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**TAR-POLYURETHANE JOINT COATING FOR
THE THREE-LAYER POLYETHYLENE
PIPELINE COATING**

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ABSTRACT

This article describes a new joint coating system implemented by Bechtel for a major international, 48 inch diameter gas pipeline. Despite the long history of use as a pipe and valve coating, the new implementation is the industry's first significant use of a thermoset hot spray coating applied to field weld areas of pipe, mill coated with a three layer polyethylene system. In the laboratory and in field trials, the coating demonstrated integrity, was applied much quicker than the traditional heat shrink sleeve, and eliminated several application contingencies. Laboratory investigations undertaken in Houston, Texas and Lyon, France were key steps in selecting the 100% solids tar-polyurethane coating. Additionally, the testing assisted in developing the surface preparation technique, and demonstrating the coating's ability to adhere to the polyethylene coating as well as the steel pipe. Serious localized corrosion, and cathodic protection shielding associated with other joint coatings are less probable with the new joint coating system. Actual field cathodic protection testing indicated very low current consumption for the completed pipeline. The efficient joint coating operation contributed to setting new construction records.

BACKGROUND**Project Description**

When Sonatrach, the Algerian National Oil and Gas Company, placed an inquiry for the 48 inch, 521 kilometer (324 mile) long GME pipeline, the mill applied, three layer polyethylene pipe coating had already been selected and purchased with the pipe. The field weld joint coating was specified, but Sonatrach, having prior experience with heat shrink sleeves, requested an evaluation of the possibilities and a recommendation for the best joint coating system considering the special circumstances of the project.

The large diameter line designed to carry natural gas from the interior gas fields of Algeria into Europe was to be constructed by several contractors each responsible for a portion of the line. The project schedule called for completion of the Algerian portion of the line across North Africa in a short 14 months from the completion of engineering. The North African temperature extremes were expected to range routinely between 0°C and 40°C (32 to 140°F) with frequent periods of strong winds and blowing desert sand. Skilled labor would be required to be brought into the sparsely populated land and housed in secure construction camps along the right-of way. The engineering and construction specifications required the highest quality work verified to internationally recognized standards.

The Three Layer Pipe Coating

Selection of the three layer, extruded, mill coating for the pipe underscores the Sonatrach's commitment to an overall coating system of preeminent quality. The three layer fusion bonded epoxy - polyolefin pipe coating was first developed and patented by Mannesmann of Germany and has been in use on pipelines since the early 1980's. The development was described by McConkey and Trzeciecki (1989), by Alexander (1991), or more recently for an adjacent section of this line by Haimbl (1996). Development was an outgrowth of efforts to synergistically combine traditional pipe coatings of different generic types and characteristics into a single pipe coating system. The favorable adhesion and cathodic disbondment properties of the thermoset fusion bond epoxy as well as the toughness of the thermoplastic polyethylene extruded coating was realized in the hybrid.

Much of the corrosion protection and cathodic disbondment resistance comes from the thermoset FBE primer. The resistance to rocks and other mechanical damage results from the thick thermoplastic polyethylene outer layer. By utilizing unterminated polymer groups -molecules with spots open for chemical linking- the thermoplastic intermediate layer adheres together the inner and outer layers.

The Field Weld Joint Coating

It follows that the field joint coating, which is a critical aspect of the coating system, must also be of the highest quality. The corrosion coating application at the weld joint area greatly affects both the life span of the pipeline as well as the construction effort. Ideally, the joint coating would be a continuation of the mill pipe coating with no discernible discontinuity between the morphology of the mill coating and that of the joint coating; molecules of each would link into a homogenous barrier affording equally strong protection over the field weld as well as over the pipe. Realistically, the circumstances of field application and characteristics of the coating prevent the replication of the automated three layer mill coating under field conditions.

Field Joint Coating Selection

Bechtel reviewed many possible joint coating systems for feasibility. In October and November of 1993, products from two major suppliers of heat shrink sleeves were test applied to 48 inch diameter pipe and destructively evaluated. Following the evaluation of the mock-up applications, several concerns about using heat shrink sleeves (and similar coatings like tapes) on this project were identified which led to an investigation of alternative joint coating systems. The study eventually concluded with selecting the tar-polyurethane or "tar-urethane (TU)" thermoset spray applied system.

The concerns identified by the Project in late 1993 for heat shrink sleeves applied to this large diameter pipeline were:

- the vulnerability of the application process to environmental extremes - cold weather and blowing sand
- the slow application speed - the large number of applicators required,
- the high level of applicator skill and endurance required,
- voids and air bubbles in the hot melt adhesive could be trapped during the application,
- the sheet backing material could "tent" over welds and chamfers creating an air gap,
- the hot melt adhesive or application preheat could melt away the intermediate layer of the 3-layer pipe coating,
- soil stress - the hot melt adhesive could permit a sleeve to creep or slide at operating temperature,
- cathodic protection shielding,
- pitting corrosion,
- stress corrosion cracking.

A discussion of these concerns is an appropriate subject for a separate paper. The reader is advised to refer to Garrity (1986), Toncre (1984), Fessler et al.(1983), Banach (1987), and Cortest Columbus, Inc. (1989) for an appreciation of the corrosion consequences arising from sheet coatings that, through application or service, become disbonded.

Acknowledging the increased technical sophistication required for plural component, heated spray application, it was recognized that the spray applied thermoset coatings without a sheet backing offered an

alternative that could obviate most of the above concerns. However, a new concern, the thermoset's compatibility to the thermoplastic 3-layer polyethylene pipe coating was identified for evaluation along with traditional industry concerns for impact strength and low cathodic disbondment.. After a literature and experience review of candidate spray applied thermoset coatings, which included epoxies and other coatings, two tar-urethane coatings were selected for test application and laboratory evaluation

Laboratory Screening Tests

Under laboratory observation the two coatings were applied over steel and over polyethylene to duplicate the joint coating configuration as much as possible. The application and laboratory evaluations were performed in Houston, Texas on steel plates obtained locally and on actual polyethylene coated pipe coupons cut from Sonatrach's coated line pipe at the mill in France and shipped to Houston. The tests performed in Houston by a prominent coatings laboratory in July, 1994 indicated that lap shear strength of the two tar-urethane coatings to steel and to polyethylene was much better than that reported on the product data sheets for candidate heat shrink sleeves.

Laboratory Testing of Trial Applications

Subsequently, on two occasions, August and November, 1994, one of the tar-urethane coating selected after the screening process was applied to simulated joints made in the actual 3- layer coated pipe at the pipe mill's facility in Gravelines, France. Sonatrach requested that coupons be cut from this coated pipe for their laboratory evaluation. Bechtel sponsored a test program at a laboratory of Sonatrach's choice to duplicate the screening tests and investigate issues Sonatrach felt pertinent. A laboratory in Lyon, France was eventually selected to carry out testing of the field trial coupons.

REVIEW OF LABORATORY FINDINGS

The initial screening test program in Houston investigated two candidate tar-urethane coatings and found them to be remarkably similar. Selection of one coating over the other was based mostly on previous field experience in similar climate conditions.

Because the testing program performed in France on the one selected coating was more extensive, the results from the French laboratory are reported here unless otherwise noted.

Lap Shear Tests Tar-Urethane/Steel

The test coupon for this test is cut from the pipe in the area where the joint coating is applied directly to the steel. This area of the joint represents 70% of the total area available to anchor the joint coating from sliding or shearing off of the pipe surface. This surface is the steel surface where corrosion protection is required. In the test, a steel fixture plate is glued to the tar-urethane coating of the pipe coupon to make a "sandwich". See Fig. 1, Appendix 1 for a sketch. The method is modified from ASTM D 1002. An increasing, measured force is applied to the sandwich parallel to the layers, tending to slide each layer over the other, similar to the force exerted on a joint coating that is on an expanding pipe in an expansive soil. The sandwich layers consist of steel fixture, glue, tar-urethane, and steel pipe. The maximum force obtained when one layer of the sandwich breaks free of another layer is recorded as the system strength, or lap shear strength.

The system lap shear strength at 23°C averaged 880psi (0.61kN/cm²) and at 65°C averaged 811psi (0.56kN/cm²). The tar-urethane did not shear off of the pipe surface at this value. In all cases, the plane of shear was through the glue used to hold the fixture plate to the outer tar-urethane surface, or through one of the interfaces with the glue - never at the interface between the tar-urethane and the steel pipe. The absolute value of the shear strength of the tar urethane/pipe interface is higher still than the system value derived in the test, which is very high.

This is perhaps the most important test result. It shows that the joint coating will not easily shear off of the pipe. Compare this value, 811psi (0.56kN/cm²) at 65°C, to the 50psi (0.034kN/cm²) lap shear strength reported at 60°C for one adhesive used to couple a popular heat shrink sleeve to a pipe. This hot melt thermoplastic adhesive is believed to be fairly representative of other low preheat types marketed for use

with 3- layer polyethylene mill coating, where the low preheat is required to preserve the intermediate layer of the mill coating.

Lap Shear Tests Tar-Urethane/Polyethylene With Thermal Cycling

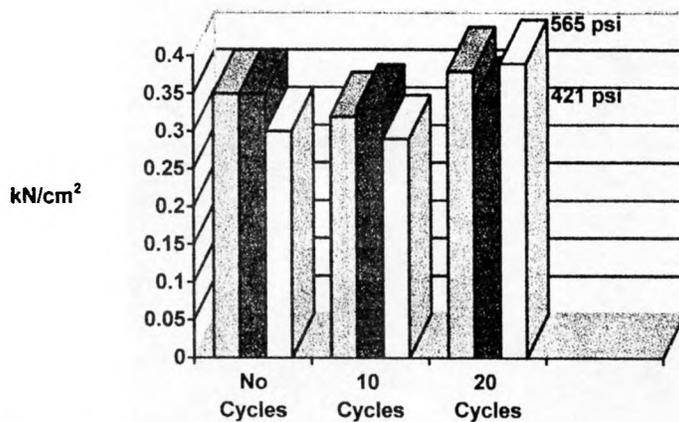
The test coupon for this test is cut from the coated pipe joint where the tar-urethane overlaps the polyethylene pipe coating. This area of the joint represents about 30% of the total joint coating surface area. As in the above lap shear tests, a “sandwich” is constructed for placement in the test fixture. Except in this case, the sandwich consists of steel, glue, tar-urethane, polyethylene, and steel pipe. See Fig. 1. Before preparation, the coupon is cut from a larger piece which has been exposed to a thermally cycling water bath for either 10 or 20 days. In one day the temperature cycles through 3°C and 62°C. The temperature of the system is 23°C during the application of the shear force. See Table 1. The average lap shear strength after 20 days in the cycling bath is higher at 536psi (0.37kN/cm²) than the average value of 428psi (0.29kN/cm²) measured after 10 days of immersed cycling. All failures occur at the tar-urethane /polyethylene interface.

This test evaluates the bonding of the joint coating to the polyethylene pipe coating. It is significant because of the traditional problems associated with joint coatings that must overlap onto a polyethylene pipe coating system. The coating/polyethylene interface is often the perceived weakest part of joint coating systems. The values obtained are very high. Again, comparison with the lap shear strength of the hot melt adhesives used with low preheat shrink sleeves commonly used with 3- layer polyethylene yields about a 10 fold increase. The apparent strength increase with time, 20 days vs. 10 days, is likely due to continued curing of the tar-urethane and the fact that the cyclic temperature extremes (3°C/62°C) have no appreciable adverse effect on the bond. (The values obtained in Houston during the screening tests were higher but showed the same trend as the data obtained in France.)

**TABLE 1
LAP SHEAR STRENGTH AFTER CYCLING**

Coupon #	* Test Conditions	Lap Shear Stress kN/cm ²	Lap Shear Stress psi	Nature of Failure
2	No Cycling	0.35	508	75% TU/PE
3	No Cycling	0.35	508	85% TU/PE
4	No Cycling	0.30	435	100% TU/PE
1	10 Cycles	0.32	464	100% TU/PE
5	10 Cycles	0.29	421	100% TU/PE
7	10 Cycles	0.33	479	100% TU/PE
8	20 Cycles	0.38	551	100% TU/PE
9	20 Cycles	0.34	493	100% TU/PE
10	20 Cycles	0.39	565	100% TU/PE

* Three values were obtained for each test condition.



**GRAPH 1
LAP SHEAR STRENGTH
AFTER CYCLING**

Lap Shear Tests Tar-Urethane/Polyethylene, No Thermal Cycling

The data presented in Table 2 was obtained without thermal cycling from coupons cut from the overlap area of the joint. The shear was applied with the coatings either at 23°C or with hot water heating to 65°C. Note that two of the three values obtained with heating exhibited glue failure and should be disregarded. The third value of 174psi (0.12kN/cm²) appears to be a true test of the tar-urethane/polyethylene interface at the elevated temperature, but elevating the temperature during the test just before the coupon is placed in the test fixture introduces technical problems that may degrade the results. It is likely that the hot water attacked the glue used to make the test sandwich. For this reason the laboratory provided additional tests using hot air heating, which proved more practical. This phenomena was previously observed during the laboratory tests in Houston. Again the 174psi (0.12kN/cm²) at 65°C value is much higher than 50psi (0.034kN/cm²) at 60°C lap shear strength reported for shrink sleeve adhesive..

**TABLE 2
Tar-Urethane/Polyethylene Lap Shear Test**

Coupon #	* Test Conditions	Lap Shear Stress kN/cm ²	Lap Shear Stress psi	Nature of Failure
2	23°C	0.35	508	75% TU/PE, 15% Glue, 10%PE/PE
3	23°C	0.35	508	85% TU, 15% Glue
4	23°C	0.30	435	100% TU/PE
14	Water @65°C	0.038	55	100% Glue
15	Water @65°C	0.041	59	Glue and/PE
19	Water @65°C	0.12	174	100% TU/PE

* Three values were obtained for each test condition.

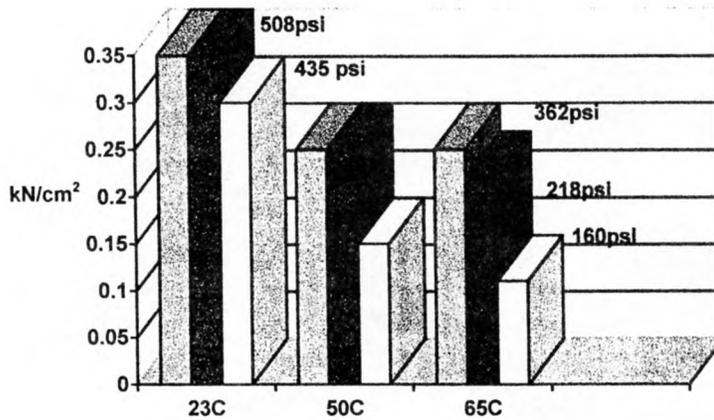
Additional Lap Shear Tests Tar-Urethane/Polyethylene

The laboratory performed additional tests at elevated temperature to bolster the one lone value obtained without glue failure in the Table 2 results above. Table 3 shows results at 50°C (incidentally closer to actual operating conditions) and at 65°C both using air rather than water as a heat transfer medium. The average value for 50°C with no glue failure is 362psi (0.25kN/cm²). The average value at 65°C with no glue failure reported is 280psi (0.19kN/cm²). These values indicate that the overlapped portion of the joint coating will resist disbondment better than heat shrink sleeves recommended for 3- layer polyethylene coated pipe. Graph 2 shows the results for coupons heated in air and at ambient temperature.

TABLE 3
Additional Lap Shear Tests at Elevated Temperature in Air

Coupon #	*Test Conditions	Lap Shear Stress kN/cm ²	Lap Shear Stress psi	Nature of Failure
2 bis	In Air @ 50°C	0.25	362	100% TU/PE
4 bis	In Air @ 50°C	0.25	362	100% TU/PE
19 bis	In Air @ 50°C	0.15	218	50% Glue, 50% TU/PE
3 bis	In Air @ 65°C	0.25	362	100% TU/PE
14 bis	In Air @ 65°C	0.22	319	100% TU/PE
15 bis	In Air @ 65°C	0.11	160	100% TU/PE

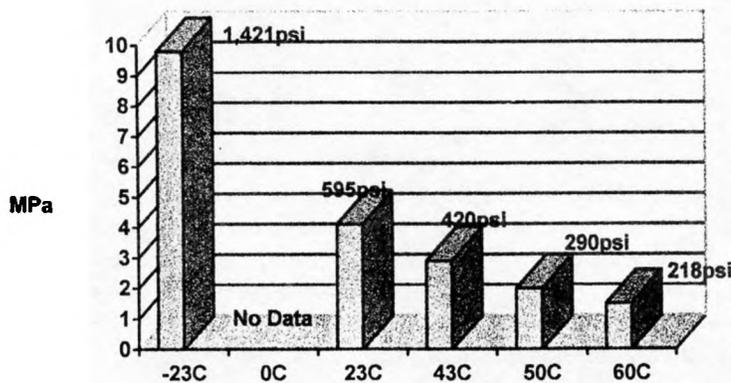
* Three values were obtained for each test condition.



GRAPH 2
LAP SHEAR STRENGTH
AT TEMPERATURE

Pull Off Tests Tar-Urethane/Polyethylene:

This test, unlike the lap shear test, exerts a force perpendicular to the plane of interfacing layers. The tests are performed in accordance with ASTM D 4541. As can be seen in Graph 3, the trend of decreasing strength remarkably follows the results of the lap shear tests. The tests appear to be executed well because no glue failures are evident and the data is consistent. The pull-off tests are cheaper and easier to perform than lap shear tests, but do not always give consistent results.



GRAPH 3
PULL-OFF STRENGTH

(1kN/cm² = 10MPa)

Determination of Tar-Urethane Elongation by Tensile Tests:

The tar-urethane coating was applied to a non-stick surface, then removed for testing as a free film. (No substrate to anchor it.) Tensile tests were performed in accordance with DIN 30671. The coating demonstrated elasticity with 1.5% elongation at 4,400 psi (30.4N/mm²) tensile strength at 0°C; and with 21% elongation at 550 psi (3.8 N/mm²) tensile at 65°C. The property of elasticity permits the coating to be applied thicker than more brittle coatings such as epoxies without disbonding. The tensile strength at 65°C indicates enough integrity to perform at the operating temperature. The elasticity accommodates differences in interfacial coefficients of thermal expansion, between polyethylene/ tar-urethane, and steel/tar-urethane..

Impact Tests The impact test, performed to the same method and specification referenced for the purchase of the 3-layer polyethylene pipe coating (NF A 49-710), indicated toughness in excess of the requirement. The tar-urethane applied over steel sustained in excess of 19 joules without a holiday being detected. Note that during the screening tests in Houston, both tar-urethane coatings applied over a variety of steel surface preparations sustained 18.6 joules of impact. This confirms the reputation for impact resistance that the tar-urethane coating has had on steel pipe for at least 16 years (Heim, 1980 and Klahr, 1981).

Cathodic Disbondment:

The cathodic disbondment for tar-urethane has been measured frequently over many years and is accepted to be relatively good (Oilweek, 1983). Our results confirm those good values. It should be noted that the French method (NFA 49710) measures a diameter including the original hole diameter rather than a radius typically used in ASTM standards. The initial hole diameter is 10mm, so the 31 day results of 30mm for the August application would convert to about $(30 - 10) / 2 = 10$ mm radius. The November coupon exhibited a disbondment of about 3.5mm radius after 31 days. This value meets the 5mm radius requirement stated on the data sheet for an epoxy primed heat shrink sleeve tested at the same temperature and duration.

Note, during the screening tests in Houston, both tar-urethane coatings exhibited cathodic disbondment of 4mm radius or less for 48 hours @ -1.5volts, 60°C in 3% salt solution using ASTM G 42 method modified for coupon configuration. One of the coatings tested for 30 days at the same conditions demonstrated a total cathodic disbondment less than 14mm.

Microscopic Visual Examination of Tar-Urethane/Polyethylene Interface:

The photomicrographs, Fig. 2 and Fig. 3, indicate:

- the tar-urethane appears capable of bonding to a remnant of the primer from the blast cleaned 3-layer pipe coating system as well as to the other layers,
- the spray application fills in the areas around the chamfer without tenting, bridging, or voids typical of shrink sleeves,
- and the applied coating appears to be a well consolidated tight film.

The connection of the joint coating to the pipe coating primer is significant because it means that the tar-urethane/polyethylene bond will be supplemented by a tar-urethane/FBE bond. The strong bond of the tar-urethane to abraded FBE coating has been demonstrated successfully for thrust bore sections on the PGT - PG&E Pipeline Expansion Project, and on other thrust bore applications (Klahr,1981). The benefit expected is better chemical and electrical impermeability for the joint.

Tenting was discussed briefly in the Background Section. It is believed that tenting over welds is a defect that can produce severe localized corrosion including stress corrosion cracking (Cortest Columbus, Inc., 1989) Tenting can also occur at the chamfer where the pipe coating is cut back. Typically a sleeve backing material does not flow into the crevice as well as the spray applied coating.

Electrical Insulance Test:

The electrical resistance of the applied tar-urethane coating at 100 days is quite high at $\cong 4 \times 10^8 \Omega$ and would satisfy the criteria for a polyethylene pipe coating system in the French method and standard, NFA 49710. Down from the initial reading of $5 \times 10^8 \Omega$, the moderate decrease in resistance over the 100 day immersion span is indicative of a coating with low water permeability. It must be recognized at the very high resistance values exhibited by the tar-urethane and polyethylene, measurement becomes difficult.

FIELD APPLICATION PARAMETERS AND RESULTS

Application Description

The joint coating subcontractor for the project, elected to manually blast clean the joint including the polyethylene overlap area using sand as the abrasive and manually spray apply the joint with the tar-urethane. Mobile rigs mounted on trucks were utilized for the two operations. Typically a blasting rig would service four blast nozzles, and a spray rig would service two spray guns. The tar-urethane was applied by plural component, heated spray equipment with mixing in a whip hose just before the gun. A third material, solvent for flushing the whip hose and gun was available at the manifold. The spray manifold is seen in Fig. 4. Constant displacement pumps with off ratio sensors and alarms were used to deliver the bulk resins to the spray guns. The material was applied in a multi-pass cross hatch spray pattern. The coating was 1 to 2mm (40 to 80 mils or 0.040 to 0.080 inches) thick over the steel section of the joint and feathered over the polyethylene overlap section. The full thickness of the coating could be obtained in one coat, minimizing the time the film was exposed to blowing sand contamination. Typical application time for hand spray application for one joint was three to five minutes. Depending on ambient temperature, the coating was dry to touch in one or two hours and fingernail hardness was achieved on the same or next day. Verification of finished joint quality was straight forward with a high level of confidence that there were no missing components, hidden voids or shielded holidays. When fingernail hardness was achieved, holiday testing at the full jeeping voltage of 12,000 volts could be performed. No Pipe heating was required, and no primer was utilized. Cadweld lead attachments and repairs of dings in the polyethylene pipe coating were accomplished with a trowel grade formulation of the tar-urethane coating.

Critical Specification Parameters

There were several application parameters that proved critical during the laboratory screening tests and during the field trial application.

The chamfer angle of the polyethylene pipe coating cut-back needed to be between 20 and 35 degrees as measured with the pipe surface. Steeper angles prevented good wetting of the root of the joint where the polyethylene joined the steel. Air bubbles here would result in electronic holiday indications. The factory bevels were generally quite acceptable, but cut-outs and tie-ins required field dressing of the bevel on the cut-back polyethylene. In some cases "whiskers" of the polyethylene would appear around this area of the joint after sandblasting and require removal with a knife. The whiskers would trap air bubbles that would cause holidays to be detected.

The anchor profile is important for coatings to achieve adequate adhesion. This is especially true for the thick joint coating that is expected to experience considerable shear forces due to soil stress. The ideal anchor profile would be about 100μ (4 mils or 0.004 inch) measured in the steel portion. Test data for the lap shear was obtained over a profile depth that ranged from 67μ to 100μ (2.7 to 4.0mils) in the steel. See Fig. 5. The anchor profile obtained by the abrasive blasting process on the polyethylene overlap is also critical. Unfortunately there are no standards for the measurement of the profile on polyethylene. The use of replica tape on this compressive material as used typically on the steel surface would produce erroneous results. Visual observations of sandblasted polyethylene indicate that the profile is much deeper than in the adjacent steel surface blasted with the same abrasive and pressure. The angle of the blast nozzle appears however, to be critical, producing the best results at about 30 to 40 degrees from the surface.

The coating thickness was a constant point of discussion through out the project. The coating manufacturer felt that about 0.8mm (32mils) was more than adequate for corrosion protection. However,

the specified thickness for the project was set at 1mm (40mils) minimum, 2mm (80mils) maximum to satisfy concerns of those who felt that the additional thickness would better match the properties, both mechanical and electrical, of the three layer pipe coating. It should be recognized that increasing the coating thickness increases the stress placed on the coating's substrate. This can be a special concern in the area of the overlap. To address this concern the specified thickness was reduced in the area over the polyethylene. This was addressed in the project specification as follows:

"The DFT of the tar-urethane coating shall transition from the specified thickness measured over the steel (no polyethylene beneath) to a thickness of Zero observed at the termination of the tar-urethane. The blast cleaning profile on the polyethylene surface shall be visible beneath the feathered-out (tapered) overlapping coating or beyond the edge of the tar-urethane coating.

When rubbed with the finger, there shall be a continuous circumferential band of roughness evident in the edge of the joint coating due to the roughened, overlapped, polyethylene pipe coating beneath."

The rough polyethylene beneath the joint coating is evident in Fig. 6.

This requirement assured that:

- the coating is not too thick in the overlap, thus capable of producing stresses that over power the adhesive force to the polyethylene,
- the edge of the coating is not a shoulder that can be easily snagged,
- the edge of the coating is anchored to the polyethylene by the blast cleaning profile.

Cathodic Protection Potential Survey Results

A continuous potential survey was conducted under natural conditions (without any cathodic protection on the line) at the test locations along a 7.5 kilometer length. The survey was conducted at one meter intervals along the pipe length, except for the area over, and one meter on either side of the weld area, where the interval was reduced to only 10cm. The test length was adjusted to include at least 6 weld areas at each test location.

A temporary cathodic protection system delivered less than 10mA of current was set up. After approximately four hours of continuous operation, the system was interrupted at a rate of 5 seconds "ON" and 2.5 seconds "OFF". Potential readings were then obtained under these conditions at all test locations. The "ON" potential readings were obtained immediately before the system turned off, while the "OFF" potential readings were obtained 2.5 seconds after the system had turned off.

The results of the tests indicate that there is no appreciable difference in the potential readings obtained on the weld areas and those obtained on the main line coating. The potential profiles show very little fluctuation in the potential readings throughout the length of the pipeline tested, regardless of whether the readings were taken above the main line coating or the joint coating.

CONCLUSION

The results presented in the French laboratory report corroborate all previous results from the screening tests performed earlier in the Texas laboratory and suggest that the tar-urethane coating can perform well as a joint coating on pipe mill coated with the 3-layer system. The good properties inherent with thermoset coatings such as low application temperature, resistance to air pockets, no tenting, high adhesion strength, and resistance to soil stress have been demonstrated. In addition, the coating can be applied quickly as a thick, tough film with low cathodic disbondment. These properties are believed to reduce the potential for pitting corrosion and stress corrosion cracking and cathodic protection shielding compared to that which

has been observed for other coatings. Field implementation of the coating has so far proved to be a practical and viable joint coating method, allowing high production rates while preserving the quality of the coating system.

ACKNOWLEDGMENT

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**APPENDIX 1
FIGURES**

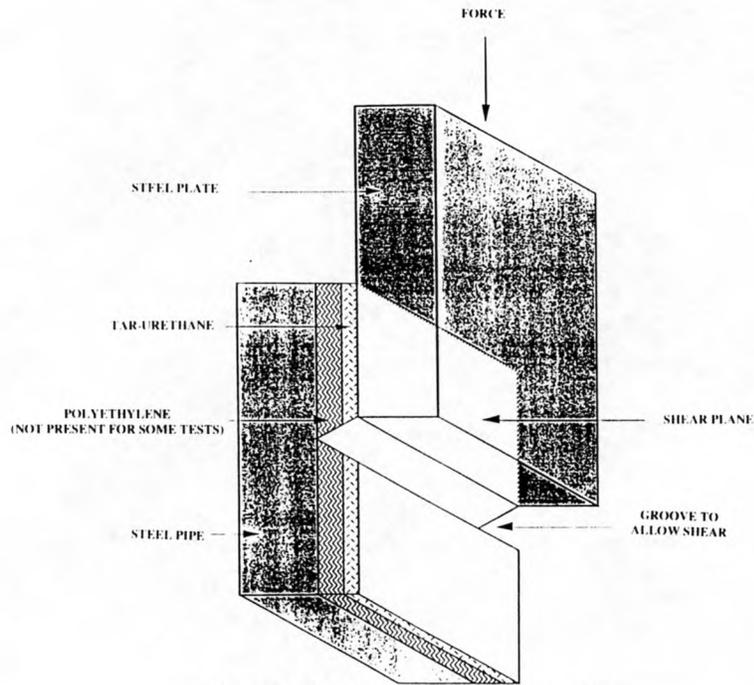


Figure 1, Sketch of lap shear test jig

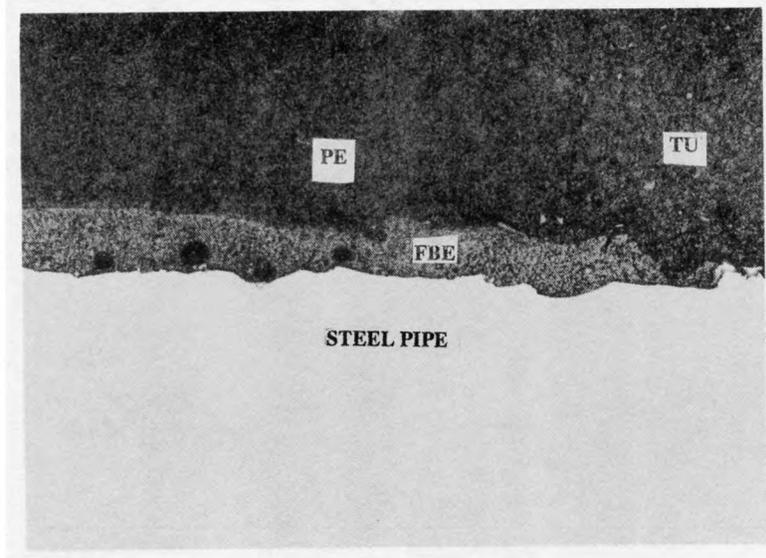


Figure 2, Photomicrograph of joint coating cross section, 100X power

APPENDIX 1 (cont'd)

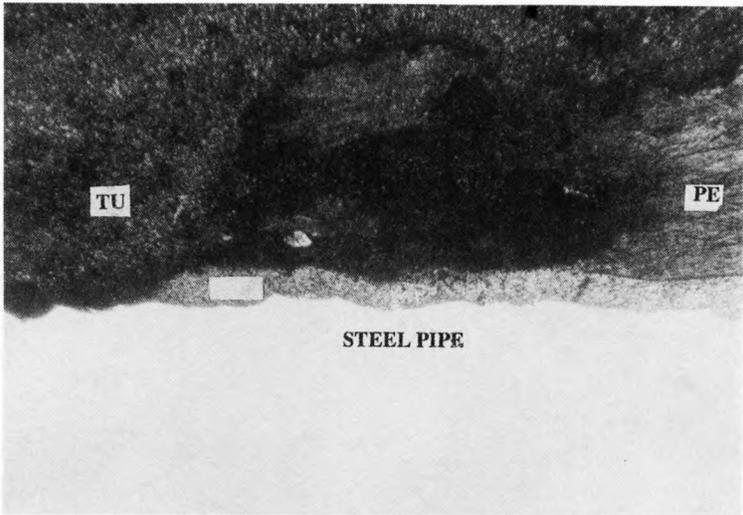


Figure 3, Photomicrograph of joint coating cross section, 100X power

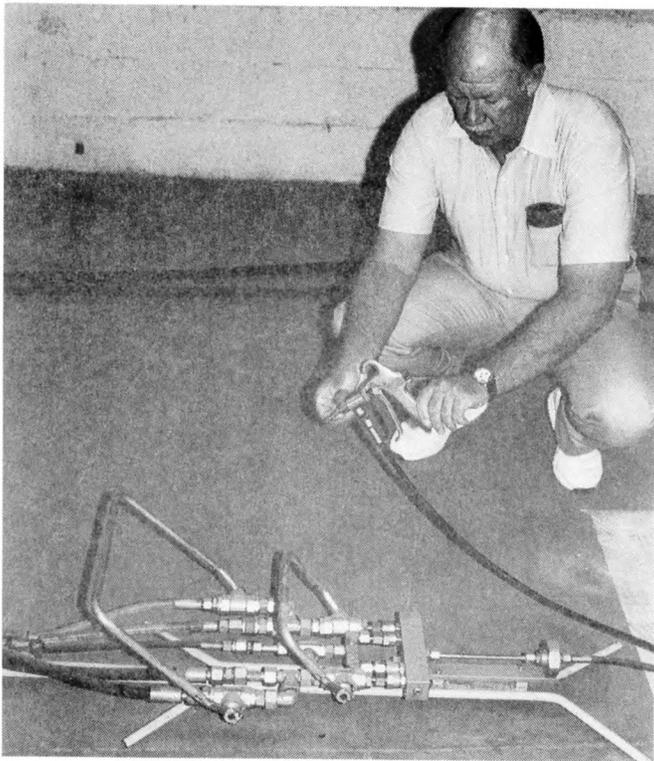


Figure 4, Spray gun manifold

APPENDIX 1 (cont'd)

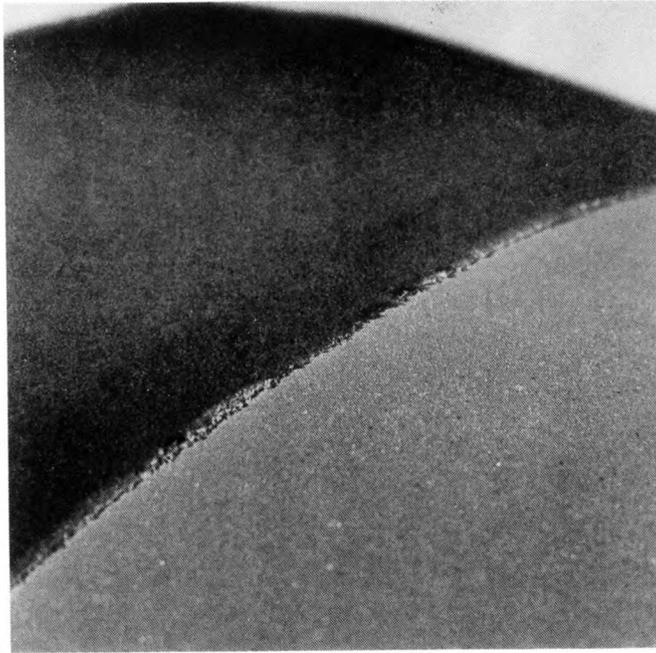


Figure 5, Anchor profile from blast cleaning



Figure 6, Coated field weld Joint