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Epoxy Lining for Shipboard Piping Systems

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13. ABSTRACT *(Maximum 200 words)*

The Naval Research Laboratory has developed an epoxy lining to prevent corrosion and erosion of copper-nickel pipe. Before being approved for use aboard ship, the lining was tested in the laboratory for resistance to chemicals found in sanitary systems and tested in a simulated ship piping system for application viscosity and hardening time. Commercially-available linings were also tested but found to be deficient in one or more critical properties. Entrained air in the applied coating is avoided more easily by control of application parameters than by the use of air-releasing additives in the lining. The process used to install the lining is described in detail. The Navy now uses this lining to restore corroded or eroded ship piping systems rapidly without lengthy disruption of shipboard operations. This technology has been shown to be a proven inexpensive alternative to replacement of pipe.

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EPOXY LININGS FOR SHIPBOARD PIPING SYSTEMS

1. INTRODUCTION

This report gathers in one place and summarizes work performed at the Naval Research Laboratory between 1987 and 1993 on the develop[illegible]ting, and installation of epoxy linings inside piping systems on aircraft carriers.

Aircraft carriers have experienced severe erosion and corrosion of piping in Collection, Holding, and Transfer (CHT) systems. The Naval Sea Systems Command Detachment responsible for planning and engineering for repairs and alterations of carriers (PERA CV, Bremerton, Washington), proposed that these piping systems be lined with bisphenol epoxy coatings as part of their Carrier Life Enhancing Repair Program. As a test, a 20-foot section of CHT piping on the USS MIDWAY (CV 41) was lined in Japan in October, 198[illegible], and was found to be in excellent condition in mid-1986.

Following this favorable test, PERA CV tasked the Naval Research Laboratory (NRL) to test commercial bisphenol epoxy coatings for properties which are significant for linings in CHT piping systems. The tests were selected jointly by PERA CV and NRL, and the results are given in Section 2 of this report. None of the commercial coatings was found to be suitable for aircraft carrier CHT systems.

NRL was then tasked by PERA CV to develop a suitable Navy reference formulation for lining 90/10 and 70/30 copper--nickel (CuNi) pipes in both CHT and potable water systems. This work is described in Section 3 of this report. These coatings have several unique requirements. They must be at least as good as the 1987-standard, commercially-available Devoe 143 Variation I (the hardening time of which is too fast for convenient use), and they must be formulated from materials approved for use with drinking water so that the same material can be used in both potable water and CHT systems. They must also be usable in commercial pipe lining application techniques which rely on a pressurized gas to propel the paint through the inside of the pipe being coated.

NRL developed a fast-hardening and chemically impervious epoxy lining known as NRL 4A. This was tested in non-ship piping systems and approved for use aboard ships. Initial applications of this epoxy pipe lining sometimes produced films which entrapped air bubbles. Such voids provide routes for oxygen, sulfides, and other reactive species to reach the copper-

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nickel pipe and corrode it, and cannot be tolerated. Additives to avoid entrapment of air were studied, as described in Section 4 of this report, and three materials were identified which decreased air entrainment. However, changes in the lining application process were implemented and successfully eliminated bubbles in the coating, making unnecessary any change to the formulation of the NRL 4A lining.

The process now used for lining shipboard sanitary pipe systems has been worked out in detail by the American Pipelining Corporation, PERA CV, and NRL during work on 12 aircraft carriers. This process is described in detail in Section 5 of this report.

2. TESTS OF BISPHENOL EPOXY COATINGS FOR USE IN SHIPBOARD PIPING SYSTEMS

Products Tested

The following three bisphenol epoxy coatings were tested:

(a) Bar Rust 235, a product of Devoe Marine Coatings Company, a Division of Grow Group, Inc. The label identified the product as Bar Rust 235, Kit 23542; Part A was identified as product MD-5126, batch N606002A.

(b) Navy Formula 150 and Formula 152 coatings conforming to military specification MIL-P-24441. In each coating, the first component contains a liquid bisphenol epoxy resin, and the second component contains a polyamide hardener. Materials were obtained from Seaguard Corporation. The batch numbers on Formula 150 for parts A and B were K5-003A and K-004B, respectively; the date of manufacture was November 1986. For Formula 152, the batch numbers were E6-001A and E6-021B, respectively: the date of manufacture was May, 1986.

(c) A lining manufactured by the Toyo Lining Company, Ltd., of Yokohama, Japan. This is a two-part lining with a very short pot life and is manufactured only for use with Toyo Lining Company's "A-S Method" for pipeline cleaning and coating. The first component, designated LST 641/H-11, contains a modified cycloaliphatic polyamine hardener.

Preparation of Coatings for Testing

The three coatings were applied to grit-blasted steel panels ⅛-inch thick, and to 1/16-inch thick Q panels. In addition, 6-, 12-, and 24-inch sections of electrical conduit piping with a 2-inch outer diameter and a 1/16-inch wall thickness were coated internally. Coatings were usually applied with air-aspirated spray at air pressures of 50 to 90 pounds per square inch, but some panels were brushed. In addition, a three-foot length of iron pipe coated by Toyo was cut into 2-inch sections, and the coating was subjected to the same tests.

The Devoe Bar Rust was applied in two coats of about 8 dry mils each, with 4 hours between coats. The Formula 150 was applied at 2 dry mils thick, allowed to dry for 24 hours, and overcoated with 2 dry mils of Formula 152. The Toyo coating was thinned with 20% by weight of methyl isobutyl ketone (MIBK) in order to make it pass through our spray gun, and was then applied in a single coat 5 dry mils thick. All coatings were allowed to dry for seven days before testing.

Test Methods

The following tests were performed. Results for each of the three coatings are described.

1. *Characteristics of the liquid coating*: The Bar Rust had a viscosity of 93 Krebs Units (KU) and a pot life of 2.5 to 3 hours. Formulas 150 and 152 had viscosities of 78 and 72 KU, respectively, and pot lives of 6 hours. The Toyo epoxy (without MIBK) had a viscosity of 116 KU when mixed, but the viscosity began to increase rapidly 5 minutes after mixing. The pot life of the Toyo coating was less than one hour.

2. *Application by brush and spray*: Formula 150 and Formula 152 sprayed and brushed well. Bar Rust sprayed poorly (perhaps because we could only achieve 90 psi with our equipment), but it brushed out quite well. We were able to spray the Toyo only after diluting it with 20% by weight of MIBK, and then it sprayed out well. Brushing performance was good without MIBK, very good with MIBK.

3. *Characteristics of dried coatings*: All coatings formed smooth, tightly-adhering films with no bubbles, blisters, or other defects.

4. *Immersion resistance tests*: Coatings were immersed in distilled water and in separate solutions of 10% sulfuric acid, 10% hydrochloric acid, 10% sodium hydroxide (lye), 2% sodium hypochlorite ("Chlorox"), 2% sodium hypobromite, and 10% sulfamic acid for 30 days. Samples of undiluted Toyo coating applied by brush were immersed for 48 days. The response of the coatings to these solutions was evaluated by ASTM Method D 714, Standard Method of Evaluating Degree of Blistering of Paints, which rates blister size on a scale of 10 (no blisters) to 0 (delamination of the paint), and the number of blisters on the scale dense > medium dense > medium > few. The results are summarized below.

Toyo Epoxy:

Distilled Water - Blistering is 6-medium dense. No softening, but some fading.

10% Sulfuric Acid - 100% delaminated.

10% Hydrochloric Acid - Blistering is 2-dense, and parts of the coating are delaminated entirely. The coating is very faded and brittle. Thick areas of the coating delaminated more readily than thin areas.

10% Sodium Hydroxide - No blistering or softening, but some fading.

2% Sodium Hypochlorite - No blistering or softening, but the coating is considerably whitened.

2% Sodium Hypobromite - Blistering is 4-dense. There is extensive fading, and slight softening of the coating.

10% Sulfamic Acid - Blistering is 4-dense, but some areas of the coating are delaminated entirely. As was seen in hydrochloric acid, thick areas of the coating delaminated more readily than thin areas.

Devoe Bar Rust:

Distilled Water - No blistering, softening or fading.

10% Sulfuric Acid - No blistering, softening or fading.

10% Hydrochloric Acid - No blistering or fading, but some softening was detected.

10% Sodium Hypochlorite - No blistering or softening, but the coating is moderately whitened.

2% Sodium Hypobromite - Partial delamination, peeling, and cracking of the coating at the bottom of the panel. There is noticeable fading, and slight softening of the coating.

10% Sulfamic Acid - No blistering, peeling, whitening, or softening, but slight fading can be noticed.

Formula 150/Formula 152:

Distilled Water - Blistering is 4-medium dense. No softening or fading.

10% Sulfuric Acid - About 30% of the coating delaminated from the panel, beginning at the bottom.

10% Hydrochloric Acid - About 20% of the coating delaminated from the panel.

10% Sodium Hydroxide - No blistering, softening, or fading.

2% Sodium Hypochlorite - No blistering, softening, or fading.

2% Sodium Hypobromite - Blistering is 4-dense, but only on the lower portion of the panel. *Slight fading and slight softening of the coating.*

10% Sulfamic Acid - Blistering is 4-dense. No fading, but some softening noticed.

5. *Heat resistance*: Coated panels were subjected to flames from welding equipment, and their behavior was recorded.

Toyo Epoxy: The flame from a welding torch was held approximately one inch from the panel and the flame was moved over the back of the panel. After about seven seconds, two large blisters (30 mm diameter) and many smaller blisters appeared. One blister burst, and burned for about sevens seconds after the flame was removed. The entire panel was charred.

Devoe Bar Rust: The flame from a welding torch was held approximately one inch from the panel, but the flame was held at the center of the back of the panel. About seven seconds later, a blister appeared on the front of the panel and began to burn; it continued to burn for about five seconds after the flame was removed. The area around the blister was scorched, but not blistered.

Formula 150/Formula 152: The flame from a welding torch was held approximately one inch from the panel and the flame was moved over the back of the panel. After 15 seconds, the coating had scorched somewhat, but had neither formed blisters nor had burned.

6. *Resistance to indentation*: The indentation hardness of the coatings was measured by moving a weighted stylus across the coating. At the maximum loading of the instrument, 11 kg, none of the coatings were indented by the stylus.

7. *Impact resistance*: Lined pipe sections were subjected to the impact of a 2-pound steel ball falling from a height of 8 feet, and the resistance of the coatings to the impact was recorded. Steel panels 6 x 6-inches were tested in the same manner.

Toyo Epoxy: The steel conduit pipe was seriously bent after eight drops of the ball, but the coating showed only a few small cracks and no loss of adhesion. In one spot, where impacts were less that 5mm apart, a single large crack occurred. The steel panel showed no loss of adhesion after 25 impacts in a 5 x 5 pattern, each impact being 3/4-inch from its nearest neighbor.

Devoe Bar Rust: Three impacts on the pipe produced major cracks in the coating. Two-thirds of the coating (16 mils thick) in the impact area was removed from the steel panel after 25 impacts as described above. However, when a coating 7 mils thick was tested, none of it was removed by impact.

Formula 150/Formula 152: Four impacts on the pipe produced major cracks in the coating, but no chipping or loss of adhesion was evident. The steel panel showed no loss of adhesion after 25 impacts as described above.

8. *Adhesion*: ASTM Method D 3359, Measuing Adhesion by Tape Test, was used. In this test, a grid pattern is cut into the coating, adhesive tape is pressed down over the grid, and the coating is removed by a sharp pull on the tape. It was very difficult to cut any of the coatings in this test, and each coating suffered no loss of adhesion in this test.

9. *Flexibility*: The flexibility of the coatings was measured by ASTM Method D 1737, Elongation of Attached Organic Coatings with Conical Mandrel Apparatus, and the behavior of the coatings was recorded. Three coated Q-panels of each coating were used for this test. The Toyo epoxy showed no loss of adhesion; the Formula 150/Formula 152 showed slight loss at the narrow end of the conical mandrel, and the Devoe Bar Rust showed extensive loss of adhesion.

10. *Erosion by Flowing Tap Water*: Panels of coatings were placed under tap water which was flowing at the rate of 10 mL/min, and were kept there for 30 days. The Toyo coating showed fading and very slight softening, but the Devoe and formula 150/Formula 152 coatings were unaffected.

Discussion

We were concerned that dilution of the Toyo epoxy with MIBK during application might have affected the chemistry of the coating and produced incompletely cured films, or films that did not adequately represent the Toyo product. We had on hand a section of 2-inch iron piping that had been coated by Toyo themselves during a field test, and we cut that pipe into 2-inch sections and repeated some of the most critical tests. In each case, the behavior of the Toyo pipe sections was equal to that of the specimens we prepared ourselves by spraying Toyo coating diluted with MIBK or by brushing out the undiluted coating.

The excellent performance of the Devoe Bar Rust in solvent resistance tests, and its poor performance in the impact and flexibility tests, may be related to its thickness. This coating was about 16 mils thick, compared to the other two coatings which were 4 to 5 mils thick. Although the added thickness provides improved protection against chemicals, it produces a strong film with high cohesive strength which can lose adhesion to the steel substrate during bending or impact.

The chemicals used in this test were chosen because they are likely to occur in sanitary systems. Thus, the failure of the Toyo and Formula 150/152 products to resist these chemicals indicates that they are not suitable for use in sanitary systems. A product similar to Devoe Bar Rust may be useful, provided its curing time can be shortened to 15 minutes or less, in order to permit it to cure before it could run off high spots such as the tops of pipes interiors.

3. DEVELOPMENT OF AN NRL REFERENCE FORMULATION FOR AN EPOXY PIPE LINING

Materials

Based on the requirements for application properties, rheological behavior, hardening time, and chemical resistance, the following resin systems were chosen for initial evaluation:

1. Epon 828, a liquid epoxy resin based on bisphenol A, cured with Ciba-Geigy HY 2964, a modified cycloaliphatic polyamine curing agent.

2. Ciba-Geigy PY 307 (an epoxy resin with greater cross-linking capability), cured with HY 2964.

3. Epon 828 epoxy resin cured with Ciba-Geigy HY 283, a amidoamine curing agent.

4. Epon 828 epoxy resin cured with Ciba-Geigy HY 2969, an aromatic polyamine curing agent.

Each of the above resin systems was formulated to provide paints of different colors and slightly different viscosities. The formulations used are given in Table I.

The first four formulations were used by American Pipelining Corporation in application trials using their licensed Air-Sand method, held at their headquarters in San Diego, California during September, 1988. In this method, warm compressed air was used to propel garnet abrasive through a 2½-inch copper--nickel pipe to give an anchor-tooth profile of 2-3 mils. This was followed by spiral air application of the paint. Four Devoe coatings were also applied for testing at this time. Table II gives the pot life, cure time, and application properties of the various coatings.

Table I
Formulations for NRL Experimental Pipeline Coatings

Ingredient	% by Weight NRL 1	NRL 2	NRL 3	NRL 4	NRL 4A
Epon 828	52.6	-	54.7	55.0	57.0
Ciba-Geigy PY 307	-	59.0	-	-	-
Cab-O-Sil R-974	2.6	-	-	-	-
Cab-O-Sil TS-720	-	1.4	1.3	0.9	0.1
Titanium Dioxide	2.7	5.9	5.4	11.0	-
Red Iron Oxide	15.8	-	-	-	8.9
Phthalo Blue -	0.3	-	-	-	
Phthalo Green	-	-	0.3	-	-
Ciba-Geigy HY 2964	26.3	33.4	- -	-	
Ciba-Geigy 283	-	-	38.3	-	-
Ciba-Geigy HY 2969	-	-	-	33.0	34.2

Table II
Physical Properties of Experimental Pipeline Coatings

Coating	Pot Life	Cure Time	Application
NRL 1	< 1 hr	1 hr	Fair, thin film
NRL 2	< 20 min	< 1 hr	Fair, thin film
NRL 3	~ 2 hr	> 2 hr	Fair, incomplete coverage
NRL 4	~ 2 hr	> 2 hr	Fair, incomplete coverage
Devoe I	< 1 hr	< 1 hr	Poor, extreme rippling
Devoe II	< 1 hr	< 1 hr	Poor, extreme rippling
Devoe 1661	~ 2 hr	~ 2 hr	Good, smooth film
Devoe 1828	~ 2 hr	~ 2 hr	Good, smooth film

Tests for Chemical Resistance

After the coatings had dried completely, 6-inch sections of each coated pipe were shipped to NRL for selective testing. The sections were received 2-3 weeks after application. The results of testing are listed in Tables III and IV.

Table III

Chemical Resistance of Experimental Pipeline Coatings

Coating	Thickness, Mils	7% Sulfuric Acid	7% Sulfamic Acid
NRL 1	2-5	ok	Blistered
NRL 2	3-9	ok	ok
NRL 3	9-10	ok	ok
NRL 4	3-8	ok	ok
Devoe I	3-25	ok	ok
Devoe II	3-25	ok	ok
Devoe 1661	4-8	Note 1	Note 2
Devoe 1828	4-9	Note 3	Note 4

Note 1: Dulled
Note 2: Chalked
Note 3: Chalking and severe blistering
Note 4: Very severe chalking and blistering

Table IV

Chemical Resistance of Experimental Pipeline Coatings

Coating	7% NaOCl[1]	140 °F 7% NaOBr[2]	140 °F 7% AFFF[3]
NRL 1	Chalking & Cu corrosion	Slight Chalking	Slight Fading
NRL 2	Chalking & Cu corrosion	Slight Chalking	ok
NRL 3	Slight Chalking	Slight Chalking	ok
NRL 4	Very Slight Chalking	Slight Chalking	ok
Devoe I	Slight Chalking	Slight Chalking	ok
Devoe II	Slight Chalking	Slight Chalking	ok
Devoe 1661	Blistering & Chalking	Slight Chalking	Slight Fading
Devoe 1828	Not Run	Slight Chalking	ok

Note 1. Sodium hypochlorite ("Chlorox")
Note 2. Sodium hypobromite
Note 3. Aqueous film forming foam

Several properties of the coating were deemed to be essential, based on the results in Tables III and IV and on the statements of American Pipelining in November, 1988, during its efforts to line 4-inch copper--nickel discharge lines in the CHT system on the USS AMERICA (CV 66). It was determined at that time that a hardening time (pot life) less than one hour, good chemical resistance, and a low viscosity range at room temperature are essential for good performance.

Application to CHT discharge piping on the USS AMERICA (CV 66)

The formulation selected for immediate application on the USS AMERICA was NRL 4A. This formulation was derived by NRL 4 by using the color pigment of NRL 1, red iron oxide, in place of titanium dioxide, and reducing the level of the hydrophobic fumed silica to a level of 0.1% based on epoxy resin. This new formulation was designated NRL 4A. A total of 35 gallons (including the Ciba-Geigy HY 2969 Curing Agent) was delivered to the USS AMERICA for lining CHT pipe systems in both the forward and aft sections. One aft section had previously been partially lined with Devoe 143, but received a coat of NRL 4A over the Devoe. All of the forward and part of the aft section were lined with two coats of NRL 4A, allowing the first coat to dry past its set-to-touch time before application of the second coat. Application appeared to be smooth with some air entrapment at the elbows and a small degree of pooling at the bottom of the pipe. The adhesion appeared to be good, although the anchor-tooth profile was only in the 1.5-1.8 mil range. Several of the lined sections were put back into service within 24 hours of application.

4. AIR RELEASING ADDITIVES FOR NRL 4A EPOXY PIPE LINING

Approach

Three criteria were established for consideration of an additive for testing. First, the material must be a commercially-available off-the-shelf material and must have previously shown potential for use in commercial products. Second, the material must not contain volatile materials of any type. Third, the material must have current or potential FDA approval as either a direct or indirect food additive, so as not to hinder approval of the modified formulation for use in potable water systems.

More than one hundred potential additives were screened against these selection criteria, using information available from the National Paint and Coatings Association, the manufacturers, and other trade literature. Twelve materials were selected from the limited number which matched the criteria, and these were then evaluated in the standard NRL 4A paint at both the minimum and maximum levels recommended by the supplier. The materials were either ground or stirred into the base component, as recommended by the supplier.

The twelve materials selected were:

1. Dow-Corning *Additive 25*, a silicone adhesion promoter.
2. Dow-Corning *Additive 29*, a silicone leveling, flow and anti-mar agent.
3. Dow-Corning *Additive 54*, a silicone leveling, flow and water repellant agent.
4. Dow-Corning *Additive 56*, a silicone leveling, flow and defoaming agent.
5. Dow-Corning *Additive 57*, a silicone flow and anti-mar agent.
6. Central Soya *Soya Lecithin*, a natural product for pigment wetting and dispersion.
7. Troy Chemical Corporation *AFP*, a mineral anti-float powder.
8. Baker Chemical Company *Polyvinyl Alcohol*, a potential adhesion promoter.
9. Byk-Chemie *Additive 080*, a defoamer.
10. Union Carbide Corporation *Tergitol NP-14*, a nonylphenol ether surfactant.
11. Rohm and Haas Corporation *Triton CF-10*, an aromatic/aliphatic ether wetting agent.
12. 3M Corporation *FC-430*, a fluoropolyester anti-mar, slip and wetting agent.
13. Control (no additive).

The base components were mixed with the curing agent (Ciba-Geigy HY 2969, lot E6070), brushed onto 3" x 6" steel panels, and allowed to cure for 24 hours. Dried coatings were examined under 30X magnification for air entrapment both on the surface and within 40-mil thick films. Ratings of the coatings are given in Table V on a scale of 10 (excellent) to 0 (unsatisfactory); unmodified NRL 4A was assigned the central value 5 in each test so that improvement or deterioration could be easily documented.

Three coatings (3a, 4a, and 6a) demonstrated some improvement over the standard formulation, and were tested for impact and knife adhesion. All were equal to the standard.

These three coatings and a standard were also subjected to several of the more severe chemical solutions for three weeks. The chemicals used were:

7% sulfuric acid in synthetic sea water (room temperature)
7% sulfamic acid in synthetic sea water (room temperature)
5% ammonium hydroxide (room temperature)
4% sodium hypochlorite ("Chlorox") (120 °F)

The chemical resistance of each of the coatings was equal to that of the standard. The additives imparted an enhanced degree of water repellency, as indicated by rapid beading of the solution on the surface of the coatings.

Suppliers of the additives were asked about existing approval of these materials for food or water contact. Dow Chemical Corporation reported that Additives 54 and 56 had not been tested for such contact and they would not speculate how such tests would turn out. Soya lecithin is approved for use as an emulsifier in food, and we anticipate that it would be approved for use in a paint for drinking water contact.

Table V.
Air release ratings of experimental coatings

Additive	Percent by Weight	Method of Addition	Air Release Rating (defect)
1a	0.5	post-addition	5
1b	3.0	"	6
2a	0.1	"	2
2b	1.0	"	0
3a	0.1	"	7
3b	1.0	"	6 (surface mottling)
4a	0.1	"	6
4b	1.0	"	6 (surface mottling)
5a	0.1	"	0
5b	1.0	"	0
6a	1.0	high speed grind	7
6b	2.0	"	7 (surface haze)
7a	0.2	"	5
7b	0.6	"	5
8a	0.1	"	5
8b	1.0	"	5
9a	0.1	post-addition	5
9b	1.0	"	5
10a	0.1	high speed grind	5
10b	1.0	"	5
11a	0.1	"	5
11b	2.0	"	5
12a	0.1	"	0
12b	0.5	"	0
Control	0.0	-	5

Discussion

Marginal improvement in the air release of NRL 4A epoxy coating is achieved when any of three additives, namely Dow Corning *Additive 54*, Dow Corning *Additive 56*, and Central Soya *Soya Lecithin*, are added at low levels. The additives do not affect the chemical resistance of the coating. Any of these three, if added to the coating, would have a small positive impact on performance and a negligible impact on cost. If the coating is intended for potable water contact, only the soya lecithin additive should be used.

Since this work began, modifications to the application process have significantly reduced void formation in the applied coating. The coating is now propelled through the pipe at a slower velocity, and the volume of foam which proceeds the bulk of the coating is now blown clear of the pipe being coated and out into the collection lines. For this reason, we believe that the original problem has been solved by other means, and we recommend that no air-releasing additive be used in the NRL-4A coating.

5. PROCEDURE FOR INSTALLING THE EPOXY LINING IN SHIPBOARD SANITARY PIPE SYSTEMS

Outline

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1.2 CAUTION

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5.1.3 Protection from Noise Hazards
5.1.4 Compressed Air
5.1.5 Communications

1. SCOPE

1.1 Scope. This standard covers the requirements for the use of epoxy pipe lining systems for corrosion control applications aboard naval surface ships. The requirements specified by this standard are applicable to epoxy lining processes using compressed air, grit and approved epoxy coatings. This standard covers certification of equipment, certification of operators, pipe cleaning and surface preparation, application procedures, production quality assurance, test procedures, and records.

1.2 CAUTION: This military standard specifically prohibits the use of compressed gases other than compressed air to propel grit or paint through shipboard piping systems. This prohibition is a safety requirement due to the large volumes of air required and the potential for accidently discharging non-life-supporting gases into shipboard compartments.

2. REFERENCED DOCUMENTS

2.1 Issues of documents. The following documents, of the issue in effect on the date of invitation for bids or request for proposal, form a part of this standard to the extent specified herein.

MANUALS

NAVSEA S9086-VD-STM-000/CH-631 - Naval Ships' Technical Manual, Chapter 631, Preservation of Ships in Service (Surface Preparation and Painting)

NAVSEA S9086-T8-STM-000/CH-593 - Naval Ships' Technical Manual, Chapter 593, Pollution Control

(Copies of specifications, standards, drawings and publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
ASTM D 3359 - Measuring Adhesion by Tape Test

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3. DESCRIPTION OF PROCESS

3.1 Epoxy pipe lining. Epoxy pipe lining in U.S. Navy surface ships is accomplished by drying the pipe and using an air-borne stream of abrasive grit to further clean the pipe and establish an appropriate anchor tooth. After inspecting the pipe to ensure that all grit and surface contaminants have been removed, solventless high solids epoxy paint is applied to the desired thickness. Epoxy paint coats the wall of the pipe, forming a smooth, hard finish that is impervious to contaminants. Three coats of paint are required to ensure complete coverage and the absence of pinholes.

4 DEFINITIONS

4.1 Acceptable. Complies with or conforms to the applicable standard or specification.

4.2 Approved (approval). The item under consideration has been sanctioned in writing by the Commander, Naval Sea Systems Command (NAVSEA) or his authorized agent.

4.3 Authorized agent. Any Government representative specifically authorized to approve equipment, materials or procedures within the scope of this standard for NAVSEA. The authorized agent shall have appropriate training and experience to implement and evaluate inspection functions of this standard. Authorized agents are as follows:

(a) For Government shipyards: The delegated representative of the Shipyard Commander.

(b) For commercial shipyards: The designated representative of the Supervisor of Shipbuilding, Conversion and Repair.

(c) For commercial activities other than shipyards: The delegated representative of the Defense Contract Management Area Office (DCMAO).

(d) The designated representative from NAVSEA (PERA-CV) for Aircraft Carriers only.

(e) The Naval Ship Systems Engineering Station (NAVSSES), Philadelphia, Pennsylvania, is also authorized to provide support for Naval Activities.

4.4 Inspector. A contractor, naval shipyard, or government agency employee designated by the appropriate Type Commander to accept or reject materials or workmanship on the basis of the results of specified tests.

4.5 Certified. The item under consideration has been approved as required by this standard.

4.6 Procedure. An epoxy pipe lining procedure is a written instruction which contains all the applicable essential elements listed in this document.

4.7 Application procedure. The method used to apply the epoxy pipe lining for corrosion control.

4.8 Surface Preparation. Methods of cleaning and surface roughening using a stream of abrasive grit of various sizes and degrees of sharpness and angularity.

4.9 Interface. The contact surface between the epoxy lining and the substrate.

4.10 Masking. The method of protecting the areas adjacent to the areas to be coated to prevent undesired epoxy paint contamination of surrounding surfaces.

4.11 Substrate. The prepared pipe surface upon which the epoxy paint lining is deposited.

5. GENERAL REQUIREMENTS

5.1 Safety precautions (personnel hazard). All personnel concerned with epoxy pipe lining shall become familiar with and follow the safety and health practices specified in Chapters 631 and 593 of the Naval Ships' Technical Manual and any other applicable safety regulations. The performing activity, contractor, and subcontractor shall be responsible for ensuring, prior to beginning the required operations, that the proper precautions are being observed to preclude personnel injury or equipment damage (including damage to surroundings).

5.1.1 Surface preparation using abrasives. Safety precautions for abrasive blasting specified below and covered by Chapter 631 of the Naval Ships' Technical Manual shall be followed.

(a) If fire or explosion hazards are present, precautions shall be taken before any blast cleaning is initiated. The pipe must purged of dangerous concentrations of flammable materials.

(b) The blast material must be totally contained in the pipe, hoses, and machinery. Face shields and air-fed dust hoods are not normally required to prevent hazards to personnel or shipboard equipment.

(c) The blasting equipment and pipe must be grounded to dissipate any static charges.

(d) The contractor is required to dispose of all waste materials safely, including used abrasives, in accordance with all federal, state and local regulations prior to completion of the job.

5.1.2 Personal protection. The following precautions shall be followed for personal protection:

(a) Never permit paint spray or dust from abrasive particles to enter eyes, mouth, cuts, scratches or open wounds. After spraying, and especially before eating food, wash hands thoroughly.

(b) Safety glasses or goggles, hard hats, and ear protection shall be worn by all persons near any blasting operation.

(c) Finely divided airborne particles can be hazardous from an explosive standpoint. Particularly, wet metal dust creates a hazard of spontaneous combustion.

(d) Observe all safety precautions listed in the Material Safety Data Sheet (MSDS) for each particular material being used.

5.1.3 Protection from noise hazards. Hearing protectors or properly fitted soft rubber ear plugs shall be used in the vicinity of loud machines. Wads of cotton for hearing protection shall not be used since they do not protect against high intensity noise.

5.1.4 Compressed air. The following safety precautions shall be followed when using compressed air:

(a) Compressed air shall not be used to clean clothing.

(b) Compressed air for epoxy pipe lining operations shall not exceed pressures recommended by the equipment manufacturers.

5.1.5 Communications. Radio and/or sound-powered telephone communications shall be in use between all equipment operators and safety inspectors whenever equipment is being operated.

5.2 Equipment.

5.2.1 Air supply equipment. Equipment must provide sufficient air volume and air stream velocity to effectively clean and line the pipe. This velocity is required to carry the blast grit through the pipe fast enough to clean the pipe and to provide an adequate anchor tooth for the epoxy lining.

5.2.1.1 Air purification filters. In-line water and oil filters shall be located between the equipment and prior to pipe entry. These filters shall be periodically inspected and serviced to ensure delivery of uncontaminated dry air. The maximum allowable airborne particle size shall be 0.03 microns for oil and 0.03 microns for water.

5.2.1.2 Air aftercooler or dryer. Moisture shall be removed from the compressed air to prevent condensation in the piping being worked.

5.2.1.3 Heater. To prevent condensation in the piping, a heater shall be used to raise the compressed air/substrate temperature downstream from the aftercooler. After reheating, the working air temperature shall be approximately 155 °F (68 °C) at 80 °F (27 °C) ambient.

5.2.2 Air pressure regulator. A machine shall be used to regulate the pressure of the air entering the pipe to be cleaned and lined.

5.2.2.1 Abrasive grit injector. The abrasive grit shall be injected into the air stream at a measured rate.

5.2.3 Dust collector. An apparatus shall be installed at the discharge of the pipe which fully collects all spent grit, contaminated dust, and excess epoxy coating during the lining process.

5.3 Materials.

5.3.1 Masking materials. Any material that provides adequate protection of the flange faces of the pipe being lined without causing corrosion or contamination may be used.

5.3.2 Abrasive blasting particles. Abrasive blasting particles of various grades may be used to clean the pipe and to provide an anchor tooth of 2 to 3 mils during final surface preparation of the substrate.

5.3.2.1 Requirements. Abrasive particles shall be clean, dry, and contain less than 5 percent fines (smaller than 30 mesh by weight). They shall not contain feldspar, iron, aluminum, or other materials which might remain embedded in the surface or create galvanic interaction with copper-nickel leading to early failures. Abrasive particles shall not be reused.

5.3.2.2 Restrictions. Abrasive particles shall be pure Idaho garnet. Idaho garnet is prescribed because it leaves very little dust residue in the pipe. The epoxy paint will not adhere to the substrate when dust is present. To prevent contamination of the substrate, previously used abrasive particles shall not be used for surface preparation.

5.3.3 Epoxy coating. The pipe lining epoxy shall be the coating developed by the Naval Research Laboratory (NRL) specifically for this application.

5.4 Process for lining the interior of pipes with epoxy paint.

5.4.1 Condition of pipe. Prior to blasting with grit, the government shall ensure that the pipe to be lined is intact, has no holes, and has a minimum wall thickness of at least 60 percent of the original. In collection, holding and transfer (CHT) pipe, the wall thickness shall be measured on the exact vertical bottom surface of the pipe and in the area within two feet downstream of the inside and outside of bends. The wall thickness on vertical pipe shall be measured by taking four readings at 90° to each other. In potable water pipe, the wall thickness shall be measured randomly on the pipe and within two feet downstream of the inside and outside of bends. The wall thickness of the pipe shall be measured at suitable intervals along the pipe. The pipe shall be marked with the thickness found. The contractor shall install flanged mechanical joints at all tees where one of the legs is not yet to be lined.

5.4.1.1 Ultrasonic tester. The recommended ultrasonic tester for pipe thickness is Panametrics Model 26 DL microprocessor-based Corrosion Gauge with built-in Data Logger, available from Panametrics, Inc., 221 Crescent Street, Waltham, Massachusetts 02254 (800-225-8330).

5.4.2 Surface preparation. Prior to applying the epoxy lining, the surfaces to be lined shall be prepared by passing air-borne abrasive grit through the pipe to clean and dry the pipe and provide an anchor tooth. Compliance with 5.2.1.1 is mandatory. The airborne abrasive grit must not come in contact with any ferrous surfaces until exiting the copper--nickel pipe.

5.4.2.1 Abrasive grit. Appropriate abrasive grits shall be used for initial cleaning and for the final surface preparation of the substrate. Only new grit which passes the following oil contamination test shall be used.

(a) Fill a clean 150 milliliter (5 ounce) vial or bottle half full of screened abrasive particles.

(b) Fill the remainder of the vial or bottle with clean water.

(c) Cap and shake vial or bottle.

(d) Inspect water for oil sheen.

(e) If any oil is observed, the abrasive particles shall not be used.

5.4.2.2 Prepared surface. The prepared surface shall have a white-metal blast appearance, and an anchor-tooth (not peened) surface profile of 2 to 3 mils which is validated (measured) at the pipe inlet and outlet with profile tape and a dial micrometer. A white-metal blast-cleaned copper-nickel surface finish is defined as a surface with a uniform metallic bright copper or nickel color, slightly roughened to form a suitable pattern for coatings. The surface, when viewed using a magnification of 1Ox, shall be free of oil, grease, dust, dirt, mill scale, corrosion products, oxides, paint, and other foreign material. The color of the clean surface may be slightly affected by the particular abrasive medium used. Prepared surfaces shall not be handled. Contact with any oil or grease (such as touching with a bare hand) will result in reduced bonding of the coating. Blasting shall not be so severe as to wear the pipe below 50 percent of the original pipe thickness. Presence of oil, oxides or other foreign material on the surface to be coated shall not be tolerated.

5.4.3 Application of the epoxy pipe lining.

5.4.3.1 Surface protection. The temperature of the substrate shall be 5 °C (10 °F) above the dew point of the air used for coating; otherwise no epoxy lining shall be conducted. The air temperature must be between 50 and 120 °F. The surface shall be protected from finger marks and other contamination.

5.4.3.2 Quality of the air. Either of the following procedures shall be used to monitor water content of the air:

(a) Open a valve downstream of the filter/dryer components slightly, allowing air to vent with a slightly audible flow into an open dry container for 1 minute. Any wetting or staining will indicate moisture or contamination.

(b) Repeat (a) above at the discharge of the pipe being lined prior to application of the epoxy coating.

5.4.3.3 Protection of the installed lining. The epoxy lining must be protected from excessive heat. Damaged epoxy lining must be repaired as specified in 5.4.3.4. The epoxy lined pipe may be placed into service after drying for 48 hours minimum at 73 °F (24 °C).

5.4.3.4 Repair procedure. Cut the pipe with a hacksaw to remove the damaged section. Chip or grind the lining 3 inches back from the ends, and install unlined flanged copper-nickel pipe or approved glass-reinforced plastic (GRP) pipe. Damaged areas may then be topcoated with fresh epoxy using a brush, or the pipe may be grit blasted and relined in accordance with this military standard. Each six months the ship's force shall ultrasonically test any unlined copper-nickel or GRP piping and replace it when the wall thickness reaches 50 percent of its original value.

5.4.4 Approved applications of epoxy pipe lining for corrosion control on Navy surface ships. Epoxy pipe linings for the control of corrosion are approved in the following applications:

(a) Collection, Holding and Transfer system discharge piping.

5.4.5 Prohibited applications of epoxy pipe lining for corrosion control. These epoxy pipe linings for use in corrosion control applications are intended for selected use on copper-nickel substrates that can achieve an anchor tooth of 2 to 3 mils using airborne abrasive grit. Epoxy pipe linings for corrosion-control applications shall not be used for the following:

(a) Plastic, rubber, painted surfaces.

(b) Internal surfaces of moving machinery (for example, pump casings, valves, etc.).

(c) Valve stems.

5.5 Markings. Label the lined pipe on the outside every 20 feet "Epoxy Lined Pipe, Hot Work Restrictions" in block letters one inch high. Markings shall appear at least once in every appropriate compartment.

6. DETAILED REQUIREMENTS

6.1 Certification for each use. Each use of this procedure shall be certified by a NAVSEA authorized agent. Naval facilities and contractors shall submit a description of the equipment, application procedures, and quality assurance tests to be performed. In order to obtain certification of these procedures, the proposed application procedure shall contain a listing of the various processes performed (such as grit blasting, epoxy lining, and inspection). Record forms as shown in Figure 8.1 shall be provided to record the performance of quality assurance examinations. Contractors shall be responsible for similar qualifications of all subcontractors. The certification of an individual use may be terminated in the event NAVSEA or its authorized agent has evidence that all the requirements (safety, equipment, materials, operators, and product quality assurance) of this standard are not being met. The application work covered by this standard may be suspended upon written notification by the authorized agent until it has been demonstrated that such deficiencies have been corrected.

6.2 Application procedure certification. Certification of each application procedure is required, and will be given to those Naval activities and commercial firms demonstrating the ability to successfully carry out the procedures described in this Standard.

6.2.1 Approval of application procedure. Prior to the utilization of an epoxy lining procedure for surface ship corrosion control, the contractor shall demonstrate the procedure and provide the supporting test qualification data to the authorized agent for approval. The contractor shall demonstrate lining of 3-inch, 4-inch, and 6-inch diameter 90:10 copper-nickel piping with at least three 90-degree bends no more than one foot apart in test sections at least 30 feet long. Data submitted shall not relieve the contractor of responsibility for conformance with other requirements of this standard. Contractors shall be responsible for similar certification of all subcontractors.

6.2.2 Certification test requirements. The application test procedure shall require a visual examination, knife test, and bond test of the epoxy lining specimens prepared by an operator using the proposed procedure. Specimens for testing shall be prepared in accordance with 6.5.1 and the written application procedures. For the visual examination, four specimens shall be prepared in accordance with 6.5.1 and tested as specified in 6.5.2 through 6.5.5; results of the test shall conform to the requirements of 6.2.2.1 through 6.2.2.4. For the knife peel test, the same four specimens shall be used and shall be tested as specified in 6.5.3; results of the test shall conform to the requirements of 6.2.2.2. For the bond test, five specimens shall be prepared as specified in 6.5.1 and tested as specified in Method A of ASTM D 3359, and shall meet the requirements of 6.2.2.3.

6.2.2.1 Visual examination. After drying and curing, the epoxy pipe lining shall consist of three coats covering the entire substrate and shall not contain any of the following:

(a) Blisters.
(b) Cracks.
(c) Chips or loosely-adhering particles.
(d) Oil or other internal contaminants.
(e) Pinholes, voids, holidays, or pits exposing the undercoat or substrate.

The inspector designated by the government shall inspect each coat of epoxy paint and shall approve the final coating.

6.2.2.2 Knife-peel test. The coating shall not be separated from the base metal when subjected to the knife-peel test specified in 6.5.3.

6.2.2.3 Bond test. When tested as specified in Method A of ASTM D 3359, the bond strength of the epoxy pipe lining shall have a 5A rating.

6.2.2.4 Thickness. The total thickness of the epoxy coating shall be at least 15 mils at any point, and no more than 20 mils at any point around the circumference of the pipe (6 mils per coat average).

6.3. Certification of epoxy pipe lining operators. Each operator shall be certified after successfully demonstrating the ability to apply the specified lining system and to use the equipment in a correct and safe manner, as specified herein.

6.3.1 Responsibility. Prior to invoking this standard, each activity, contractor, or subcontractor shall establish that each epoxy pipe lining operator to be employed in the application of the epoxy pipe lining for corrosion-control applications has been certified.

6.3.2 Operator certification.

6.3.2.1 Certification tests. An operator shall be certified to conduct pipe lining operations aboard Navy ships only upon satisfaction of all requirements of this standard.

6.3.2.2 Limits of certification. Operators meeting the requirements for certification shall be deemed "certified operators" only for the lining process and equipment stipulated in the written application procedure prepared and submitted in accordance with 6.2.1.

6.3.2.3 Retest of operators. An operator failing its initial certification tests may be permitted to perform one retest for each type of test failed. If the operator fails the retest, he shall not be certified until completion of training or retraining and subsequent complete certification retesting.

6.3.3 Maintenance of operator certification.

6.3.3.1 Term of certification. Operator certification shall remain in force provided that a period of six months does not elapse between production use of the applicable epoxy pipe lining process. Production use shall be defined as lining 300 feet or more of pipe within in a consecutive 30 day period.

6.3.3.2 Renewal of certification. Operators whose certification has lapsed may be recertified by satisfactorily completing the certification tests in 6.5.1 and 6.3.2.

6.3.4 Withdrawal of certification.

6.3.4.1 Withdrawal. At the discretion of NAVSEA or its authorized agent, certification may be withdrawn at any time an operator's performance is questionable, as evaluated by production quality assurance.

6.3.4.2 Retest of operators. An operator whose certification has been withdrawn shall not be recertified until completion of training or retraining and subsequent complete certification retesting.

6.4 Production quality assurance. Production quality shall be assured by certification of applicators and by the maintenance of production records and an inspection system by the performing activity, contractor, or subcontractor. Production records and inspection requirements shall be subject to modification by the contracting agency as stated in the contract (see 6.6).

6.4.1 Production records. The performing activity, contractor, or subcontractor shall maintain production records for pipe lining sections. A production record form shall be prepared prior to commencement of work by the performing activity, contractor, or subcontractor. The record shall assign responsibility and provide accountability for performing work and assuring quality control. These records shall be submitted to the Type Commander or his agent upon completion of the lining contract. The sample record form shown in 8.1 (Figure 1) may be used as a guide for preparing production records. Other forms used for this purpose shall require as a minimum all the information required in Figure 8.1.

6.4.2 Number of coats. At 75 °F (24 °C) ambient, time between successive coats shall not exceed 24 hours. Should the 24-hour limit be exceeded, an anchor tooth profile must be reestablished. An additional 12 hours between successive coats is allowed for every 18 °F (10 °C) drop in temperature.

6.4.3 Sampling and inspection System. Sampling and inspection of end items shall at a minimum consist of the following:

(a) Sampling and inspection of materials used in the process; for example, epoxy paint components A and B; grit used for cleaning/establishing anchor tooth profile; and quality of air used.

(b) Inspection of the prepared substrate prior to lining to include: anchor tooth profile, presence of contaminants such as dust, water, oil, or scale, and absence of leaks in the system by hydrostatic pressure test at 150 psi. (CHT system discharge piping shall be hydrostatically tested at 70 psi.) Ship's boiler feedwater is preferred for the hydrostatic test, but potable water is acceptable where boiler feedwater is not available. The system shall be dried and lightly grit blasted after the hydrostatic test to remove any contaminants introduced by the water.

(c) Inspection of the lining (see 6.4.3 and 6.4.4).

6.4.4 Visual inspection. The inlet and outlet of each lined pipe section shall be examined visually at a magnification of 1O X as soon as practical after lining has been completed. The lining shall have a smooth, uniform appearance. The lining shall not contain any blisters or loosely adhering particles, nor shall it contain any cracks, pinholes, fisheyes, or chips which expose the metal substrate. The visual inspection should be validated with a flexible borescope inspection to ensure full coverage of the lining. Minor hanging paint spikes and paint pooling less than 12.7 mm (0.5 inch) deep in the bottom of the pipe shall not be justification for relining the pipe. The entire metal substrate shall be covered with three coats of epoxy paint.

6.4.5 Thickness measurement. Thickness measurements shall be performed at the inlet and outlet end of each lined pipe section as specified in 6.5.5 as soon as practical after lining has been completed.

6.5 Certification test procedures.

6.5.1 Preparation of test specimens. Three-foot long pieces of 90:10 copper-nickel pipe, two for each diameter of pipe to be lined, shall be lined using the blast and lining procedure described in this standard. The anchor tooth shall be 2 to 3 mils deep and the lining shall be 9 mils minimum thickness. The same sections may be used for the visual and knife-peel tests. Identical sample sections shall be blasted and not lined. These shall be used to demonstrate the anchor tooth depth.

6.5.2 Visual examination. Both prepared test sections shall be split longitudinally and examined under a magnification of 1O X. The surface appearance shall meet requirements of 6.2.2.1.

6.5.3 Knife-peel test. The knife-peel test consists of a single knife cut 40 mm (1.5 inches) long through the epoxy pipe lining to the substrate. If any part of the coating system along the cut can be separated from the base metal using the knife, the bond shall be deemed unsatisfactory.

6.5.4 Bond test. The bond test shall be performed as specified in Method A of ASTM D 3359, and shall meet the requirements of 6.2.2.3.

6.5.5 Thickness measurements. Thickness measurements shall be performed using a calibrated wet film thickness gage (Nordson Wet Film Gage Number 790010, Nordson Corp., Amherst, Ohio, or equivalent), or using a micrometer with readings taken before and after application of the epoxy lining. The required thickness of the lining system shall be as specified in 6.2.2.4.

6.5.6 Test results. The results of all tests and inspections shall be documented and included in the application procedure certification package.

6.6 Records. Records of equipment, application procedures and operator certification, including certification test results and production records, shall be maintained by each performing activity, contractor or subcontractor. These records shall be available to the contracting agency for review and audit. The performing activity, contractor, or subcontractor shall maintain these records for a period of 24 months after completion of the contract work. Copies of the records shall be made available to the contracting agency upon request. Disposition of the records shall be as agreed upon in the contract.

6.7 Suspension of work for noncompliance. In the event the contracting agency or his representative has evidence indicating that the requirements of this standard are not being met, the applicable work covered by this standard may be suspended at no cost to the Government immediately upon written notification to the contractor. The work may not be resumed until the contractor has demonstrated that such work deficiencies have been corrected.

7. NOTES

7.1 Applications.

7.1.1 Approved applications. The applications of epoxy pipe linings for corrosion-control that have been approved by NAVSEA are listed in 5.4.4. Selection of one of the listed applications does not eliminate the need for the application certification tests required by this standard.

7.1.2 Unauthorized applications. The applications of epoxy pipe linings for corrosion-control that are not authorized by NAVSEA are listed in 5.4.5. The assistance of NAVSEA 05M1 shall be requested for controlling corrosion in these areas.

7.1.3 Proposed applications. The use of epoxy pipe linings for corrosion control in areas other than those listed in 5.4.4 requires prior approval of NAVSEA.

8. RECORDS

8.1 Epoxy pipe lining record format. Figure 8.1 is provided as a guide for recording pipe lining operations. Other forms may be used, but they must contain as a minimum all of the information listed in Figure 8.1.

EPOXY LINING PRODUCTION REPORT

Run Number ________________ Date: ______________

Ship: ____________________________ Job Control No: __________

Ship System Description: ____

Pipe To Be Lined: ____

Diameter: ______________________ Base Material: ____________________

Location: ______________________ Length: ____________________________

DRYING TEMPERATURES: Inlet: _________________ Outlet: ______________

ABRASIVE CLEANING:	Abrasive Type	Size/Quantity
Initial Cleaning	______________	______________
Final Surface Preparation	______________	______________

Pipe Profile: Inlet: ____

Outlet: ____

Anchor Tooth: Inlet: ______________ Outlet: ______________

HYDROSTATIC TEST: (150 psi - 30 minutes) Results: ____________________________

EPOXY COATING:	1st Coat	2nd Coat	3rd Coat
Manufacturer: Epoxy Resin	________	________	________
Product Description:	________	________	________
Lot/Batch #/Date Manufactured	________	________	________
Manufacturer: Hardening Agent	________	________	________
Product Description:	________	________	________
Lot/Batch #/Date Manufactured	________	________	________
Temperature: Inlet/Outlet	________	________	________
Relative Humidity:	________	________	________
Wet Film Thickness: Inlet/Outlet	________	________	________

INSPECTION:	1st Coat	2nd Coat	3rd Coat
Visual Inspection:	________	________	________
Knife Peel Test:	________	________	________
Bond Test:	________	________	________
Knife Peel Test:	________	________	________
Thickness:	________	________	________

ITEM ACCEPTED (Yes/No): _____

OVERALL REMARKS: ____

Figure 8.1. Epoxy Pipe Lining Production Report Form