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NRL Report 4435

THE PREVENTION OF CORROSION ON MAGNESIUM SHIPBORNE RADAR ANTENNAS

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November 16, 1954

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ABSTRACT

A suitable protective system for magnesium radar antennas has been selected by investigating the characteristics of a number of coatings and considering their ability to prevent corrosion by salt atmosphere, their ability to withstand heat, and the rf loss in the coatings. The HAE anodic treatment was observed to be an excellent paint base and to improve considerably the corrosion-preventing quality of any paint used over it. The best paint combination found for use in conjunction with the HAE coating consisted of a wash coat (MIL-P-15328) followed by zinc chromate prime (MIL-P-6889A) and aircraft gloss enamel (MIL-E-7729).

Cast and wrought panels bearing this system withstood 70 days exposure to salt fog and a temperature of 480°F. When the system was applied to the inside walls of magnesium waveguide, the rf attenuation was increased only 0.03 db/meter at X-band.

PROBLEM STATUS

This is a final report on this phase of the problem; work on other phases is continuing.

AUTHORIZATION

NRL Problem R02-02
Project NR 682-020 and NE 050-552-51
BuShips Problem S-1192

Manuscript submitted September 29, 1954

Throughout this report, MIL-P-15328 is used to indicate Woolsey's wash pretreatment; but the specification number now has been changed to MIL-C-15328A.

THE PREVENTION OF CORROSION ON MAGNESIUM SHIPBORNE RADAR ANTENNAS

INTRODUCTION

The recent approval by the Bureau of Ships of the use of magnesium for constructing a shipborne radar antenna has necessitated the study of suitable protective coatings for this material. Although exhaustive research^{1,2,3} has been conducted in selecting good finishes for the magnesium parts of Naval aircraft, none of these are suitable for radar use. Radar antennas have special requirements since in addition to providing adequate protection from salt spray and stack gas corrosion, the coating must have low rf loss. To determine the most suitable protective system for use on antennas, a series of panels were treated with various proprietary as well as experimental coatings. These were subjected to simulated stack gas and salt corrosion at the Industrial Test Laboratory of the Philadelphia Naval Shipyard. By applying these same coatings to the inside walls of magnesium waveguide, it was possible to measure the increase in rf attenuation caused by the particular coating.

PREPARATION OF TEST SAMPLES

Protective Systems

After the samples had been suitably precleaned, they were protected with a surface pretreatment followed by a paint finish. The paint combinations which were selected for test were those which previous information indicated to be the most promising. Several other combinations which appeared to merit investigation were eliminated in order to get all of the panels into the salt fog boxes in a single exposure run. Also, all protective systems which require baking were ruled out since many antenna parts are so large that this operation is not feasible. The surface pretreatments used are listed in Table 1 and the paint combinations are listed in Table 2.

Panels

Since any large radar antenna consists of both cast and wrought parts, half of the panels were cast and the remainder were cut from rolled sheets. It is well known that the porous nature of cast metal makes it vulnerable to latent corrosion and, therefore, more

¹Freriks, R., Arndt, F., and Suther, H. A., "Anti-Corrosive Coatings for Magnesium - I- Salt Spray Resistance," NRL Report P-2835, May 1946

²Cowling, J. E., Freriks, R., and Suther, H. A., "Anti-Corrosive Coatings for Magnesium - II- Tide Level Resistance," NRL Report P-3012, December 10, 1946

³Seagrave, H. J. E., "Anti-Corrosive Coatings for Magnesium - III," NRL Report C-3393, December 7, 1948

TABLE 1
Surface Pretreatments

Type	Thickness (in.)	Jobber †
Dow No. 7 (Dichromate) Chemical Coating	0.0001	(1)
Manodyz (ac process) Anodic Coating*	0.0040	(2)
Dow No. 17, Anodic Coating	0.0012-0.0015	(3)
HAE, Anodic Coating	0.0010-0.0012	(4)

*also known as the Simpson-Cutter or Consolidated-Vultee
No. 1 Process

†see Appendix A

TABLE 2
Paint Finishes

Paint Finishes	No. of Coats	Total Thickness (in.)	Jobber †
Woolsey's Wash Coat, Spec: MIL-P-15328, thinned 1:1 with ethanol	1	0.0003-0.0005	(1)
Zinc Chromate Prime, Spec: MIL-P-6889A	1	0.0007-0.001	
Aircraft-Gloss Enamel, Formula 623, Spec: MIL-E-7729 Sea Blue pigmentation, Type II	2	0.002	
Woolsey's Wash Coat, Spec: MIL-P-15328, thinned 1:1 with ethanol	1	0.0003-0.0005	(1)
Vinyl Prime, Formula 120, Spec: MIL-P-15930	1	0.0007-0.001	
Vinyl-Alkyd Topcoat, Formula 122-17, Spec: MIL-P-15934	2	0.002	
Amercoat No. 32, applied according to manufacturer's specifications			(5)
Amercoat No. 23, applied according to manufacturer's specifications			(5)
Ucilon Primer No. 405-P Ucilon Topcoat No. 400-10 Both applied according to manufacturer's specifications			(6)
Stanley Primer No. 40X64	1		(7)
Stanley Gloss Enamel Topcoat	2	0.002	
Both applied according to manufacturer's specification			
Zinc Chromate, Spec: MIL-P-6889A	1	0.0007-0.001	(1)
Outside Haze Gray Paint, Formula 27, Spec: MIL-P-15130	2	0.002	

†see Appendix A

difficult to protect than wrought metal. The 4 by 6 in. rectangular panels (Fig. 1) were cut from 1/16-in. thick rolled sheets of Dow alloy FS-1a and 1/4-in. thick cast sheets of Dow alloy HT-6. Since it is easier to avoid using dissimilar metals with magnesium than it is to prevent the resultant galvanic corrosion, no rivets or washers of other metals were attached to the panels.

Various combinations of the four surface pretreatments and seven paint finishes were applied to both cast and rolled panels. For each of the 24 resulting protective systems 6 cast panels were made, of which 2 were scored with a single scratch through the paint and into the metal, 2 were left unscored, and 2 were held in reserve for later use in the stack gas corrosion study. A similar set of panels was made up from rolled stock. The purpose of scoring the panels was to indicate what protection could be expected when a break in the finish occurred due to mechanical damage, and also to indicate the degree of protection which could be obtained at corners, edges, and other areas which are difficult to coat. The edges of the panels were not banded with heavy enamel as is customary, but an effort was made to maintain a coating of uniform thickness at these points. All edges of the panels were rounded prior to painting.

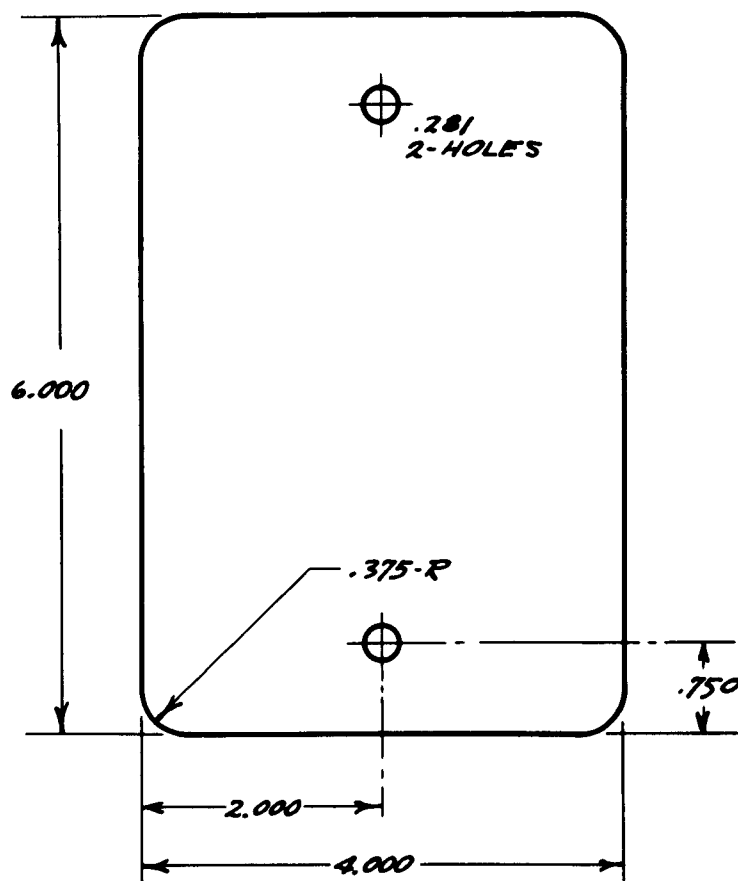


Fig. 1 - Design of panels

Waveguides

Lengths of magnesium waveguide, with outside dimensions of 1-1/4 by 5/8 in. and 0.0064 in. wall thickness, were coated with the same protective systems as the panels in order to measure the increase in rf loss due to the coatings. A special technique which had been developed by J. E. Cowling of the Naval Research Laboratory Chemistry Division was found to deposit a smooth, thin, even coat of paint on the inside walls of the waveguide.⁴ The procedure was to fill the guide completely with the paint and drain it out at a controlled rate. The length of waveguide to be painted was mounted upright and sealed at one end with a blank flange connector (Fig. 2). A hole of specific size which has been drilled through the connector was temporarily taped shut. After the paint had been poured into the guide and an air regulator had been attached at the top, the tape was removed and air pressure was applied in order to drain the guide at a rate of two to six inches of length per minute. The thickness of the film of paint adhering to the walls of the waveguide was found to increase with the drain rate. By catching the paint in a calibrated container, the rate of flow could be determined. After all of the paint had been drained, the air inside the waveguide was observed to be saturated with volatilized solvents and thinners from

the paint. This condition prevented the paint from drying and it was necessary to remove the blank flange and blow out the waveguide with a slow stream of air in order to avoid creeping of the paint. Table 3 lists the diameter of the drain orifice for various sizes of waveguide as determined by the Tobe Deutschmann Corporation, Canton, Massachusetts, consultants to the Bureau of Ships. It was determined at the Naval Research Laboratory, however, that holes smaller than 1/32 inch in diameter tended to clog with the paint. Good results were obtained when the paint was drained from the RG-51/U waveguide through a 1/32-in. diameter orifice.

The samples used for the purpose of checking the rf loss in 1-1/4 by 5/8 in. waveguide were made 35.02 in. long in order to be 23 λ g at a wavelength of 3.2 cm. When 2 psig of air pressure was applied, the 10-3/4 fluid ounces of paint in the filled guide drained out in eight minutes. The viscosity of all paints used ranged from 60 to 70 Krebs-Stormer units. For very long waveguides, it is necessary to increase the air pressure as the height of the paint column decreases in order to maintain an even flow from the guide.

Radar Reflector Section

It was believed that any protective system which is applied to the surfaces of a radar antenna would be most vulnerable to damage at the reflecting screen if this unit were of open-type construction. To test this theory, two sections of a typical radar reflector were constructed by stringing 12-in. lengths of 1/4-in. diameter magnesium tubing, spaced 9/16 in. on centers, through holes in magnesium bars 12 in. long. Each section (Fig. 3) was treated with the vinyl system without benefit of a surface pretreatment. One of the units was twisted and flexed many times prior to exposure in order to set up any breakage in the protective film which could typically be anticipated. The other was kept undamaged as a control.

Fig. 2 - Waveguide-painting equipment

⁴The Electronics Installation Practice Manual," NAVSHIPS 900171, Change 2 (to be printed)

TABLE 3
Diameter of Waveguide
Drain Orifice

Waveguide	Orifice Diameter (in.)
RG-69/U	1/8
RG-104/U	1/16
RG-48/U	1/32
RG-49/U	1/32
RG-50/U	1/64
RG-51/U	1/64
RG-52/U	1/64
RG-91/U	1/34
RG-53/U	1/64

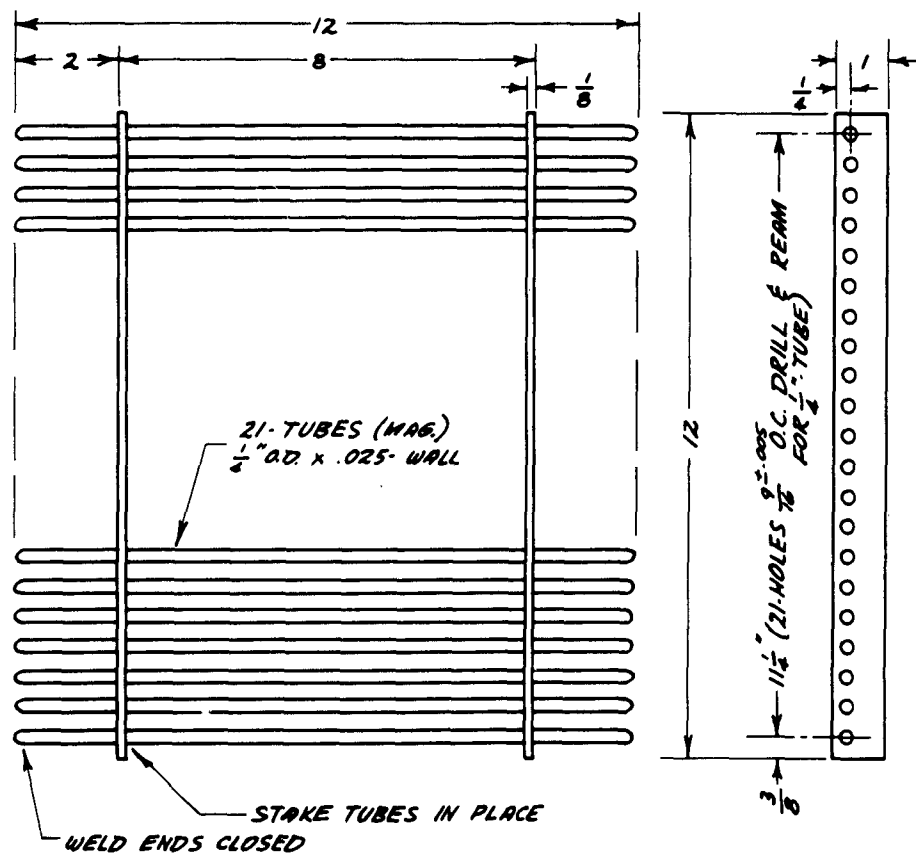


Fig. 3 - Design of reflector sections

SALT SPRAY EXPOSURE

Panels

The panels were exposed to salt fog at the Industrial Test Laboratory of the Philadelphia Naval Shipyard in accordance with method 601.1 as outlined in Federal Specification TT-P-141b. They were mounted at an angle of 15 degrees from the vertical in boxes which

maintained a 4 percent sodium chloride fog at a temperature of 96° F. This angle facilitates condensation and the condensate runs down the face of the panel, thereby causing significantly more film breakdown and corrosion on the face than on the back of the panel. The samples were moved periodically from front to back in order to assure all panels being in the vicinity of the fog atomizers for the same period of time. All materials under test were marked with a code designation in a manner which did not disclose their identity to the persons performing the test. During the course of exposure, the panels were examined daily and notes made on the progress of corrosion. When a panel had corroded to the point of disintegration, it was removed from the box to avoid clogging the drainage system. After 70 days of continuous exposure the test was concluded and the panels were photographed (Figs. 4, 5, 6, and 7).

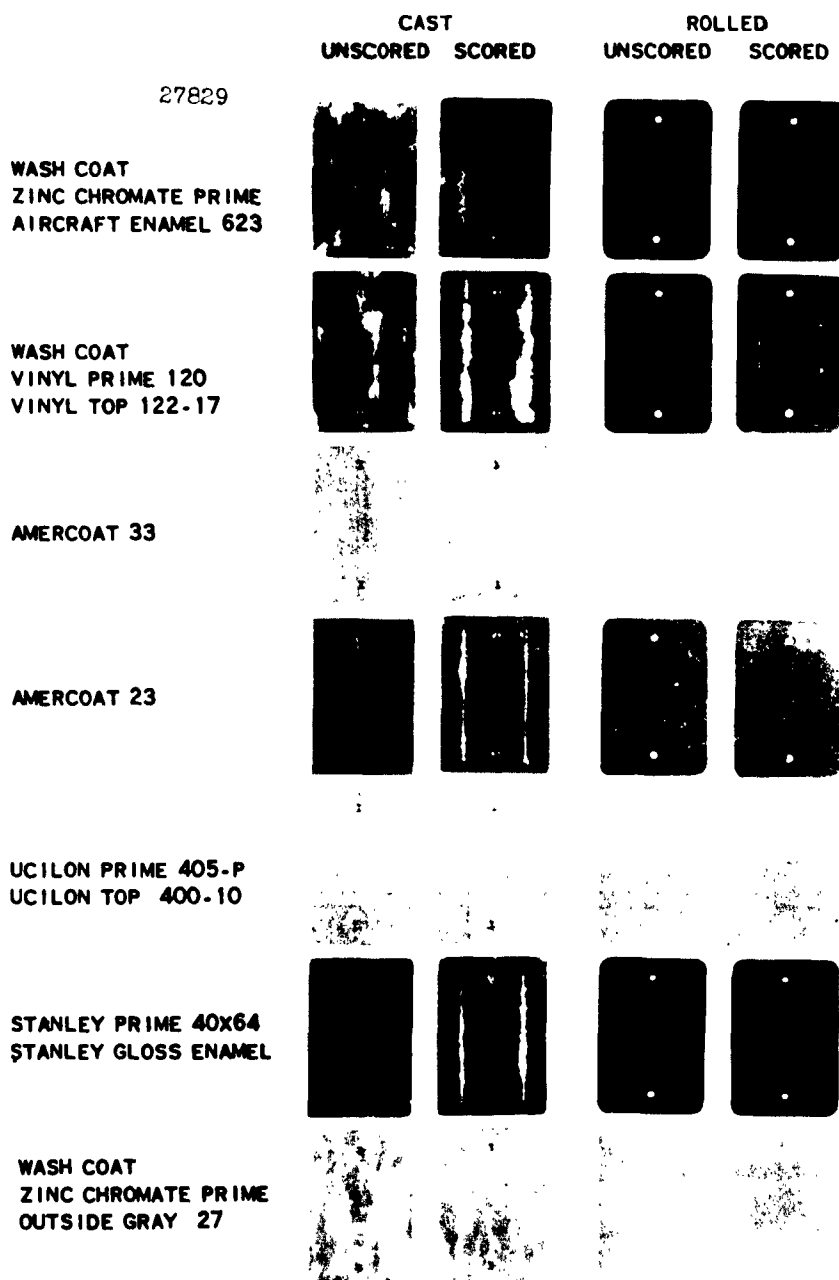


Fig. 4 - Corrosion effects on panels pretreated with Dow 7 after 70 days of salt fog exposure

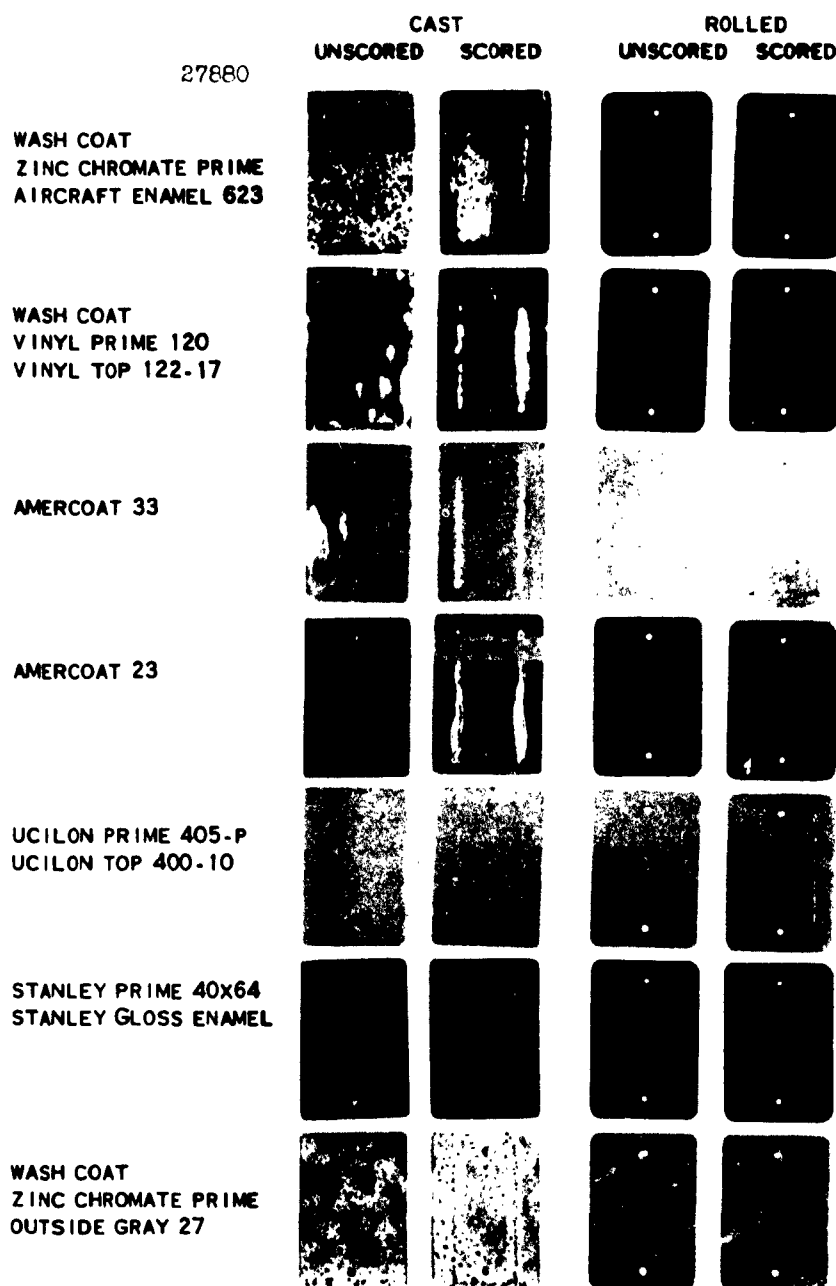


Fig. 5 - Corrosion effects on panels pretreated with Manodysz after 70 days of salt fog exposure

The panels deteriorated by the process of corrosion or by the process of blistering, or by combinations of both. The bar graph in Fig. 8* shows the extent of deterioration after 70 days. A value of zero on the graph represents no deterioration and is plotted to a height of 0.4 in order to make the bars visible. Table 4 describes the panel conditions represented in Fig. 8. A comparative listing of all of the protective systems which were tested is given in Table 5 where system number one is the best from a salt corrosion

*Based on a description in the Naval Industrial Test Laboratory final report to BuShips, Code 322, on test No. 5199, dated February 25, 1953

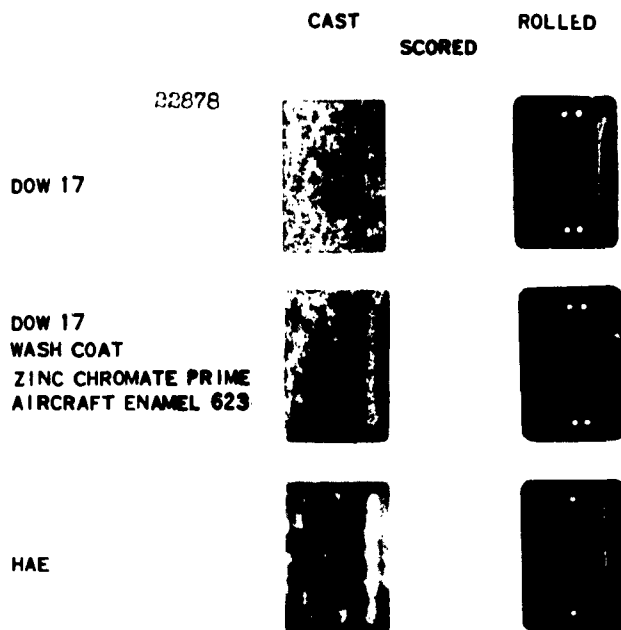


Fig. 6 - Corrosion effects on panels pretreated with Dow 17 and HAE after 70 days of salt fog exposure

prevention standpoint. It can be seen that the HAE treated panels were significantly better than panels bearing other pretreatments regardless of the paint finish used.

Radar Reflector Section

After 70 days of exposure to salt fog neither of the reflector sections showed significant corrosion at the junctions where the parallel tubes were inserted into the frame bars. They had both corroded, however, at the ends of the tubes where Heliarc welding had been used to seal them after spinning the ends shut. It is believed that the ends of the tubes were imperfectly sealed and that condensate seeped into the tubes where it was trapped and there set up latent corrosion. The flexed section, after exposure, is shown in Fig. 9.

CYCLIC HEAT-SALT EXPOSURE

Shipborne radar antennas are subjected to corrosion by the exhaust gases from the ship's stacks in addition to the salt atmosphere. Almost nothing has been written about the composition of stack gases, owing partly to the fact that the continual improvement in fuel oil refinement techniques results in better combustion, and consequently the composition of the exhaust wastes is constantly changing. Moreover, fleet units of destroyer size and larger all burn Navy Special Fuel Oil which is a bunker-grade residual product varying in composition from day to day at the refineries. When this material is mixed together in bulk storage it loses all identity. The main components of this oil are carbon and hydrogen with three to four percent of sulphur and a trace of phosphorus and ash. The composition of stack waste also varies depending on whether the vessel is under forced draught, or whether excessive air is being pumped into the stacks to eliminate smoke. Normally, the wastes consist of sulphur dioxide, sulphur trioxide, hydrogen sulphide (in a limited amount), carbon monoxide, carbon dioxide, colloidal carbon, various phenol derivatives, hydrochloric acid, hydrochlorous acid, and chlorine. The last three result from the fact that empty

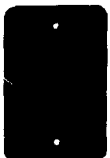
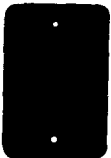
	CAST		ROLLED	
	UNSCORED	SCORED	UNSCORED	SCORED
27877				
WASH COAT ZINC CHROMATE PRIME AIRCRAFT ENAMEL 623				
WASH COAT VINYL PRIME 120 VINYL TOF 122-17				
AMERCOAT 33				
AMERCOAT 23				
UCILON PRIME 405-P UCILON TOP 400-10				
STANLEY PRIME 40x64 STANLEY GLOSS ENAMEL				
WASH COAT ZINC CHROMATE PRIME OUTSIDE GRAY 27				

Fig. 7 - Corrosion effects on panels pretreated with HAE
after 70 days of salt fog exposure

fuel tanks are ballasted with sea water, some of which remains in the tanks after refueling and is pumped into the combustion chambers. The most corrosive components of stack waste are sulphur trioxide and the traces of acids; however, stack gas disperses so rapidly that the concentration of these would be low in the vicinity of a radar antenna. No attempt was made to compound this mixture of materials for a stack gas corrosion test. Instead, it was believed that the heat from the stacks would cause the most damage to any protective system which had been applied to an antenna.

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TABLE 4
Explanation of Deterioration After
70 Days of Salt Fog Exposure
As Reported in Fig. 8

Deterioration Index No.	Extent of Corrosion and/or	Extent of Blistering
0	None	None
1	One spot of corrosion	Pimpling
2	Spots of corrosion at score	Few blisters at score
3	Spots of corrosion at edge or at hole	Few blisters at edge or at hole
4	Slight corrosion	Slight blistering
5	Corrosion at edge or hole	Blistering at edge or hole
6	Over-all corrosion	Over-all blistering
7	Bad corrosion at edge or hole	Bad blistering at edge or hole
8	Bad over-all corrosion	Bad over-all blistering
9		
10	Start of disintegration	
11		
12	Removed from test in 53 days	
13		
14	Removed from test in 30 days	
15	Removed from test in 23 days	
16	Removed from test in 17 days	
17		
18	Removed from test in 10 days	
19		
20	Removed from test in 3 days	

TABLE 5
Comparative Evaluation of Protective Systems
After 70 Days Exposure to Salt Fog

Order of merit	Paint Finish
1	Aircraft Gloss Enamel Combination on HAE
2	Uclon Combination on HAE
3	Stanley Combination on HAE
4	Amercoat No. 33 on HAE
5	Vinyl Combination on HAE
6	Amercoat No. 23 on HAE
7	Outside Gray Paint Combination on HAE
8	Amercoat No. 23 on Dow 7
9	Stanley Combination on Dow 7
10	Aircraft Gloss Enamel Combination on Dow 7
11	Outside Gray Paint Combination on Dow 7
	HAE, unpainted and unwaxed
12	Aircraft Gloss Enamel Combination on Manodyz
	Aircraft Gloss Enamel Combination on Dow 17
13	Amercoat No. 33 on Manodyz
	Amercoat No. 23 on Manodyz
14	Uclon Combination on Manodyz
15	Uclon Combination on Dow 7
	Stanley Combination on Manodyz
16	Vinyl Combination on Dow 7
	Vinyl Combination on Manodyz
17	Amercoat No. 33 on Dow 7
18	Outside Gray Paint Combination on Manodyz
19	Dow 17, unpainted and unwaxed

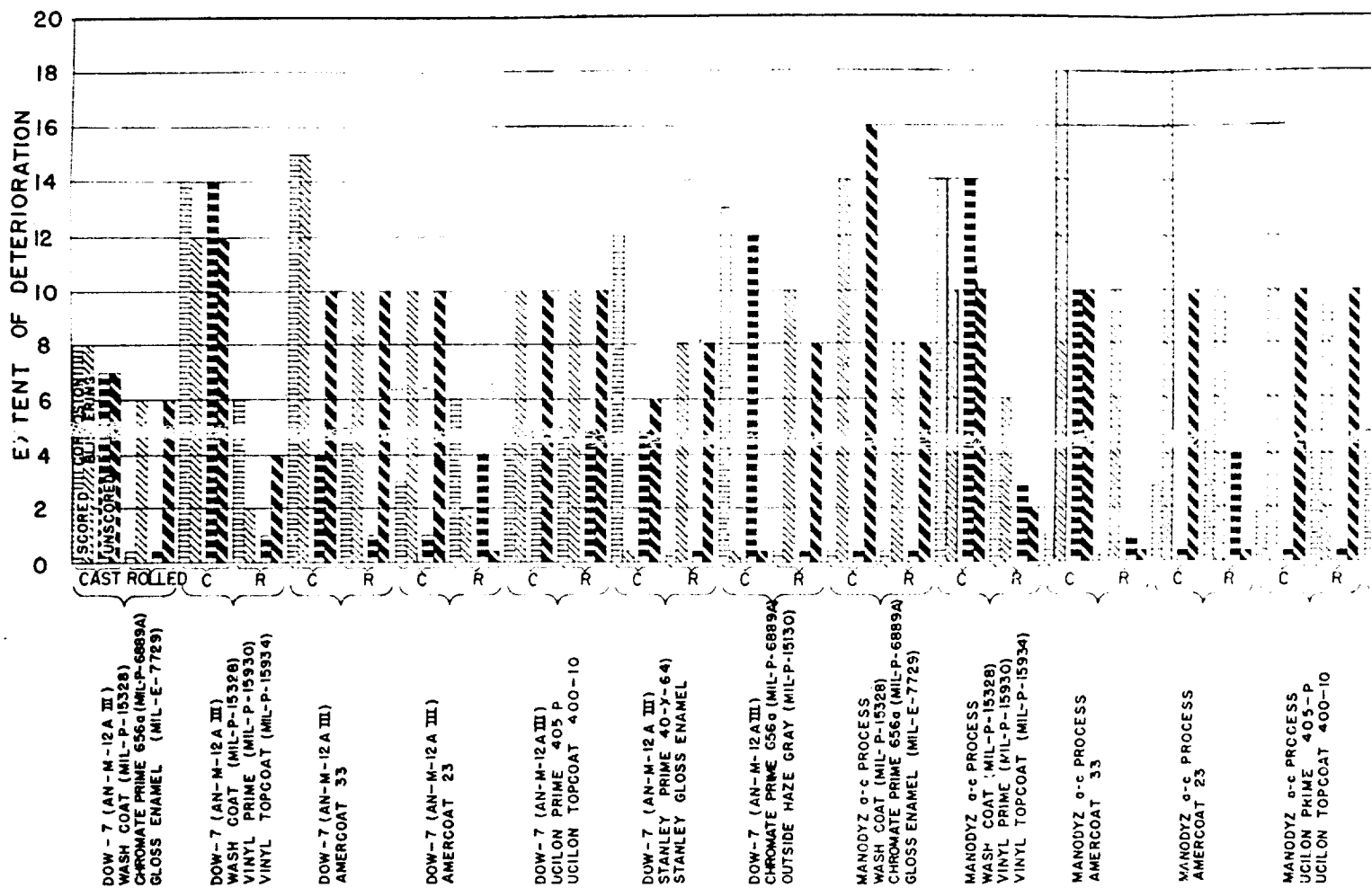
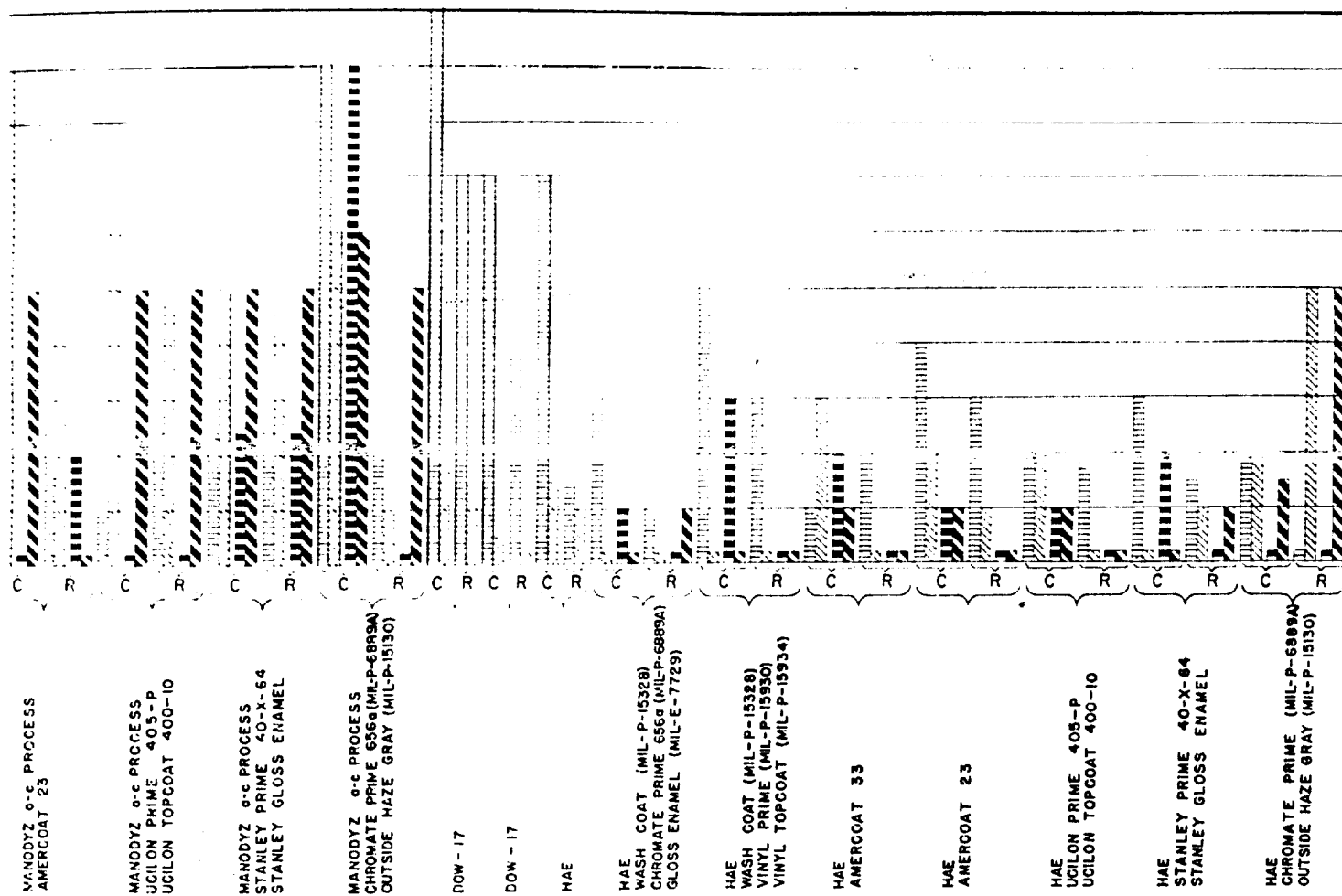


Fig. 8 - Extent of deterioration of panels after 70 days



of panels after 70 days of exposure to salt fog

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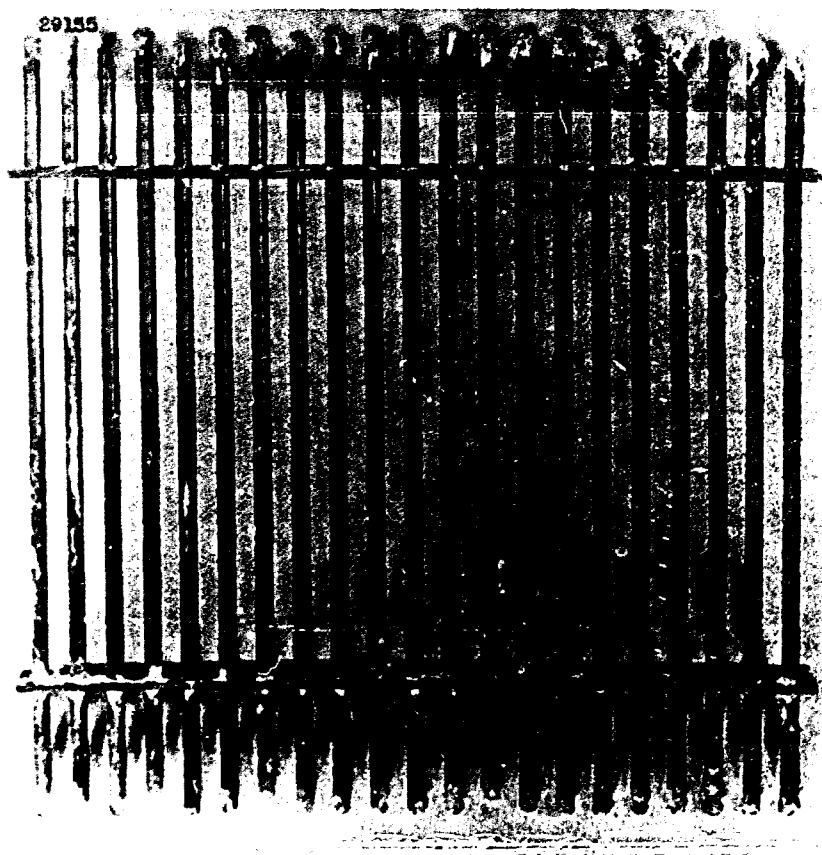


Fig. 9 - Flexed screen section after 70 days of exposure to salt fog (no pretreatment)

Owing to the variation of wind direction and ship's course, it is difficult to state what degree of heating could be anticipated on a radar antenna. It has been estimated that temperatures as high as 600° F could be anticipated on an antenna very near the stack. This condition would be far more destructive to a paint system than corrosive stack wastes. Therefore, it was decided to subject those panels which best withstood the salt fog exposure to an alternate heating and spraying test; the belief was that this would validly indicate the extent of damage which could be anticipated from the stack. Only panels which had been pretreated with the HAE process were submitted to this test since HAE-treated panels had been much superior to Dow 7, Dow 17, and Manodyzed panels in the salt fog test. Again both cast and rolled panels in the scored and unscored condition were used. The panels were exposed to a continuous temperature of 180° F for four hours and then sprayed with salt fog at 70° F for twenty hours. This procedure was repeated, elevating the temperature in 100-degree steps until 580° F had been reached. The condition of the panels following this test is described in Table 6. The protective systems are listed in the order of their ability to withstand heat in Table 7, where number one is the best coating. It can be seen that some of the coatings which stood up best in salt fog were not so successful when heat was applied. Some of the panels were withdrawn from the test ovens prior to 580° F (Fig. 10); other panels survived exposure to 580° F (Fig. 11).

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TABLE 6†
Description of Deterioration
After Cyclic Heat-Salt Exposure

Paint Finish (on HAE)	Exposure					
	4 hr at 180°F	4 hr at 280°F	4 hr at 380°F		4 hr at 480°F	4 hr at 580°F
	20 hr fog at 70° F	20 hr fog at 70° F		20 hr fog at 70° F	5 days fog at 70° F	
Aircraft Enamel (cast and rolled)	A	A	A	A	B	F
Vinyl (cast and rolled)	A	E	*			
Amercoat No. 33 (cast)	A	D	*			
Amercoat No. 33 (rolled)	A	A	A	E	*	
Ucilon (cast and rolled)	A	A	A	A	A	F
Stanley (cast and rolled)	A	A	C	*		
Legend: A - No failure C - Bad peeling E - Bad blistering, cracking, and corrosion B - Pimpling D - Blistering F - Very powdery film * Removed from test						

†from Naval Industrial Test Laboratory final report to BuShips, Code 322, on Test No. 5199, dated 25 February 1953

TABLE 7
Comparative Evaluation of Coatings
After Cyclic Heat-Salt Exposure

Order of Merit	Paint Finish
1	Ucilon Combination on HAE
2	Aircraft Gloss Enamel Combination on HAE
3	Amercoat No. 33 on HAE
4	Stanley Combination on HAE
5	Vinyl Combination on HAE

PLATED MAGNESIUM

Electroplating

It is well known that electroplated magnesium surfaces are porous and therefore analogous to castings since latent corrosion takes place in the pores. A process* has been developed which is intended to produce a smoother electroplated surface. The technique is to prepare the surface for plating by wet blasting with a colloidal suspension of talc in

*see Appendix A, No. (8)

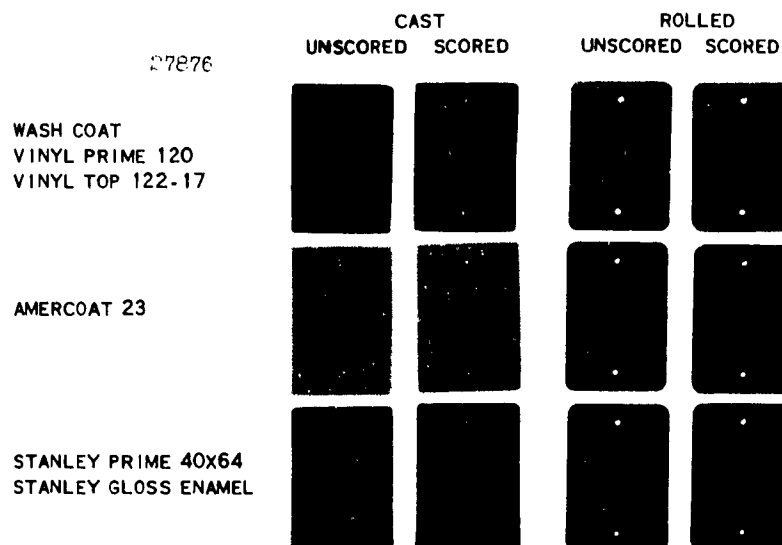


Fig. 10 - Panels removed from heat-salt test
prior to 580°F (HAE pretreatment)

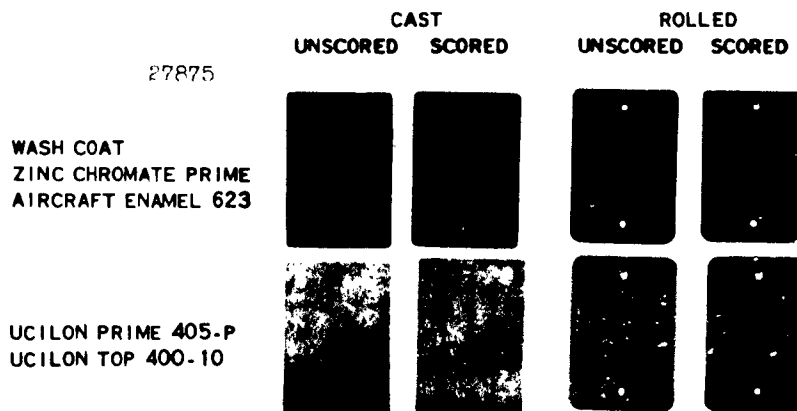


Fig. 11 - Panels surviving 580°F in heat-salt test
(HAE pretreatment)

water. When this process was used on magnesium panels, a mirror-like finish was obtained. Various metals were plated onto these specially smoothed surfaces in the normal manner. The metal coatings were copper on magnesium, zinc immersion plate, copper on zinc immersion plate, cadmium immersion plate, and copper on cadmium immersion plate. Immersion plating consists of reducing a metal from its salt with an agent such as sodium thiosulfate. The metallic ion which is reduced out adheres to the supercleaned surface of another metal in a complex manner. In the British process⁵ silver citrate, $\text{Ag}_3\text{C}_6\text{H}_5\text{O}_7$, was reduced with ammonia to form ammonium citrate, $(\text{NH}_4)_3\text{C}_6\text{H}_5\text{O}_7$, and to deposit the silver on the magnesium.

⁵Vivian, A. C., "The Immersion Silvering of Aluminum and Magnesium," Telecommunications Research Establishment, Report TN 44, September 6, 1949

The plating seemed to accelerate corrosion; all panels were removed from the salt fog boxes after only 18 hours because all of the coatings had deteriorated by this time. Before insertion in the salt fog boxes galvanic corrosion had begun on the magnesium-copper panel which was used as a control.

Laminating

Magnesium which has been clad with a thin layer of a noble metal has two advantages over electroplated magnesium: the resulting surfaces are smooth and coatings of uniform thickness can be obtained on the inside corners of waveguides. Panels* were clad with palladium, gold, and platinum, deposited under pressure at 550°C in one, two, and three coats. Although these panels stood up better in the salt fog boxes than did the electroplated panels, they had to be removed in five days because deterioration had begun.

RF ATTENUATION MEASUREMENTS

Purpose

Since a loss of just one decibel in antenna gain causes a 10 percent reduction in radar range, it is important that the loss due to the coating be kept at an absolute minimum. The need of a protective coating on the inside surfaces of an antenna is evidenced by the fact that extreme temperature variations, such as are experienced in the tropics and under other conditions, cause sealed internal areas of a radar antenna to "breathe" in salt air. Temperature differentials also cause condensation on internal walls which leads to corrosion. Although pressurizing reduces this hazard, the antenna designer must consider situations when the pressurizing equipment is stowed or out of order, and provide paint to retard the resultant corrosion. At microwave frequencies there will be some attenuation of the wave in any material which is added to the walls of areas through which the energy is conducted.

Procedure

The rf loss of all the coatings included in this investigation was determined by coating the inside walls of magnesium waveguides having the same cross-sectional dimensions as the RG-51/U, and applying the VSWR method. The first consideration was the selection of the equipment (Fig. 12). It was found that square-wave-modulated oscillators suffered from excessive FM which caused the VSWR minimum to be unnaturally high. A Sperry type SK-12 signal source was available and was used unmodulated with a type 2K39 klystron.

At first the tube was immersed in a temperature-regulating oil bath, but it was found that this arrangement was messy and did not stabilize the frequency any better than air cooling. A strong, steady signal was obtained which was 60 db above noise. The rf output of the probe in the slotted line was fed to a type TSX-4SE spectrum analyzer where a pulse, having an amplitude proportional to the rf voltage in the probe, could be seen on the cathode-ray tube. This analyzer is unique since the input contains a waveguide-beyond-cutoff attenuator which is linear in db beyond the fifteenth dial division. The spectrum analyzer was the best cw signal indicator available at the time of the experiment. By moving the probe of the slotted line to a position for minimum pip height, a minimum-voltage point in the line was found; the pip was adjusted by means of the calibrated attenuator to a convenient height. The length selected for the shorted waveguide section was an odd multiple of $\lambda_g/4$.

*see Appendix A., No. (9)

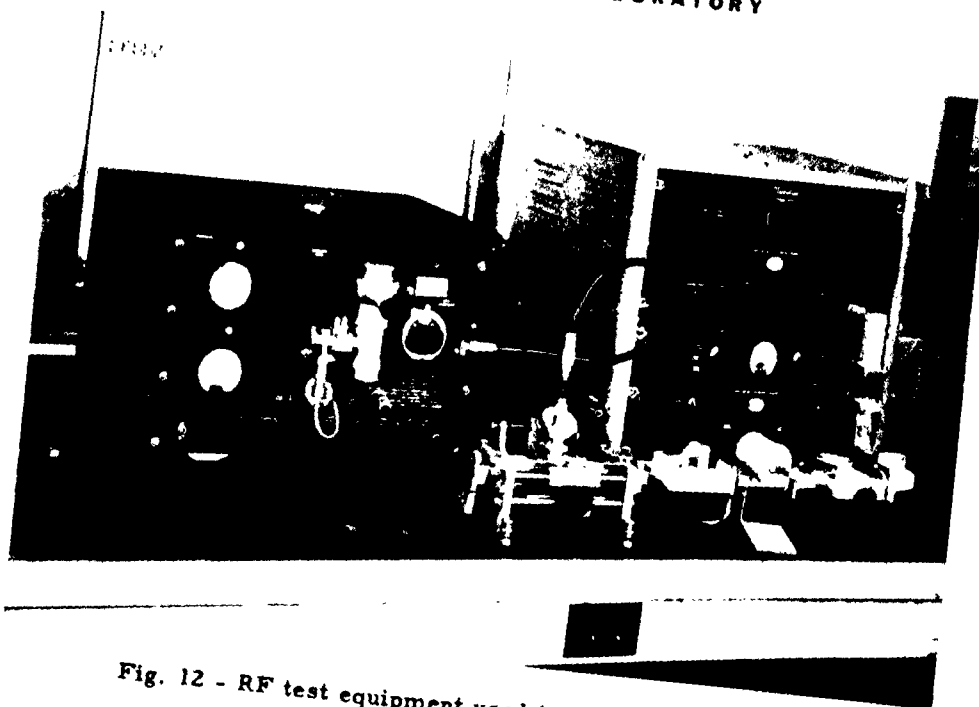


Fig. 12 - RF test equipment used in attenuation studies

Before the experiment was started, the slotted line was shorted alternately with the shorted waveguide section and a flat plate. The frequency was adjusted until the voltage minima for the two conditions were exactly $\lambda_g/4$ apart. A voltage maximum (current minimum) then occurred at the cover-flange to cover-flange connection, thus minimizing the loss due to contact resistance. The position of the slotted-line carriage at a voltage minimum, when the shorted waveguide section was attached, was recorded as a reference point.

To measure the loss in a length of coated waveguide, the sample was inserted between the shorted waveguide section and the slotted line. Due to minor variations in sample length and variations in the propagation constant due to the coatings, a minute adjustment of the frequency (2 to 3 Mc) was then necessary to bring the current minimum back on the connector junction. This was equivalent to adjusting the frequency for minimum dip of the pip on the oscilloscope when the slotted-line carriage was set at the reference point. The height of the pip was carefully observed and then reduced 3 db by means of the calibrated attenuator. By moving the slotted-line carriage on both sides of the minimum so as to restore the pip height, the distance between double power points was measured. The loss can then be determined using the well-known relationship:

where

$$\alpha = 8.686 \frac{\pi \delta X}{L \lambda_g}$$

- α = the loss in decibels per meter
- δX = the distance between double power points
- λ_g = the guide-wavelength in centimeters
- L = the sample length in meters.

Results

By measuring the loss before and after coating, the loss due to the coating was determined. The losses in the shorted waveguide section and the portion of slotted line past the

were measured and subtracted from each reading. Ten determinations of the value of δX were made for each sample. The increase in loss in db per meter for each protective coating under consideration is given in Table 8. The variation in the observed values of δX was about 0.0015 cm, and the corresponding error in α was ± 0.01 db per meter. Therefore the attenuation values have been rounded to the nearest hundredth. For comparison, Table 9 lists several measured loss values for uncoated waveguides.

TABLE 8
Increase in RF Loss Due to Protective Coatings

Pretreatment	Paint Finish	Increase in Loss (db/meter)
None	Amercoat No. 33	0.13*
HAE	Amercoat No. 33	0.17*
None	Woolsey's Wash Coat and Zinc Chromate prime No. 656a	0.02
None	Woolsey's Wash Coat, Zinc Chromate prime No. 656a, and Aircraft Gloss Enamel, Formula 623	0.03
HAE	Woolsey's Wash Coat and Zinc Chromate prime No. 656a	0.01
HAE	Woolsey's Wash Coat, Zinc Chromate prime No. 656a, and Aircraft Gloss Enamel, Formula 623	0.03
HAE	Stanley Primer No. 40X64	0.00
HAE	Stanley Primer No. 40X64 and Stanley Gloss Enamel Topcoat	0.01
None	Ucilon Primer No. 405P	0.17*
None	Ucilon Primer No. 405P and Ucilon Topcoat No. 400-10	0.165*
HAE	Ucilon Primer No. 405P and Ucilon Topcoat No. 400-10	0.08*
None	Woolsey's Wash Coat and Vinyl Prime Formula 120	0.00
None	Woolsey's Wash Coat, Vinyl Prime Formula 120, and Vinyl-Alkyd Topcoat Formula 122-17	0.03
HAE	Woolsey's Wash Coat, Vinyl Prime Formula 120, and Vinyl-Alkyd Topcoat Formula 122-17	0.10
Dow 7	None	0.04
HAE	None	0.01
Manodyz	None	0.02

*High loss is believed to be the result of excessively thick coatings of paint on the available samples. No effort was made to keep the thickness of the paint coatings uniform.

TABLE 9
RF Loss of Untreated Waveguide
(RG-51/U Type)

Waveguide	Loss (db/meter)
Magnesium (Dow FS-1a)	0.16
Brass	0.10
Aluminum	0.08

CONCLUSIONS

It was observed that the HAE surface pretreatment greatly improved the corrosion-preventing qualities of any protective system. Also, this treatment caused the least increase in rf attenuation of the three surface pretreatments observed. The order of merit of the best five of all the tested paint systems is given in Table 10.

TABLE 10
Rating of Protective Systems

Paint Finish	Order of Merit Rating		
	Salt Fog	Heat-Salt	RF Loss
Ucilon Combination on HAE	1	1	3
Aircraft Gloss Enamel Combination on HAE	2	2	2
Stanley Combination on HAE	3	3	1
Amercoat No. 33 on HAE	4	3	5
Vinyl Combination on HAE	5	5	4

The aircraft gloss enamel combination on HAE was selected as the best protective coating for a shipborne magnesium radar antenna. This combination consists of one coat of wash coat (MIL-P-15328), one coat of zinc chromate prime (MIL-P-6889A), and two coats of aircraft gloss enamel (MIL-E-7729). It was unfortunate that the painted waveguides used for measuring the rf loss in the Ucilon combination were all thickly coated with paint, which may have made these readings inordinately high.

It should be clearly understood that this report does not imply that any of the paint products described are not suited for their intended purpose. This evaluation rates protective coatings in regard to properties which their manufacturers do not claim — a procedure which is necessary because no protective coating has been developed to date which meets the requirements for protecting radar antennas in marine atmosphere.

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* * *

APPENDIX A
List of Jobbers

- (1) The American Machine and Foundry Company, 170 Fifty Third Street, Brooklyn 20, New York
- (2) Philip Sievering, Inc., 199 Lafayette Street, New York 12, New York
- (3) The Dow Chemical Company, Midland, Michigan
- (4) The Pitman-Dunn Laboratory, Frankford Arsenal, Philadelphia 37, Pennsylvania
- (5) American Pipe and Construction Company, Box 3428, Los Angeles 54, California
- (6) United Chromium, Inc. Cartaret, New Jersey
- (7) The Stanley Chemical Company, East Berlin, Connecticut
- (8) The Cro-Plate Company, Inc., Hartford 5, Connecticut
- (9) Baker and Company, Inc., Newark 5, New Jersey

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