NAVAL FACILITIES ENGINEERING SERVICE CENTER
Port Hueneme, California 93043-4370

SITE SPECIFIC REPORT
SSR-2525-SHR

PIPELINE COATING CONDITION ASSESSMENT AND INSTALLATION ASSESSMENT, SAN NICOLAS ISLAND

by

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EXECUTIVE SUMMARY

This report documents the efforts of the Naval Facilities Engineering Service Center's (NFESC) Coating Specialist's response to a request by the Mechanical Systems Branch (Code 231) of NFESC to perform a pipeline coating condition assessment and an installation assessment.

Findings from NFESC's assessments are as follows: A) San Nicolas Island rock and soil produced coating scratches equivalent to 60 – 400 grit sandpaper, B) Field repairs contained surfaces with flash rusting and most likely contain high levels of chloride ion contamination, C) The fully cured coating has a Shore A Hardness value of 95, D) The pipe has a 1 – 2 mil grit blasted anchor profile, E) The coating has poor gouge resistance (manufacturer's data), F) The coating has poor impact resistance (manufacturer's data) G) Average coating loss from taber abrasion was 345 mg and represents low abrasion resistance, H) Coating loss from simulated abrasion over a 900 ft horizontal pull ranged from 50 – 100 mils (0.97218 – 1.94436 gram coating loss/in^2), I) Coating has an average cohesive strength of 716 psi (maximum shear bond strength), and J) A putty knife using hand pressure gouged and removed coating chunks (cohesive failures).

If the applied coal tar urethane has greater than 700 psi adhesion and field repairs contain less than 7 ug/cm^2 of chloride ion contamination at the pipe/coating interface, then several options may be used to increase the coating's abrasion and gouge resistance: A) Apply either a chemically compatible adhesive or a layer of the coal tar urethane over the existing coating system followed by round polyethylene sheet, B) Apply either a chemically compatible adhesive or a layer of the coal tar urethane over the existing coating system followed by a hot applied shrink sleeve, and C) Apply an additional layer of coal tar urethane containing a high loading of either sand or aluminum oxide. Options A – C require laboratory testing to confirm acceptable performance and to determine the correct application procedure. If new pipe with an abrasion resistant shop applied system is desired, several commercially available options exist.

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INTRODUCTION

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BACKGROUND

Approximately 3,600 ft of Schedule 80 Grade D pipe was grit blasted, shop coated at 80 mils using a 100 % solids coal tar urethane coating, and transported to San Nicolas Island. Through angles equivalent to an exponential curve, a pre-drilled hole lubricated with bentonite clay will be used to pull the coated pipe a subterranean distance of 3,400 ft. The resulting pipe installation will be used to transport fuel. After viewing the applied coating system, the project engineer is concerned that the coating system will not pull through the pre-drilled subterranean hole either 100 % holiday free or with sufficient coating thickness to protect the pipe.

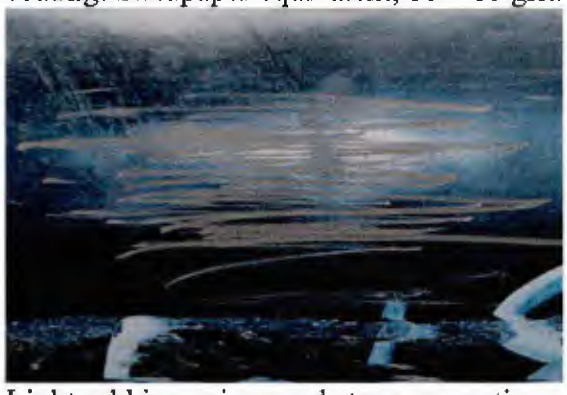
FIELD INVESTIGATION

ABRASIVE PROPERTIES OF SOILS AND ROCKS

In an attempt to quantify soil and rock abrasion on the coating, representative rock and soil samples, taken from the island, were lightly rubbed against the coating. The resulting scratches were visually matched to equivalent sandpaper scratches made from known grit sizes. San Nicolas Island rock and soil produced coating scratches equivalent to 60 – 400 grit sandpaper. In the laboratory investigation, the sandpaper equivalent of island soils and rocks were used (see section titled "Abrasion Resistance").

Light rubbing using shell embedded soil on coating: Sandpaper equivalent, 60 – 80 grit.

Light rubbing using a pumice type rock on coating: Sandpaper equivalent, 60 grit.



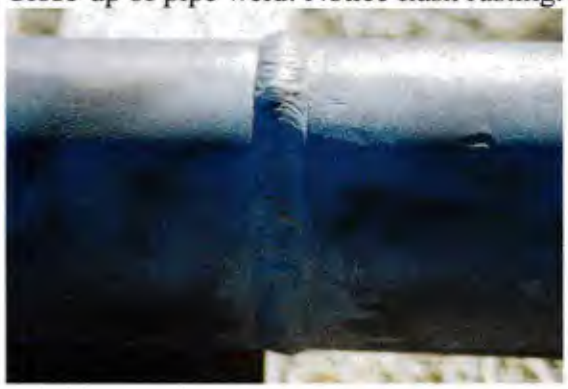
Light rubbing using sand stone on coating: Sandpaper equivalent, 80 grit.

Top to Bottom (L to R): Shell embedded soil, soil, pumice type rock, and sand stone.

FIELD REPAIRS

Close-up of pipe weld: Notice flash rusting.

Pipe surface requiring field coating.



Grit blasted pipe weld.

Holiday surface preparation.

Field surface preparation consists of a combination of #60 grit blasting, wire wheel abrading, and power grinding. Power grinding and wheel abrading are acceptable techniques for coating removal; however, they are unacceptable when used to prepare steel surfaces for coatings requiring immersion service. Only grit blasting is capable of producing the required angular anchor profile. Furthermore, the contractor's choice of #60 grit appeared to be producing a 1 – 2 mil anchor profile in lieu of the desired 2 – 4 mil anchor profile. Larger grit is required to produce a 2 – 4 mil anchor profile.

The majority of pipe requiring a field coating contained visually significant quantities of flash rusting. Prior to coating, flash rusting requires complete removal by re-blasting. Flash rusting decreases the adhesion of coatings to steel and results in a reduced coating service life. On San Nicolas Island, flash rusting is good indication that chloride ions have contaminated steel surfaces. If chloride ions are not removed to acceptable concentrations (less than 7 ug/cm^2 of chloride ion contamination), chloride ions will attract water of a lower chloride ion concentration into contaminated surfaces. The chloride ion effect will not stop until the contaminated steel surface is at equilibrium with surrounding liquids. Prior to the field application of coatings, exposed pipe surfaces should be washed with hot potable water followed by grit blasting to produce a 2 – 4 mil anchor profile. All field applied coatings where the above procedure was not employed may experience reduced performance.

SHORE A HARDNESS

Numerous Shore A Hardness values were determined throughout coated sections of pipe. It appears that the fully cured coating displays a Shore A Hardness value of 95. As a side note, the PVC used for rollers has a Shore A Hardness value of 98 which is higher than the coating (harder material). As such, PVC is an unacceptable roller material. Rollers

with a Shore A Hardness value below 95 should be used (rubber has a Shore A Hardness of 65).

SURFACE PROFILE OF PIPE

A visual comparison of pipe adjacent welded surfaces and beneath a section of removed coating appears to contain a grit blast at 1 – 2 mils anchor profile. For immersion service, coal tar coatings prefer a 2 – 4 mil grit blasted anchor profile. A portable adhesion tester may be used to determine if the coating system's adhesion to the existing anchor profile is acceptable. Acceptable adhesion results should be based upon the anticipated shear force produced during the pipe pull (the coating system's adhesive strength is equivalent to the coating's maximum shear bond strength).

MANUFACTURER'S THIRD PARTY TESTING

GOUGE RESISTANCE

A 4" length panel with 42 mils of coating was pull across a steel sphere (d = 100 mils) under the following loads: 66 lbs, 88 lbs, and 110 lbs. The resulting average gouge depths were produced: A) 27 mil gouge @ 66 lbs (64.3 % coating penetration), B) 28 mil gouge @ 88 lbs (66.6 % coating penetration), and C) 31.5 mil gouge @ 110 lbs (75 % coating penetration). It appears the coating has poor gouge resistance.

FLEXIBILITY

The manufacturer's reported data on flexibility is unclear and requires further clarification. Mandrel diameter and the sample bend angle are required.

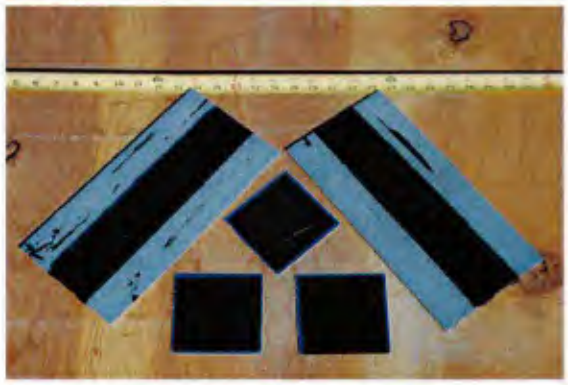
IMPACT RESISTANCE

A 3 lbs weight with a 0.625" spherical contact point was dropped from a height of 26.5" (9 joules) onto 43 mils of coating at 68°F. A singular drop produced 3 holidays in 43 mils of coating. Results indicate low impact resistance at 68°F.

ELCOMETER ADHESION

The coating displays an average cohesive strength of 1750 psi to grit blasted Fusion Bonded Epoxy (FBE). Results signify high adhesion.

LABORATORY INVESTIGATION



Coal tar urethane samples.

TABER ABRASER

Three taber abraser tests were performed in accordance to ASTM-D-4060 using a CS – 17 wheel, 1 kg weight, and 1000 cycles. Testing was performed at 18 hours cure and

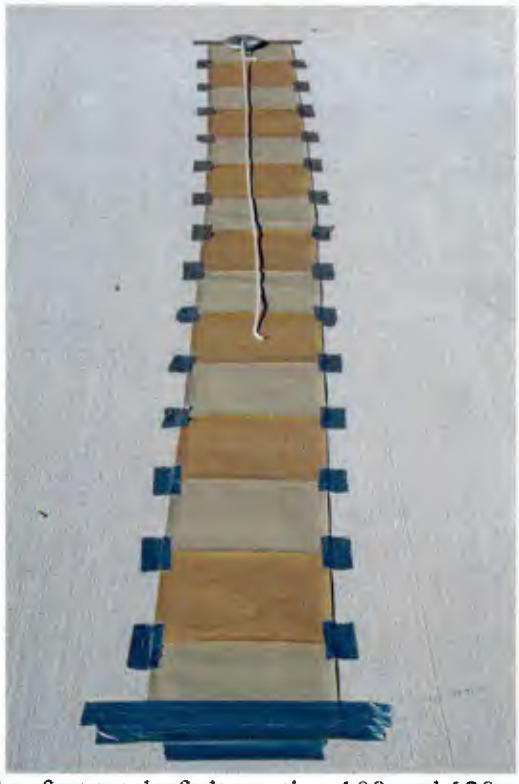
coated samples displayed a Shore A Hardness value of 91 (4 Shore A points below full cure). The coating displayed an average weight loss of 345 mg. Two component urethane floor coatings display a weight loss of 38 – 60 mg whereas high build industrial urethanes display a weight loss of 155 mg. Taber abraser results suggest the coal tar urethane has poor abrasion resistance when compared to other commercially available urethanes.

ABRASION RESISTANCE

The following test was performed to simulate the abrasion effects of pulling the coated pipe over 900 feet of a horizontal surface with soil containing shells, sand stone, and pumice type rocks. A distance of 900 feet represents a pull through 26 % of the total bore length whereby the bentonite clay lubrication, over the above materials, is insufficient.

Assumptions: 1) Force acting on coating is the pipe weight normal to a 1.5" width (0.377 psi), 2) Coated pipe is pulled parallel to a horizontal surface, 3) 100 to 120 grit sandpaper represents abrasive properties equivalent to uniform layers of abrasive soil, and 4) Abrasive surfaces do not contain material sufficient to produce gouging.

Test Parameters: A) Coated sample size, 7.854 in^2, B) Initial sample weight, 149.62735 g, C) Coating thickness on sample, 75 – 85 mils, D) Shore A Hardness of coating, 95 (full cure), E) Weight attached to sample, 2.5 lbs (0.361 psi), F) Sandpaper type, 100 grit (7 sheets) & 120 grit (8 sheets), G) Total length of sandpaper, 10 feet, and H) Weighted sample pulled 9 times through the complete length of sandpaper.



Ten feet total of alternating 100 and 120 grit sandpaper.

Resulting sandpaper surfaces after nine pulls: Notice black coating deposits

Coating sample attached to a 2.5 pound weight.

Results: 1) Coating weight loss, 0.76355 g (over a 7.854 in^2 area), and 2) Coating thickness loss, 5 – 10 mils (0.0194436 – 0.0097218 g/mil, in^2).

To determine the effects of a 900 foot pull, the above results are multiplied by 10 and produce the following values: A) 7.6355 g coating weight loss (over a 7.854 in^2 area), and B) 50 – 100 mils coating thickness loss (0.97218 – 1.94436 g/in^2).

ADHESION

Coal tar urethane sample with 3/4" pull-off coupons and adhesion tester.

Five adhesion tests in accordance to ASTM-D-4541 were performed on 80 mils of coating applied to grit blasted steel. The test was performed at 45 hours coating cure and, based upon a Shore A Hardness value of 95, represents a fully cured coating. Each adhesion test produced a cohesive failure in the coating at an average value of 716 psi. The resulting average adhesion is 59 % lower than the average value reported by the coating vendor's testing laboratory. The above adhesion value represents the coating's maximum shear bond strength.

SHEAR BOND STRENGTH

A hammer and chisel and, in addition, a putty knife were used to qualitatively determine the shear bond strength of the coating to grit blasted steel. The coating could not be removed using the chisel and hammer however, the putty knife gouged and removed coating chunks (hand pressure, cohesive failures). Results from the putty knife test are an indication of the coating's poor resistance to materials that gouge.

DISCUSSION

The coating manufacturer reports a coating weight of 0.0087 lbs/ft^2, mil (0.0273619 g/in^2, mil). When this value is used to calculate abrasion resistance following the experimental 900 foot drag, 36 mils of coating are lost instead of the reported 50 – 100 mils. However, the calculated coating loss is based exclusively upon a 1.5" pipe contact width and a force equal to the pipe's weight (0.361 psi). If either the pipe's contact width becomes less than 1.5" or the force and resulting angles used to pull the pipe through the hole exceeds the pipe's weight, then the coating loss will also increase accordingly. If the resulting force increases from the experimental 0.361 psi to 10 psi, then the coating loss may increase by a factor of 27 (36 mil coating loss increased to 972 mil coating loss). The above abrasion resistance testing did not combine coating loss resulting from either gouging or impact. Manufacturer's third party testing reported 75 % coating loss from gouging (110 lbs over a 100 mil diameter sphere) and 100 % coating failure from impact (3 lbs weight attached to a 625 mil sphere dropped from 26.5"). It is highly improbable that the bentonite clay will eliminate pinpoint rock loading (gouging) by uniformly covering the area directly above each high spot. As such, additional coating loss from gouging must be included in the above coating loss values.

FINDINGS

- San Nicolas Island rock and soil produced coating scratches equivalent to 60 – 400 grit sandpaper.
- Field repairs contained surfaces with flash rusting and most likely contain high levels of chloride ion contamination.
- The fully cured coating has a Shore A Hardness value of 95.
- The pipe has a 1 – 2 mil grit blasted anchor profile.
- The coating has poor gouge resistance (manufacturer's data).
- The coating has poor impact resistance (manufacturer's data).
- Average coating loss from taber abrasion was 345 mg and represents low abrasion resistance.
- Coating loss from simulated abrasion over a 900 ft horizontal pull ranged from 50 – 100 mils (0.97218 – 1.94436 gram coating loss/in^2).
- Coating has an average cohesive strength of 716 psi (maximum shear bond strength).
- A putty knife using hand pressure gouged and removed coating chunks (cohesive failures).

RECOMMENDATIONS

If the applied coal tar urethane has greater than 700 psi adhesion and field repairs contain less than 7 ug/cm^2 of chloride ion contamination at the pipe/coating interface, then several options may be used to increase the coating's abrasion and gouge resistance: A) Apply either a chemically compatible adhesive or a layer of the coal tar urethane over the existing coating system followed by round polyethylene sheet, B) Apply either a chemically compatible adhesive or a layer of the coal tar urethane over the existing coating system followed by a hot applied shrink sleeve, and C) Apply an additional layer of coal tar urethane containing a high loading of either sand or aluminum oxide. Options A – C require laboratory testing to confirm acceptable performance and to determine the correct application procedure. If new pipe with an abrasion resistant shop applied system is desired, several commercially available options exist.