined rate. (shown in Figure one) The slurry is thus distributed uniformly throughout the length of the pipe joint. The open end of the pipe is capped and the pipe joint is ready to spin. This procedure for introducing cement into the pipe is necessary to maintain the integrity of the slurry throughout the pipe length. If the slurry is distributed by gravity, separation of materials occurs and the resulting lining will be laminated.

Once capped, the pipe is rolled onto the spinning machine, a series of steel wheels on 4' centers that support the pipe in a horizontal position. (See Figure 2) Hydraulic actuated rams with wheels are lowered to hold the pipe in place during spinning. The pipe is then spun at approximately 2,500 surface ft/min for a fixed period of time based on the pipe diameter. The pipe is next ejected from the spinning machine, the caps removed and excess water drained out. Because of the high centrifugal force generated, water remaining in the cement approaches the theoretically ideal cement/water ratio which contributes to the outstanding quality of the final cement product. (5) At this point in the process, the lining is carefully inspected for integrity, uniformity and proper thickness. (See Figure 3) Although the lining is still completely uncured, it is so dense and hard that striking the pipe with a hammer (not denting the pipe) will result in no damage to the lining.

Once the spun lining has passed first inspection, the ends of the lining are finished by hand to insure that a perfectly smooth,. flush end results. (See Figure 4) The pipe is then steam kiln cured at approximately 135 degrees F for 18 hours, the equivalent of a 28 day atmospheric cure. (See Figure 5) After curing, the pipe is again inspected, the ends are buffed smooth and square, and any irregularities are corrected. A small amount of water is injected into the pipe, and it is capped and racked, ready for transporting to the field.

TECHNIQUES FOR CEMENT LINING TUBING

The lining procedure for tubing is essentially the same as that for line pipe with three principle exceptions:

1. Some arrangement must be made for protecting the threads in the "J" section of the tubing collar and the tubing pin threads. One method utilizes plastic inserts in the tubing ends prior to spinning in the lining so that the inserts become an integral part of the lining. (See Figure 6) These provide the protection of the thread areas by sealing off those areas from corrosive fluids. (See Figure 7)

2. After the lining has been placed in the tubing, a sizing ball is blown through the pipe and a drift bar is used to insure a proper ID.

3. After curing, a soft, putty like acrylic compound is injected into the plastic coupling insert to complete the protective seal in the thread areas.

Because many injection wells require occasional acidizing and it is often desirable to acidize through the injection tubing, acid resistant cement linings were developed in 1966. This class of lining has been used extensively since that time, and has proved very successful. The most widely accepted acid resistant cement lining is produced by pickling the uncured cement lining in a solution of magnesium silica fluoride. In recent years, acid resistant cement has also been utilized in some line pipe applications.

CEMENT LINING TECHNIQUES FOR FITTINGS

All types of fittings and flanges may be cement lined, but because they are typically not cemetrical around a common spinning axis, spinning the lining into the fittings is not possible. Fittings are hand lined, using the same basic mix as previously described, however, the mix must be made with reduced water content to form a no-slump mix (about the texture of molding clay). A small amount of short, alkaline resistant glass fibers are added to the mix for stability during application. (See Figure 8) Curing and end finishing is the same as for line pipe.

INSTALLATION OF CEMENT LINED LINE PIPE

The most commonly accepted method of joining cement lined pipe is with a butt weld. This method employs a heat resistant gasket placed against the face of the cement, leaving the steel ends exposed for welding. The gasket is highly compressed by weld shrinkage and serves to fill the gap between the cement lining ends. The gasket is very effective in forcing corrosive fluids through the cement lining to reach the weld area, bringing into play the passivating characteristics of the cement. During installation, cement lined pipe can be flexed or curved to any angle which does not cause the minimum yeild of the pipe to be exceeded. Any hairline cracks created during installation will quickly self heal once the pipe is put into service . Specific welding procedures and specifications are outlined in "APE RP-10E" (4) A cement lined pipe weld can be inspected by x-ray, however interpretation requires an experienced x-ray interpreter.

Ditching and laying procedures are primarily dictated by the external coating, not the cement lining. Thousands of feet of cement lined pipe have been laid on the surface in Montana and North Dakota where freezing is a frequent occurence. No damage to cement linings has ever been reported from this practice.

INSTALLATION OF CEMENT LINED TUBING

Installation procedures for running cement lined tubing are essentially the same as for any other type of lined or coated tubing. Wrap around tongs, coupling back-ups, thread protectors and a stabbing guide are prerequisite. Conventional tubing testing tools can be used as long as the test packer rubbers are properly sized. Test tools utilizing double cups are recommended for cement lining.

APPLICATIONS OF CEMENT LINED PIPE AND TUBING

During the past fifty years, many millions of feet of cement lined pipe and cement lined injection tubing have been used successfully in waterfloods and in salt water disposal systems throughout the United States and Canada. However, in more recent years, end users have discovered many additional applications. Cement linings are being widely and successfully used for CO_2 injection systems. (6) Another use is in production gathering systems where CO_2 and H_2S are being produced with the oil and water. Cement lined tubing may also be used in flowing oil and gas wells where corrosion is a problem. Gas systems where corrosive, wet gases are geing gathered have also been successful applications.

CONCLUSIONS

Cement lining provides a long lasting and economic solution for protecting steel line pipe and tubing from corrosive fluids in many applications. The proven longevity of cement linings, coupled with their low cost, indicate that they should be considered as a viable solution to corrosion problems in many oil field pipeing systems.

REFERENCES

1. Hatten, N. M.: "Autogenous Healing - Concrete Bulletin 10", Humes Ltd, Melbourne, Australia.

2. Runyan, E. E.: An Engineered Approach to Cement lined Tubing", Society of Petroleum Engineers of AIME, Paper No. SPE 995, 1964.

3. Evett, Jack B. & Liu, Chang: "Fundimentals of Fluid Mechanics", 1987

4. API "Recommended Practice for Application of Cement Linings to Steel Tubular Goods, Handling, Installation, and Joining". API Recommended Practice 10E (RP-10E) Second Edition, July 1, 1987

5. Lea, F. M. & Desch, C. H.: "The Chemistry of Cement and Concrete". 1971.

6. Newton, L. E.: "SACROC Co2 Project - Corrosion Problems and Solutions". Corrosion/84 April. 1984.

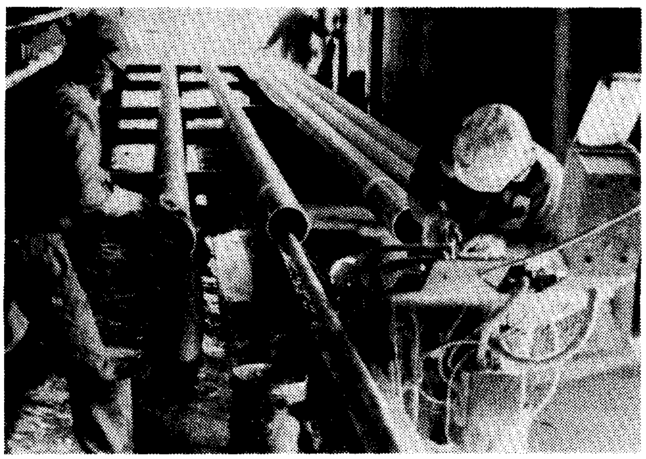

Figure 1 - Cement-lining lance

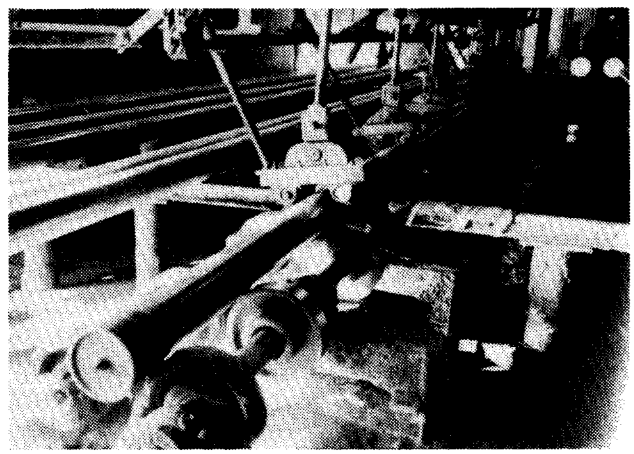

Figure 2 - Pipe-spinning machine

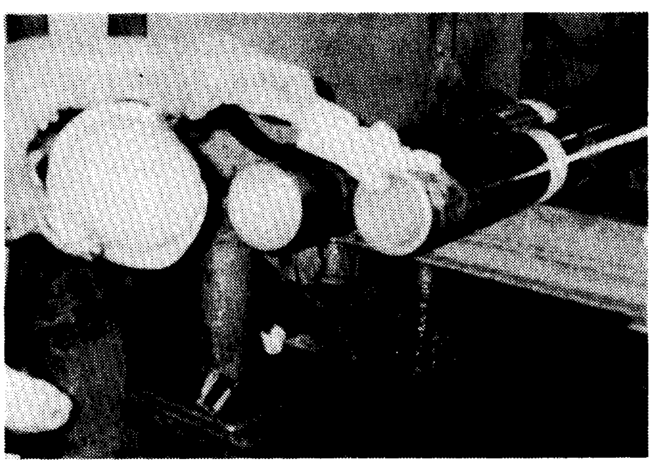

Figure 3 - Lining inspection

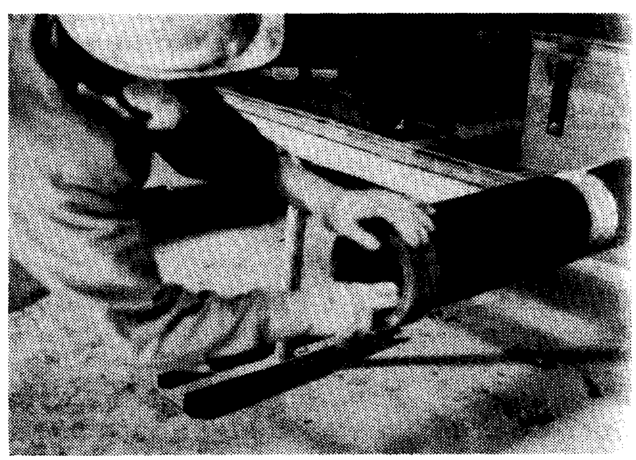

Figure 4 - End finishing

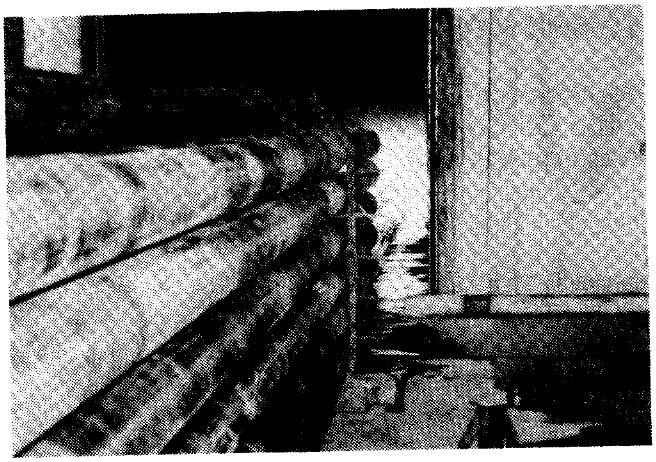

Figure 5 - Steam kiln

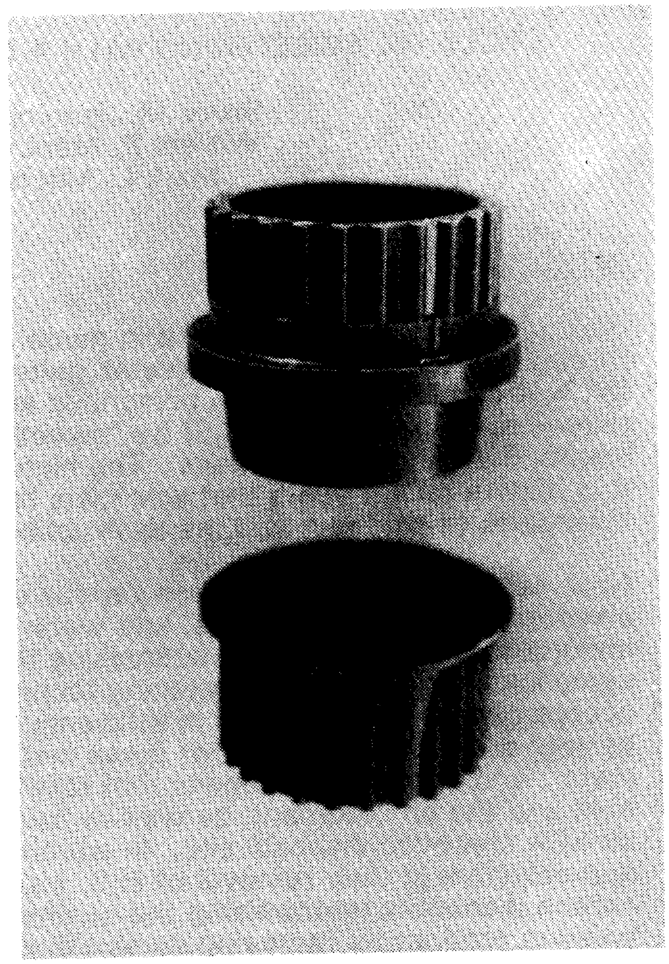

Figure 6 - Plastic inserts

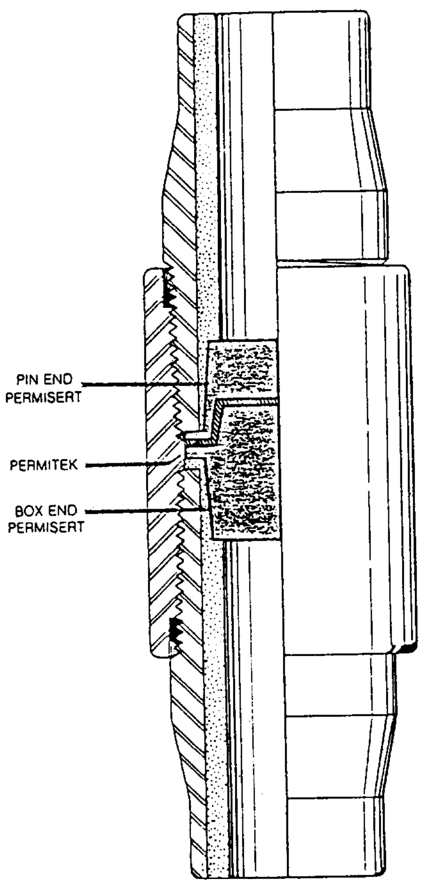

Figure 7 - Tubing joint with inserts

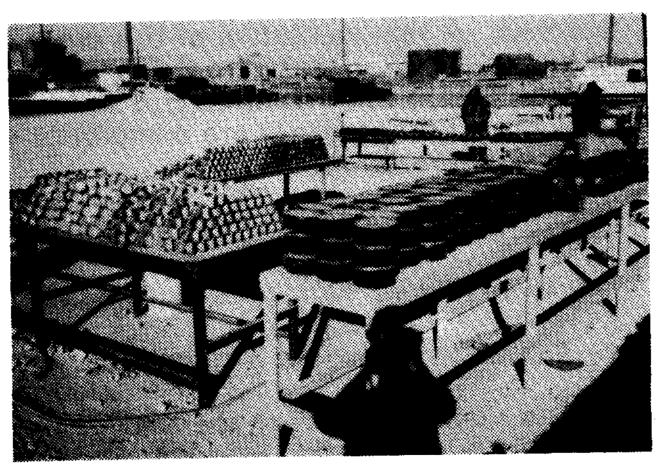

Figure 8 - Cement-lined fittings