Carderock Division
Naval Surface Warfare Center
Philadelphia, PA 19112-5083

CARDIVNSWC-TR-62-00-05 June 2000

Survivability, Structures, and Materials Directorate
Technical Report

LABORATORY EVALUATION OF LABEL PLATE MATERIALS AND ATTACHMENT METHODS CONSIDERED FOR USE ON LPD-17

by

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13. ABSTRACT (Maximum 200 words)

This report documents a performance evaluation of various label plate materials and fastening systems being considered for use on board the LPD-17 ship class. The purpose of this work was to evaluate various label plate materials and fastening systems for exterior use that will provide adequate performance. The evaluated label plate materials were Monel 400, photosensitized anodized aluminum (Metalphoto), CRES 316, CRES 304, and 3M 480 Series Vinyl plates with and without model 1160 protective overlaminate. The attachment methods evalutated were various DOW Corning™ sealants, 3M™ 4946 double-sided foam tape, CRES fasteners and combinations of the three. The label plates were mounted onto carbon steel panels painted with the silicone alkyd chelating paint system topcoat that will be used on LPD-17. The label plate materials and adhesives were subjected to environmental testing which included cyclic salt fog, ultraviolet light (UV)/Weathering exposure, and temperature and humidity extremes in an environmental chamber. Tensile testing and peel strength were determined to quantify adhesive strength.

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ABSTRACT

This report documents a performance evaluation of various label plate materials, DOW Corning® adhesives/sealants, and 3M™ Corporation Model 4946 double-sided foam tape and Corrosion Resistant (CRES) fasteners being considered for use on board the LPD-17 ship class. The label plate materials and adhesives were subjected to a series of laboratory based environmental conditions which included cyclic salt fog, ultraviolet light (UV)/weathering exposure, and extreme temperature and humidity cycling in an environmental chamber. Tensile testing and peel strength of the adhesives/sealants and double-sided tape were also conducted to quantify pull-off strength. The evaluated label plate materials included the following:

- Monel 400™, some plates engraved and painted with Del Star Acrylic Enamel-DAR 9000.
- 304/316 stainless steel, engraved and painted with Del Star Acrylic Enamel-DAR 9000.
- Metalphoto® anodized aluminum with Hitef2™ Teflon paint shedding overlaminate.
- Metalphoto® anodized aluminum with 3M™ Series 1160 Premium Protective Overlay Film.
- Metalphoto® anodized aluminum with red and black lettering.
- Metalphoto® anodized aluminum with red only lettering.
- Metalphoto®anodized aluminum with gold background and black lettering.
- 3M™ 480 series vinyl label plate with 3M™ Series 1160 Premium Protective Overlay Film.
- 3M™ 480 series vinyl label plate with no overlaminate.
- 3M™ gray 3861 vinyl Scotchcal laminated to 3970-G prismatic backing, no overlaminate.
- 3M™ 3970-G with black and red print, no overlaminate.

The label plate attachment methods employed various DOW Corning® sealants/adhesives, 3M 4946 double-sided foam tape, CRES fasteners and various combinations of the three. The label plates were mounted onto painted carbon steel panels blasted to a 75 μm (3 mil) profile. Each panel was painted with one coat of MIL-P-24441/20(SH) F-150 Type III, one coat of MIL-P-24441/21(SH) F-151 Type III, and a topcoat of Interlac® Anti Stain Finish (Silicone Polyester) which will be the topcoat paint used on the LPD-17.

The environmental exposure results indicate that the Metalphoto® photosensitized anodized aluminum label plates attached with 3M™ 4946 double-sided foam tape were in excellent condition following all phases of exposure. The Hitef2™ Teflon paint shedding overlaminate was also in excellent condition; however, was not very abrasion resistant. The 3M™ series 480 vinyl label plates did show evidence of slight yellowing and slight color fading which was less noticeable on the labels coated with the 3M™ series 1160 overlaminate. This overlaminate did provide some degree of UV protection. As expected, the Monel 400™ showed evidence of greenish brown surface staining while the stainless steels showed evidence of surface rust staining. Use of CRES fasteners for attachment of label plates will require the use of adhesive/sealant in the fastener holes to ensure corrosion of the bulkhead does not occur at the fastener attachment points which results in running rust. The use of adhesive/sealant around all edges of an exterior label plate regardless of attachment method would prevent water intrusion behind the label plate and corrosion of the bulkhead due to imperfections that may be present in the paint film.

CARDIVNSWC-TR-62-05: Laboratory Evaluation of Label Plate Materials and Attachment Methods Considered For Use on LPD-17

ADMINISTRATIVE INFORMATION

The Marine Coatings and Corrosion Engineering Branch, Code 624, of the Naval Surface Warfare Center-Carderock Division (NSWCCD), conducted this evaluation. The work was requested by the Naval Sea Systems Command (NAVSEA) LPD-17 Program Office, New Orleans, LA. All work was performed under the supervision of Ms. Theresa Steck, Head, Code 624 NSWCCD.

REFERENCES

(a) Ocean City Research Report, Ship Equipment Label Plates 2-Year Exposure Test Program, September 1987
(b) Naval Ships Technical Manual Ch. 631, Vol 1, 19 Dec 96
(c) Email SUPSHIP New Orleans (R. Kellogg)/NSWCCD 624 (S. Murray) @1805 of 10 Dec 99

ATTACHMENTS

(A) Environmental Chamber Temperature/Humidity Cycling Program

INTRODUCTION

Label plates aboard ship are used to designate compartment/passageway locations, equipment descriptions, equipment operating instructions, etc. throughout a ship. Label plate corrosion issues must be considered due to their overall shipboard function. Dissimilar metal contact between a label plate, the mounting surface, and fasteners in a marine atmosphere frequently results in galvanic corrosion. In some instances, corrosion has been significant enough to cause severe pitting of the bulkhead behind a label plate to the point of perforation. Exposure of label plates to sunlight (ultraviolet radiation, UV) can cause deterioration of the inks and paints used for lettering and illustrations. Corrosion and loss of legibility are considered failures for label plates. Attachment methods also present problems. Adhesive failures result in lost label plates. Crevice corrosion is also an issue. If measures are taken to prevent dissimilar metal contact, any crevices formed between a label plate and the mounting surface and where fastener heads contact the label plate provide areas that trap water which can exacerbate corrosion.

Previous evaluation of label plate materials and attachment methods has been conducted. Reference (a) reported on a two-year natural marine exposure study of CRES 304/316 stainless steel and hard and standard anodized aluminum label plate materials with various lettering and attachment configurations to simulated bulkheads. This evaluation was done to determine an improved label plate attachment system for the CG 47 class in which galvanic corrosion of the aluminum bulkheads was occurring. The results of this study concluded that the best overall label plate system in a marine environment was a hard anodized aluminum plate material manufactured in accordance with MIL-A-8625, titled Anodic Coatings For Aluminum and Aluminum Alloys. The label plates had photoetched lettering and field applied adhesive.

The work conducted for this current evaluation was initiated, in part, by LPD-17 Action Item Request (AIR) 0948 and discussions with the LPD-17 Program Office, SUPSHIP New Orleans. The AIR raised many issues pertinent with label plate materials and attachment methods in different areas of the ship. Specifically cited was consideration for use of Monel 400™ and anodized aluminum for label plate materials, use of paint shedding overlaminates on vinyl and anodized aluminum, permitting the use of 3M™ model 4946 double-sided tape as an attachment method, and the use of adhesives without mechanical fasteners when practical.

CARDIVNSWC-TR-62-05: Laboratory Evaluation of Label Plate Materials and Attachment Methods Considered For Use on LPD-17

Following a meeting at the LPD-17 Program Office, a test plan was developed and approved that would subject all of the label plate materials and attachment methods under consideration for LPD-17 to laboratory based environmental testing. The evaluation included the following:

- Intermittent salt fog and ultraviolet light (UV)/weathering exposure based on ASTM D 5894 titled Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating exposures in a Salt Fog /Dry Cabinet and a UV/Condensation Cabinet)(modified).

- Extreme temperature and humidity cycling in an environmental chamber to validate label plate adhesion with the various adhesives/sealants and double-sided tape.

- Tensile testing of the adhesives/sealants and double-sided tape in accordance with ASTM 4541 titled Pull-Off Strength of Coatings Using Portable Adhesion Testers (modified) to quantify pull off strength.

- Peel Testing based on ASTM D 429 titled Rubber Property-Adhesion to Rigid Substrates and ASTM D 3167 titled Floating Roller Peel Resistance of Adhesives to quantify the force required to peel the label plate from the bulkhead plate as a measure of adhesive strength.

All label plate materials evaluated were provided by Avondale Shipyard and/or the LPD-17 program office, New Orleans, LA.

METHOD OF APPROACH/EXPERIMENTAL PROCEDURE

The table below summarizes the test plan used to evaluate the label plate materials:

Shipboard Actual Environmental Exposure	Corrosion/Failure Risk Mode	Test Regimen
Marine Atmosphere with Salt Spray -Alternate wet and dry	General corrosion of label plate material Galvanic/Crevice corrosion under plate Fastener corrosion	Salt Fog-Alternate Wet/Dry
Sunlight/UV	Label Ink -Legibility -Failure -Fading Non-metal label/Tape/Adhesive failure Label printing fading/failure	UV/Weathering chamber
Temperature/Humidity Variation -20°F to + 140°F 30% to 75% Relative Humidity	Adhesive Sealant Failure -Brittle/Cracking -Drying Out Δ Thermal Expansion	Environmental Chamber -Cycling
Adhesive/Tape Strength	Adhesive/sealant failure or coating failure	Patti Adhesion Tensile Testing -Ambient temperature and Environmental Chamber Cycling conditions -Tensile Strength of Adhesives/Tape Peel Test -Quantify peel strength

Materials

The following label plate materials were submitted for evaluation:

- Monel 400™, some plates engraved and painted with Del Star Acrylic Enamel-DAR 9000.
- 304/316 stainless steel, engraved and painted with Del Star Acrylic Enamel-DAR 9000.
- Metalphoto® anodized aluminum with Hitef2™ Teflon paint shedding overlaminate.
- Metalphoto® anodized aluminum with 3M™ Series 1160 Premium Protective Overlay Film.
- Metalphoto® anodized aluminum with red and black lettering.
- Metalphoto® anodized aluminum with red only lettering.
- Metalphoto®anodized aluminum with gold background and black lettering.
- 3M™ 480 series vinyl label plate with 3M™ Series 1160 Premium Protective Overlay Film.
- 3M™ 480 series vinyl label plate with no overlaminate.
- 3M™ gray 3861 vinyl Scotchcal laminated to 3970-G prismatic backing, no overlaminate.
- 3M™ 3970-G with black and red print, no overlaminate.

The following adhesives/sealants and double-sided tape were submitted for evaluation:

- DOW Corning 732™ Multi-Purpose RTV Sealant, clear, use range -76°F to 400°F.
- DOW Corning 832™ Multi-Surface RTV Adhesive Sealant, gray, use range -65°F to 300°F.
- DOW Corning 9-1363™ Industrial Assembly Adhesive Sealant, grey.
- DOW Corning 1437™ Industrial Adhesive and Sealant, clear.
- 3M™ Model 4946 Foam Tape (acrylic foam), 45-mil thickness, one inch wide, white, Lot no. 09-08-99.

The material used to simulate bulkhead plate for mounting of the label plates was 1010 carbon steel. The paint system applied to the bulkhead plates was one coat of MIL-P-24441/20(SH) epoxy-polyamide green primer, formula F-150, Type III, one coat of MIL-P-24441/21(SH) epoxy-polyamide haze gray, formula F-151, Type III, and two coats of Interlac® Anti Stain Finish (Silicone Polyester) manufactured by International Marine Coatings. Two coats of silicone alkyd were applied based on the five coat paint system being considered for use on LPD-17 which includes two coats of Interlac® silicone alkyd. Reference (c) pertains.

Evaluation References

The following standard test methods/references were used or referred to during the course of this evaluation:

Operating Salt Spray (Fog) Apparatus.......................................ASTM B 117
Pull-Off Strength of Coatings Using Portable Adhesion Testers.........ASTM D 4541
Field Measurement of Surface Profile of Blast Cleaned Steel............ASTM D 4417
Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating
Exposure in a Salt Fog/Dry Cabinet and a UV/Condensation
Cabinet (Modified)...ASTM D 5894
Rubber Property-Adhesion to Rigid Substrates............................ASTM D 429
Floating Roller Peel Resistance of Adhesives..............................ASTM D 3167

Bulkhead Panel Preparation

Preparation of the panels that would represent shipboard bulkhead was based on proper painting practices outlined in reference (b). The panels were prepared as follows:

- Mild steel panels 6" x 12" x 1/8" were sheared to 3" x 6". The panel edges were filed to remove burrs. The coupon surfaces were solvent wiped with acetone to remove any dirt and oil.
- One face of each panel was grit blasted with 36 grit aluminum oxide to achieve an approximate 75 µm (3 mil) profile to ensure good paint adhesion. The abrasive grit was renewed every twelve panels to ensure a consistent profile was achieved. The surface profile of the panels was determined using Testex "Press-O-Film" tape in accordance with ASTM D 4417, method C.
- The panels were blasted with compressed air to remove any adherent blast grit followed by thorough cleaning with acetone to remove any remaining blast grit fines and leave a clean surface for paint application.
- Each panel was coated with the paint system noted above. Each coat of paint was applied by brush and allowed to cure for 24 hours between primer coats and 5 days between the application of the silicone alkyd topcoats.
- Dry film measurements were made following each coat of paint using a Elcometer Digital Coatings Thickness Gauge, Model 345, Serial No. 107973.
- Following complete cure, the panels were wiped with a solution of 50% by volume isopropyl alcohol in deionized water in order to assure a clean surface for proper adhesion of the label plates.

Label Plate Preparation

Prior to attachment of the label plates to the test panels, the as received plates were prepared for mounting as follows:

- Label plate samples not of a suitable size were sheared to approximately 2" X 3" or smaller to accommodate the bulkhead panel size.
- The mounted face of all metallic label plates were wiped with a 50% by volume isopropyl alcohol in deionized water solution to ensure a clean surface. The label plates were mounted to the test panels with the appropriate adhesive, sealant or double-sided tape combination in accordance with the test matrix shown in Table 1.
- Label plates attached with an adhesive had the adhesive spread evenly on the back of the label plate to a thickness of approximately 1/8-inch. The label plate was gently pressed to the painted test panel with even pressure to ensure an even squeeze out of adhesive along the label plate edges allowing the label plate to float on adhesive. The excess adhesive was removed by scraping with a square edged spatula from the painted panel surface toward the edge of the label plate and pulling up. This ensured a good seal of adhesive to the edges of the label plate.
- Label plates adhered with the 3M™ model 4946 acrylic foam tape were fastened by applying the tape to the back of the label plate first, cutting around the edge of the label plate with scissors to remove any excess tape. The tape backing was then removed and the label plate was applied to the painted panel surface, holding for 30 seconds with moderate pressure to ensure a good seal. Label plates that were wider than a single strip of adhesive tape required a second piece of tape butted up against the first piece to minimize any gap. The tape was then trimmed to fit the label plate dimensions.

- The adhesives and double-sided tape were allowed to cure for 72 hours before any environmental testing was conducted.

- Monel 400™ label plates mounted with mechanical fasteners (drive rivets) required that through holes be drilled into the bulkhead panels which lined up with holes drilled in the label plates. Label plate holes were drilled to 5/32-inch to provide clearance for the drive rivet. The bulkhead panels had 1/8" holes drilled to ensure that the drive rivet was securely attached. A drive rivet was hammered into each label plate mounting hole. Since the bulkhead panels were only 1/8 inch thick, the drive rivet extended beyond the panels by 1/16-inch. DOW Corning 732™ sealant was applied to the back of the panel over each drive rivet hole to seal the fastener. This would ensure that no moisture intrusion from the backside of the panel would occur.

- Monel 400™ and Metalphoto® anodized aluminum label plates were also prepared to conduct a peel test in order to gain some information related to adhesive strength. Strips of Monel 400™ and anodized aluminum label plate material were sheered 1" wide by 4 inches long. A one-inch tab was bent 90° on each label. The remaining 3 inches of the label plate was adhered to the bulkhead panel in accordance with the test matrix outlined in Table 2 and allowed to cure for 72 hours. In addition, a sample of each adhesive/sealant was placed directly onto the surface of each label plate material to visually determine if there was any reaction with the base metals. Following the environmental exposure period, these label plates were peeled from the surface using an Applied Test Systems (ATS) Inc., Model 900 Universal Test Machine, Serial No. A911168-8-91. This method was based on ASTM methods D 429 titled Rubber Property-Adhesion to Rigid Substrates and D 3167 titled Floating Roller Peel Resistance of Adhesives (modified). The average force in pounds required to peel the label plate from the panel was determined.

- Tensile testing in accordance with ASTM D 4541 titled Pull-Off Strength of Coatings Using Portable Adhesion Testers was conducted to gain comparative data on the adhesive strength of each of the adhesive/sealants and double-sided tape. Mild steel panels, 6" X 12" X 1/8" were abrasive blasted to a 75 µm (3 mil) profile. The paint system applied to the original test panels was also applied to these panels except the silicone alkyd top coat was limited to a 50 to 75 µm (2 to 3 mil) dry film thickness (4 mils wet). Patti Adhesion pull stubs were glued to these panels using the adhesives/sealants and the double-sided tape used for this evaluation. Two sets were prepared. One set of panels was left at ambient temperature. The other set was exposed to the extreme temperature and humidity conditions used for the other label plates in the environmental chamber for seven days following a three day ambient cure period.

- The salt fog cabinet was prepared for operation in accordance with ASTM B 117. The bulkhead panels were placed on plastic racks that maintained the proper exposure angle. The panels were spaced on the racks to prevent any shadowing effects from one panel to another. Throughout the exposure period, the position of the coupon racks was changed in the cabinet to ensure even exposure. Intermittent salt fog exposure would take place in two stages; at the beginning of the evaluation for an initial 10 day period and following the environmental chamber exposure for a 7 day period. This was done to extend the aggressive exposure environment on the label plate materials. Following exposure, the label plate conditions were noted. Figure 1 shows the arrangement of the label plate test panels in the salt fog chamber.

- Following the initial salt fog exposure, the UV/weathering chamber was prepared for operation. The panels were transferred to the chamber for a 7-day exposure. Every two days, the panels were rotated in order to ensure consistent exposure. Following exposure, the panels and label plate conditions were noted.

- Following UV/Weathering exposure, the panels were placed into an environmental chamber for temperature/humidity extreme testing. The chamber was programmed to cycle temperatures from

–20° F to 140° F and vary relative humidity conditions from 30% to 75%. Attachment (A) shows the temperature/humidity cycling sequence.

- Photographs were taken before and at the completion of exposure of the label plates.

RESULTS

Profile Depth Measurement

Profile depth measurement of the blasted bulkhead panels was determined in accordance with ASTM D 4417, method C. The average profile ranged from 71.1 to 81.3 µm (2.8 to 3.2 mils). The blasted surface was similar to a near white appearance, being free from corrosion products and surface staining.

Paint Application

After application and curing of the paint system, the dry film thickness (DFT) of the coatings was measured. A total DFT of approximately 253 to 305 µm (10 to 12 mils) was desirable for this paint system, however average DFT's ranged from 253 to 406 µm (10 to 16 mils)

Initial Salt Fog Spray Exposure Results

The salt fog chamber was operated in accordance with ASTM B 117. Exposure of the label plates was in accordance with ASTM D 5894 (modified). The specification was modified by exposing the label plates to 10 consecutive days of intermittent salt fog (24 hours on, 24 hours off exposing the label plates to air) followed by 7 consecutive days of UV/Weathering exposure. The specification calls for alternating between salt fog and UV/weathering on a daily basis. Modification of the ASTM specification was done in order to provide a more aggressive environment to encourage corrosion. Securing the salt fog and exposing the label plates to air allowed the salts to concentrate on the surface in the presence of oxygen. When the salt fog unit was turned on again, the warm moist air with the additional surface salt would increase the corrosive environment at the surface.

After the first 24 hours of exposure, the label plates were inspected. The Monel 400™ label plates with 3M™ 4946 double-sided tape and mechanical fasteners without sealant in the fastener holes showed running rust coming from the fastener attachment points due to corrosion of the bulkhead panel at the fastener attachment points. This is shown in figure 2. The Monel 400™ plates mounted with double-sided tape coated with DOW 732™ sealant with sealant in the fastener holes and around the edges of the label plates did not exhibit any sign of rusting. There was no sign of surface staining on the Monel 400™, 304 or 316 stainless steel label plates at this point. All other label plate materials appeared to be unaffected.

Following the 10-day exposure period, the only additional change in the condition of the label plate materials was the presence of surface staining on the Monel 400™, and the 304 and 316 stainless steels. This is shown in figures 3 and 4. As expected, the Monel 400™ exhibited a greenish brown surface coloration. The stainless steels exhibited light rust staining in areas adjacent to the engraved areas. At the engraved areas, the rust staining was enhanced, probably due to the use of iron tooling used in the engraving process.

The Metalphoto® anodized aluminum label plates with the Hitef2™ Teflon and the 3M™ Premium Protective Overlay Film, Series 1160 paint shedding overlaminates did not show any sign of degradation. The colored Metalphoto® label plates did not show any signs of fading or degradation. The 3M™ 480 series vinyl label plates with and without the 3M™ Premium Protective Overlay Film, Series 1160 overlaminate did not show any evidence of yellowing.

There was no evidence of separation of the label plates from the bulkhead panels for any of the fastening systems. The DOW Corning 732™ sealant remained well adhered.

QUV UV/Weathering Chamber Results

Following the initial salt fog exposure, the label plates were placed in the UV/weathering cycling chamber for a 7-day exposure period. Cycling was split between 4 hours UV exposure at 60°C (140°F) and 4 hours condensation exposure at 50°C (122°F) for a 168-hour period. The temperatures used for each cycle are common values in accordance with ASTM D 5894. There is also the possibility that these temperatures could also be obtained at the surface of a bulkhead under extreme natural weather conditions.

Following the exposure period, the label plates were evaluated. The only difference noted in any of the label plates was a slight yellowing of the 3M™ 480 series vinyl labels with and without the 3M™ series 1160 overlamanate. The labels covered with the overlaminate did show a lesser degree of yellowing. The black and red areas of both label types also showed some degree of fading, which was also less on the labels with the overlaminate. The overlaminate is most likely providing some UV protection.

Environmental Chamber Cycling Results

The label plates were placed in an environmental chamber in order to subject the adhesives, double-sided tape and the label plate materials themselves to large temperature and humidity changes over a relatively short period of time. This was designed to indicate if adhesive failure would occur and any label plates would fall off. The panels were placed in the environmental chamber in a vertical position. The temperature ranged from –20°F to 140°F and relative humidity from 30% to 75%. The rate of temperature cycling was over a six-hour period. The exposure period lasted for 10 days. The label plates were then examined. There were no noticeable differences in label plate condition. The adhesives/sealants and double-sided tape did not show any signs of degradation. All adhesives/sealants remained very pliable. None of the label plates fell off the bulkhead panels. There was no evidence of lifting of any label plates from the bulkhead panel surface.

Secondary Salt Fog Exposure Results

Following the environmental chamber exposure, the panels were placed back into the salt fog chamber for an additional week of intermittent exposure. There were no additional changes in label plate condition upon inspection.

Destructive Testing

After completion of the exposure phase, the Monel 400™ label plates fastened with drive rivets were peeled from the painted surface. The rivet heads were ground off and the plate peeled back. The plates that were fastened with the 3M™ 4946 double-sided tape only peeled the silicone alkyd topcoat from the primer layer, figure 5. The label plates attached with the double-sided tape covered with DOW 732™ peeled cleanly away leaving approximately half of the sealant on the bulkhead panel, figure 6. The sealant was completely cured. There was concern that sealant behind a label plate of significant size would not cure due to the lack of moisture required by many room temperature vulcanizing (RTV) materials. There was no evidence of corrosion behind these label plates. The Hitef2™ Teflon and the 3M™ series 1160 overlaminates on the Metalphoto® label plates were evaluated for abrasion resistance. A fingernail with moderate pressure was scratched across the surface of the label plates. In all cases, the fingernail dug into the overlaminates and caused rippling. This scratch test was also done on the 3M™ 480 series vinyl label plates with and without the 3M™ series 1160 overlaminate. The vinyl labels with the overlaminate showed the same rippling effect. In addition, picking at the edge of the label lifted the overlaminate from the label where it could be peeled off. Scratching the vinyl label without overlaminate resulted in removal of the printing.

Peel Test Results

The label plate samples prepared with a bent tab were subject to a peel test in order to quantify adhesive strength. The ATS Test Machine used to conduct this test is shown in figure 7. The bulkhead panel was placed in a roller jig that allowed the panel to slide while the label plate was pulled from the panel surface at a 90° angle. This allowed for a perpendicular pull from the bulkhead panel surface to occur.

The Monel 400™ label plates, even though thin, are somewhat rigid. As a result, these label plates did not exhibit a continuous peel from the bulkhead plate, making the results questionable. The anodized aluminum label plates, being more flexible exhibited a consistent peel. Since the adhesive systems used were duplicated for each label plate type, the results for the anodized aluminum are considered more definitive. The results are shown in Table 2. The data indicate that the DOW 1437™ industrial adhesive and the DOW 832™ adhesive/sealant provided the most peel resistance strength. In each case, the failure occurred within the adhesive layer (cohesive failure). This failure mode indicates that the paint to adhesive bond and adhesive to label plate bond is stronger than the adhesive itself. The 3M™ model 4946 double-sided tape peeled cleanly from the painted surface.

The data also indicate that for the DOW 1437™ and 832™ adhesives, their use alone provides better adhesion than when used in conjunction with the 3M™ model 4946 double-sided tape. The opposite is true for the DOW 732™ sealant and the 9-1363™ adhesive sealant. Because there is only one of each sample type, it cannot be determined if this is an anomaly. The large spread of the data does suggest that the DOW 1437™ and 832™ adhesives would probably exhibit the most adhesive strength for this type of label plate removal.

There was no evidence of reaction between the Monel 400™ and the anodized aluminum base metal with the adhesive/sealants tested in this evaluation.

The 3M™ 480 series vinyl labels peeled cleanly from the painted surface and exhibited an adhesion strength close to the DOW 732™ sealant.

Patti Adhesion Tensile Test Results

To better determine adhesive strength based on a larger sample size, tensile testing was conducted in accordance with ASTM D 4541. Generally, tensile adhesion testing is used to determine how adherent a coating is to a particular substrate. A pull stub is glued down to a painted surface with epoxy. Once the epoxy cures, the pull stub is pulled from the surface and the mode of failure within the paint system is determined. For this evaluation, the adhesives and double-sided tape were used in place of the epoxy to adhere the pull stubs to the painted surface. Two sets of plates were prepared for each adhesive and tape. Six pull stubs were glued down for each adhesive system in order to provide an average tensile strength for each material. One set was allowed to cure at room temperature for 10 days. The other set was allowed to cure for 72 hours at room temperature, then placed in the environmental chamber for temperature/humidity cycling using the same program used for the label plates. Exposure was for a seven day period. Figure 8 shows the Patti-Adhesion Tensile instrument. Table 3 shows the tensile adhesion results.

The data indicate that for the ambient tensile pull strength for the adhesives and double-sided tape tested, the materials could be ranked in the following order from best to worse:

DOW 832™ > 3M™ 4946 double-sided tape > DOW 732™ > DOW 9-1363™ > DOW 1437™

The result obtained for the DOW 1437 product is surprising since the peel strength was so much better.

The tensile strength data for the panels that were subject to the environmental chamber testing were ranked as follows:

3M™ 4946 tape >> DOW 832™ > DOW 732™ > DOW 9-1363™ > DOW 1437™

The tensile adhesion strength overall was increased for all of the adhesives/sealants following exposure in the environmental chamber. This is most likely due to more complete curing of the adhesives and double-sided tape due to the higher heat and humidity exposure which most likely caused more thorough curing of the materials. Room Temperature Vulcanizing (RTV) materials cure by reacting with moisture in the air. The most noticeable difference in tensile adhesion strength was with the 3M™ 4946 double-sided tape. The data show an average 21-fold increase in tensile strength over the ambient test results. The actual tensile strength exceeded the limitations of the instrument. Evaluation of these pull stubs indicated that the tape exhibited a very elastic quality, probably due to the high temperature of the environmental chamber. For all of the adhesives/sealants and tape tested, extreme temperature cycling did not affect the functionality of these materials. Product use temperature for all of the tested materials were within the range of the environmental chamber test conditions.

DISCUSSION/SUMMARY

This evaluation compared various materials being considered for label plates for LPD-17. The laboratory testing was designed to provide demanding corrosive environmental exposure conditions in a relatively short period of time. Since all of the prospective label plate materials were evaluated under the same conditions, comparative results are possible.

The surface appearance of the 304 and 316 stainless steel, and Monel 400™ label plates would be a concern. As expected, the stainless steels showed evidence of surface rust staining, especially in the areas where engraving of the label plates was conducted, most likely due to the engraving tooling leaving behind surface particles of iron that rust upon exposure to atmospheric moisture. The Monel 400™ surface showed the appearance of a light greenish brown staining, especially at the areas of the engraving. The overall surface appearance showed a greenish surface discoloration that is indicative of a nickel/copper alloy. From an appearance standpoint, the Monel 400™ surface discoloration would blend in more readily with the gray silicone alkyd topcoat than the rust stained surface of the stainless steels. One issue discussed in the project proposal for this study, but not evaluated here would be electropolishing of the stainless steel and Monel 400™ label plate materials following the engraving process but before paint application. The electropolishing process removes a very thin surface layer of material which includes the iron particles leaving a very smooth surface that is much more resistant to staining. The overall condition of the Monel 400™ plates indicated that they would be a feasible option for LPD-17, especially in areas where fasteners are required, if electropolishing was accomplished. Galvanic corrosion issues associated with fasteners contacting the Monel label plate would not be a concern. Use of sealant in fastener holes would be required to exclude running rust from corrosion of the bulkhead at the fastener points. Sealant applied behind and around the edges of the label plate would preclude moisture penetration between the label plate and the bulkhead. The use of an engraved CRES label plate in interior areas such as machinery spaces is a viable option since direct moisture contact and rusting from the engraved areas should be minimal.

All varieties of the Metalphoto® label plates were in excellent condition following all phases of exposure. There was no evidence of surface discoloration, pitting or fading. Figures 9, 10 and 11 pertain. The 3M™ Premium Protective Overlay Film, Series 1160 and the Hitef2™ Teflon paint shedding overlaminates were in excellent condition. There was no evidence of wrinkling or delamination from the environmental exposure. However, scratching of these surfaces with a fingernail did cause the overlaminates to mark and wrinkle suggesting that they are not very abrasion resistant.

The 3M™ series 480 vinyl label plates, while clearly legible following exposure, did show evidence of slight yellowing and slight color fading when compared to the unexposed labels. The vinyl labels covered with the 3M™ 1160 overlaminate were not as faded as the label with no overlaminate suggesting that the 3M™ series 1160 overlaminate provided some degree of UV protection. The overlaminate did wrinkle when scratched with a fingernail and could be lifted from the edge of the label and removed. The printing on the vinyl labels without overlaminate was removable if scratched with a fingernail. These labels are not considered very abrasion resistant. The adhesion of the vinyl label plates to the Interlac 1® silicone alkyd paint was excellent. There was no lifting or bubbling of the labels from the surface. The peel test data indicate a relatively low adhesion strength on the order of the DOW 732™ sealant.

Fastening of a label plate to the bulkhead with mechanical fasteners, adhesive tape or adhesives/sealants in all cases appeared to be a viable option. The results indicate, that if a mechanical fastener is used, the fastener holes must be filled with sealant prior to the drive rivet being hammered in place. Trapped water will eventually corrode the bare steel surface in the drive rivet hole around the rivet causing running rust from the fastener attachment point if a sealant is not used as shown in figure 2.

The data determined for the peel test and the tensile pull test indicate that on a comparative basis, the DOW 832™ Sealant and the 3M™ model 4946 double-sided adhesive tape would be expected to have the greatest holding power on the Interlac 1® paint system. It should be noted that the tensile testing was performed by applying the sealants and tape to a ½ inch diameter pull stub which is a relatively small surface area (but does provide comparative data). The use of either adhesive or tape on a normal size label plate of a few square inches would greatly increase the force required for removal.

The running rust shown on the painted bulkhead plates, figure 5 is somewhat disconcerting. The Interlac 1® paint used for this evaluation contains a chelating agent that is designed to control the degree of rust staining. This evaluation was not designed to evaluate the effectiveness of the paint; however, the degree of rust staining was noted.

This laboratory evaluation was designed to investigate how environmental factors would affect various combinations of label plate materials and attachment methods within a short time period. The exposure time under each analysis condition cannot be extrapolated to a time period under actual outdoor environmental conditions. Outdoor and laboratory exposure must be accomplished simultaneously with the same materials to determine a correlation between the two that can be applied to future evaluation of the same materials. Therefore, in this case, the laboratory results cannot be compared to results that might be obtained under actual outdoor exposure conditions. The results reported in reference (a) do indicate good performance obtained for the anodized aluminum label plates after an actual two year outdoor exposure.

The use of adhesive tape to attach a rigid label plate to a bulkhead may present some problems. The bulkhead panels and label plate samples used for this study were flat which allowed the adhesive tape to completely adhere to the surface providing a good bond. Frequently, shipboard bulkheads are not flat but have some degree of waviness to them. The 304/316 stainless steel and Monel 400™ label plates are very rigid. The adhesive tape has a thickness of approximately 1/16th of an inch. The stiffness of these label plate materials does not allow for the label plate to bend easily and conform to a less than ideal bulkhead surface. The anodized aluminum label plates are very bendable and would conform well to a surface that was not flat. If the 3M™ model 4946 double-sided tape is available in a thicker form, this would provide for more complete bonding over a non-flat bulkhead.

During this project, ship visits were made to DDG-79 at Bath Iron Works (BIW), Bath, Me and the DDG-80 at Ingalls Shipbuilding, Inc., Pascagoula, Ms. for another purpose. While there, the use of exterior label plate materials and fastening methods was noted. BIW has outfitted the exterior of the ship with vinyl label plates with black lettering on gray background similar in appearance to the 3M™ gray 3861 Scotchcal label shown in figure 12. Ingalls Shipbuilding has outfitted the ship with Metalphoto® anodized aluminum label plates held to the bulkhead with 3M™ model 4962 neoprene double-sided tape. The edges of the label plates were sealed with GE model 157 gray RTV High Strength sealant. In both cases the label plates were very well adhered to the bulkhead. Representatives from the Ingalls label plate shop indicated that they were looking to switch from the 3M™ model 4962 tape currently used to the 3M™ label plates.

CONCLUSIONS/RECOMMENDATIONS

The use of 304/316 stainless steel or Monel 400™ will resist corrosion in the marine environment. As discussed above, surface staining will eventually occur which affects the overall appearance of these label plates. Tooling used for engraving will most likely show surface discoloration unless electropolishing was accomplished following the engraving step prior to painting. The Del Star Acrylic Enamel paint used in the engraved areas of the stainless steel and Monel 400™ label plates did not show any evidence of wearing away or fading. Consideration should be given to using engraved Monel label plates in interior spaces requiring engraved plates such as machinery spaces where direct moisture contact and rusting from the engraved areas of the label plates would be minimal.

The issue of the rigidness of the CRES label plates and the ability to conform the label plate to a bulkhead surface that was not flat with adhesive tape or adhesive/sealant may be difficult if fasteners are not used to hold the label plate in place. If a label plate lifted from the bulkhead surface, water would penetrate behind the plate. This could result in corrosion of the bulkhead if there were imperfections in the paint system and most likely loss of the label plate.

The vinyl label plates held up very well as far as the material itself is concerned. They remained well adhered to the painted surface. The slight fading and yellowing seen after a relatively short time of exposure to UV is a concern. Wrinkling and removal of the overlaminate and printing from these labels with a fingernail indicates that these labels are not very abrasion resistant. These colored vinyl plates are not recommended for exterior use. The black lettering on gray vinyl label plates seen on the DDG-79, which appeared to be the 3M™ gray 3861 vinyl Scotchcal label were clearly legible and have been installed on the ship for a few months at this point. Fading of the black lettering was not evident. This label type did not show any evidence of fading from this evaluation. The printing was not removed when scratched with a fingernail.

Based on this evaluation, the use of Metalphoto® label plates, provided the highest degree of performance. The plates are photosensitized anodized aluminum and are resistant to many chemicals and abrasion. There was no evidence of fading. Because the plates are very thin and flexible, they would adhere very well with the 3M™ model 4946 double-sided tape to a bulkhead with irregularities in the surface. The benefit gained from the use of a protective overlaminate is questionable since the overlaminate itself is not very abrasion resistant.

The tensile pull and peel strength data and the results of the destructive testing show that the DOW 832™ adhesive sealant and the 3M™ 4946 double-sided tape used alone would provide adequate adhesion of any of the metallic label plate materials evaluated. From a practical standpoint, the use of the 3M™ model 4946 double-sided tape to adhere the label plate to the bulkhead is the easiest adhesion method. The label plate will stay where it is placed. If adhesive sealant were used alone, there is a chance that the label plate would slide on the bed of adhesive before curing. Sealing around the edge of the label plate with DOW 832™ adhesive sealant, and fairing the adhesive sealant on the edge will prevent water intrusion behind the label plate, fill in any gaps that might occur, and add additional adhesive strength.

If mechanical fasteners are required, such as in flight deck areas, the recommended label plate material is Monel 400™ backed with 3M™ model 4946 double-sided tape with DOW 832 adhesive sealant in the drive rivet holes and around the edges of the label plate. The downside of using engraved Monel 400™ in these locations would be the likelihood of running rust from the engraved areas. Consideration should be given for electropolishing engraved CRES label plates that would be used in this area. The use of CRES mechanical fasteners with the anodized aluminum label plates should be avoided due to the galvanic couple that would be set up between the rivet head and the label plate. If anodized aluminum label plates were used in flight deck areas of the ship, fastener holes should be filled with a generous amount of sealant. When the drive rivet is driven in, sealant squeeze out occurring between the rivet head and the label plate would provide a dissimilar metal barrier.

ACKNOWLEDGMENT

The author wishes to thank Mr. Norman Clayton, Code 624 for his assistance in technical guidance throughout this project and also Mr. Jeffrey Duckworth, Code 624 who assisted in laboratory equipment preparation used to conduct this evaluation.

TABLE 1

LABEL PLATE MOUNTING TEST MATRIX

MATERIAL	FASTENING SYSTEM
Monel 400™	3M 4946 tape covering back of label, 4 mechanical fasteners.
Monel 400™	3M 4946 tape covering back of label, DOW 732 completely covering the tape and placed in mechanical fastener holes, mechanical fasteners, edge seal of DOW 732.
Monel 400™	3M 4946 tape, completely covering the back of the label plate.
Monel 400™	DOW 732 sealant only covering back of the label plate.
304 Stainless Steel	3M 4946 tape, completely covering the back of the label plate.
316 Stainless Steel	3M 4946 tape, completely covering the back of the label plate.
3M 480 series vinyl label plate with 3M series 1160 overlaminate.	Factory applied adhesive.
3M 480 series vinyl label plate with no overlaminate.	Factory applied adhesive.
Metalphoto® anodized aluminum with Hitef2 Teflon™ overlaminate.	3M 4946 tape, completely covering the back of the label plate.
Metalphoto® anodized aluminum with 3M™ series 1160 overlaminate.	3M 4946 tape, completely covering the back of the label plate.
Metalphoto® anodized aluminum, various colored backgrounds and lettering.	Submitted premounted on aluminum panels.

TABLE 2

PEEL STRENGTH TEST RESULTS

MATERIAL	PEEL STRENGTH (lbs. Pull)	FASTENING SYSTEM
Monel 400™	18	DOW Sealant 832™
	43	DOW Sealant 832™ applied over 3M™ 4946 acrylic foam tape
	15	DOW Sealant 9-1363™
	38	DOW Sealant 9-1363™ applied over 3M 4946 acrylic foam tape
	38	DOW Sealant 1437™
	38	DOW Sealant 1437™ applied over 3M 4946 acrylic foam tape
	5	DOW Sealant 732™
	32	DOW Sealant 732™ applied over 3M 4946 acrylic foam tape
	38	3M™ 4946 acrylic foam tape

MATERIAL	PEEL STRENGTH (lbs. Pull)	FASTENING SYSTEM
Metalphoto® Anodized Aluminum	38	DOW Sealant 832™
	28	DOW Sealant 832™ applied over 3M™ 4946 acrylic foam tape
	23	DOW Sealant 9-1363™
	27	DOW Sealant 9-1363™ applied over 3M 4946 acrylic foam tape
	42	DOW Sealant 1437™
	26	DOW Sealant 1437™ applied over 3M 4946 acrylic foam tape
	11	DOW Sealant 732™
	25	DOW Sealant 732™ applied over 3M 4946 acrylic foam tape
	29	3M™ 4946 acrylic foam tape

MATERIAL	PEEL STRENGTH (lbs. Pull)	FASTENING SYSTEM
3M™ 480 series vinyl label plate with 1160 overlay	3.5	Factory applied adhesive
3M™ 480 series vinyl label plate with no overlay	3.2	Factory applied adhesive

TABLE 3

PATTI ADHESION TENSILE TEST RESULTS

ADHESIVE	AMBIENT PULL STRENGTH (psi)	ENVIRONMENTAL CHAMBER PULL STRENGTH (psi)
DOW 732™	165	219
DOW 832™	197	260
DOW 9-1363™	130	215
DOW 1437™	122	213
3M™ 4946 Double-Sided Tape	182	3,826

* Average of six pulls per adhesive type.

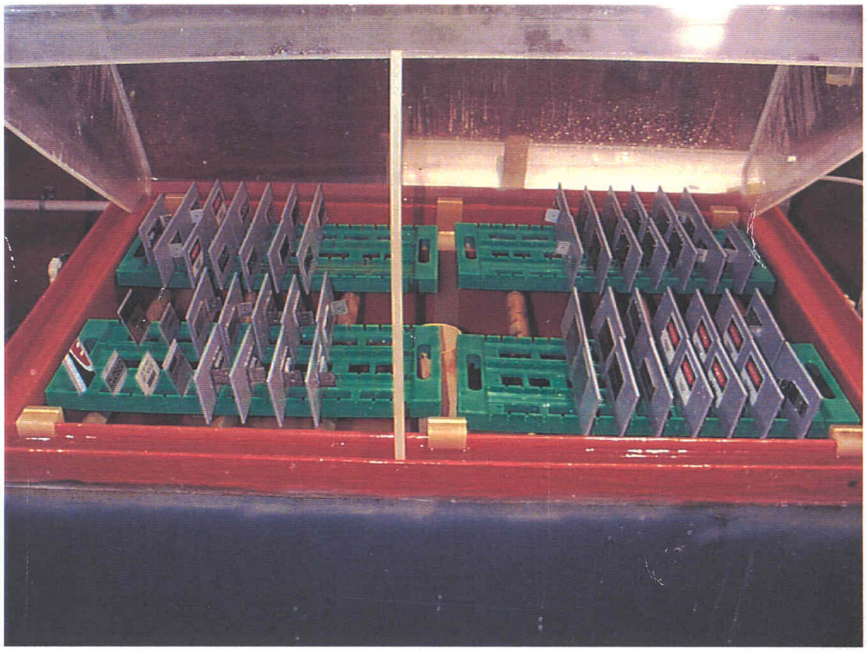


Figure 1: Arrangement of label plate panels in salt fog chamber.

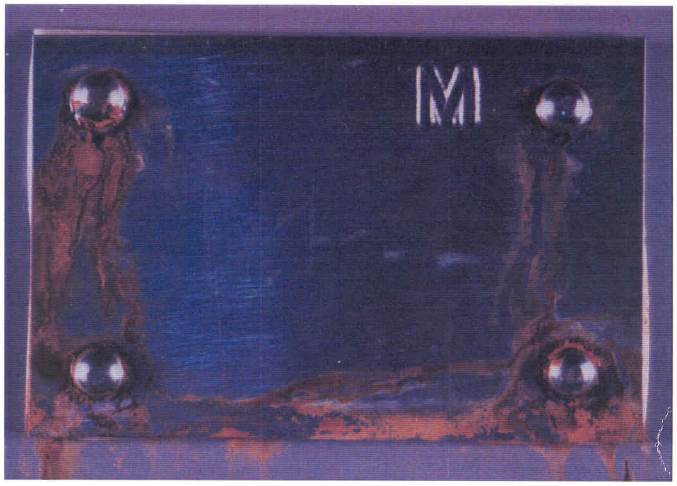


Figure 2: Monel 400™ label plate with 3M™ model 4946 double-sided tape, no sealant in fastener holes. Bulkhead panel has corroded at fastener attachment points resulting in running rust.

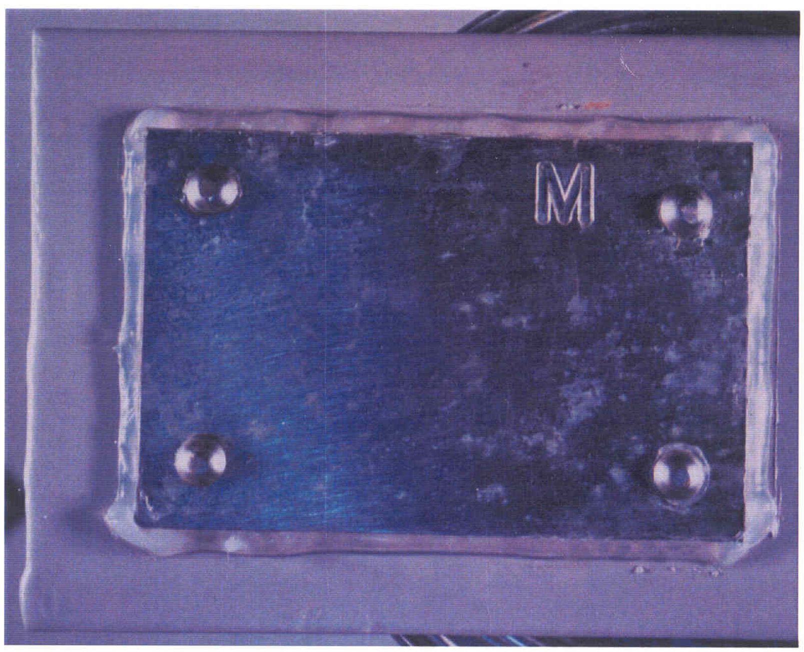


Figure 3: Monel 400™ label plate with sealant in fastener hole, around edges and coating the double-stick tape. There is no evidence of rusting. Note the greenish surface staining indicative of Monel alloys.

Figure 4: Monel 400™, 316 and 304 stainless steel label plates showing running rust from engraved areas most likely due to iron particle contamination of the surface from engraving tooling.

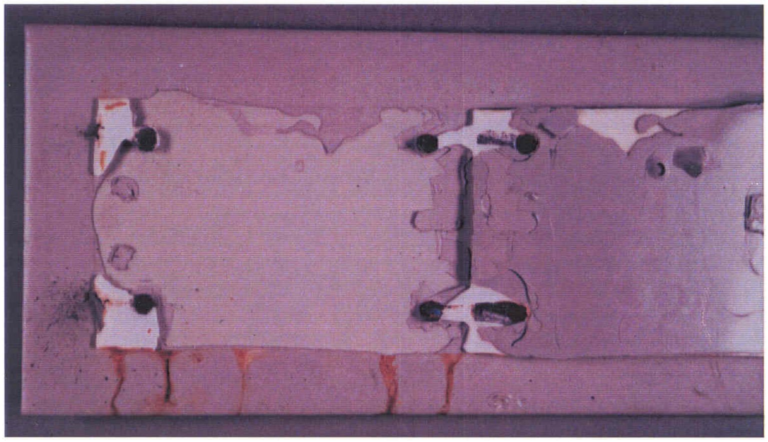


Figure 5: Monel 400™ with 3M™ 4946 double-sided tape covering the back. The rivet heads were ground off and the label plate peeled away. The silicone alkyd top coat was removed from the primer.

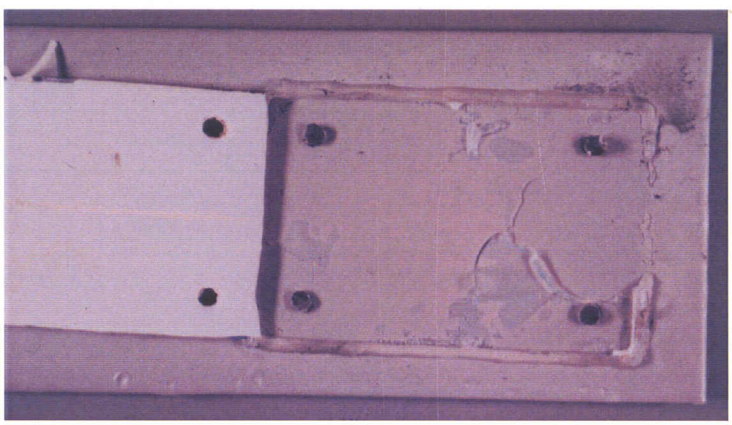
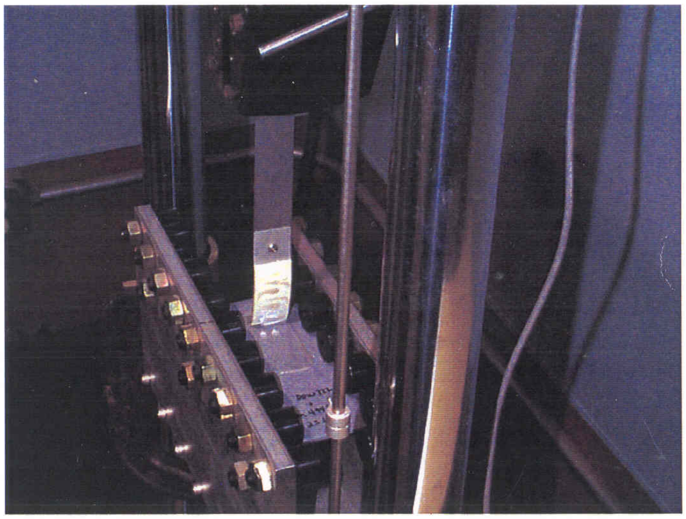


Figure 6: Monel 400™ label plate with 3M™ 4946 double-sided tape covered with DOW 732™ sealant covering the tape. The rivet heads were ground off and the plate peeled away. The tape peeled away leaving half of the sealant behind. The sealant was completely cured.



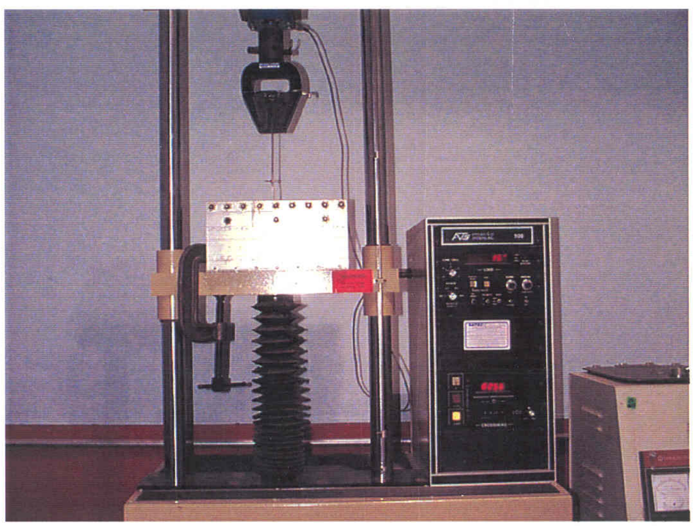


Figure 7: Applied Test Systems (ATS) Model 900 Universal Test Machine. The roller jig allows the panel to slide, which maintains a 90° peel angle to the surface.

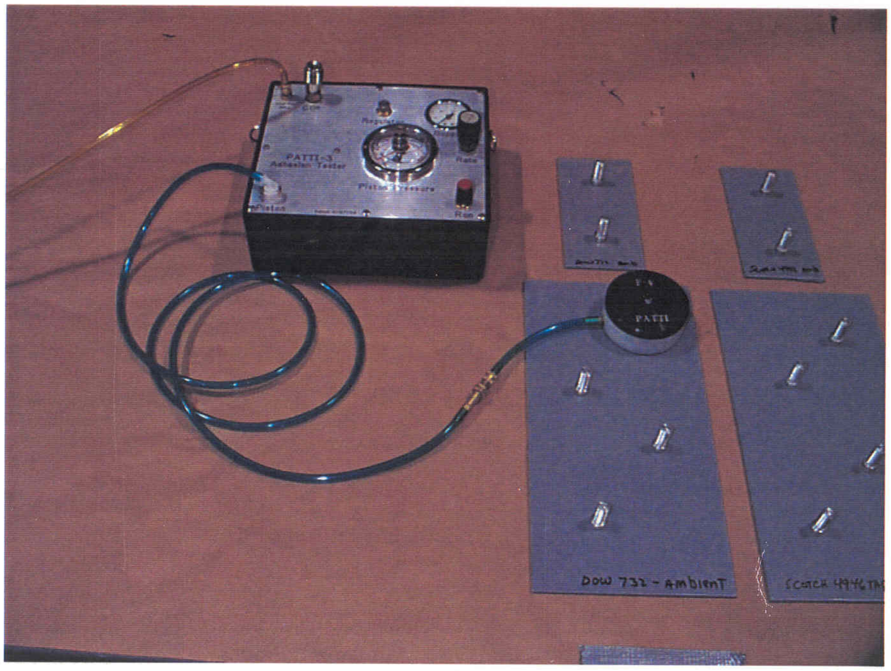


Figure 8: Patti Adhesion Tester. The pull stubs were glued down with the various adhesives, sealants and double-sided tape used in this evaluation.

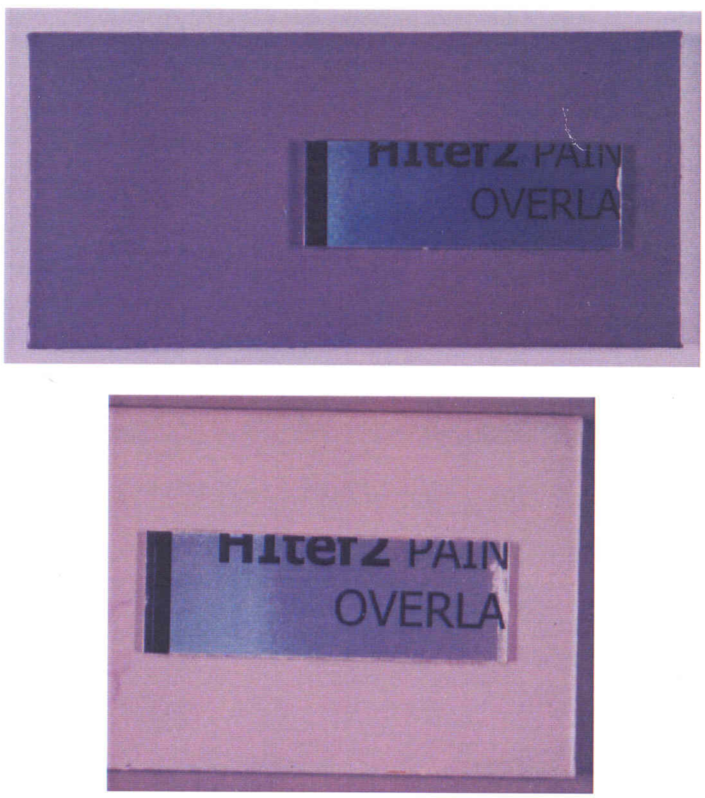
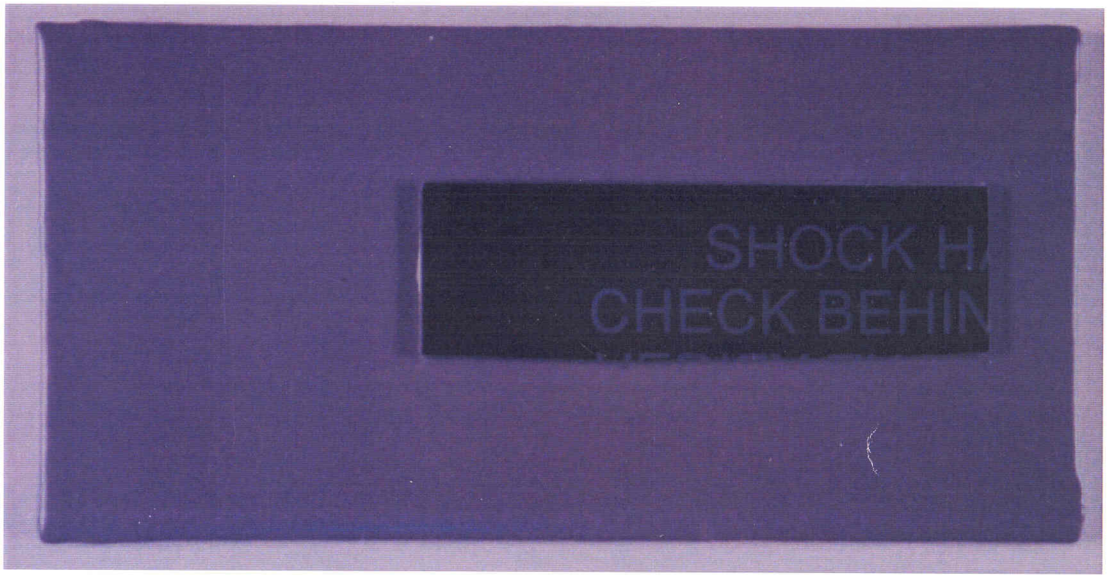


Figure 9: Metalphoto® anodized aluminum with Hitef2™ Teflon overlaminate before (upper) and after (below) environmental exposure.



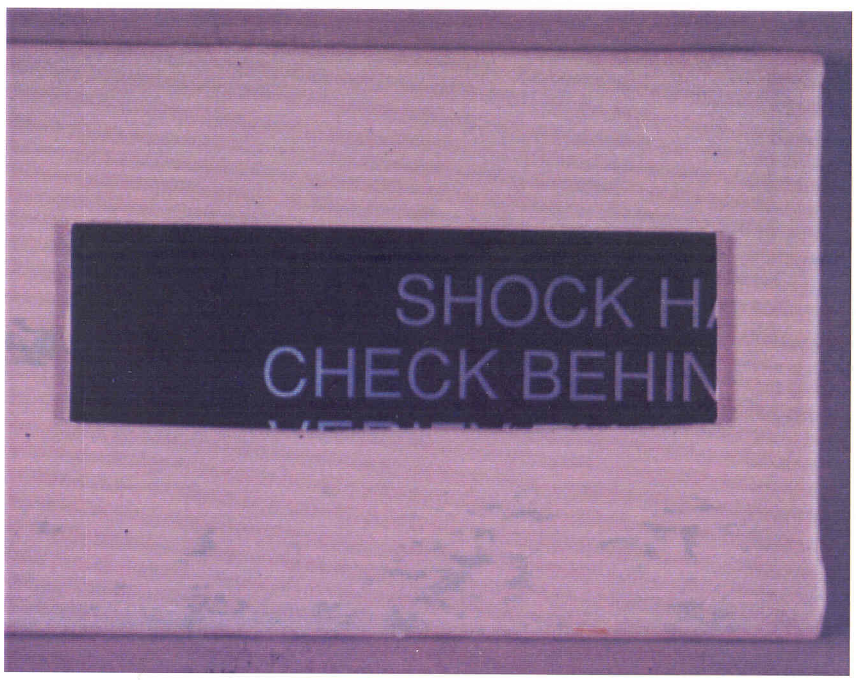


Figure 10: Metalphoto® anodized aluminum label plates with 3M™ Series 1160 Premium Protective Overlay Film before (upper) and after (below) environmental exposure.

Figure 11: Colored Metalphoto® label plates following environmental exposure. There is no fading or loss of clarity of the printing on these labels.

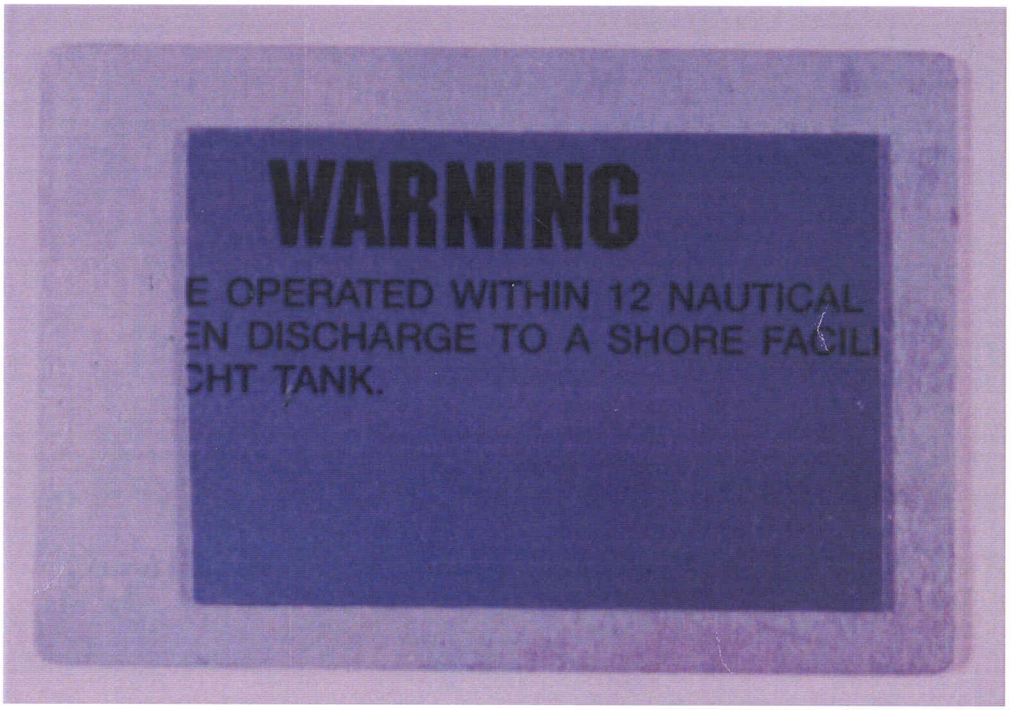


Figure 12: Vinyl label plate similar in appearance to that used on the DDG-79 at Bath Iron Works (BIW).

ENVIRONMENTAL CHAMBER CYCLING PROGRAM FOR LPD-17 LABEL PLATE EVALUATION

Interval	Start	End	Duration
1	75°F/30%H	75°F/30%H	30 Minutes
2	75°F/30%H	140°F/75%H	2 Hours
3	140°F/75%H	140°F/75%H	3 Hours
4	140°F/75%H	140°F/30%H	2 Hours
5	140°F	-20°F	3 Hours
6	-20°F	-20°F	6 Hours
7	-20°F	140°F	2 Hours
8	140°F/30%H	140°F/75%H	1 Hour

Loop Back To Interval 3

Attachment (A)

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