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Division of The Dow Chemical Company

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PROTECTIVE COATINGS ON MAGNESIUM ALLOYS INTENDED FOR USE ON COMPONENTS OF AIRBORNE VEHICLES

Final Report (Detailed)
June 1, 1960 to September 5, 1961
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PROTECTIVE COATINGS ON MAGNESIUM ALLOYS
INTENDED FOR USE ON COMPONENTS OF AIRBORNE VEHICLES

Abstract

Tin compound additions to polyvinyl butyral type clear primers provided very effective corrosion inhibition when applied to magnesium-steel galvanic couples. A combination of tributyltin oxide and finely divided metallic tin dust added to the clear primer offered the best protection by increasing the corrosion resistance 90% over non-inhibited primers.

A major program evaluating the most promising finishing systems developed during this and previous contracts was initiated and involved 20% salt spray, rural and marine exterior exposures. Salt spray tests again showed the advantages of tin electroplated fasteners over cadmium plate when used in conjunction with Dow #17 Anodizing and various paint systems. The stannate coating gave results superior to Dow #17 and cadmium or phosphate coated steel fastener systems.

After prolonged periods of exposure at minus 40°, electroplated tin on steel showed a slight transformation from Beta "white tin" to Alpha "gray tin", however, salt spray tests indicated no detrimental effects in corrosion resistance. Known methods of eliminating this phenomenon include additions of impurities such as 0.1% bismuth to the metal.

Weatherometer tests of LA124 alloy magnesium panels that were part of the finishing studies for the M113 hull were completed. After 650 hours exposure, the corrosion characteristics of painted and unpainted panels, with and without steel fasteners comparing Dow #17 anodizing and the stannate coating were very encouraging. Similar panels exposed to rural exterior atmospheres for 15 months showed the same good results with very little or no galvanic corrosion. Good paint adhesion characteristics of the stannate coating were also shown.

Electrical resistivity measurements to determine the conductivity of the stannate coating showed only 8.0 microhms per square inch as compared to 7.0 microhms for bare magnesium and a high of 74,000 microhms for Dow #17 thin anodize.

The development, improvement and finalization of the stannate process involved considerable effort during this contract period. Several factors relating to known or expected problems such as chromate poisoning of the bath, powdery coatings, failure of steel components to coat, and pretreatment methods were explored.

Steady improvements of the stannate application process were achieved and tentative processing bulletins were revised to include the new developments as they were proven. The most recent bulletin includes the best known procedures for applying the stannate coating. The operational limits of the bath, methods of analysis, a few operational difficulties that may arise, and sources of supply of chemicals.

The stannate process was finalized for patent coverage and the case was filed on August 8, 1961. Patent coverage for the addition of tin dust to clear primers has also been in process for some time and should be ready for filing in the near future.

Introduction

This is the final detailed progress report covering the period from June 1, 1960 to September 5, 1961 on Modification No. 1 - Supplemental Agreement to Contract DA-20-018-ORD-19650. This project was initiated to develop new methods and materials for producing a superior protective finish on magnesium alloys intended for use on components of airborne vehicles.

Efforts during this contract were divided into three major fields: (1) methods of preventing bimetallic couple corrosion by paint primer inhibition. (2) further development and improvement of the stannate immersion coating process and (3) evaluation of complete finishing systems by exposure to various environments.

The best methods of minimizing galvanic couple corrosion with additions of tin compounds to clear resin primers were studied. Considerable effort was directed towards the improvement of the stannate treatment and preparation of a detailed processing bulletin covering suggested methods of application, controls, etc. Well over

300 panels with and without galvanic couples were prepared to evaluate complete finishing systems when exposed to 20% salt spray, rural and marine exterior atmospheres.

Conclusions

1. A combination of TBTO (tributyltin oxide) and tin dust additions to Unichrome AP10 clear primer, baked, offers the best corrosion protection for magnesium-bare steel assemblies.

2. Non-chromate type base treatments are slightly better for use with tin inhibited primers where galvanic couple corrosion is concerned.

3. The stannate coating and tin dust inhibited primers will withstand long periods of low temperature exposure without any noticeable change in form or effect on salt spray corrosion resistance of galvanic couples.

4. The stannate immersion coating applied to LA142 alloy magnesium provides protection equal to Dow #17 anodizing when exposed to weatherometer test and prolonged periods of rural exterior atmospheric exposure. Painted panels have shown good adhesion characteristics during these exposures.

5. Due to variations in water in different localities, it is essential that the stannate bath be prepared with the addition of the NaOH first. This decreases the tendency for initial precipitation by raising the pH prior to adding the potassium stannate.

6. Electrical grounding through the stannate coating does not appear to be a problem since high sensitivity measurements have shown the electrical resistivity to be nearly equivalent to bare magnesium.

7. No serious problems should be experienced in applying the stannate coating if the procedures recommended are followed.

8. The stannate coating displays the best characteristics when applied to galvanic couple assemblies. However, it is not a cure-all for corrosion problems and is intended as a paint base similar to other conversion coatings.

9. When Dow #17 Anodizing is used as the base treatment for the magnesium in galvanic couples, tin electroplating the dissimilar steel member of the couple greatly reduces the galvanic corrosion when compared to cadmium plated or phosphate treated steel.

10. The stannate immersion coating applied to magnesium-bare steel assemblies provides protection superior to Dow #17 anodized magnesium-phosphate coated steel couples regardless of the paint system used and, in many cases, is equivalent to Dow #17 - tin plated systems.

11. The first results of complete finishing systems used in conjunction with the stannate coating indicated that better primer adhesion is maintained with the use of a Mil-C-15328 Wash Coat Primer pretreatment.

Recommendations

1. Tin plating of dissimilar metals coupled to magnesium is recommended for retarding galvanic corrosion when conversion coatings other than the stannate treatment are used.

2. For the utmost in galvanic corrosion protection, tin inhibited primers, such as those described in this report, be incorporated in the finishing system.

3. The stannate immersion treatment is recommended where:

a. It is necessary to apply a treatment to complete magnesium dissimilar metal assemblies using steel, brass, copper, etc.

b. A good paint base conversion coating is desired and no electrical equipment is available or desirable, such as used for Dow #17 anodizing.

4. For successful application of the stannate coating, the methods presented in this report be followed.

5. A Mil-C-15328 wash coat primer pretreatment be used in conjunction with the stannate coating to provide good paint anchorage.

6. Marine and rural exterior exposure tests for various finishing systems now in progress be continued to accumulate at least one year total time under these conditions.

Results and Discussion

A. Tin Inhibited Paint Primers

The addition of tin compounds to clear primers as galvanic corrosion inhibitors were previously demonstrated on magnesium-steel couple assemblies. The additions of tributyltin oxide (TBTO) and finely divided metallic tin dust to Unichrome AP10 clear polyvinyl butyral primer have repeatedly provided the most pronounced supression of galvanic couple corrosion. The first indications of these beneficial effects were obtained on unscribed panels and the final cure before testing was air drying. Additional tests indicated that the good characteristics of the AP10 inhibited primer could be further improved by baking for 20 minutes at 300F.

This system applied to galvanic couples that were scribed to simulate the most severe condition that might be encountered in actual use, gave results that were superior to any previously obtained. (Table I, Figure 1). The inhibited primer was applied to galvanic couples consisting of Dow #17 (light) anodized magnesium and bare mild steel in these tests. On a relative basis, the TBTO and tin dust combination showed only 20% failure during 100 hours in the 20% salt spray tests as compared to 90% failure for non-inhibited primer. Tin dust and TBTO used separately were slightly less effective than when combined, showing 30 and 25% failure respectively in the same test.

Since it was believed that the use of chromate type base treatments might hinder the true merits of tin inhibition, HAE anodizing and the stannate coating(non-chromate type treatments) were evaluated using galvanic couples primed with tin inhibited primer that was baked and scribed. Both the HAE and stannate coatings gave the best results thus far achieved in salt spray tests of galvanic couples when only primers were involved. With only 10% failure shown after 100 hours exposure, the non-chromate type base treatments were approximately 10% more effective. (Table II, Figure 2).

Preliminary tests have also shown that AP10 clear primer inhibited with tributyltin oxide applied to bare magnesium with sanded surfaces and bare steel couples resulted in a pronounced beneficial effect. During 100 hours exposure to 20% salt spray, good adhesion was maintained and a marked improvement in the galvanic corrosion resistance was shown. (Table III, Figure 3). In these tests the primer was air dried and it was assumed that a final baking step would have shown additional advantages.

B. Low Temperature Effects on Various Tin Applications

Magnesium-steel galvanic couple assemblies with the stannate coating, tin inhibited primers and tin electroplated steel were subjected to a temperature of minus 40° for 800 hours to determine if a transformation from "white" to "gray" tin was possible.

If a true transformation takes place, the original Beta "white tin" with a tetragonal structure and a density of 7.29 will change to Alpha "gray tin" with a cubic structure and a density of 5.8. The decrease in density results in more than 20% expansion which would explain the tendency to flake and spall. Known methods for eliminating this transformation include the addition of impurities such as 0.1% bismuth to the metal.

The stannate treated unpainted assemblies and the tin dust inhibited primer assemblies showed no visible change. The unpainted tin electroplated steel stringer assemblies withstood approximately 400 hours at minus 40° without any visible change. At 400 hours a slight breakdown of the tin plate appeared around the heads of the steel fasteners. After an additional 400 hours the change in the electroplated tin had increased a considerable amount and indicated that a transformation had taken place. The tin in these areas turned dark gray, became flaky and spalled from the steel surfaces. (Figure 4).

After the low temperature exposure these and similar assemblies stored for the same period at room temperature were exposed to the 20% salt spray test. The electroplated tin assemblies that showed the transformation had no noticeable difference in the degree of corrosion, however, the spalled areas become rusty. The corrosion resistance was also equal for stannate treated assemblies and those primed with tin inhibited primer comparing low temperature and room temperature exposure. (Figure 5).

C. LA-142 Alloy Magnesium Finishing Evaluation

1. Weatherometer Tests.

The weatherometer tests of LA-142 (Mg-Li) alloy magnesium panels that were part of the finishing studies for the M113 hull were completed with a total exposure time of 650 hours. The stannate treatment and Dow #17 anodize were evaluated on painted and unpainted panels, with and without steel fasteners.

The paint system used consisted of one coat of Mil-C-15328 wash primer plus three coats of Truscon Speed Rex Chemical and solvent resisting gray epoxy enamel. In addition to the tin coated fasteners applied by the stannate process in an assembly, bare mild steel, tin and cadmium electroplated fasteners were evaluated.

The tests were conducted in an Atlas XW Weatherometer under the following conditions:

a. The temperature was maintained at approximately 140F.

b. The arc light intensity was controlled to simulate sunlight and was operated continuously. All light with wavelengths below 2900A was filtered out using Cordex D filters.

c. Water was sprayed on the panels for nine minutes each hour.

d. The panels were mounted on a circular rack and revolved at the rate of one revolution per minute.

In general, the overall corrosion resistance was good and no significant attack was noticeable on the panel surfaces or at the galvanic couple area of unpainted panels. Tin plated fasteners on Dow #17 anodized unpainted panels showed a slight advantage over cadmium plate, while the magnesium-bare steel stannate treated assembly was best. Considerable spalling of the Dow #17 anodized coating was noted while the stannate coating appeared to be intact. (Figure 6).

The same fastener variables were evaluated with the painted panels but two of the four fasteners were scribed across the heads over onto the adjoining magnesium to expose bare metal. Panels without fasteners were scribed once on the bottom half.

The overall corrosion resistance and paint adhesion were good for the panels without fasteners and there was no significant attack at the scribe areas. About the same characteristics were noted for the various steel fasteners with very little or no corrosion at the couple junction or general areas. (Figure 7). One stannate coated panel with cadmium plated fasteners inserted after treatment showed considerable discoloration and the paint had lifted at the scribed areas. Since there was no noticeable corrosion, it was assumed that it was due to an adhesion characteristic caused from improper neutralization.

2. Rural Exterior Exposure

Similar LA142 panels duplicating the various fasteners and finishing methods evaluated in the above tests were also exposed to inland rural exterior atmosphere at the Midland, Michigan test site. The panels were initially exposed during May, 1960 and accumulated 15 months total exposure time before being removed from test. As a result, all of the various weathering conditions in this locale were experienced due to the complete cycle of seasonal changes.

The unpainted panels withstood this exposure considerably well and the true merits of the stannate coating as well as Dow #17 anodizing were realized when used as base treatments on the more corrosive LA142 magnesium alloy. (Corrosion rate of the material used was 26 MCD in the 3% NaCl alternate immersion test.) There were no visible signs of galvanic corrosion regardless whether the steel fasteners were bare, tin and cadmium electroplated, or coated as a magnesium-steel assembly in the stannate immersion bath.

The general surface conditions favored the stannate coating since the Dow #17 surfaces became discolored, spalled and showed indications of more corrosion. The resulting corrosion is not a true characteristic of the anodizing treatment as applied to standard alloys or those with normal surfaces and therefore was attributed to the nature of the surface condition of the LA142 metal used in these studies. The short time anodizing for a thin coating apparently left some minute unprotected areas, whereas the stannate coating applied by 20 minutes immersion in a hot bath penetrated the porous surface and gave a more complete continuous coating. (Figure 8).

The same treatments and fastener variables were evaluated with painted panels, but two of the four fasteners were scribed and plain non-couple panels were scribed once on the bottom half.

Again, the galvanic couple corrosion protection was very satisfactory for both the scribed and unscribed areas, and good paint adhesion characteristics were shown for the stannate coating during this long exposure period. Apparent corrosion under the painted surfaces of the Dow #17 anodized panels was further indication that small unprotected areas were involved. (Figure 9). It was also noted that the Truscon Chemfast Gray Epoxy topcoat had developed a thin chalky film due to the weathering. This was a characteristic of the paint used and reflected no effects of the metal or base treatments used.

In summation, the use of LA142 alloy magnesium should present no serious problems when properly treated and painted and exposed to various weathering conditions.

D. Stannate Immersion Treatment

Throughout the course of this contract the stannate immersion treatment was progressively improved by considerable effort directed towards further development, improvement, and finalization of the application process. At the onset of this second phase of the original contract the stannate treatment had not been thoroughly proven and some of the possible problems had not been encountered or solved. It is believed that through the following discussion, a more thorough understanding of the process, possible problems, and advantages for use in certain applications can be realized.

1. Background

The stannate process is the outcome of extensive attempts to apply a tin coating on magnesium by the immersion process. The first indication of suitable coatings appeared when magnesium-bare steel galvanic couples were coated as an assembly in a bath consisting of potassium stannate and tetrasodium pyrophosphate. During the immersion process a coating of equal parts of magnesium stannate ($MgSn(OH)_6$) and tin (Sn) was formed on the magnesium while a true tin coating was simultaneously formed on the steel component connected to the magnesium with positive electrical contact. The addition of NaOH to the bath resulted in a better coating and at the same time minimized the formation of magnesium stannate precipitate during the immersion process. An activator prepickle step was necessary at this time and attempts to include a surface activator in the bath composition were successful with the addition of sodium acetate. It was also found that minute amounts of hexavalent chromate would poison the stannate bath, however, this was overcome with the addition of sodium hydrosulfite which converted the chromate to a harmless trivalent form.

2. Bath Composition and Preparation

The stannate bath is prepared by adding the chemicals to water in the order given. (*) (**).

Sodium hydroxide (NaOH)--------10 gms./l. (1 1/3 oz./gal.)
Potassium stannate ($K_2SnO_3 \cdot 3H_2O$)---50 gms./l. (6 2/3 oz./gal.)
Sodium acetate ($NaC_2H_3O_2 \cdot 3H_2O$)--10 gm./l. (1 1/3 oz./gal.)
Tetrasoidum pyrophosphate ($Na_4P_2O_7$)-50 gm./l. (6 2/3 oz./gal.)
Tank material: Mild steel is suitable. Mild steel heating coils are also satisfactory.

* Note: 0.2% (2 grams/liter - 0.27 oz./gal.) sodium hydrosulfite ($Na_2S_2O_4$) is also added to the bath when there are possibilities of chromium contamination. The presence of hexavalent chromium compounds in small amounts will retard or prevent proper coating formation. The hydrosulfite changes the hexavalent chromium to the less harmful trivalent state.

** Note: It is essential that the NaOH be added to the water first to raise the pH before the potassium stannate is added. Extensive studies of bath preparation using various types of water have shown that when hard untreated water with high calcium content was used, the solution would become milky and a precipitate consisting of $CaSn(OH)_6$ would form if the potassium stannate was added preceeding the NaOH. When the stannate was added first to hot or near boiling distilled or de-ionized water a precipitate consisting of SnO_2 would form. Both precipitates were greatly increased with the addition of tetrasodium pyrophosphate following the stannate and prior to adding the NaOH. Tap water is suitable for use in the bath preparation but de-ionized or distilled water can also be used if it is readily available.

Cold water can be used throughout the bath preparation, although a longer period of agitation may be required to completely dissolve the tetrasodium pyrophosphate. All of the chemicals except the tetrasodium pyrophosphate can first be dissolved in cold water in the order previously known, then the solution can be heated to 140 to 150F. for faster dissolution of the pyrophosphate when added.

3. Procedure

The stannate coating is applied as outlined in the flow chart shown in Figure 10 which gives a preferred method as well as alternative methods.

a. Alkaline Cleaning

Heavy duty alkaline cleaners are most satisfactory for magnesium, especially when old chrome pickle or dichromate coatings as well as oil and grease are to be removed.

A suitable cleaner consists of the following:

Sodium hydroxide (NaOH)----60 gm./l. (8 oz./gal.).
Trisodium phosphate ($Na_3PO_4 \cdot 10H_2O$)--10 gms./l (1 1/3 oz./gal.)
Wetting agent (such as Nacconal NR)-0.5 gms./l. (0.067 oz./gal.
Parts are immersed for 3-15 minutes at 180-212F. and then rinsed in water.
Tank material: Steel tanks are satisfactory.

The alternate deoxidizer - alkaline cleaner bath contains the following:

Tetrasodium pyrophosphate ($Na_4P_2O_7$)-40 gms./l.-5 1/3 oz./gal.
Sodium tetraborate (Borax-$Na_2B_4O_7 \cdot 10H_2O$)-70 gm.l.-9 1/3 oz./g.
Sodium fluoride (NaF)------15 gms./l. (2 oz./gal.)
The parts are immersed for 2-5 minutes at 170-190F. and then thoroughly rinsed in water.
Tank material: stainless steel.

b. Hydrofluoric Acid Pickling

Hydrofluoric acid pickling cleans and activates the magnesium surfaces and also conditions the steel surfaces of inserts or fasteners coupled to magnesium. In addition it removed chromate coatings including the Dow #7 treatment. The parts are immersed in the following solution for a minimum of 5 minutes at room temperature.

15-20% (V./V.) hydrofluoric acid (as 100% HF)-150-200 ml/l.-
19-25.5 fl. oz./gal.
Minimum HF concentration during production use - 10%
The immersion period is followed by rinsing in cold running water.
Tank material: lead, rubber or synthetic rubber lined.

c. Nitric Acid Pickling

The alternate method of nitric acid pickling can be used when surface contamination is such that it cannot be removed by the hydrofluoric acid pickle. This is especially true for LA-142 (Mg-Li) magnesium to remove the heavy dark gray to black oxide film common to this alloy. This pickle should not be used after machining or close tolerance surfaces. It is suitable prior to machining or for parts not requiring close dimensions.

The parts are dipped for 1 to 2 minutes in the following solution at room temperature:

5% (V./V.) nitric acid (HNO_3 as 70%)-50 ml/l.(6.4 fl. oz./gal)
This pickle is then followed by thorough rinsing in cold running water. The work is then cycled back to the preferred system commencing with the HF pickle.
Tank material: ceramic, rubber lined or aluminum.

d. Chromate Acid Cleaning

Parts machined to close tolerances but still bearing corrosion or heavy oxide coatings not removed in the HF pickle should be cleaned in the following solution at room temperature to 190F. for 1 to 15 minutes, depending on the bath temperature and condition of the parts.

Chromic acid (CrO_3)----------24 oz. (180 grams/liter)
Water------------------------to make one gallon

After chromic acid cleaning the parts should go through the regular procedure of alkaline cleaning and hydrofluoric acid dipping to be sure all residual chrome is removed before going into the stannate bath.

Tank material: lead lined steel, stainless steel or 1100 aluminum.

e. Stannate Coating Application

The stannate coating is applied by immersion in the bath of the composition previously shown for 20 minutes minimum operated at 180F. (range 170-190F.).

This treatment is followed by cold water rinsing. Parts can then be rinsed in hot water to facilitate drying if a subsequent neutralizing treatment is not required.

A detailed tentative processing bulletin covering the stannate treatment has been prepared and is now available.

f. Painting

If parts are to be painted it is necessary to neutralize the stannate coating by dipping into a 5% W./V. (50 grams/ liter or 6 2/3 oz./gal.) sodium acid fluoride ($NaHF_2$) solution for 30 seconds (2 mins. maximum) at room temperature. This is followed by cold water rinsing (running water required). Parts can then be hot water rinsed (160-180F.) to facilitate drying.

(Note: The sodium acid fluoride must be a good commercial grade or a technical grade containing less than 0.5% total impurities. The major harmful impurities are chlorides, sulphates, silico-fluorides, and borofluorides. Impurities such as these in larger amounts will attack either the stannate coating or magnesium surfaces through the pores in the coating bearing a loose powdery residue.)

4. Coating Thickness

Microscopic measurements of the coating formed by the stannate immersion treatment have shown the magnesium stannate-tin coating on the magnesium to be .0001" to .0002". The tin coating formed on the threads of a 1/4" steel bolt inserted in the magnesium during immersion was .0004" to .0006" and .0004" to .0008" on the nut. A larger 1/4" x 1" x 2 1/2" piece of steel coupled to a 3 1/2" x 3 1/2" magnesium panel showed a tin thickness of .0002" to .0003".

5. Electrical Grounding

The electrical grounding characteristics of the stannate coating were determined by electrical measurements using a "Ducter" Low Resistance Ohmmeter.

It appeared that the coating would not present any grounding problems since the resistance measured was only 8.0 microhms per square inch as compared to 7.0 microhms for bare magnesium. In comparison, other coatings following in order were Dow #1 with 12.0 microhms; 3000 microhms for Dow #7 and a high of 74,000 microhms for Dow #17 thin anodize. Electroplated tin surfaces showed a very low resistance of 0.6 microhms per square inch. (Table IV).

6. Chromate Poisoning of Bath:

It was found that the stannate bath could be poisoned and become inoperative with the introduction of chromates. The addition of 0.1% $Na_2CrO_4 \cdot 4H_2O$ (0.005% CrO_4 ion) affected the bath to such an extent that the normal coating could not be applied. However, the addition of 0.02% sodium hydrosulfite ($Na_2S_2O_4$) to the same bath allowed the normal application of the coating to both the magnesium and the steel inserts. The addition of the sodium hydrosulfite reduces the hexavalent chromium to the less harmful trivalent state. Tests have indicated that as much as 0.4% hydrosulfite can be added without affecting the process.

It was therefore, recommended that at least 0.2% sodium hydrosulfite be added to the bath composition to counteract any chromates present.

7. Control

A few operational difficulties which may arise in applying the stannate coating are listed below:

a. Powdery Coatings

Extremely heavy coatings due to overtreatment in the stannate bath may result in a loose powdery coating condition on the magnesium that could affect paint adhesion. For most magnesium alloys the suggested 20 minute immersion period is sufficient if the bath is operated at 170-190F.

Prolonged dipping or high concentration of fluoride in the neutralizing sodium acid fluoride bath can also cause powdering of this coating. The concentration of the sodium acid fluoride should not be above 6% (W./V.) nor allowed to fall below 3% (W./V.). The dipping time should not exceed 2 minutes with 30 seconds being preferred.

Improper initial cleanup may be another cause of the final coating to be powdery. Smut or loose surface powdery deposits must be removed prior to immersion in the stannate bath.

b. Steel Inserts - Failure to Coat

The inability of the stannate coating to "take" on steel inserts is due to inadequate cleaning of the steel of foreign material of an oily or greasy nature or incomplete removal of all iron oxide films. The steel should be properly cleaned by degreasing and pickling or where heavy rust is present it may be necessary to remove this mechanically by blasting, sanding, etc. Steel parts must be in electrical contact with the magnesium to receive a tin coating.

8. Advantages

Perhaps the most significant advantage of the stannate coating is that it can be applied to magnesium-dissimilar metal (steel-copper, brass, etc.) galvanic couple assemblies in one immersion process. Aluminum is attacked due to the high alkalinity of the bath, therefore, this treatment should not be applied to magnesium parts containing aluminum inserts, etc. Previous work had proven the merits of tin electroplating the steel component of a galvanic couple assembly when used with treatments such as Dow #7 and Dow #17 anodize. Parts containing steel components can be given the Dow #7 treatment but the steel remains bare and there are no significant benefits obtained where galvanic corrosion is concerned. For Dow #17, any steel inserts or components present must be completely masked off prior to anodizing. Therefore, the stannate treatment is recommended chiefly for galvanic couples and is intended as a paint base similar to other conversion coatings. It is especially suitable for castings such as those shown in Figure 11. The stannate coating was successfully applied to these AZ91 alloy production sand castings with and without steel inserts.

The salt spray corrosion resistance of AZ91 alloy treated with the stannate coating was better than Dow #17 treated panels both with and without steel fasteners inserted. (Figure 12). AZ31B-O magnesium-steel galvanic couples treated with the stannate coating and primed with non-inhibited clear primer showed almost perfect corrosion resistance when exposed to 104 hours in the 20% salt spray test. (Figure 13, Table V).

The results of several additional tests of the stannate coating are given in the following section.

E. Various Treatment and Paint System Evaluations

An evaluation in various environments of complete finishing systems incorporating Dow #17 anodizing and the stannate coating was initiated. The tests involved were 20% salt spray; inland rural exterior exposure at the Midland, Michigan test site; and marine exterior exposure at the 80' station, Kure Beach, North Carolina.

Cadmium plated, tin plated and phosphate coated mild steel fasteners were used in conjunction with Dow #17 anodizing. The phosphate coating used on the mild steel fasteners was Cryscoat No. 47 (iron phosphate) produced by Oakite Products, Inc., 52 H. Rector St., New York 6, New York and was applied according to the manufacturers recommended methods.

Bare magnesium-bare mild steel fastener couples were stannate coated as assemblies. Unichrome AP10 polyvinyl butyral clear primer inhibited with 10% tributyltin oxide (TBTO) was used for all stannate treated panels. The same primer inhibited with 10% TBTO + 3 oz./gal. tin dust was used for the Dow #17-phosphate coated fastener assemblies. Various Federal and Military Specification topcoats were used for both series with and without an initial wash coat primer. The cadmium and tin plated fastener assemblies were primed with various Federal and Military Specification primers and topcoats with and without the Mil-C-15328 wash coat pretreatment.

The various systems, methods and salt spray results are shown in Table VI and VII. Photographs of the panels containing steel fasteners that were tested in 20% salt spray are shown in Figures 14, 15, 16, and 17.

In general, the use of tin plated fasteners in conjunction with Dow #17 anodizing was again proven to be beneficial. The galvanic corrosion was greatly minimized in the 20% salt spray tests and the advantage over cadmium plate was reproduced regardless of the paint system used. Similarly, the stannate coating gave results superior to cadmium plated or phosphate coated fastener - Dow #17 assemblies.

Two of the four steel fasteners in each panel were scribed across the head and over onto the adjoining magnesium to expose bare metal. Very little difference was noted in the corrosion between the scribed and unscribed areas. The degree of corrosion was rated on a relative basis from 0 to 10, 0 being the most severe condition with an area corroded 1/4" or more in width from the fastener and 10 being perfect. As an example, Dow #17 anodized magnesium containing cadmium plated fasteners and painted with TT-P-666 chromate primer and TT-E-485 topcoats was given a rating of 1. When tin plated fasteners were used with the same paint system the rating increased to 7, indicating much less corrosion. The stannate coated panels and the phosphate coated fastener panels, both painted with tin inhibited primer and TT-E-485 topcoats showed ratings of 7 and 0 respectively.

All of the phosphate coated fastener assemblies showed ratings of 0 while the stannate treated assemblies had ratings of from 5 to 8 for the various topcoats used. The best results were obtained with cadmium and tin plated fasteners were given by 405P and AP10 chromate primers with EV1223 vinyl organosol topcoats.

Results of duplicate finishing systems evaluated with non-couple sheet panels in the salt spray test are given in Tables VIII and IX. Good adhesion and corrosion resistance were shown for all paint systems evaluated with Dow #17 anodized magnesium. In a few cases the adhesion was not entirely satisfactory for stannate coated panels without wash coat primer but was greatly improved with the use of the wash coat.

Since the stannate coating is relatively new and only one primer was used with the various topcoats in these studies, it is believed that there are still several paint systems that should be evaluated.

The rural and marine exposure panels were placed on test during the month of April and May, 1961 and it is expected that at least 12 months exposure will be necessary to show any trends in corrosion characteristics.

F. <u>Evaluation of Various Chromate Epoxy Primers</u>

Experimental lots of epoxy primers pigmented with various chromates were evaluated using AZ81 sand cast panels simulating the simplified procedures recommended for ordnance wheel finishing. The primers were obtained from Kish Industries, Inc., Kanartex Coating Division, Lansing, Michigan, and consisted of the following:

1. U.S.A.F. Spec. Mil-P-27316, Calcium Chromate Primer.
2. TiO_2 and Zinc Chromate Pigmented Primer.
3. TiO_2 and Strontium Chromate Pigmented Primer.
4. TiO_2 and Basic Zinc Chromate Pigmented Primer.
5. TiO_2 and Basic Lead Silico Chromate Pigmented Primer.

All primers were used in conjunction with Dow #17 anodized magnesium and EV1223 Egyptian Lacquer Co. vinyl organosol topcoats. A reference standard finished to meet specifications using 405P yellow vinyl primer was also included. Tests were run as specified with two impressions formed by a 10 MM ball and 1500 KGM load "Brinell" and an additional scribe near one impression. Results of 200 hours 20% salt spray tests are shown in Table X and Figure 18.

The reference standard panel with 405P primer again duplicated previous results with no corrosion in the impressions or general areas and only slight corrosion at the scribe. The only epoxy primer that duplicated these results was U.S.A.F. Specification Mil-P-27316. The other primers allowed corrosion in the impressions and moderate to considerable corrosion at the scribe, although the general areas were good.

G. Patent Applications

Two patents are contemplated as a result of developments under this contract. The "Stannate Immersion Treatment" was finalized for patent coverage and the case was filed on August 8, 1961. The use of "Metallic Tin Powder as an Inhibitive Paint Pigment" is also being processed and should be ready for filing in the near future.

CWG:vlr
10-18-61

TABLE I

TIN DUST AND TBTO AS GALVANIC CORROSION INHIBITORS IN PAINT PRIMERS

BARE STEEL STRINGERS AND FASTENERS

SCRIBED ASSEMBLIES

Panel No.	Paint System	20% Salt Spray Mg Corrosion Rating* 100 Hours
1	Unichrome AP10 Clear Non-Inhibited Primer - Baked	1
2	10% TBTO in Unichrome AP10 Clear Primer - Baked	7 1/2
3	10 Oz./Gal. Tin Dust in Unichrome AP10 Clear Primer - Baked	7
4	10% TBTO + 3 Oz./Gal. Tin Dust in Unichrome AP10 Clear Primer - Baked	8 1/2

Tin Dust and Tributyltin Oxide were added to as packaged primer.

*Rating System: Rating is relative, with 10 being perfect and 0 being 100% failure of the general areas only.

0.250" AZ31B-O Dow #17 (thin) anodized magnesium and bare steel stringers and fasteners were used.

Method of Assembly:

1. The magnesium and steel stringers were spray painted with one coat of primer.
2. Assembled.
3. The assembly was spray painted with one coat of primer and baked 20 mins. at 300°F.

TABLE II

TIN DUST AND TBTO AS GALVANIC CORROSION INHIBITORS IN PAINT PRIMERS
DOW #17 - HAE - STANNATE IMMERSION BASE TREATMENTS
SCRIBED GALVANIC COUPLE ASSEMBLIES

Panel No.	Type of Assembly	Paint System	20% Salt Spray Mg Corrosion Rating* 100 Hours
1	Dow #17 (thin) anodized magnesium Bare steel stringer	Unichrome AP10 Clear Non-Inhibited Primer - baked.	0
2	Dow #17 (thin) anodized magnesium Bare steel stringer	Unichrome AP10 Clear Primer + 10% TBTO - baked.	5
3	Dow #17 (thin) anodized magnesium Bare steel stringer	Unichrome AP10 Clear Primer + 10% TBTO + 3 oz./gal. Tin Dust - baked.	8
4	HAE (thin) anodized magnesium Bare steel stringers	Unichrome AP10 Non-Inhibited Clear Primer - baked.	5
5	HAE (thin) anodized magnesium Bare steel stringers	Unichrome AP10 Clear Primer +10% TBTO + 3 oz./gal. Tin Dust - baked.	9
6	Stannate Immersion Coated Magnesium-bare steel stringer	Unichrome AP10 Clear Primer +10% TBTO + 3 oz./gal. Tin Dust - baked.	8 1/2
7	Magnesium-bare steel stringer Assembly - stannate coated	Unichrome AP10 Clear Primer + 10% TBTO - baked.	9

Tin dust and tributyltin oxide were added to as packaged primer.

*Rating System: Rating is relative with 10 being perfect and 0 being 100% failure of the general areas only.

AZ31B-0 magnesium

Method of Assembly:

1. The magnesium and steel stringers were spray painted with one coat of primer.
2. Assembled.
3. The assembly was spray painted with one coat of primer and baked 20 mins. at 300F.

Note: Panel No. 7 was stannate coated after assembly then painted with two coats of primer and baked for 20 mins. at 300F.

TABLE III

EFFECT OF TIN INHIBITED PAINT PRIMERS ON BARE MAGNESIUM-BARE STEEL GALVANIC COUPLES

Panel No.	Paint System	20% Salt Spray Mg Corrosion Rating* 100 Hours
1	Unichrome AP10 Clear Non-Inhibited Primer	0
2	10% TBTO in Unichrome AP10 Clear Primer	8 1/2

Tributyltin oxide was added to as packaged primer.

*Rating System: Rating is relative, with 10 being perfect and 0 being 100% failure of the general areas only.

0.250" AZ31B-O bare magnesium with sanded surfaces and bare steel stringers and fasteners were used.

Method of Assembly:

1. The magnesium and steel stringers were spray painted with one coat of primer.
2. Assembled.
3. The assembly was spray painted with one coat of primer and air dried.

TABLE IV

ELECTRICAL GROUNDING CHARACTERISTICS OF VARIOUS COATINGS ON MAGNESIUM

Type of Coating	Resistance Microhms per Square Inch
Bare Magnesium	7.3
Dow #1	11.7
Dow #7	3,330
Dow #17 (Thin)	74,000
Tin Electroplate	0.61
Stannate Immersion	8.0

AZ31B-O Magnesium was used.
The resistance measurements were obtained with a "Ducter Low Resistance Ohmmeter".

TABLE V

STANNATE IMMERSION COATINGS FOR GALVANIC COUPLE CORROSION PROTECTION

Panel No.	Type of Assembly	20% Salt Spray Mg Corrosion Rating* 104 Hours
1	Dow #17 (Thin) on magnesium - bare steel stringer and fasteners. Primed with Unichrome AP10 Clear Primer	0
2	Dow #17 (Thin) on magnesium - bare steel stringer and fasteners. Primed with Unichrome AP10 Clear Primer + 10% TBTO**	8 1/2
3	Bare magnesium - steel stringer assembly treated in stannate immersion bath*** Primed with Unichrome AP10 Clear Primer	9

*Rating System: Rating is relative with 10 being perfect and 0 being 100% failure of the general areas only.
**Tributyltin Oxide was added to as packaged primer.
***Neutralized in 5% sodium bifluoride post dip 2 min. for paint adhesion.

0.250" AZ31B-0 Magnesium plate was used - 1/8" x 1" x 5" mild steel stringers were fastened to the magnesium with 1/4" x 1" round head bolts.

Method of Assembly:

Panels 1 & 2

1. The magnesium and steel stringers were spray painted with one coat of primer.
2. Assembled.
3. The assembly was spray painted with one coat of primer.

Panel No. 4

1. The complete treated assembly was spray painted with two coats of primer.

TABLE VI

EVALUATION OF VARIOUS PRIMERS AND TOPCOATS ON GALVANIC COUPLES DOW #17 (THIN) ANODIZED MAGNESIUM

Type of Fastener	Wash Coat	Primer	Topcoat	Corrosion Rating* 100 Hrs. 20% Salt Spray Unscribed Fasteners	Scribed Fasteners
Cadmium Plated	None	TT-P-666	TT-E-485	1	1
Tin Plated	"	"	"	7	7
Cadmium Plated	Mil-C-15328	"	"	1	1
Tin Plated	"	"	"	7	7
Cadmium Plated	None	Mil-P-15930	Mil-P-15936 Gray	5	5
Tin Plated	"	"	" "	7	7
Cadmium Plated	Mil-C-15328	"	" "	5	5
Tin Plated	"	"	" "	7	7
Cadmium Plated	None	Mil-P-27316	Mil-L-52043 O.D.	2	2
Tin Plated	"	"	" "	6	6
Cadmium Plated	Mil-C-15328	"	" "	1	1
Tin Plated	"	"	" "	6	5
Cadmium Plated	None	Mil-P-6889A	Mil-L-7178 Aluminized	2	2
Tin Plated	"	"	" "	7	6
Cadmium Plated	Mil-C-15328	"	" "	2	2
Tin Plated	"	"	" "	7	7
Cadmium Plated	None	Mil-P-6889A	Mil-L-27227	2	2
Tin Plated	"	"	"	7	6
Cadmium Plated	Mil-C-15328	"	"	2	2
Tin Plated	"	"	"	6	5
Cadmium Plated	None	Ucilon 405 P	EV1223 Organosol	7	6
Tin Plated	"	"	" "	9	8
Cadmium Plated	Mil-C-15328	"	" "	5	5
Tin Plated	"	"	" "	9	8

TABLE VI (CONT'D)

EVALUATION OF VARICUS PRIMERS AND TOPCOATS ON GALVANIC COUPLES
DOW #17 (THIN) ANODIZED MAGNESIUM

Type of Fastener	Wash Coat	Primer	Topcoat	Corrosion Rating* 100 Hrs. 20% Salt Spray: Unscribed Fasteners	Corrosion Rating* 100 Hrs. 20% Salt Spray: Scribed Fasteners
Cadmium Plated	None	AP10 Zinc Chromate	EV1223 Organosol	8	7
Tin Plated	"	" " "	" "	8	8
Cadmium Plated	Mil-C-15328	" " "	" "	7	7
Tin Plated	"	" " "	" "	8	8
Cadmium Plated	None	Mil-P-15930	Mil-E-13515	7	6
Tin Plated	"	"	"	8	8
Cadmium Plated	Mil-C-15328	"	"	5	5
Tin Plated	"	"	"	8	8

*Rating System: Rating is relative with 10 being perfect and 0 when the magnesium corroded a width of 1/4" or more from the fastener.

Type of Assembly: AZ31B-O 0.250 x 3" x 6" Magnesium - Holes drilled and countersunk before anodizing. Each panel contained four 1/4" x 3/4" mild steel bolts electroplated as shown.

Method of Assembly:

1. The fasteners were inserted in the anodized magnesium.
2. Resistance measurements were made between each fastener and the magnesium to insure electrical contact.
3. Mil-C-15328 wash coat was applied to panels as indicated.
4. One coat of primer was applied and allowed to air dry.
5. Two coats of topcoat were applied and allowed to air dry. The EV1223 Organosol was baked 20 mins. at 350°F.
6. The bottom two fasteners were scribed across the heads and over onto the adjoining magnesium exposing bare metal.

TABLE VII

EVALUATION OF VARIOUS PRIMERS AND TOPCOATS ON GALVANIC COUPLES

DOW #17 WITH PHOSPHATE COATED STEEL FASTENERS VS STANNATE COATED Mg AND STEEL FASTENER ASSEMBLIES

Type of Assembly	Wash Coat	Primer*	Topcoat	Corrosion Rating** 100 Hrs. 20% Salt Spray Unscribed Fasteners	Scribed Fasteners
Dow #17-Phosphated Fasteners	None	AP10 + 10% TBTO + 3 oz./gal. Tin dust	TT-E-485	0	0
" " " "	MIL-C-15328	" " " " " " " " " "	" " "	0	0
Stannate immersion	None	AP10 + 10% TBTO	" " "	7 PA***	7 PA***
" "	MIL-C-15328	" " " "	" " "	8	7
Dow #17-Phosphated Fasteners	None	AP10 + 10% TBTO + 3 oz./gal. Tin dust	MIL-L-15936 gray	0	0
" " " "	MIL-C-15328	" " " " " " " " " "	" " " "	0	0
Stannate immersion	None	AP10 + 10% TBTO	" " " "	7	7
" "	MIL-C-15328	" " " "	" " " "	7	7
Dow #17-Phosphated Fasteners	None	AP10 + 10% TBTO + 3 oz./gal. Tin dust	MIL-L-52043 O.D.	0	0
" " " "	MIL-C-15328	" " " " " " " " " "	" " " "	0	0
Stannate immersion	None	AP10 + 10% TBTO	" " " "	6	6
" "	MIL-C-15328	" " " "	" " " "	6	6
Dow #17-Phosphated Fasteners	None	AP10 + 10% TBTO + 3 oz./gal. Tin dust	MIL-L-7178 aluminized	0	0
" " " "	MIL-C-15328	" " " " " " " " " "	" " " " "	0	0
Stannate immersion	None	AP10 + 10% TBTO	" " " " "	[illegible]	7
" "	MIL-C-15328	" " " "	" " " " "	[illegible]	7
Dow #17-Phosphated Fasteners	None	AP10 + 10% TBTO + 3 oz./gal. Tin dust	Chemfast Gray Epoxy	0	0
" " " "	MIL-C-15328	" " " " " " " " " "	" " " "	0	0
Stannate immersion	None	AP10 + 10% TBTO	" " " "	5	5
" "	MIL-C-15328	" " " "	" " " "	5	5
Dow #17-Phosphated Fasteners	None	AP10 + 10% TBTO + 3 oz./gal. Tin dust	EV-1223 organosol	0	0
" " " "	MIL-C-15328	" " " " " " " " " "	" " "	0	0
Stannate immersion	None	AP10 + 10% TBTO	" " "	5	5
" "	MIL-C-15328	" " " "	" " "	5	5
Dow #17-Phosphated Fasteners	None	AP10 + 10% TBTO + 3 oz./gal. Tin dust	MIL-E-13515	0	0
" " " "	MIL-C-15328	" " " " " " " " " "	" " "	0	0
Stannate immersion	None	AP10 + 10% TBTO	" " "	5	5
" "	MIL-C-15328	" " " "	" " "	6	5

TABLE VII (CONT'D)

EVALUATION OF VARIOUS PRIMERS AND TOPCOATS ON GALVANIC COUPLES

DOW #17 WITH PHOSPHATE COATED STEEL FASTENERS VS STANNATE COATED Mg AND STEEL FASTENER ASSEMBLIES

* Tributyltin oxide and tin dust were added to as packaged Unichrome AP10 Polyvinyl Butyral clear primer.

** Rating System: Rating is relative with 10 being perfect and 0 when the magnesium corroded a width of 1/4" or more from the fastener.

*** PA - indicates poor adhesion of the paint system to the treated magnesium.

Type of Assembly: AZ31B-0 0.250" x 3" x 6" magnesium

Dow #17 Panels: Holes were drilled and countersunk before anodizing.
Four 1/4" x 3/4" phosphate coated mild steel bolts were inserted after anodizing and checked for electrical contact.

Stannate Panels: Four 1/4" x 3/4" bare mild steel bolts were inserted in the bare magnesium panels and checked for electrical contact.
The Standard Stannate Immersion coating was then applied.
The coating was neutralized for painting in a 5% $NaHF_2$ solution.

Painting Procedure:

1. One coat of Mil-C-15328 was applied to panels as indicated.
2. One coat of primer was applied and air dried.
3. Two coats of top coat were applied and air dried
   The EV1223 Organosol was baked for 20 mins. at 350F.
4. The bottom two fasteners were scribed across the heads and over onto the adjoining magnesium exposing bare metal.

TABLE VIII

EVALUATION OF VARIOUS PRIMERS AND TOPCOATS ON MAGNESIUM SHEET DOW #17 ANODIZED (THIN)

Wash Coat	Primer	Topcoat	Corrosion Rating* 10C Hrs.-20% Salt Spray Rating	Adhesion
None	TT-P-666	TT-E-485	9.5	Good
Mil-C-15328	"	"	9.5	"
None	Mil-P-15930	Mil-P-15936	10	Good
Mil-C-15328	"	"	10	"
None	Mil-P-27316	Mil-L-52043	10	Good
Mil-C-15328	"	"	10	"
None	Mil-P-6889A	Mil-L-7178 Aluminized	10	Good
Mil-C-15328	"	" "	10	"
None	Mil-P-6889A	Mil-L-27227	10	Good
Mil-C-15328	"	"	10	"
None	Ucilon 405 P	EV1223 Organosol	10	Good
Mil-C-15328	" "	" "	10	"
None	AP10 Zinc Chromate	EV1223 Organosol	10	Good
Mil-C-15328	" " "	" "	10	"
None	Mil-P-15930	Mil-E-13515	10	Good
Mil-C-15328	"	"	10	"

*Rating System: Rating is relative - 10 being perfect and 0 when corrosion is 1/8" or more in width from the scribe.

Finishing Methods: AZ31B-0 .064" x 3" x 6" Magnesium Sheet Dow #17 Anodized.
One coat of Mil-C-15328 applied as indicated.
One coat of primer applied and air dried.
Two coats of topcoat applied and air dried.
The EV1223 Organosol was baked 20 mins. at 350°F.
The panels were scribed across one face to expose bare metal.

TABLE IX

EVALUATION OF VARIOUS PRIMERS AND TOPCOATS ON MAGNESIUM SHEET

DOW #17 ANODIZE VS STANNATE IMMERSION COATING

Base Treatment	Wash Coat	Primer	Topcoat	Corrosion Rating** 100 Hr. 20% Salt Spray Rating	Adhesion
Dow #17 (thin)	None	AP10 + 10% TBTO + 3 oz./gal. tin dust	TT-E-435	9.5	Good
"	Mil-C-15328	"	"	9.5	Good
Stannate	None	AP10 + 10% TBTO	"	5	Poor
"	Mil-C-15328	"	"	9	Good
Dow #17 (thin)	None	AP10 + 10% TBTO + 3 oz./gal. tin dust	Mil-P-15936 gray	9.5	Good
"	Mil-C-15328	"	"	9.5	Good
Stannate	None	AP10 + 10% TBTO	"	9.5	Good
"	Mil-C-15328	"	"	8.5	Good
Dow #17 (thin)	None	AP10 + 10% TBTO + 3 oz./gal. tin dust	Mil-L-52043	10	Good
"	Mil-C-15328	"	"	10	Good
Stannate	None	AP10 + 10% TBTO	"	9.5	Good
"	Mil-C-15328	"	"	9.5	Good
Dow #17 (thin)	None	AP10 + 10% TBTO + 3 oz./gal. tin dust	Mil-L-7178 aluminized	9.5	Good
"	Mil-C-15328	"	"	9.5	Good
Stannate	None	AP10 + 10% TBTO	"	5	Poor
"	Mil-C-15328	"	"	9	Fair-Good
Dow #17 (thin)	None	AP10 + 10% TBTO + 3 oz./gal. tin dust	Chemfast Gray Epoxy	9.5	Good
"	Mil-C-15328	"	"	10	Good
Stannate	None	AP10 + 10% TBTO	"	9.0	Good
"	Mil-C-15328	"	"	9.0	Good
Dow #17 (thin)	None	AP10 + 10% TBTO + 3 oz./gal. tin dust	EX-1223 organosol	9.5	Good
"	Mil-C-15328	"	"	10	Good
Stannate	None	AP10 + 10% TBTO	"	9	Good
"	Mil-C-15328	"	"	9	Good
Dow #17 (thin)	None	AP10 + 10% TBTO + 3 oz./gal. tin dust	Mil-E-13515	10	Good
"	Mil-C-15328	"	"	10	Good
Stannate	None	AP10 + 10% TBTO	"	9	Good
"	Mil-C-15328	"	"	9.5	Good

TABLE IX (CONT'D)

EVALUATION OF VARIOUS PRIMERS AND TOPCOATS ON MAGNESIUM SHEET

DOW #17 ANODIZE VS STANNATE IMMERSION COATING

* Tributyltin oxide and tin dust were added to as packaged Unichrome AP10 Clear Polyvinyl Butyral Primer.

** Rating System: Rating is relative 10 being perfect and 0 when corrosion was 1/8" or more in width from scribe.

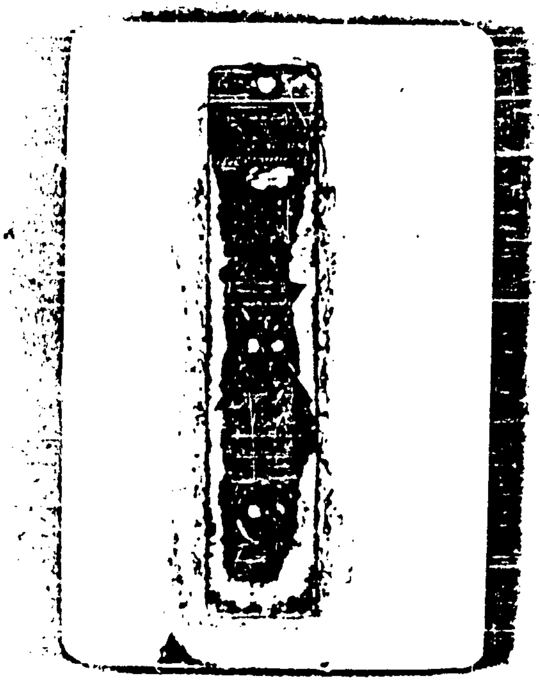
Finishing Methods: AZ31B-O 0.064" x 3" x 5" sheet used.
Dow #17 Anodize or Stannate Immersion applied as indicated.
One coat of MIL-C-15328 wash coat applied as indicated.
One coat of primer applied and allowed to air dry.
Two coats of topcoat applied and allowed to air dry.
The EV-1223 Organosol was baked for 20 mins. at 350F.
The panels were scribed across the face to expose bare metal.

TABLE X

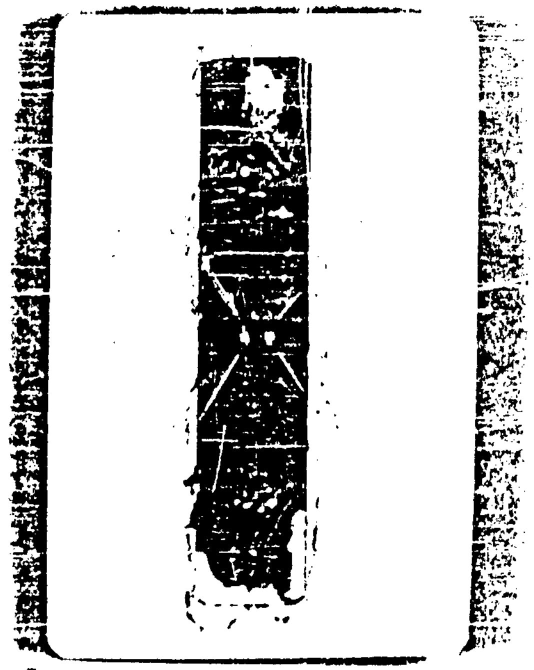
EVALUATION OF EPOXY PRIMERS FOR SANDCAST AZ81 MAGNESIUM ORDNANCE WHEELS
EV1223 ORGANOSOL TOPCOATS

Panel No.		
1	Mil-P-27316 - Epoxy	General areas good, Fair to Good in scribe. Impressions Good
2	TiO_2 and Zinc Chromate - Epoxy	General areas good, considerable corrosion in scribe. Impressions corroded.
3	TiO_2 and Strontium Chromate - Epoxy	General areas - one 1/4" diameter chip. Moderate corrosion inscribe. One impression corroded.
4	TiO_2 and Basic Zinc Chromate - Epoxy	General areas good. Moderate corrosion in scribe. One impression corroded.
5	TiO_2 and Basic Lead Silico Chromate - Epoxy	General areas good. Moderate corrosion in scribe. One impression corroded.
6	Ucilon 405 P Strontium Chromate - Vinyl (Specification DAPD 239)	General areas good. Fair to Good in scribe. Impressions good.

AZ81 Sand Cast 3" x 8" x 3/8" panels. Dow #16 30 sec. + Dow #17 (thin) + prebaked for 20 mins. at 350°F. Double passed primed with primers shown. Epoxy primers were baked for 10 mins. at 250°F. before topcoats were applied. The EV1223 Organosol topcoats were thinned 4:1 and applied with two double consecutive passes to give a thickness of 4 mils. The panels were air dried 10 mins., force dried 20 mins. at 200°F. and baked for 20 mins. at 350°F. Panels were "Brinelled" in two places with a 10 MM ball - 1500 KGM load. The panels were also scribed thru to the base metal slightly off to one side of one impression.



UNICHROME A... CLEAR
PRIMER + BAKED AN... ...



N... M... A...
... BAKED AND ...

NICHROME API... CLEAR
PRIMER + ... GAL... TIN DUST
BAKED AND ...

UNICHROME A... ...
PRIMER + ...
TIN DUST + BAKED AN... ...

FIGURE [illegible]

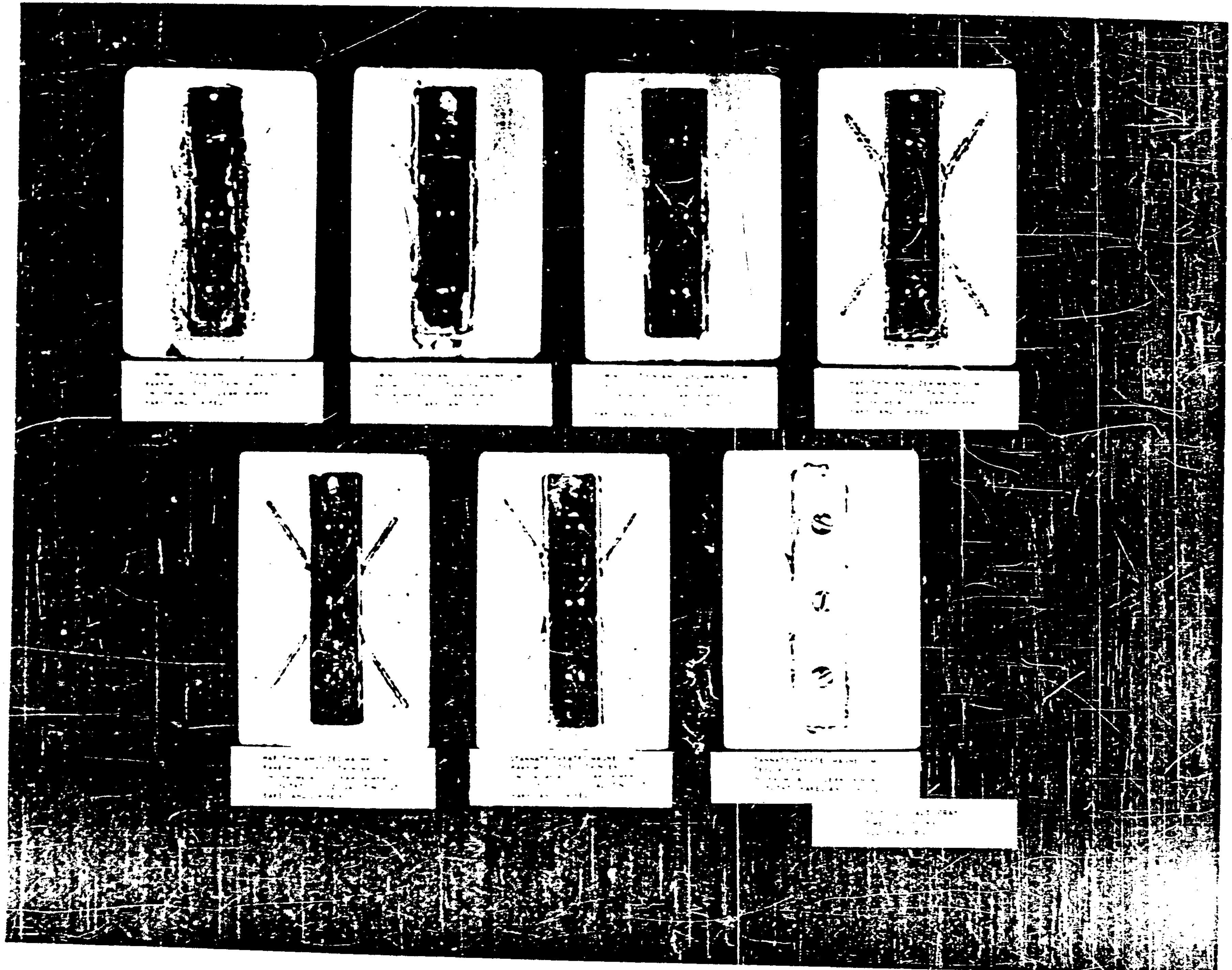


Figure 2

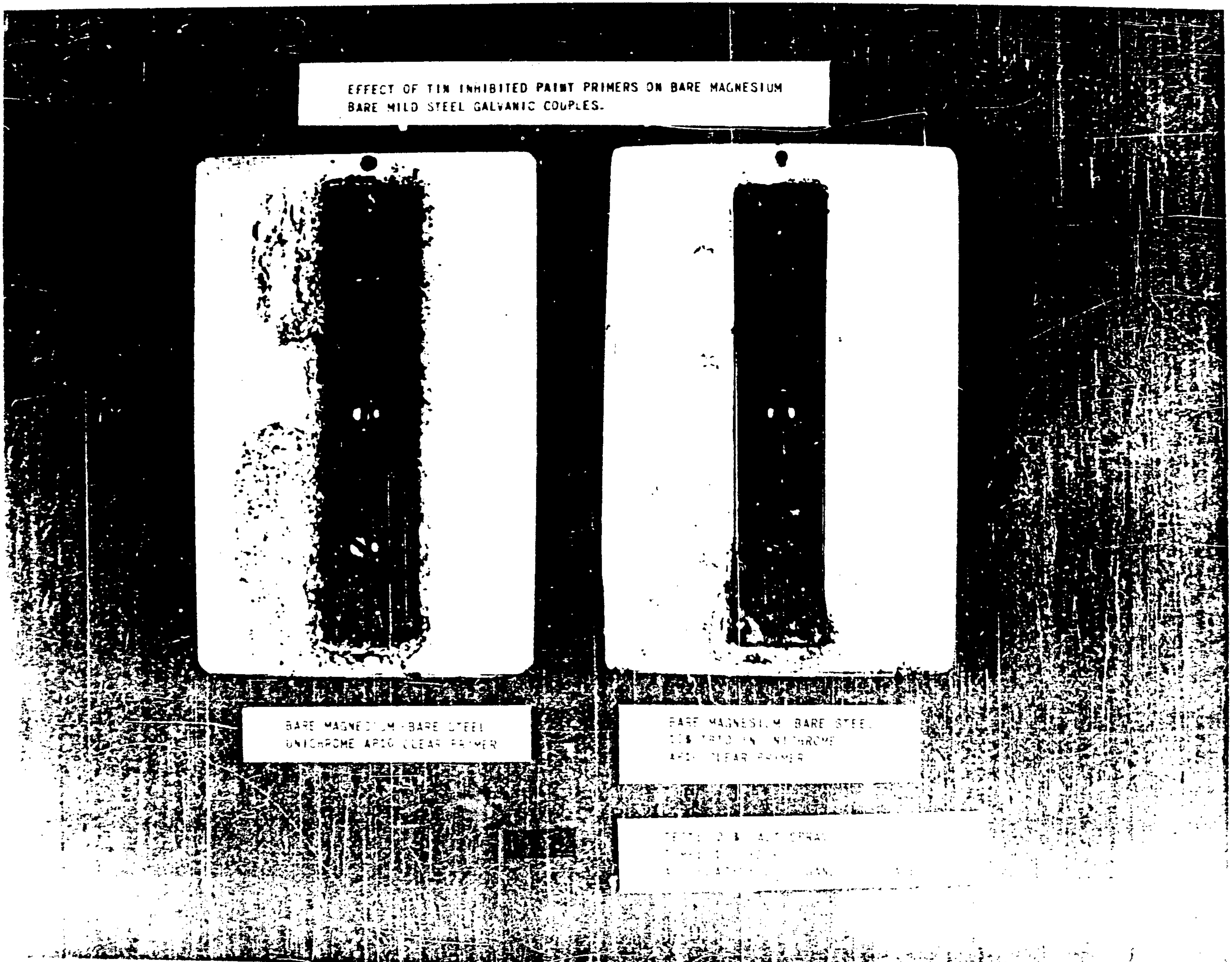

EFFECT OF TIN INHIBITED PAINT PRIMERS ON BARE MAGNESIUM
BARE MILD STEEL GALVANIC COUPLES.

Figure 3

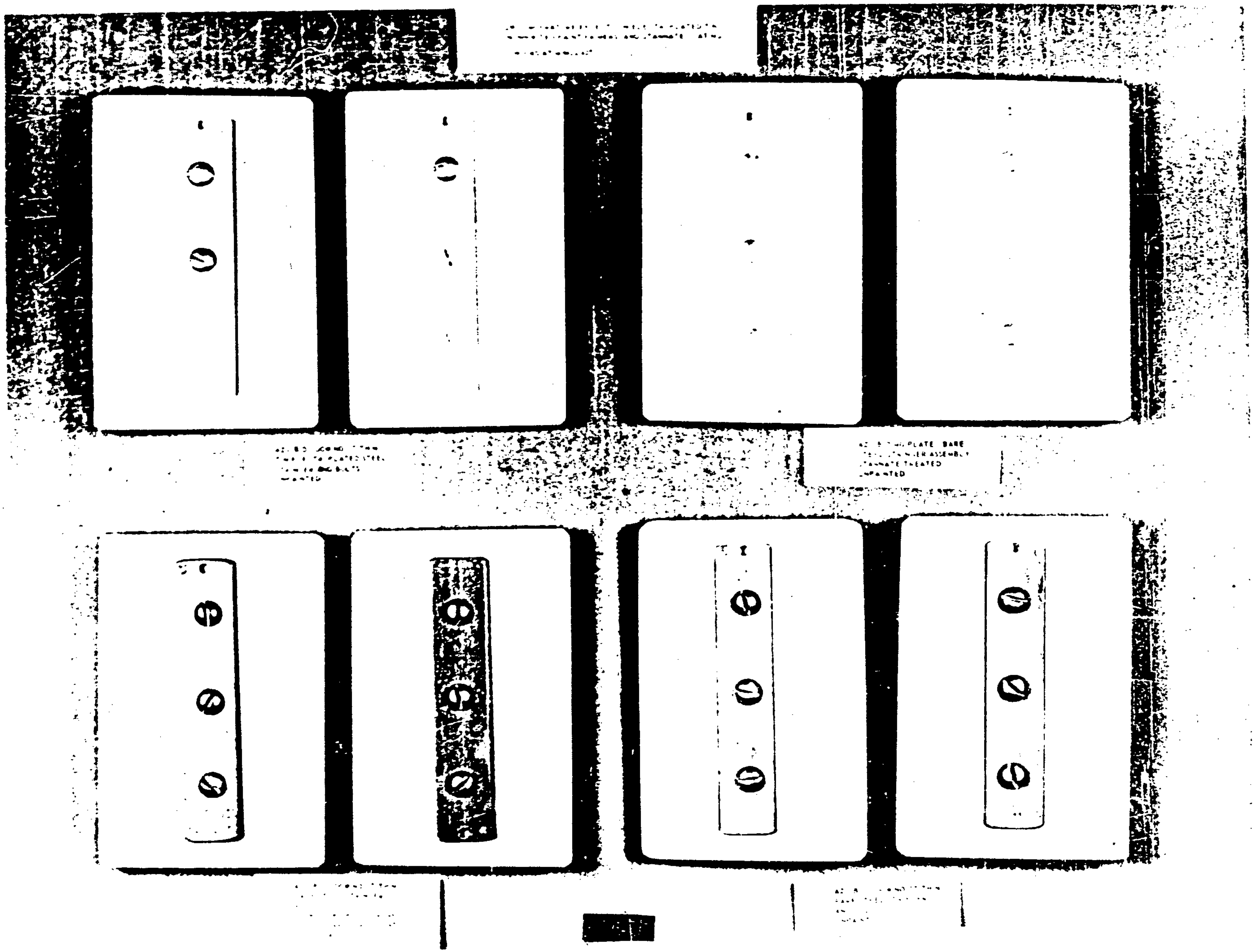


Figure 4

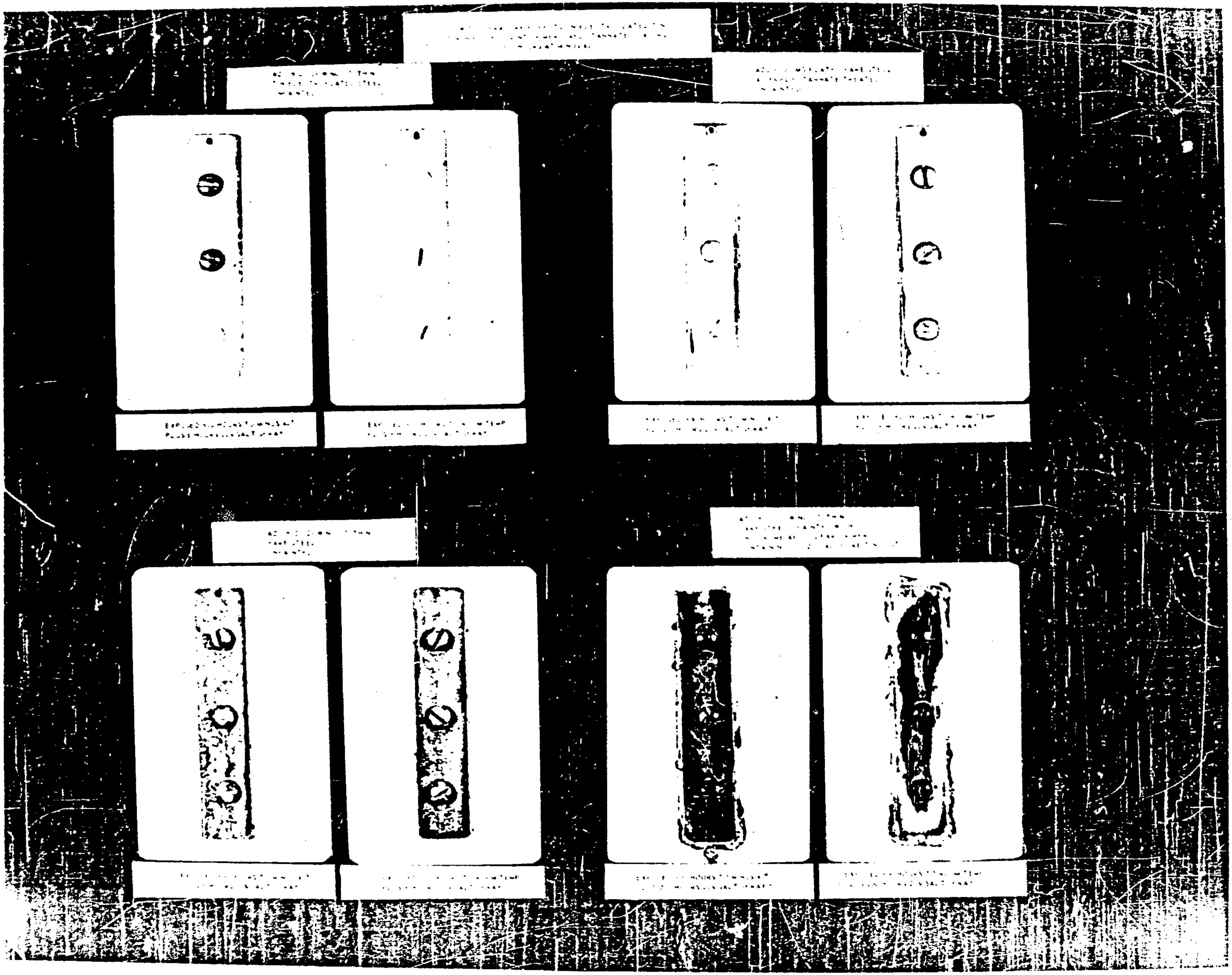


Figure 5

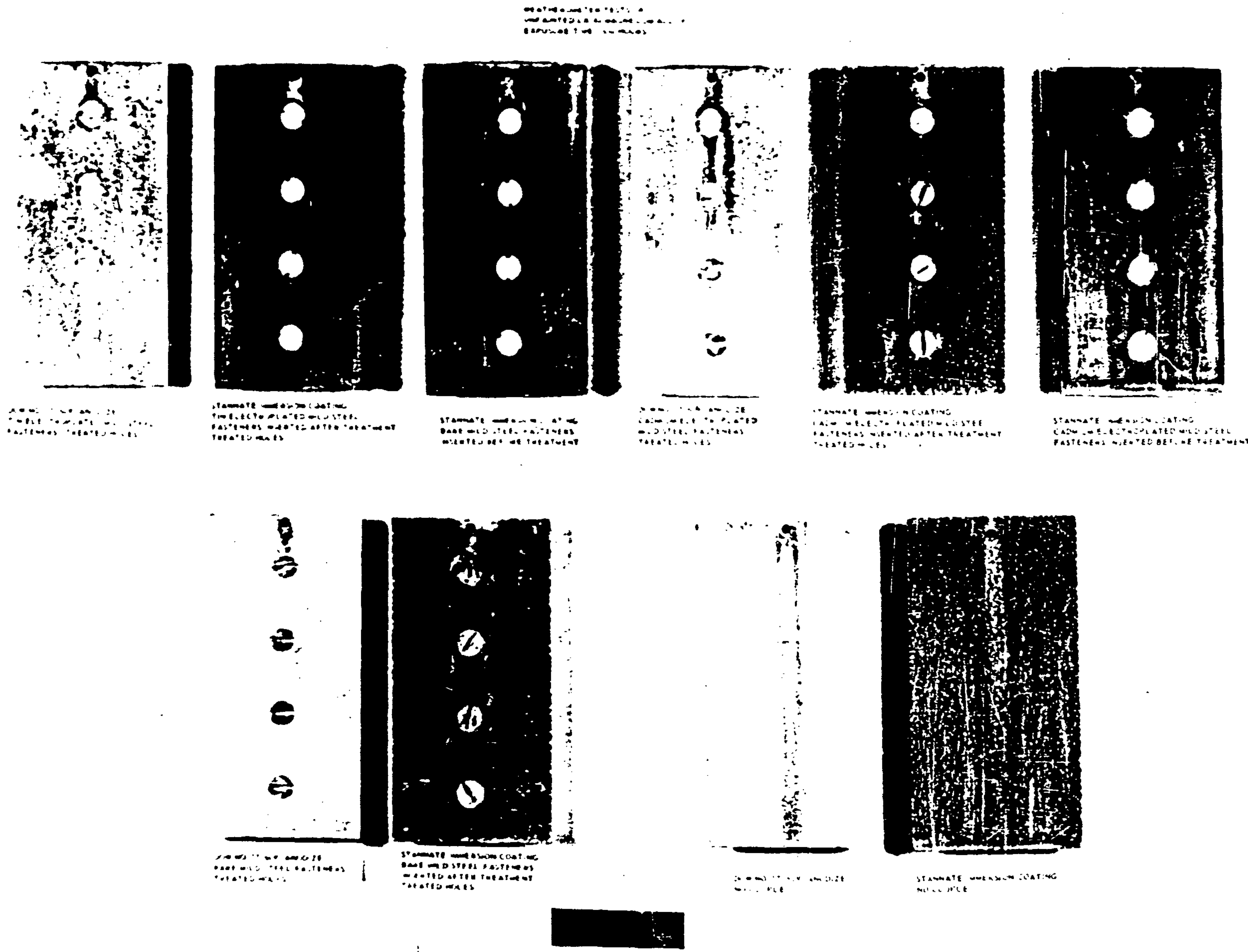


Figure 6

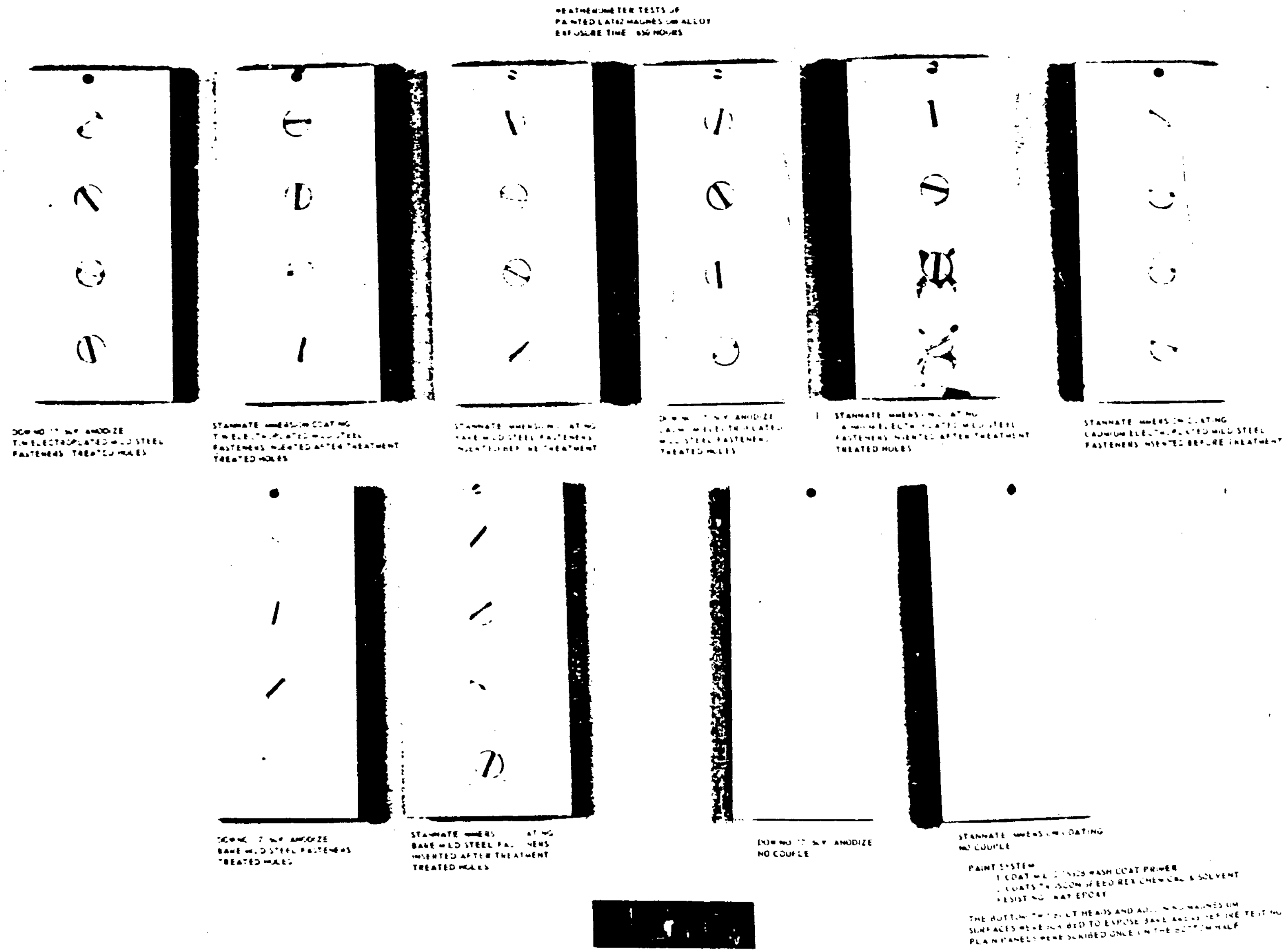


Figure 7

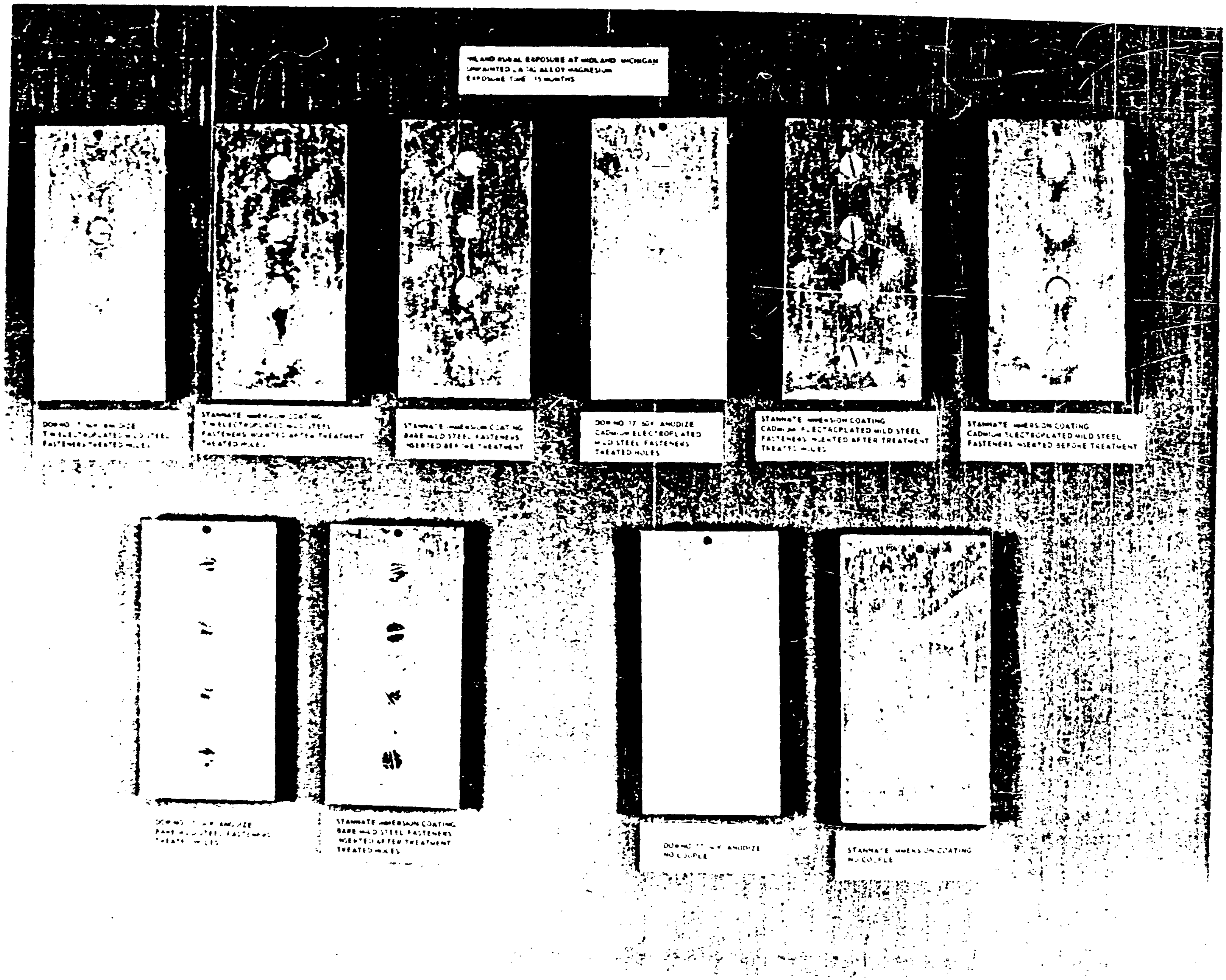

CADMIUM ELECTROPLATED
TREATED HOLES
STANNATE
CADMIUM ELECTROPLATED MILD STEEL
STANNATE
FASTENERS INSERTED BEFORE TREATMENT

Figure 8

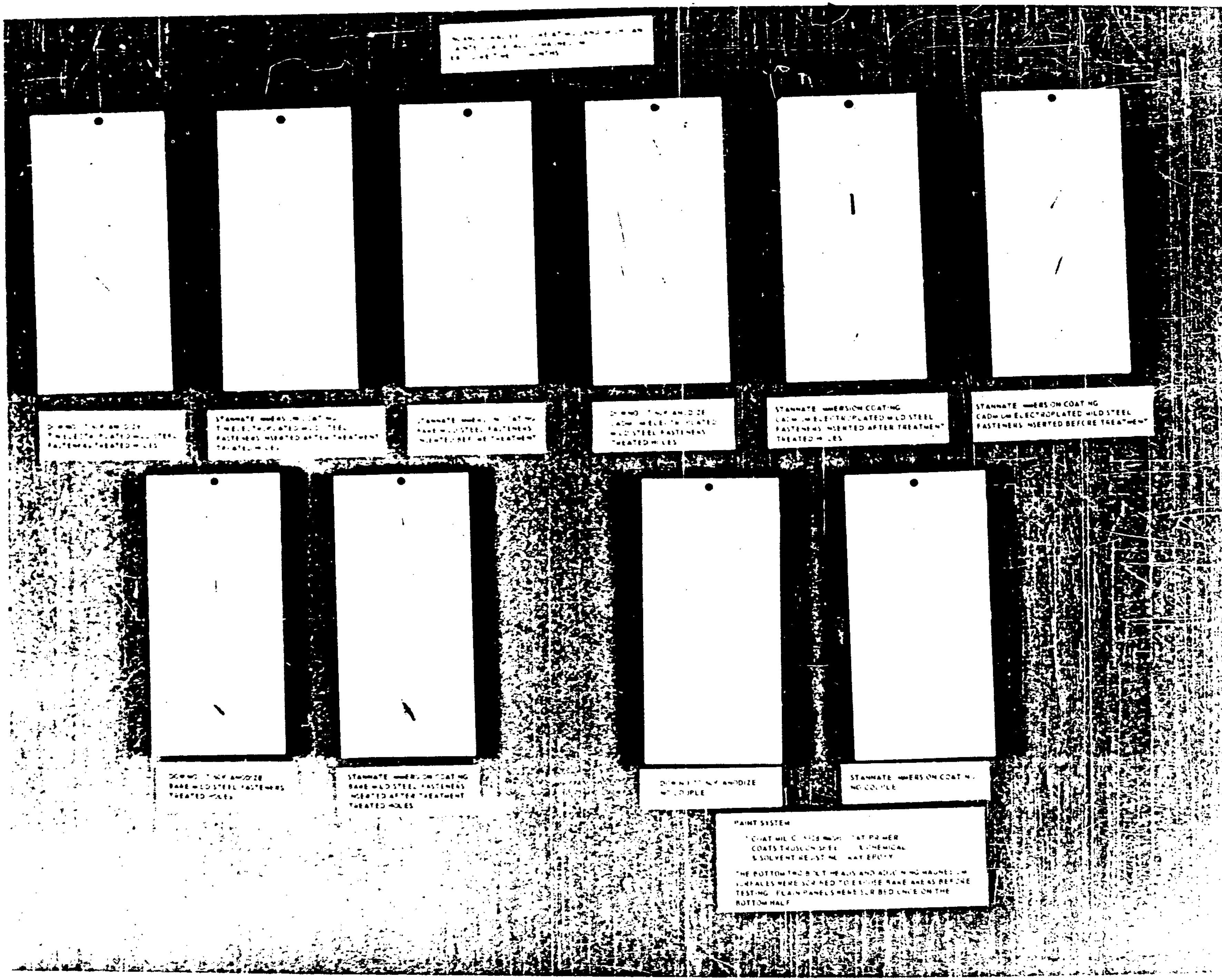
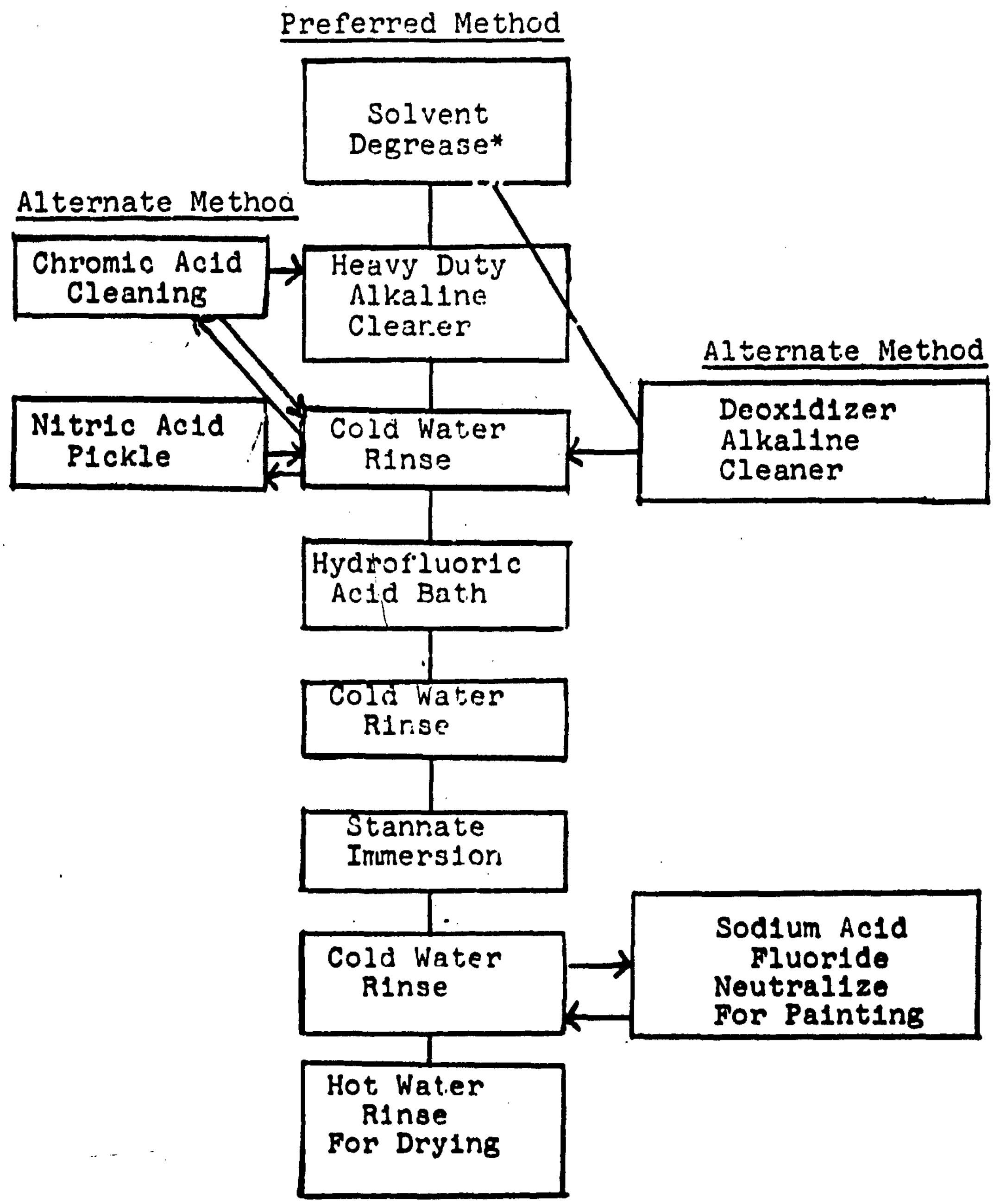


Figure 9



*Note: Solvent degreasing is necessary only to remove heavy oil and grease coatings before alkaline cleaning or can be used to replace heavy duty cleaner if carefully and thoroughly performed when the nitric acid or hydrofluoric acid pickle is to follow.

Figure 10

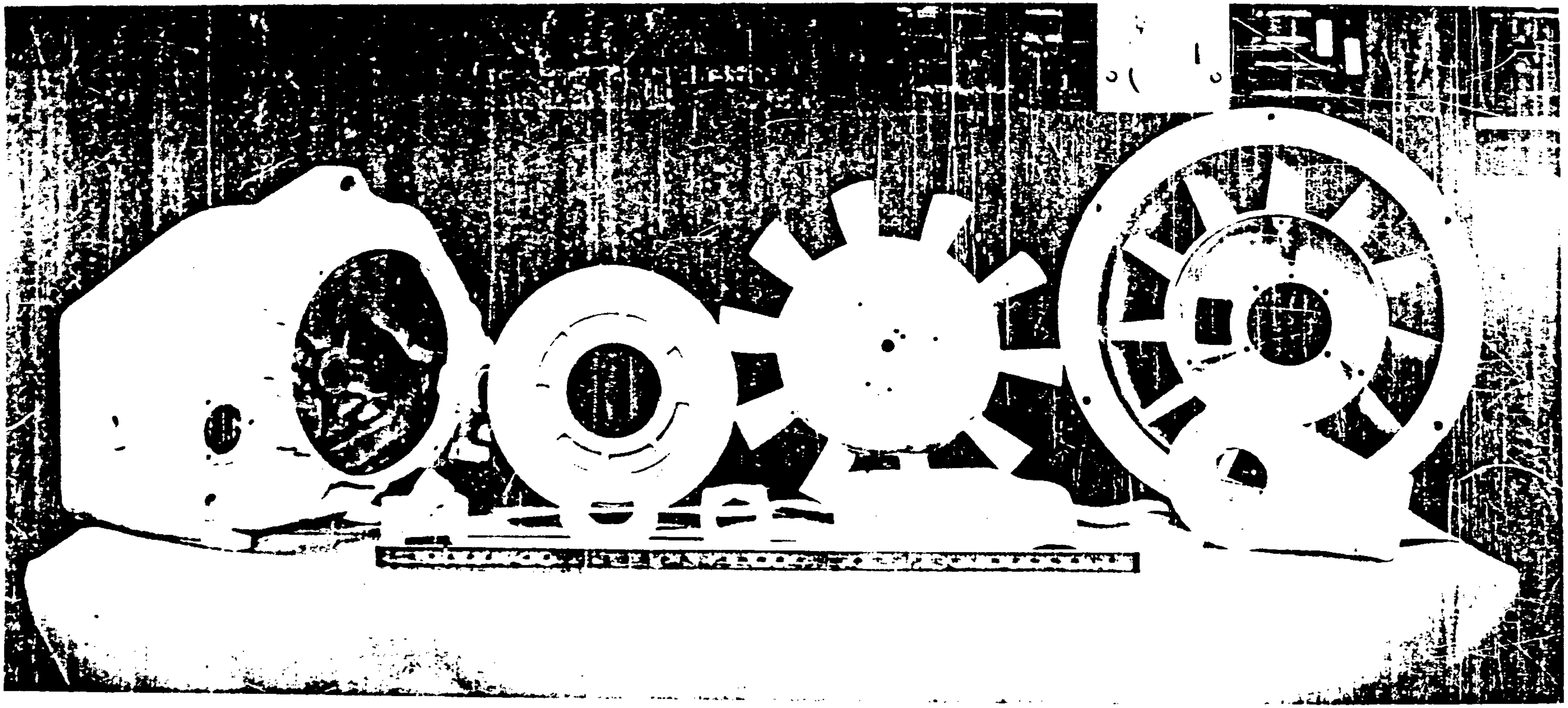


Figure 11

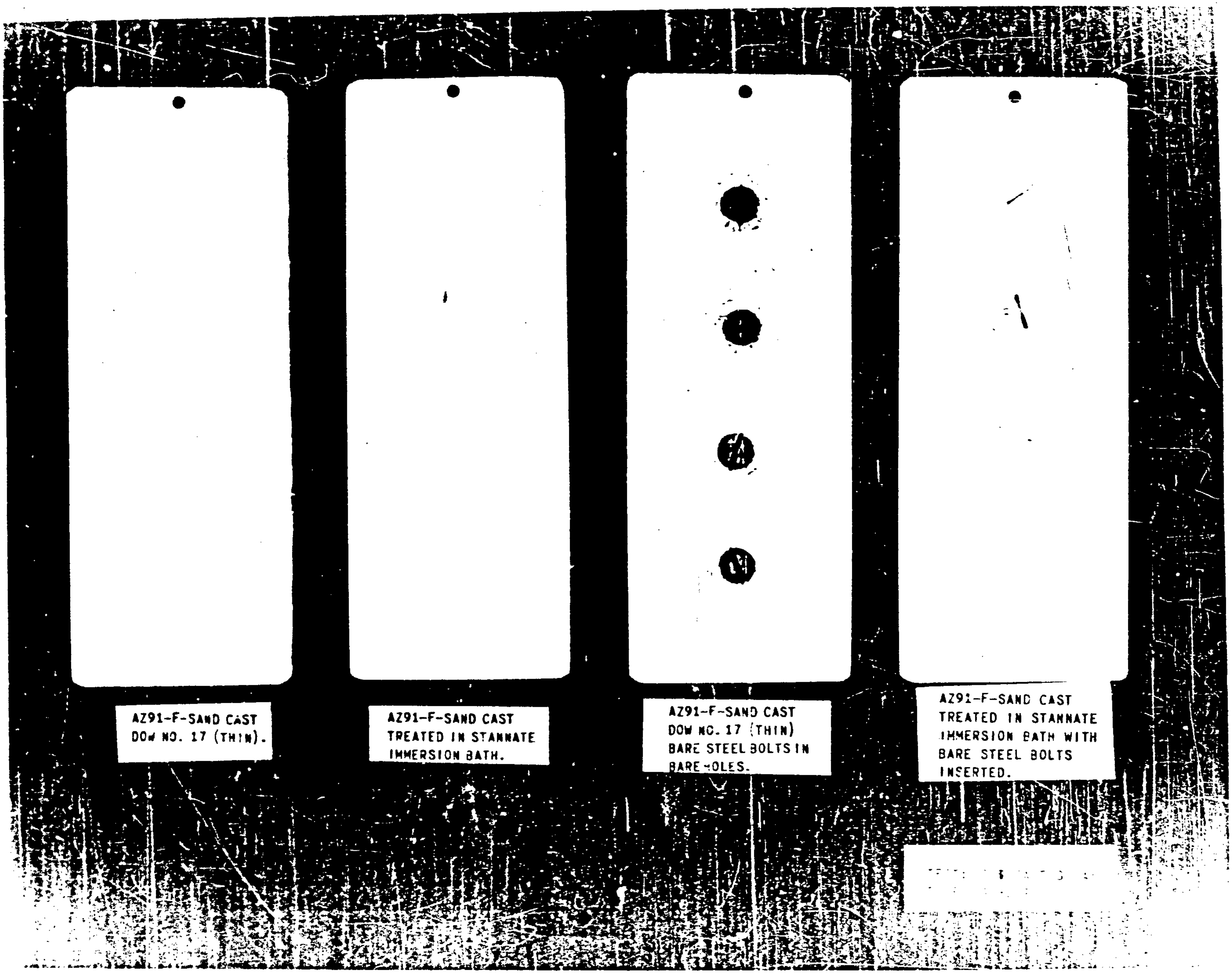

AZ91-F-SAND CAST DOW NO. 17 (THIN).
AZ91-F-SAND CAST TREATED IN STANNATE IMMERSION BATH.
AZ91-F-SAND CAST DOW NO. 17 (THIN) BARE STEEL BOLTS IN BARE HOLES.
AZ91-F-SAND CAST TREATED IN STANNATE IMMERSION BATH WITH BARE STEEL BOLTS INSERTED.

Figure 12

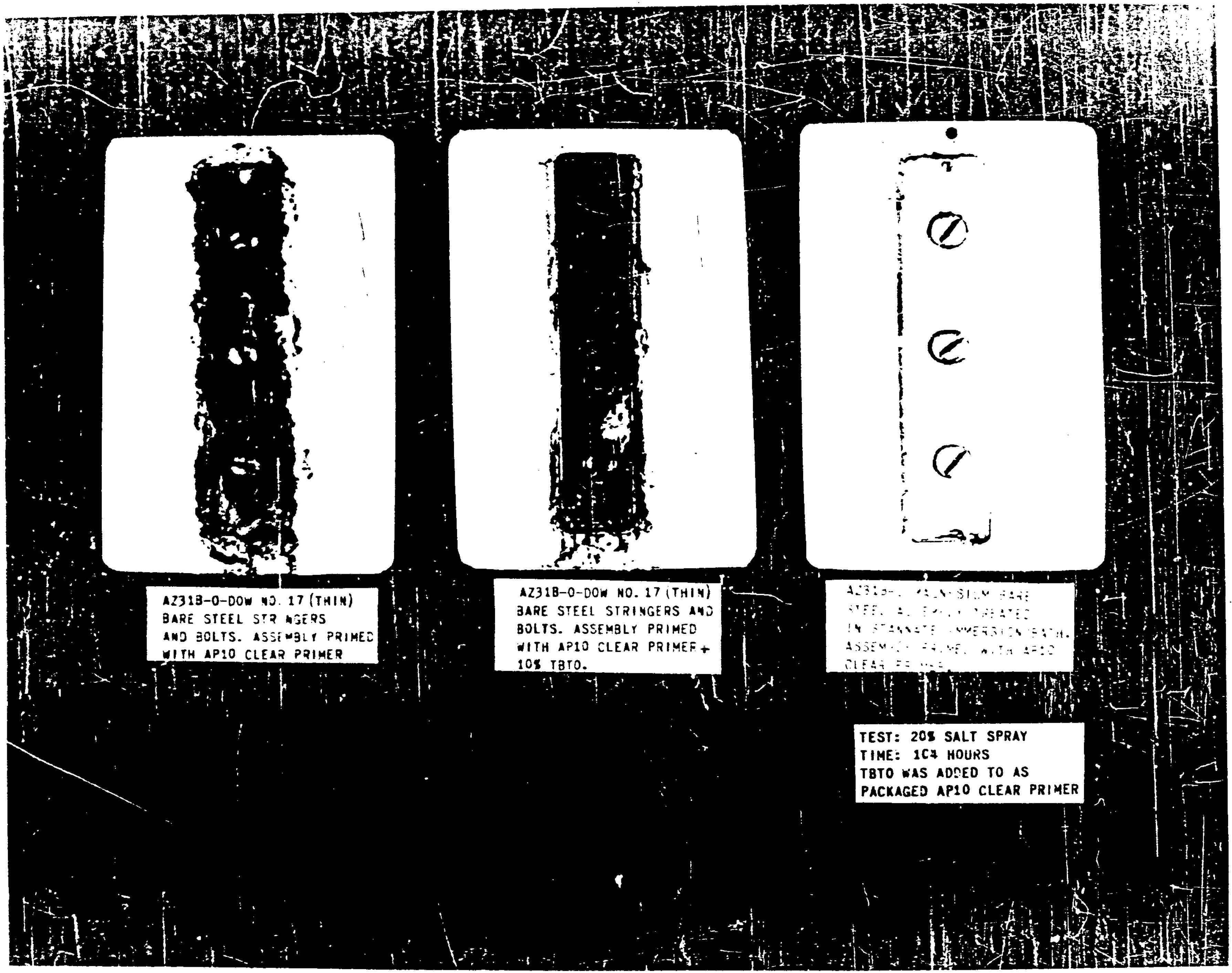

AZ31B-O-DOW NO. 17 (THIN)
BARE STEEL STR NGERS
AND BOLTS. ASSEMBLY PRIMED
WITH AP10 CLEAR PRIMER
AZ31B-O-DOW NO. 17 (THIN)
BARE STEEL STRINGERS AND
BOLTS. ASSEMBLY PRIMED
WITH AP10 CLEAR PRIMER +
10% TBTO.
TEST: 20% SALT SPRAY
TIME: 1C4 HOURS
TBTO WAS ADDED TO AS
PACKAGED AP10 CLEAR PRIMER

Figure 13

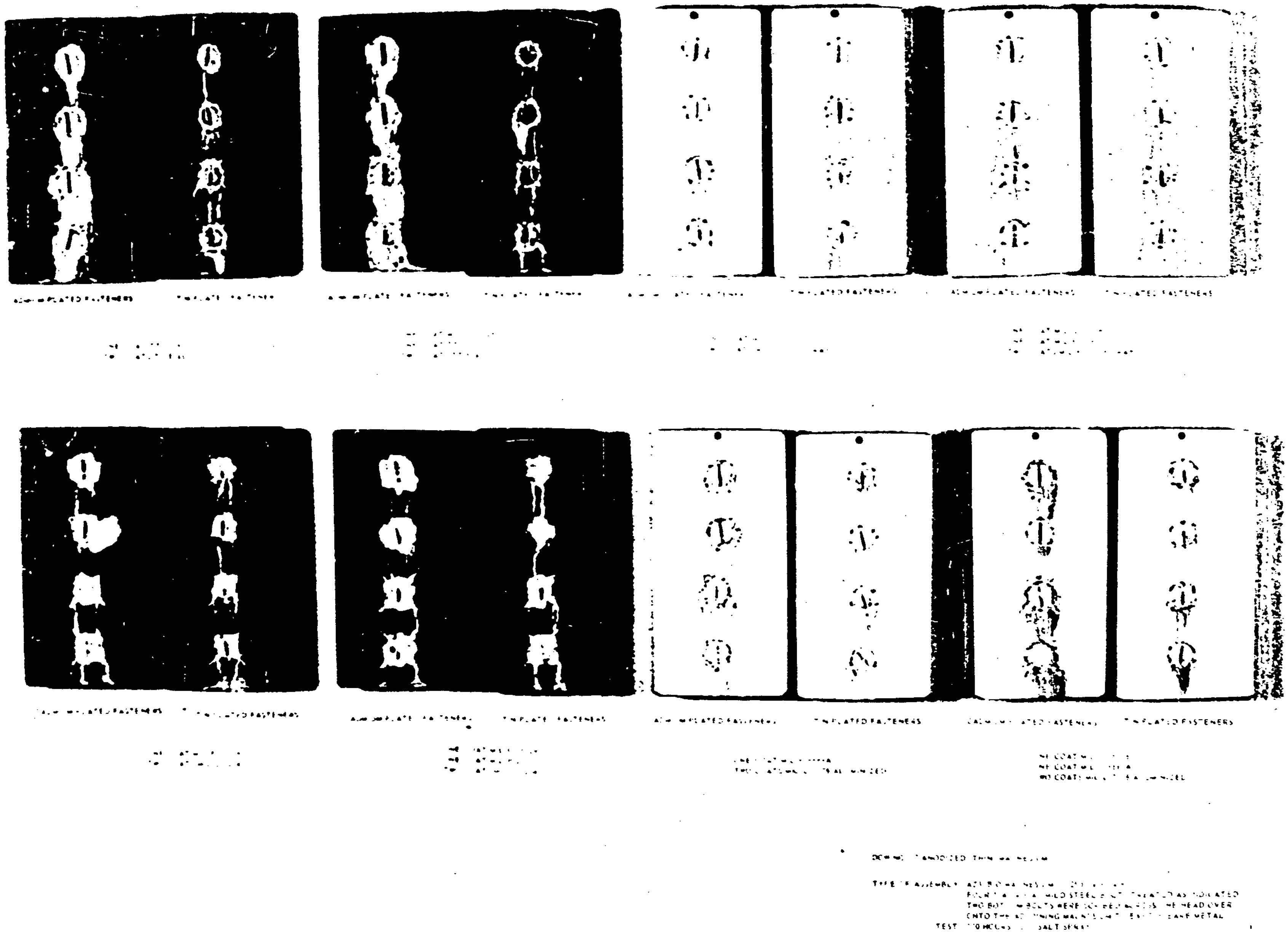


Fig. 14

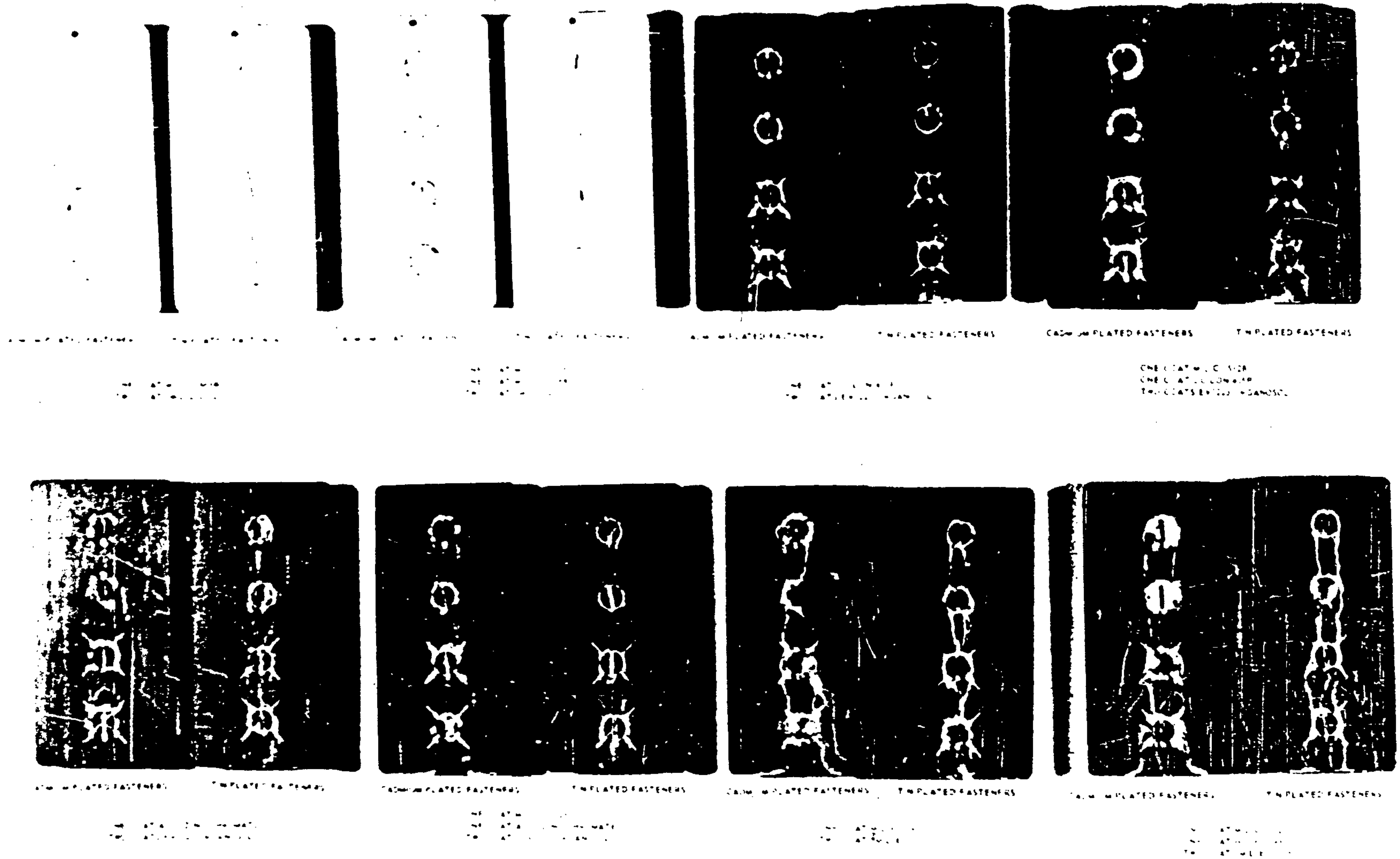


Fig. 15

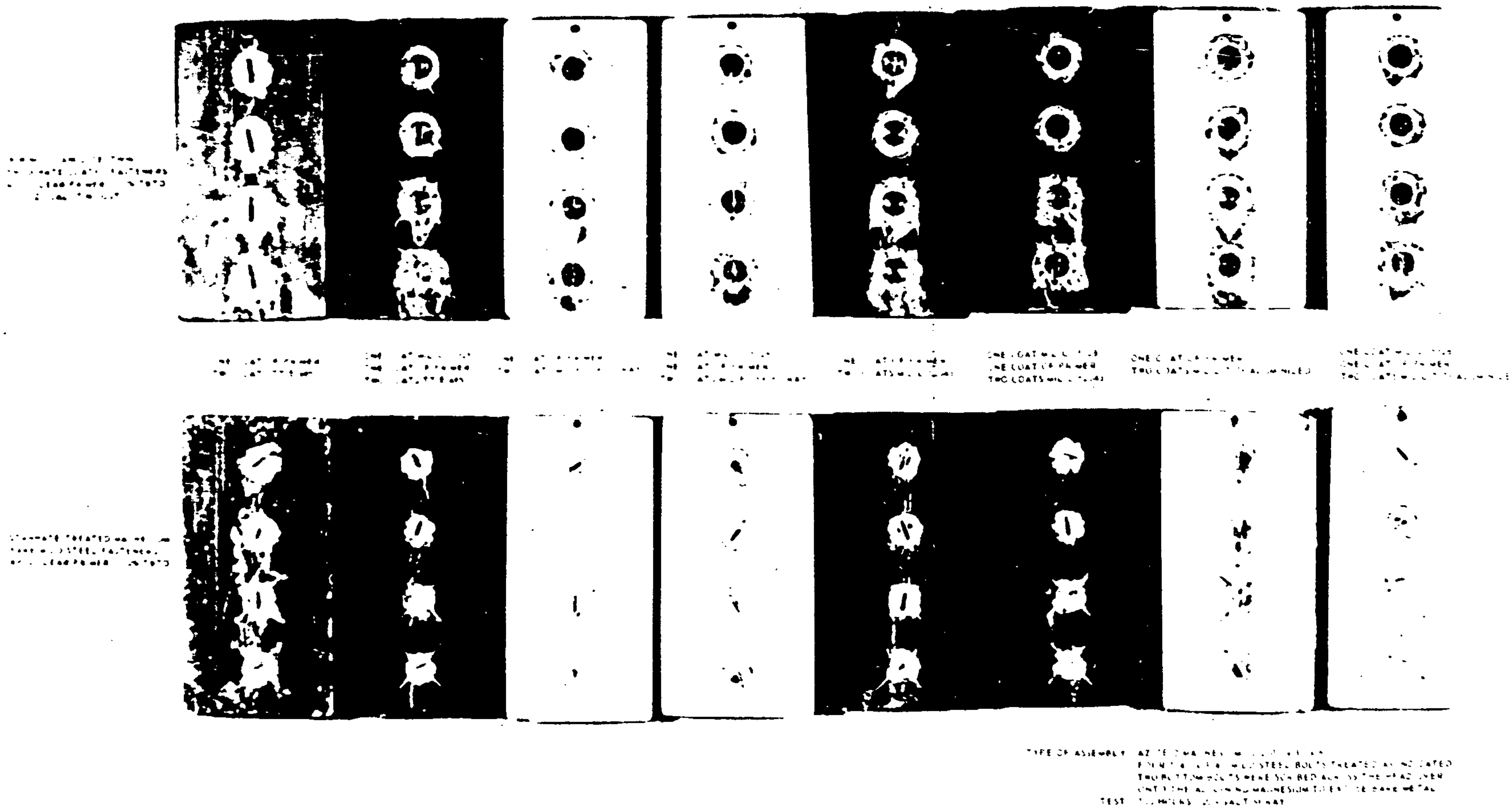


Fig. 16

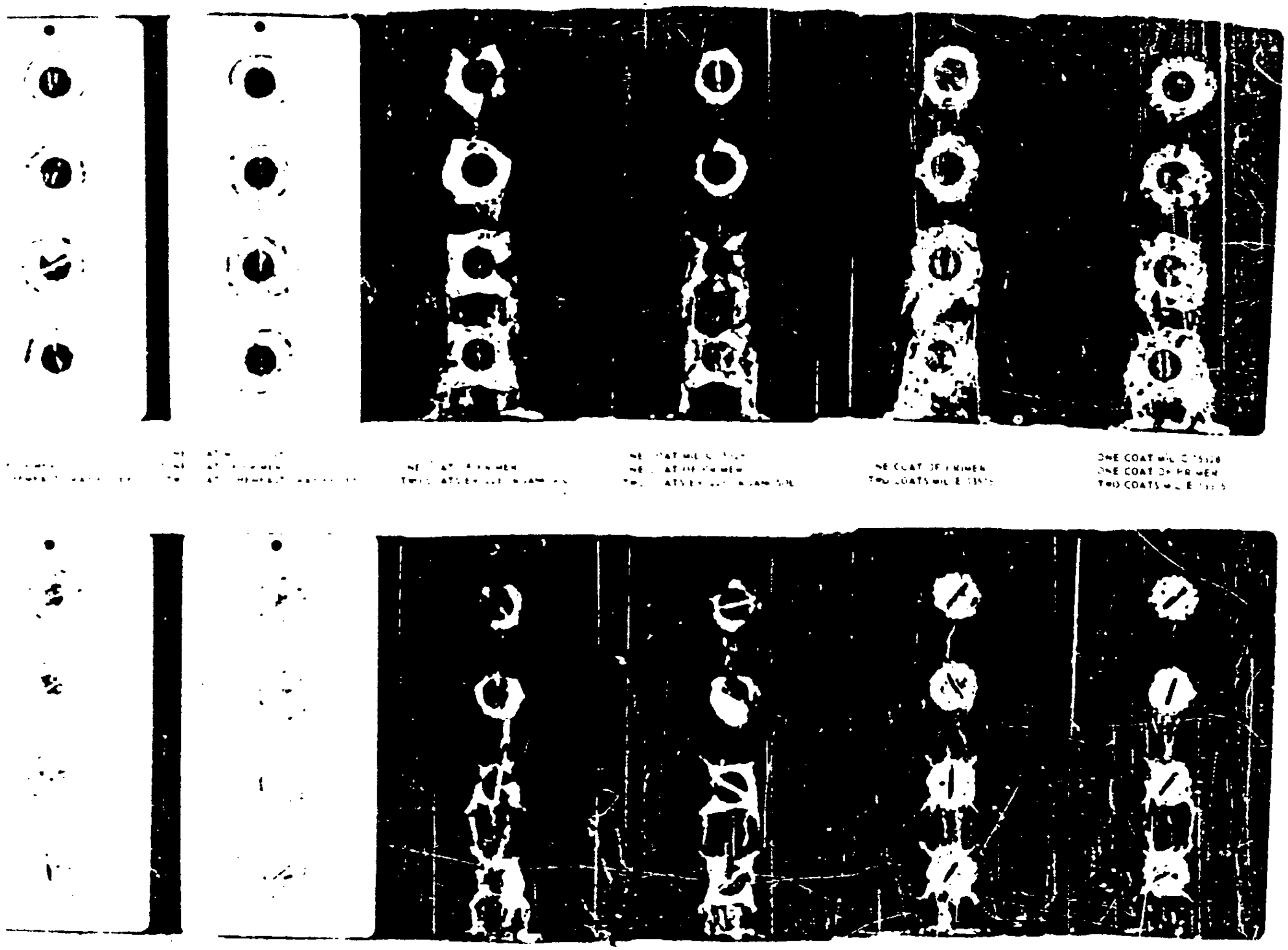


Fig. 17