Testing of Pipeline Maintenance and Rehabilitation Coatings

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Twenty-Nine *(29)* different pipeline coatings were tested, evaluated and then ranked, based upon the results.

Tapes, shrink sleeves and brushable coatings were included. All Known manufacturers were invited to submit the coating's of their choice.

Highlighted here is what we consider pertinent information. However, reading the complete paper provides interesting and unbiased information for those involved in Coating Selection.

The Polyguard RD-6 Coating System was ranked number one.

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TESTING OF PIPELINE MAINTENANCE AND REHABILITATION COATINGS

By Richard Norsworthy

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In an effort to provide information needed to determine which coatings are best suited for use in repairing or replacing pipeline coatings during normal maintenance or rehabilitation, a test program was developed and implemented. This testing program was designed to give specific information that is important for determining the best coating in the different categories tested as well as the best types to be used in different conditions.

Many of the tests are adaptations of standard tests. Changes in these test procedures were usually made by changing the length of the test, voltages and temperatures. When there was not a suitable standard to test for parameters that were important, new tests were developed. Most of these tests were developed by using the expertise of Paul Partridge (Technical Inspection Services, Inc.) and Gary Cox (ITI Anti-Corrosion, Inc.). Paul and Gary helped to take the needs and ideas for different test parameters and adapt these into a very good test program.

One of the new cathodic disbondment (CD) test parameters involved determining how the coating performs at longitudinal and girth welds. Each sample had a longitudinal weld and one girth weld. As seen in some of the results, many of the failures did occur at the weld areas. Three eights (3/8) inch holidays (larger than usual) were intentionally placed at the intersection of the longitudinal and girth welds. **Some of the tape and shrink sleeve coatings allowed water penetration along the weld seams. Some of the brushable coatings developed problems along the welds and not in other areas.**

Another test was developed to determine the peel resistance a coating may have when compared to other coatings of the same type. This test could only be performed on the tape and shrink sleeve coatings. The particular test involves determining the differences of peel strength at cathodic disbondment and impact areas to find out what kind of peel strength is lost (if any) at areas of damage. Many tape and shrink sleeve manufacturers make claims that their products "self heal" when minor damage occurs, but is the integrity of the coating bond in these areas as good as before the damage? This condition will be referred to as the "weakened bond radius" and will be determined by comparison to the average peel strength on the original coating. The average "weakened bond radius" was considered to be cathodic disbondment or water permeation.

Pull off tests were performed on all the brushable coatings to determine the extent of adhesion. Most results were good with one or two being exceptional. The cathodic disbondment area was easier to identify with these coatings. A problem did develop on some of the mor brittle coatings that kept chipping past the CD ring. However since there was good adhesion, no metal corrosion or water penetration in these areas, this was not considered to be further failure.

The tensile and tear properties of the tapes and shrink sleeves were compared before and after approximately 3000 hours in the prohesion exposure equipment. This test was to determine what changes are seen in these coatings after they have been exposed to burial conditions. The break strength and percent elongation at break were also used to determine **what coatings would perform best in soil stress situations. The best ratings were given to those coatings that had a high break strength and the least amount of elongation.** Some coatings actually showed an improvement in these properties after the prohesion exposure.

The attached information will give the basic information for the test program and an example of how the results were distributed. All participating company names have been deleted and generic descriptions used for each coating type. Of course for Mobil's use, this information was included.

Plans are to continue this test program on an annual basis or at least at times when there are enough new or different coatings to test. By reusing the same testing labs and test parameters, a continual updating process will exist. This gives the opportunity to look at existing coating technology as well as new coating systems that are being developed. After comparing the results, pipeline repair and rehabilitation coatings can be selected on a basis of tests and performance, not just cost or popularity.

I would like to thank each participating company, both testing labs and each of you for support and help during this program
.

The purpose of this testing is to have the information needed to recommend a variety of the best coatings to be used for repair and rehabilitation of pipeline coatings. Selected independent testing lab(s) are to be used for each type of testing. Each coating supplier will be given the rest results of each coating they supplied for the test, but not the overall test results.

I. TYPES OF COATINGS TO BE TESTED

A. Tapes

1. Cold applied
2. Hot applied

B. Shrink Sleeves

C. Brushable* Coatings

1. Epoxies
2. Mastics
3. Wax or petroleum based coatings
4. Other coatings not classed as a tape or shrink sleeve.

* Brushable may be applied with rollers, mits, etc. Spray applied coatings will be considered if process does not require considerable investment in specialized equipment.

II. SAMPLES TO BE TESTED

A. All coatings to be applied by testing lab personnel or coating supplier representative at the lab site. Each supplier may be present to direct and assist in the application of their particular coatings. The coating application procedure will be videotaped by lab personnel. Photographs and videotapes of the results and testing in progress may also be made.

B. Each coating will be applied to a 3 or 4 inch diameter hot rolled pipe, ten feet in length, blasted to a commercial finish. Blast medium to be medium grit coal slag, with a 2 to 4 mil profile. Maintain the pipe at 70°F ± 5° and less than or equal to 75% relative humidity between blasting and coating. Each pipe to have simulated longitudinal and girth welds conforming to API 5L and API 1104 specifications. Coatings to be applied within one hour of blasting.

C. Each coating will be given the manufacturer recommended time to cure before any testint or cutting of samples.

   1. Each coating must be applied holiday free.

   2. Each coating must be applied at the manufacturer's suggest thickness.

   3. Each coating will be tested for holidays at the manufacturer's suggested DC voltage.

D. Samples will be cut from these ten foot pieces of pipe as needed for testing. Each sample shall have a girth weld and a continuous longitudinal weld seam.

E. Each supplier will furnish to the testing lab all manufacturer's data on each coating regarding:

   1. Generic type
   2. Recommended service conditions
   3. Chemical and physical characteristics
   4. Safety related precautions
   5. MSDS sheets
   6. Application information
   7. The temperature range at which the coating should be tested; ranges are 150 or 200°F.

F. Each supplier must furnish to the testing lab:

   1. Enough of each coating material to be tested so each piece of pipe can be properly coated.

   2. Enough primer to properly prime each pipe for that particular coating.

   3. Enough thinner to properly thin and clean up after applying coatings.

   4. Any special tools needed for properly applying each coating, such as, hand wrapping machines, special torches, propane bottles, etc.

G. Selected testing lab(s) will furnish all pipe, equipment, and personnel for testing.

H. The Corrosion Specialist or designee will have free access to observe any of the testing, application, and evaluation of the coatings tested in this program.

I. The Corrosion Specialist will receive all videotapes, photographs, reports and results of all coatings tested in this program and will be responsible for sending results to the coating suppliers.

J. The Corrosion Specialist will make all decisions about which coatings will be tested and recommended for use on their pipeline systems. The results of these tests will be used as part of that decision making process.

III. TESTS TO BE PERFORMED

A. Cathodic Disbondment/Moisture Permeation (The moisture permeation will be done to test the effect of cathodic protection on the moisture permeation of the coating.)

1. Test conditions:
   a. Electrolyte: NaCl, 3%
   b. Potential: -3.0 VDC
   c. Temperatures:
   (Coating suppliers will decide at what temperature(s) their coating will be tested.) 150 or 200°F ± 5°

   d. Holiday diameter: 3/8" (three per sample) One will be drilled at the intersection of the girth and lingitudinal weld seams, one in the overlap of tape coatings away from the weld and one in the regular thickness of the coating away from the weld.

   e. Ends will be sealed to prevent moisture from entering the inside of the sample.

2. Duration of tests
   a. Begin with three samples per coating system.

   b. Evaluate one sample per coating system at 30 days.

   c. Discontinue CD testing on any coating system that disbonds enough to require a significant increase in amperage to maintin the test voltage.

   d. Evaluate one sample per remaining coating system at 60 days.

   e. Discontinue CD testing on any coating system that disbonds enough to require a significant increase in amperage to maintain the test voltage.

   f. Evaluate the remaining coating systems after 90 days.

   g. If all of the one type of coating system fails at the 30 or 60 day interval, the samples will be evaluated to determine which coating of that type will perform the best.

3. Evaluate criteria for cathodic disbondment

    a. Using a utility knife, make eight radial cuts through the brushable coatings to the substrate, with the holiday being in the center. Radial cuts shall be at least 1" in each direction.

    b. Cool the samples to room temperature. For tapes and shrink sleeves, a 1" strip will be cut, beginning wt the holiday, circumferentially, completely around the sample. This strip will be cut 180° from the holiday and peeled back enough to be gripped by the peel adhesion machine.

    c. For brushable coatings insert knife blade under the coating and use a lever action to chip off or remove the coating.

    d. For tape coatings and shrink sleeves, the coating must have the same characteristic and strength of bond at the holiday as it did in peel tests performed on the original samples of the coating. The average weakend bond radius* will be considered to be cathodic disbondment. Tape coatings (such as hot applied coal tar tapes) on which peel tests cannot be performed because they are brittle and do not have the tensile strength needed for a peel test, will be evaluated the same as brushable coatings.

* The weakened bond radius will be that point at which the peel strength of th4e coating is the same as the average peel strength of the original samples. This strength will be determined by a peel test comparable to the one taken on the original sample.

    e. Average CD radius will be measured from the holiday edge.

4. Evaluation for moisture permeation from CD testing:

    a. Brushable coatings will be tested by cutting 1" scribes (insuring that cuts penetrate to the substrate) crosswise at 45° angles at three areas 180° from the holidays.

    b. Air cool the samples to room temperature, but not longer than two hours. For tapes and shrink sleeves, prepare samples as in part III.A.3.b. above.

    c. For brushable coatings, insert the knife blade under the coating at the junction of the cuts and flip upwards. Note any chipping or peeling of the coating.

d. Tape coatings on which peel test cannot be performed will be evaluated the same as brushable coatings.

e. All coatings will be checked in the first ten minutes after removal for blistering, swelling, and change in color and texture.

f. Rating:
Excessive blistering or swelling may be cause for rejection. Change in color or texture will be recorded. For brushable coatings there may be chipping but no peeling of the coating. For tape and shrink sleeve coatings the peel strength should be comparable to that of the original peel strength.

B. Moisture Permeation/Impact

1. Test conditions

a. Electrolyte - Tap water

b. Temperatures - 150 or 200°F ± 5°.

c. Three impacts will be made on each sample and marked. Impacts will be at least four inches from each other and from the end of the sample. Impacts will be one each at 40 inch-pounds, 60 inch-pounds and 100 inch-pounds. Each impact will be tested for holidays at manufacturer's recommended voltage for the coating thickness and type. Holidays, cracking, and other damage from the impacts will be evaluated and recorded before immersion.

d. Ends of pipe will be sealed to prevent moisture from entering the inside of the pipe.

2. Duration of tests

a. Begin with two samples per coating system.

b. Evaluate one sample after 30 days.

c. Discontinue testing on any failed coating system.

d. Evaluate remaining samples after 60 days.

e. If all of one type of coating system fails at the 30 day interval, the testing lab will evaluate the rate the performance of these coatings.

3. Evaluation criteria

   a. Brushable coatings wll be tested by cutting 1" scribes (insuring that cuts penetrate to the substrate) at 45° angles across the impacted areas and at three areas 180° away from the impacted areas.

   b. Air cool the samples to room temperature, but not longer than 2 hours. For tapes and shrink sleeves, 1" wide strips will be cut circumferentially around the pipe with the impact area being in the center of the cut. These areas will be tested for peel strength by cutting the coating 180° from the impact areas and peeling the coating back enough to insert it in the peel strength test machine. The piece will be peeled around the pipe and at least 1" past the impact area.

   c. For brushable coatings, insert the knife blade under the coating at the junction of the cuts and flip upwards. Note any chipping or peeling of the coating.

   d. For tapes and shrink sleeves, the peel strength will be evaluated and compared to the original peel strength values (refer to part III.C). tape coatings (such as hot applied coal tar tapes) on which peel tests cannot be performed will be evaluated the same as brushable coatings.

   e. All coatings will be checked in the first ten minutes for blistering, swelling and change in color and texture.

   f. Rating:
      Any blistering or swelling may be cause for rejection of the coating. Change in color or texture will be recorded. Moisture permeation or lack of adhesion around weld seams (girth or longitudinal) will be cause for rejection. For brushable coatings there may be chipping but no peeling* of the coating. For tape coatings and shrink sleeves the peel strength should be comparable** to that of the original peel strength.

* Some peeling may occur at the impact area, but should not extend beyond the size of the area when compared to the earlier impacts at these same values.

** Comparable means no more than a 10% loss in peel strength when compared to the original peel test of that coating.

C. Peel Test - Tape Coatings and Shrink Sleeves

1. Test conditions

   a. Cured coatings

   b. Temperature of sample - all samples tested at ambient (room temperature).

   c. The 200°F test samples will also be peel tested at a substrate temperature of no less than 170°F.

   d. Same apparatus to be used for all peel tests including CD and moisture permeation tests.

2. Test procedure

   a. Cut two 1" wide strips circumferentially around the pipe.

   b. Cut the strip and peel the coating back enough to attach it to the peel test apparatus.

   c. Attach peel test apparatus.

   d. The strips will all be pulled at the same rate of inches per minute (to be determined by the testing lab).

3. Rating/Evaluation

   a. These test results will be used for comparison values for the CD and moisture permeation tests.

   b. The results will be given in a value that can be used for ranking each coating according to peel strength.

D. Impact Testing

1. Test conditions

   a. Cured coatings

   b. Temperature of sample - all samples tested at ambient (room temperature).

c. The 200°F test samples will also be impact tested at a substrate temperature of no less than 170°F.

d. Same apparatus used for moisture permeation/impact testing.

2. Test procedure

a. Perform impact tests beginning at 20 inch-pounds and increasing by 10 inch-pounds per test on each sample until the impact causes the area to fail a holiday detection test. Each impact will be performed on the coating at an area at least one inch from previous impacts and from the end of the sample.

b. Perform impact tests of 40, 60 and 100 inch-pounds on each sample, whether failure occurs or not. These three impacts will be evaluated for use on the moisture permeation/impact testing results.

3. Rating/Evaluation

a. Record the impact value in inch-pounds at which each sample fails holiday detection.

b. Evaluate each sample at 40, 60, and 100 inch-pounds of impact to determine the amount and type of damage done to the coating (such as disbonding, cracking, etc.)

c. Record results.

E. Tensile Properties of Tapes and Shrink Sleeves

1. Test conditions

a. Tapes and shrink sleeves only

b. Performed on each coating in applied form (This may require shrink sleeves to be heated, tapes to be stretched, etc.)

c. To be performed on original coating before exposure.

d. To be performed after 3,000 hours of prohesion exposure.

2. Test procedure
a. Evaluate break strength and percent elongation at break.

b. Evaluate tear strength.

c. Tape to tape peel strength (adhesion at overlaps).

2. Rating/Evaluation

   a. Each coating will be rated as to break strength and percent elongation.

   b. Each coating will be rated as to tear strength.

   c. Each coating will be rated as to peel strength or adhesion strength at overlaps.

F. Pull-off Test for Brushable Coatings

1. Test conditions

   a. Roughen surface of coating with 60-grit sandpaper or approved method.

   b. Roughen surface of an Elcometer adhesion dolly.

   c. Mix and apply adhesive in thin film to both the pipe surface and dolly surface.

   d. Sprinkle #4 sand on the epoxy on both surfaces.

   e. Apply dolly to coating and press firmly, avoid trapping air.

   f. Allow to cure 12 hours at 100°F to 150°F.

   g. Cool to room temperature (approx. 72°F).

   h. Attach to tensile machine and pull off at a rate of one inch per minute.

3. Rating/Evaluation

   a. Record maximum load at failure.

   b. Note type and location of failure.

   c. Rate each coating as to pull-off strength.

*** For 200°F coatings, an attempt will be made to perform the adhesion test when the substrate is no less than 170°F.

Any changes or deviations in this testing program shall be approved by the Corrosion Specialist shown below. In some cases, equpment or procedures may have to be changed or may not be available as described in the above specifications. Any changes or deviations shall be made before testing begins.

The testing lab must furnish an evaluation report for each coating that includes, but is not limited to the following:

1. Comments on eacse of application.
2. Procedure followed for each application.
3. Procedure for surface preparation.
4. Manufacturer's datea for each coating.
5. List of materials supplied by each coating supplier.
6. Results and procedure of each test performed.
7. Additional comments about each coating and test parameters that may help with future testing programs or proper use of the coating.
8. All results shall be sent to the Corrosion Specialist listed below by an agreed upon date.

All reports, additional information or questions should be directed to:

(Corrosion Specialist Name and address)

TESTING LABS AND COSTS

As indicated by the previous test procedures, this testing may be more stringent than some testing that has been done in the past. Please review these procedures, costs and requirements before submitting any coating for testing. This information will be used to select field applied repair and rehabilitation pipeline coatings for the future.

The following indepedent testing lab has been chosen for testing <u>all tape coatngs (hot and cold applied) and all shrink sleeves:</u>

ITI Anti-Corrosion, Inc.
10175 Harwin
Suite 110
Houston, TX. 77036
Telephone (713) 771-0688
Fax: (713) 776-9634

The following indepedent testing lab has been chosen for testing all brushable coatings, wax type coatings and coatings that can not be tested as described for tapes and shrinks sleeves:

TECHNICAL INSPECTION SERVICES, INC.
5202 South Shaver
Houston, TX. 77034
Telephone (713) 947-6630
Fax: (713) 947-7796

Please contact "Corrosion Specialist - Phone Number" if your company wants to participate in this program.

END

TEST RESULTS OF PIPE LINE REPAIR & REHABILITATION COATINGS

INTRODUCTION

The purpose of this testing was to have the information needed to recommend a variety of the best coatings to be used for repairs and rehabilitation of pipeline coatings. These coatings are for normal temperature (-20 to 150°F) underground or submersed pipelines, must be compatible with cathodic protection, be simple to apply and withstand the environment in which they are used.

A variety of pipeline coatings have been used by industry in the past. Some of these coatings have been successful, others have not. A testing program evaluates the coatings that are available and eliminates those that do not meet the company standards for coatings of this type.

Twenty-nine coatings were tested as shown in the following report. A discussion about the ranking and test results of each coating will be latter in this report.

Since this will be an ongoing test program in which the vendors of the products pay for the cost of the testing, the recommended coatings should be used for repair or replacement of coatings on all buried or submerged pipelines in the organization. Other coatings that are being used should be tested for comparisons to the tested coatings. Any company that promotes a coating should be encouraged to participate in future testing programs. The purpose of the continuing program is to evaluate coatings that come on the market or existing coatings that have not been tested or used. The recommended list will change and be updated after each set of tests are completed.

All referrals for testing should be made through the Corrosion Specialist. The Corrosion Specialist will oversee the testing programs and make recommendations from the results of the tests, comparisons with other coatings that have been tested and past experiences with particular coating sytems. Field input and experiences with particular coatings systems will be very valuable information in determining the recommended coatings for the future.

The generic types of coatings tested were cold and hot applied tapes, shrink sleeves, brushable (liquid) types and petrolatum tape systems.

RANKING

(Ranking - Number 1 represents the best product from the group and will be highly recommended for use in the areas indicated in the discussion. The larger the number the lower the ranking. Those not ranked should not be used for any reason.)

COLD AND HOT APPLIED TAPES

RANKING	TEST #	DESCRIPTION
1	**12**	**Primer/Outer Wrap**
2	13	Primer/Weld Seam Tape
3	1	Primer/Weld Seam Tape/Inner Wrap/Outer Wrap

4	8	Outer Wrap over 2-Part Epoxy Primer
5	15	Primer/Inner/Outer
6	6	Primer/Outer Wrap
7	14	Primer/Inner/Outer

NOT RANKED BECAUSE OF MASSIVE CD FAILURE.

	5	Primer/Tape

SHRINK SLEEVES

RANKING	TEST #	SYSTEM
1	3	Shrink Sleeve
2	2	Primer/Shrink Sleeve
3	4	Primer/Shrink Sleeve

NOT RANKED BECAUSE OF MASSIVE CD FAILURES.

	7	Shrink Sleeve
	9	Shrink Sleeve
	10	Shrink Sleeve
	11	Experimental Shrink Sleeve

BRUSHABLE COATINGS

RANKING	TEST #	SYSTEM
1	V1	Brushable Amine Adduct Cured 100% Solid Epoxy
2	C2	Coal Tar Epoxy Mastic (2 Coats)
3	N1	Epoxy Amine Adduct with Reinforced Wrap
4	C5	Epoxy Amine
5	P1	Epoxy/Polymer
6	V2	Modified Ureathane Polymer
7	A2	Pentaglycidalether of Cyclosilicon
8	C3	Epoxy Amine Adduct
9	C4	Epoxy Phenolic

NOT RANKED BECAUSE OF MASSIVE CD FAILURES

C1	Zinc Rich Moisture Cured Ureathane
W1	Coal Tar Moisture Cured Ureathane
5	Primer/Tape

PETROLATUM TAPE SYSTEMS

RANKING	TEST #	SYSTEM
1	TR	Primer/Wax Tape
2	S1	Primer/Wrap
3	TA	Primer/Wrap

DISCUSSIONS OF EACH COATING SYSTEM

COLD APPLIED TAPES.

#12 COLD APPLIED TAPE

This coating system was ranked number 1 because of its cathodic disbondment results, overall performance, ease of application and the design of the coating.

#12 had the best results in the cathodic disbondment test of all the coatings tested. This is the most stringent test for a coating. The overall test performance was also excellent for this coating. The peel and adhesion tests were difficult to perform on this coating because of the fiber mesh make up of the coating. The most important result from the moisture permeation/impact test was the fact that no moisture or rust was seen under the coating. This coating can be pulled extremely hard when applying to a structure, therefore it can be pulled down tight during application. The fabric backing (mesh) will not cause the same CP shielding problems as other tapes or shrink sleeves that have solid plastic backings. This has been a major problem with many tapes in the past. The application of #12 involves preparing the surface, applying the primer and then wrapping the tape by machine or by hand. **An advantage is that #12 can be backfilled immediately after coating. (See data sheets for specific application** and information.)

USUES:

#12 system should be used on all pipelines that require a cold applied tape wrap. This coating is recommended to be used as the number one choice because of the excellent test results, ease of application and the use of the mesh filber to help eliminate the shielding problem of other tapes.

#13 - PRIMER/WELD TAPE/INNER/OUTER

This coating had very good results in the cathodic disbondment tests and good overall results on the other tests. The major disadvantage is the application because of the requirements of the seqm tape and double wrapping.

The #13 coating did very good in the CD testing. #13 also did very good in the moisture permeation/impact testing with no moisture or rust detected under the tape. The use of the weld seam tape probably helped to prevent water penetration around the weld seams. The double wrapping also helps from an impact standpoint. The coating can be backfilled immediately after application. The coating can be applied by hand or machine, but machine would be recommended for large areas. The tested system involved using a primer, weld seam tape, an inner and outer wrap which could be labor intensive and provide more opportunity for error of application. The time required and the amount of coating used could also be more expensive.

USES:

This #13 system will be an excellent choice for areas that may have severe environmental stress and require the use of a tape wrap. This #13 system should be considered as a second choice and is recommended for use on all underground or submerged systems. This system requires use of a primer, seam tape, and inner and outer wraps and amy be more expensive and time consuming to install.

#1 - PRIMER/WELD SEAM TAPE/INNER WRAP/OUTER WRAP

This coating system had good results on the cathodic disbondment test and good overall results on the other tests. The major disadvantage is the application because of the requirements for seam tape and double wrapping.

The #1 tape did good in the CD test, but not as good others. The moisture permeation/impact results were also good. The peel strength results actually improved over the 90 days, which may indicate an improvement in peel strength with ageing. Once again the use of the weld seam tape may have helped with the water penetration at the welds. The coating can be backfilled immediately after coating. The coating can be applied by hand or machine. The tested system consisted of using a primer, weld seam tape, an inner wrap and an outer wrap which could be labor intensive and provide more opportunity for error of application. The time required and the amount of coating used could also cause the coating to be more expensive.

USES:

This #1 system would be an alternative to the #13 system, but the test results were not as good overall, therefore it is not recommended to use except when the #12 or #13 systems are not available. Once again it requires the use of four different steps and products to complete the coating system.

#8-PRIMER/OUTER WRAP

This coating had very good results on the cathodic disbondment test and good overall results on

the other tests. The major disadvantage of this coating is the use of the primer which requires

considerable curing time, especially on cool damp days or cold pipe.

This #8 system did very good in the CD test and very good in the moisture permeation/impact with no water penetration. This is a two coat system that is fairly simple to apply. The primer is brushed on and the tape can be applied by hand or machine. The major problem with this coating is the cure time of the primer. During a demonstration in January, the day was rainy and cool. The primer took between one to two hours to cure enough the #8 Representatives could apply the tape. If there is plenty of tie for curing the primer this could be a second choice to the #12.

USES:

This #8 system is recommended to be used only when there is sufficient time to allow the primer to cure properly. The application is similar to the #12 (two coats), but the test resultsd were not as good and the primer takes a long time to cure (especially on cold days or cold pipe).

THE FOLLOWING COATINGS WILL NOT BE RECOMMENDED FOR USE UNDER ANY CIRCUMSTANCES. THESE COATINGS ALL HAD POOR RESULTS ON THE CATHODIC DISBONDMENT TESTS AND OVERALL LOWER RATINGS ON THE OTHER TESTS.

#15 - PRIMER/INNER WRAP/OUTER WRAP

#06 - PRIMER/OUTER WRAP

#14 - PRIMER/INNER WRAP/OUTER WRAP

THE FOLLOWING COATINGS HAD MASSIVE FAILURE IN THE CD TESTING AND WOULD NOT BE RECOMMENDED FOR ANY PURPOSE.

#5 - PRIMER/TAPE

SHRINK SLEEVES -

#3 - SHRINK SLEEVE - NO PRIMER

This shrink sleeve had excellent results on the cathodic disbondment tests and very good overall results on the other tests. This sleeve does not require a primer and is fairly easy to apply.

The #3 shrink sleeve had excellent CD results and very good results on the other tests. The moisture/impact results were very good with no moisture penetration or rust. Shrink sleeves are applied with an open flame torch, require training and use of the proper equipment. The sleeve needs to cool a few minutes before backfilling. The open flame torch can be a safety problem and requires training and use of the proper torch. Shrink sleeves may not bond well to cold pipes or inservice pipes that have cold (under 50°F) product.

USES:

The #3 sleeve will be excellent to use on out of service or new construction pipe when the proper surface preparation and preheat can be applied to the pipe steel. **The test results were excellent and this could be an overall second choice to the #12 tape wrap coating and may be first choice on new or out-of-service pipes.** This will depend on cost and application cocnerns.

THE FOLLOWING SHRINK SLEEVES ARE NOT RECOMMENDED FOR USE BECAUSE OF MOISTURE PERMEATION PROBLEMS AND POOR CD RESULTS.

#2 - Primer/Shrink Sleeve

#4 - Primer/Shrink Sleeve

THE FOLLOWING SHRINK SLEEVES ARE NOT RECOMMENDED FOR USE UNDER ANY CIRCUMSTANCES BECAUSE OF MASSIVE CD FAILURES.

#7 - Shrink Sleeve

#9 - Shrink Sleeve

#10 - Shrink Sleeve

#11 - EXPERIMENTAL Shrink Sleeve

BRUSHABLE COATINGS -

V1 - BRUSHABLE AMINE ADDUCT CURED 100% SOLIDS EPOXY

This two part epoxy coating has very good cathodic disbondment results, overall perforamnce and is easy to apply. This coating has been used for field joints and patching on FBE and FBE/polyolefin coated pipelines for approximately two years with good results.

The CD results for this coating may be hard to evaluate because of the formulation used in the test tended to chip easily from the steel. This may have lead the testing lab to assume this chipping was caused from CD. As the photo indicates, the CD discoloration rings are much smaller than those indicated in the test results. The supplier has also reformulated slightly to decrease the chipping. Moisture permeation/impact testing results were very good with no moisture or rust under the coating. This coating had the best adhesive test results of any of the coatings. This coating is a two part epoxy that is mixed in correct proportions and applied directly to the pipe steel after surface preparation. The supplier can supply this coating in different size containers that will eliminate the need for measuring and waste. Curing has to take place before backfilling. Curing time is dependent on the temperature of the pipe and air. An advantage of this coating over tape coating is the fact that it will not have the same shielding characteristics as tapes or shrink sleeves, can be applied to irregular shapes and is ery compatible with FBE coatings.

USES:

The V1 Brushable Epoxy should be first choice for repairs, field joints and rehabilitation of FBE or FBE/polyolefin coated pipelines. This product is easy to apply and requires only one coat without a primer. The coating must cure before backfilling, but there are some ways to possibly speed up the cure or protect the uncured coating during backfilling. The time for curing will be determined by the pipe temperature and the air temperature. This coating could also be used for valves and irregular shapes, especially if mostly coated ahead of time in the shop.

C2-COAL TAR EPOXY MASTIC

This coating had good results in the cathodic disbondment test and performed good in most of the other test. The test coating was applied in a two coat system, but could be applied in a one coat if given enough time to cure priperly.

The results were good on the CD tests. Moisture permeation/impact test were very good with no blisters or holidays. The adhesion test results were good and impact resistance only fair. The curing time will be a factor in the field, but using one coat will speed up the time to backfill. This coating is simple to apply in either a one coat or two coat system.

USES:

The C-2 Black Mastic will be a very good coating for use on valves and other irregular shaped components. This coating should be very compatible with coal tar and asphalt coatings. This coating will not cause shielding like many tape coatings. The C-2 would be a second choice to the V1 Brushable Epoxy coating.

N1 - EPOXY AMINE ADDUCT WITH REINFORCED WRAP

N1 had very good results in nearly all the testing and might be the number one coating recommended if it were not for the application problems. The application is basically a three step operation.

This coating had very good CD results and very good moisture permeation/impact results. The N1 is a very thick coating and has the potential for causing shielding problems similar to heavy tape coatings. Impact resistance is excellent because of the thickness. Adhesion is also very good. This coating is very labor intensive and messy to apply.

USES:

N1 has potential for very agreesive environments where other coatings may have difficulties. If the application problems with this coating are not a concern for a particular application this is a very good coating. When conditions allow for proper application and cure times N1 would be recommended.

C5 - EPOXY AMINE

The C5 had good results in all the tests. This system requires a primer and top coat system.

The results of this system were similar to the V1 Brushable Epoxy. It had good CD and moisture permeation/impact results and very good adhesion results. The major difference in the two coatings is that the C5 requires a primer that must cure before the top coat is applied. If the application allowed for time to cure the primer and the top coat before backfilling this coating could possibly be used in the place of the V1 Brushable Epoxy.

USES:

C5 does not have the past experience with Mobil that the V1 Brushable Epoxy has at this time, therefore it will not be recommended for use except when the V1 Brushable Epoxy is not available.

P1 - EPOXY POLYMER

P1 IS STILL AN EXPERIMENTAL COATING, BUT HAS PROMISE FOR THE FUTURE. AT THIS TIME P1 IS NOT RECOMMENDED FOR USE AS A PIPELINE COATING.

THE FOLLOWING COATINGS ARE NOT RECOMMENDED FOR USE A A PIPELINE COATING BECAUSE OF THEIR POOR TEST RESULTS.

V2 - MODIFIED UREATHANE POLYMER

A2 - PENTAGLYCIDALETHER OF CYCLOSILICON

C3 - EPOXY AMINE ADDUCT

C4 - EPOXY PHENOLIC

C1 - ZINC RICH MOISTURE CURED UREATHANE

W1 - COAL TAR MOISTURE CURED UREATHANE

PETROLATUM TAPE SYSTEMS.

TR - WAX TAPE

TR had very good results in most of the tests. As with all petrolatum based coatings, the impact resistance was poor. The petrolatum coatings were tested at lower temperatures (75°F) than the other coatings (150°F).

TR did very good in the cathodic disbondment and mositure permeation/impact testing with no water penetration to the pipe steel. This coating is very easy to apply and will conform well around irregular shapes. The prime coat of TR primer is very effective in stopping water after it is top coated with the wax tape. These type coatings do not handle heat or impacts very well. Petrolatum coatings are more forgiving than most coatings to a poor surface preparation.

USES:

TR coating is recommended for use in special cases where other coatings may not work because of pipe or weather conditions (cold, wet, etc.). The wax tape can be used to coat

valves and other irregular shaped components. This coating is very easy to apply. Limitations

USES:

on mechanical strength and temperature must be considered before using this coating. This would also be an excellent coating for short term projects and old gathering lines where coating requirements are not as stringent. This coating would be good to use in areas where poor coditions exist for coating at the time, but the hole needs to be backfilled. In this case the recommended procedure would be to coat with the wax tape then return and recoat with other coating at a time when the conditions are right.

S1 - PRIMER/WRAP

S1 also did very good in the testing and has many of the same characteristics as the TR. The one exception is in the make up of the coatings.

S1 had very good resulsts in the cathodic disbondment and moisture permeation/impact testing with poor results on the impact test. The main difference in the coatings is that the S1 tape has an inert filler material that may leach out and mix with backfill materials, therefore causing deterioration of the coating. This is probably not a major problem but is one that has been reported by others.

USES:

S1 could be used as a substitute for the TR when it is not available.

TA

TA is not recommended for use at this time because of its poor performance in the cathodic disbondment testing program.

!!!!! CAUTION !!!!!

DO NOT USE PRODUCTS OTHER THAN THOSE SPECIFICALLY LISTED UNTIL THEY ARE TESTED AND RECOMMENDED! THERE ARE MANY VARIETIES OF COATINGS AND SIMILAR PRODUCTS BY THE SAME COMPANIES OR COMPETITORS THAT HAVE NOT BEEN TESTED AND MAY NOT PEFORM UP TO THE STANDARDS RECOMMENDED.

DO NOT USE OUTER WRAPS ON THESE OR OTHER COATINGS THAT WILL CAUSE SHIELDING OF CATHODIC PROTECTION CURRENTS! THE USE OF ANY ROCK SHIELD OR OTHER PROTECTIVE LAYERS SHOULD BE APPROVED BY CORROSION PERSONNEL.

APPLY THESE PRODUCTS AS SPECIFIED BY THE MANUFACTURER! USE ONLY THOSE PRODUCTS SPECIFIED TO BE COMPATABLE WIEN MORE THAN ONE COMPONENT IS USED IN A COATING SYSTEM!