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SHIP BOTTOM PAINT SYSTEMS -
I - THE ROLE OF FATTY ACIDS
AND SOAPS IN THE ADHESION OF
UNDERWATER PRIMER

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- Report P-2763 -

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ABSTRACT

Recent experience with systems for the protection of underwater surfaces of ships has indicated poor performance due to loss of adhesion. This report describes an investigation of the primers designed for direct application to steel over which anti-fouling paints are applied. A number of primers were prepared in which the pigment-volume ratio was varied as well as the type of pigment. The composition of the primer matrix was varied between wide limits. Exposures were made of each system for periods up to seven months. The data indicate the preference for zinc oxide over zinc chromate as an underwater primer pigment for steel.

INTRODUCTION

A. Authorization

1. This investigation was authorized by Bureau of Ships letter S19-1-(3)(336) 60153 dated 23 September 1944, to which Panel Service Test No. 6 was appended as part of Enclosure (C).

B. Statement of Problem

2. The details of the problem are adequately set forth in Appendix A, which consists of the original outline of the subject study. Some of the techniques of preparation have been changed due to incompatibilities among ingredient materials which could not be foreseen without experiment. The immediate objective of the subject study is to determine the role of fatty acids and soaps in contributing to the adhesion of protective coatings to steel during complete sea water immersion. The outline of appendix A follows a pattern developed for determining statistically the results obtained by varying paint constituents gradually between wide limits.

3. In addition to a study of the vehicle ingredients, an effort has been made to determine the relative values of zinc chromate and zinc oxide for use in anti-corrosive primers along with an optimum pigment-volume ratio between 20% and 30%. With reference to the study of vehicle quality, experiments were designed in which it was hoped to show the difference in adhesion properties between vehicles composed of linseed fatty acids and rosin, and linseed oil and rosin. Furthermore, the role of metallic soaps in such formulations was explored by incorporating varying amounts of manganese lineoleate into the formulas. Inasmuch as many of the most effective plastic anti-fouling paints are relatively soft, the possibility was explored of adding toughness to the formulation by the incorporation of small proportions of pliclite.

4. The immediate objectives stated in the foregoing paragraphs consist of particular phases of the over-all problem of improving the performance of currently used anti-corrosive and anti-fouling systems applied to the hull bottoms of ships.

C. Known Facts Bearing on the Problem

5. This report describes the experimental work performed by this laboratory in the study of primers to be used with standard cold plastic anti-fouling paint undertaken according to an outline developed by Code 333 of the Bureau of Ships, as a means of studying paint formulations statistically. The fundamental considerations involved in such a study are classified under three major factors: (a) Pigment quality; (b) Vehicle quality; (c) Pigment quantity. The study reported herein yields conclusive evidence as to the performance of one type of pigment over another and points strongly to an optimum pigment-volume ratio which appears more efficient than others investigated. However, the evidence as to vehicle quality is somewhat confused and no valid conclusions may be made regarding this factor on the basis of the evidence produced.

6. Currently specified anti-fouling paints for the protection of the hull bottoms of ships perform adequately so long as good adhesion is maintained and severe fouling does not occur usually until the paint has been removed through lack of adhesion. Sometimes the anti-fouling paint is removed from the anti-corrosive film, but more often the entire paint system becomes loose and falls off as a result of blistering and corrosion beneath the anti-corrosive film which points to a deficiency in the undercoat. It follows, therefore, that by improving the performance of the undercoat the adequacy of the over-all system could be maintained at a sufficiently high level to guarantee improved performance throughout the life of the system, that is, between docking periods. Experience with anti-corrosive coatings for ships' bottoms has indicated a preference for thick flexible films rather than thin hard matrices which are commonly used under enamels or topside paints. This has been found necessary due to the inadequacy of cleaning methods applicable to the conditioning of the metal comprising hull bottoms over which the paint must be applied. In order to produce thick heavy films, resort has been made to the use of materials such as ester gum, rosin, metallic soaps, and waxes, plasticized with vegetable oils or their acids. The current study describes experiments using all of the above-mentioned ingredients in a wide variety of proportions. Pigments have been varied along with pigment-volume ratios. It is believed that the data contained herein lends support to theories already in existence as to optimum P/V ratios which will be of value in the revision of current practices.

METHODS

A. Materials

7. The raw materials used in the formulations were obtained largely from the paint factory at the Norfolk Navy Yard and were as follows:

- (1) Bodied linseed oil
- (2) Linseed oil fatty acids
- (3) Ester gum
- (4) W. W. Rosin
- (5) Manganese lineolate

The pliclite used in these experiments was obtained from the Goodyear Tire and Rubber Company.

8. Exposure panels size 2-1/4 x 3-1/4" were prepared from cold rolled steel and sand blasted before the application of the first coat of primer.

B. Experimental

9. An effort to prepare a series of base paints containing two standard pigments dispersed in each of the raw materials listed in paragraph 7 was abandoned inasmuch as some of the vehicles used alone were incompatible

with the specified pigments, for example, no base paint could be prepared using equal parts of zinc oxide and mica in linseed oil fatty acids solution. Such a combination reacts rapidly to form a gel, commonly known as "livering". Furthermore, manganese lineolate is only poorly soluble in coal tar naphtha and does not permit a solution of sufficiently high solids content to be handled feasibly in blending and grinding operations. Therefore, each combination of raw materials shown in Table I was prepared independently and was pigmented by grinding separately with pigment combinations A and B as follows:

A
50% Zinc Chromate
50% Mica

B
50% Zinc Oxide
50% Mica

In addition to composition Table I indicates the circumstances peculiar to the preparation of individual batches.

10. The procedure used in the preparation of vehicle combinations 1 through 41 was as follows. The ingredient materials were heated together in the solid form until they were thoroughly melted and fused together, forming a homogeneous mixture. In most instances about 10 minutes heating was required between 150 and 200° C. Upon cooling the batches were thinned with an amount of coal tar naphtha calculated to produce a grinding viscosity at room temperatures. Such a procedure made it possible to disperse the manganese lineolate quite easily in solvent while at an elevated temperature, and no incompatibility was noticed with the other materials upon cooling. The oils, acids, and resins evidently performed as fluxing agents in dispersing the manganese lineolate in solution to perform a stable vehicle. The quantity of solvent required to produce vehicles of grinding viscosity varied from 0 to 52%. It was significant that those materials containing free carbonyl groups such as linseed oil fatty acids and rosin appeared to disperse the manganese lineolate much more readily than those void of such active groups. It was possible to prepare vehicles of all the combinations listed except those containing 100% manganese lineolate.

11. A slightly modified procedure was adopted for the preparation of the vehicles No. 42 through 82 containing 20% pliolite. The pliolite could not be heated together with the other ingredients but was cold cut by agitation with a portion of the solvent. The remaining ingredients were heated and thinned as described above and the pliolite solution added after cooling. Considerable difficulty was encountered in attempts to use chlorinated rubber which was found to be incompatible with bodied linseed oil and linseed fatty acid combinations. Preliminary experiments indicated pliolite to be compatible and all formulations were prepared with this material.

12. The vehicles listed in Table I were pigmented at 20% and 30% pigment-volume with the pigment combinations listed in paragraph 9, consisting of mica and zinc oxide and mica and zinc chromate. The batches were given

two passes on a 3-roller mill. In a number of instances where high percentages of linseed oil fatty acids were present, incompatibility resulted where large percentages of zinc oxide were included in the formulation.

13. Exposure panels were prepared from each primer by application to small steel panels which had been sand blasted previously. A uniform film thickness as measured by a GE thickness meter from 2.5 - 3.0 mils was maintained throughout. A single coat of anti-fouling paint formula 143E was applied to all panels at film thicknesses of 1.5 - 2.0 mils within 24 hours after application of the final primer coat. After drying, the coated panels were edged with Ceresin wax to hold edge effects at a minimum. An attempt to wax the edges before the application of the anti-fouling paint was unsuccessful inasmuch as poor adhesion of the top coat was obtained along the edges. The finished panels were shipped to the Woods Hole Oceanographic Institution where they were submerged in the sea for a period of 7 months. Monthly inspections were made which became most significant as the panels began to deteriorate. Photographs were prepared in 35 millimeter kodachrome at the end of each month's exposure. The monthly reports along with a visual examination of the photographs formed the basis for the data on the performance of these materials.

14. At the end of 7 months' exposure the vast majority of all systems had deteriorated to a point at which the tests were discontinued and the panels returned to the laboratory.

DATA OBTAINED

15. The monthly reports of the WHOI are contained in Appendix B. Tables I through VI of Appendix B list the complete data of the condition of each panel at monthly inspection periods. Due to the voluminous nature of the data obtained, supplementary tables have been prepared on which the significant conclusions have been based. The data of Appendix B, however, may be found useful for further statistical studies which may be correlated with similar experiments to be reported subsequently.

16. A quantitative method for accurate evaluation of the performance of exposure panels is obviously lacking. The adopted method consists of giving a perfect panel a rating of 10, with gradations down to 0 for a specimen which has failed completely. Over a period of 7 months, the panel having a perfect rating throughout would receive a final value of 70 and systems failing rapidly would show a low value depending on the extent and rate at which they failed. The data of the Tables of Appendix B have been considered in arriving at these values along with the examination of colored photographs.

17. In an effort to determine characteristics peculiar to the panels showing perfect performance throughout the exposure period of 7 months, a list was made of those possessing a perfect rating at the end of the exposure period. These panels are listed in Table II and represent a relatively small percentage from the total number included initially.

18. In an effort to include a more representative number of the better performing combinations, the formulas were listed in Table III which maintained a performance rating of 10 through 6 months and were rated no lower than 8 at the final evaluation. The data of Tables II and III represent the most acceptable of the combinations examined.

19. While the data relative to the type of pigments and the optimum pigment-volume ratios appears to be rather significant from the data of Tables II and III, no clear-cut conclusions could be drawn relative to vehicle quality. Since so many failures occurred within a few months, Table IV was compiled to list those combinations showing a performance rating below 5 at the end of 3 months' exposure. Here again information relative to the type of pigments is quite conclusive, but no clear lines may be drawn relative to optimum vehicle combination.

20. While the detailed exposure data appears too voluminous for consideration in this discussion, a summary of performance of each system has been made and is set forth in Table V. The data appearing under the heading Summary of Monthly Ratings (Table V) was obtained by adding the monthly ratings. This was considered as giving a good index to the over-all performance of the individual systems from a consideration of the extent and rate of failure which under this system are given equal importance. Table V was compiled with the thought that certain trends might be obvious as graded variations occur in vehicle compositions.

DISCUSSION OF RESULTS

A. Pigment Quality

21. Since one of the primary objectives of this study was to determine the relative value of zinc chromate and zinc oxide in corrosion inhibition, a strong argument in favor of zinc oxide used in combination with mica appears obvious from the data of Tables II through V. Table II listing the systems of perfect performance throughout exposure periods contains only one system using zinc chromate, whereas no system containing zinc chromate appears in the data of Table III. On the other hand, of the systems which failed most rapidly, as indicated in Table IV, only two contained zinc oxide and the failures were found to be most rapid with the zinc chromate pigments in combination with mica.

B. Pigment Quantity

22. The determination of the optimum pigment-volume ratio does not appear so clearly defined as for the type of pigment; however, an inspection of the data of Table IV indicates that a vast majority of the early failures were pigmented at a ratio of 20%. When considering the best systems, Tables II and III, it is obvious that P/V ratios are pretty well distributed and neither pigmentation appears outstanding; therefore, on the basis of the evidence available it is difficult to conclude that one pigmentation ratio is superior to the other.

C. Vehicle Quality

23. From a study of Table V, it is impossible to make any generalizations as to the efficacy of one type vehicle relative to another. For example, based on performance ratings, there seems to be little difference whether linseed oil or linseed oil fatty acids are used in combination with ester gum or rosin in providing vehicles of equal integrity. In an effort to classify the vehicle ingredients according to superior performance, Table VI was compiled from the monthly inspection data in a similar manner as described for Table V. Here again it appears impossible to select a vehicle composition which shows superior performance to the others. One fact is emphasized, however, that a larger number of systems containing no pliolute appeared to have final performance ratings above 55 than those containing pliolute. This would indicate that no advantage is to be gained by this addition to the formulation. This observation is further substantiated by the data of Tables II and III which show a majority of the better formulations free of pliolute. On the other hand a small majority of the poorly performing materials (Table IV) contain none.

24. On the basis of the data obtained it appears impossible to determine the relative value of linseed fatty acids and linseed oil. Likewise, no particular case may be made for adding manganese linoleate to the formulation.

TABLE I
 PANEL SERVICE TEST No. 6

Amount of Material Used in Grams									
No.	Bodied Linseed Oil	Linseed Fatty Acid	Ester Gum	W.W. Rosin	Manganese Linoleate	Pliolite	Solids	Specific Gravity	Remarks
1	1000	0	0	0	0	0	100%	.994	No heating or thinning necessary.
2	500	500	0	0	0	0	100%	.953	Heated together at 100°C until well dispersed in each other. No thinner necessary.
3	500	0	500	0	0	0	100%	1.047	Heated at 150°C until ester gum went in solution, was liquid when cool. No thinner necessary.
4	500	0	0	500	0	0	100%	1.032	Heated at 150°C until rosin went into solution, was liquid when cool. No thinner necessary.
5	0	1000	0	0	0	0	100%	.912	No heating or thinning necessary. Was liquid.
6	0	500	500	0	0	0	100%	1.006	Heated at 150°C until ester gum dissolved. Was liquid when cool. No thinner necessary.
7	0	500	0	500	0	0	100%	.991	Ditto.
8	0	0	1000	0	0	0	60%	1.10	Heated at 150°C until ester gum all melted. Thinned with coal tar naphtha.
9	0	0	500	500	0	0	60%	1.08	Heated at 150°C until all melted and dissolved together. Thinned with coal tar naphtha.
10	0	0	0	1000	0	0	60%	1.07	Heated at 150°C until all melted. Thinned with coal tar naphtha.
11	0	0	0	0	1000	0	-	1.023	Would not go into solvent. Left out.
12	250	0	0	0	750	0	49.5%	1.051	Heated at 150-200°C until homogeneous. Thinned while warm with cold tar naphtha. Very heavy body.
13	500	0	0	0	500	0	59.5%	1.008	Ditto. Easier to thin.
14	750	0	0	0	250	0	84%	1.008	Ditto. Easier to thin.
15	125	125	0	0	750	0	50%	1.04	Ditto. Very heavy body.
16	250	250	0	0	500	0	100%	.989	Heated together at 150°C until all dispersed. Was smooth liquid when cool. No thinner necessary.
17	375	375	0	0	250	0	100%	.970	Ditto.
18	125	0	125	0	750	0	50%	1.029	Heated at 150°C until all melted and homogeneous. Thinned while warm with coal tar naphtha.
19	250	0	250	0	500	0	54%	1.036	Ditto.
	375	0	375	0	250	0	71.6%	1.040	Ditto.
	125	0	0	125	750	0	55%	1.026	Ditto. Dispersed very easily. Fairly thin body.
	250	0	0	250	500	0	71.5%	1.028	Ditto.
23	375	0	0	375	250	0	100%	1.030	Heated at 150°C until all melted and homogeneous. Was liquid when cool. No thinner necessary.
24	0	250	0	0	750	0	60%	.992	Heated at 150-200°C until all melted and homogeneous. Thinned with warm coal tar naphtha. Fairly thin.
25	0	500	0	0	500	0	78%	.967	Ditto.
26	0	750	0	0	250	0	100%	.939	Heated at 150-200°C until all melted and homogeneous. Was liquid when cool. No thinner necessary.
27	0	125	125	0	750	0	50%	1.015	Heated at 150-200°C until all melted and homogeneous. Thinned while warm with coal tar naphtha. Fairly heavy body.
28	0	250	250	0	500	0	59%	1.015	Ditto. Fairly thin.
29	0	375	375	0	250	0	100%	1.007	Heated to 150-200°C until all melted and homogeneous. Was liquid when cool. No thinner necessary.
30	0	125	0	125	750	0	50%	1.010	Heated to 150-200°C until all melted and homogeneous. Thinned while warm with coal tar naphtha. Fairly heavy.
31	0	250	0	250	500	0	77%	1.008	Ditto. Fairly thin.
32	0	375	0	375	250	0	83%	.999	Ditto.
33	0	0	250	0	750	0	52.3%	1.043	Ditto.

Table I (Continued)
 PANEL SERVICE TEST No. 6
 (Contd)

No.	Bodied Linseed Oil	Linseed Fatty Acid	Ester Gum	W.W. Rosin	Manganese Linoleate	Pliolite	Solids	Specific Gravity	Remarks
34	0	0	500	0	500	0	56%	1.061	Heated to 150-200°C until all melted and homogeneous. Thinned while warm with coal tar naphtha. Fairly thin.
35	0	0	750	0	250	0	55%	1.081	Ditto.
36	0	0	125	125	750	0	55%	1.039	Ditto.
37	0	0	250	250	500	0	60%	1.055	Ditto.
38	0	0	375	375	250	0	62%	1.070	Ditto.
39	0	0	0	250	750	0	58.4%	1.034	Ditto.
40	0	0	0	500	500	0	66%	1.046	Ditto.
41	0	0	0	750	250	0	61.5%	1.058	Ditto.
42	800	0	0	0	0	200	62.6%	.95	Added portion of coal tar naphtha to linseed oil, cold cut pliolute into coal tar naphtha, blended together.
43	400	400	0	0	0	200	62.6%	.92	Ditto.
44	400	0	400	0	0	200	62.6%	.99	Heated oil and resin at 150°C until melted together, thinned with portion of solvent, cold cut pliolute into remaining solvent. Blended two together.
45	400	0	0	400	0	200	62.6%	.98	Ditto.
46	0	800	0	0	0	200	50%	.89	Ditto.
47	0	400	400	0	0	200	50%	.96	Ditto.
48	0	400	0	400	0	200	50%	.95	Ditto.
49	0	0	800	0	0	200	50%	1.04	Ditto.
50	0	0	400	400	0	200	50%	1.02	Ditto.
51	0	0	0	800	0	200	50%	1.01	Ditto.
52	0	0	0	0	800	200	-	.97	Out.
53	200	0	0	0	600	200	50%	.97	Same procedure as in #44.
54	400	0	0	0	400	200	50%	.96	Ditto.
55	600	0	0	0	200	200	60%	.96	Ditto.
56	100	100	0	0	600	200	50%	.96	Ditto.
57	200	200	0	0	400	200	59%	.94	Ditto.
58	300	300	0	0	200	200	60%	.93	Ditto.
59	100	0	100	0	600	200	50%	.98	Ditto.
60	200	0	200	0	400	200	50%	.99	Ditto.
61	300	0	300	0	200	200	50%	.99	Ditto.
62	100	0	0	100	600	200	50%	.98	Ditto.
63	200	0	0	200	400	200	50%	.98	Ditto.
64	300	0	0	300	200	200	59%	.98	Ditto.
65	0	200	0	0	600	200	50%	.95	Ditto.
66	0	400	0	0	400	200	59%	.93	Ditto.
67	0	600	0	0	200	200	62.5%	.91	Ditto.
68	0	100	100	0	600	200	50%	.97	Ditto.
69	0	200	200	0	400	200	50%	.97	Ditto.
70	0	300	300	0	200	200	62.5%	.97	Ditto.
71	0	100	0	100	600	200	50%	.97	Ditto.
72	0	200	0	200	400	200	58.6%	.96	Ditto.
73	0	300	0	300	200	200	62%	.95	Ditto.
74	0	0	200	0	600	200	50%	.99	Ditto.
75	0	0	400	0	400	200	50%	1.00	Ditto.
76	0	0	600	0	200	200	50%	1.02	Ditto.
77	0	0	100	100	600	200	50%	.99	Ditto.
78	0	0	200	200	400	200	50%	1.00	Ditto.
79	0	0	300	300	200	200	67%	1.01	Ditto.
80	0	0	0	200	600	200	50%	.98	Ditto.
81	0	0	0	400	400	200	59%	.99	Ditto.
82	0	0	0	600	200	200	62.6%	1.00	Ditto.

TABLE II

Panels with Perfect Ratings (10) Through Seven Months' Exposure

Panel No.	Composition						Pigmentation	
	Linseed F.A.Acids	Ester Gum	Mn. Linoleate	Bodied Linseed	W. W. Rosin	RC1	P/V%	Type*
191	12.5%	12.5%	75				30	A
349			75	12.5	12.5		20	B
350			50	25	25		20	B
422			75	25			30	B
425	12.5		75	12.5			30	B
446		12.5	75		12.5		30	B
395	60		20			20	20	B
401	30		20		30	20	20	B
407		30	20		30	20	20	B
477	60		20			20	30	B
483	30		20		30		30	B

* A = 50% Mica, 50% Zinc Chromate

B = 50% Mica, 50% Zinc Oxide

TABLE III

Panel Service Test #6

Panels with Perfect Ratings (10) Through Six Months
Ratings of 8 Through Seven Months

Panel No.	Resinous Composition of Primer						Pigmentation	
	Bodied Linseed	Linseed F. A.	Ester Gum	W. W. Rosin	Mn. Linoleate	RC1	P/V Ratio	Type*
371	40	40				20	20	B
373	40			40		20	20	B
379				80		20	20	B
392	30			30	20	20	20	B
393		20			60	20	20	B
460			40	40		20	30	B
461				80		20	30	B
478		10	10		60	20	30	B
482		20		20	40	20	30	B
329	100						20	B
347	25		25		50		20	B
355		12.5	12.5		50		20	B
360		37.5		37.5	25		20	B
363			75		25		20	B
417		50		50			30	B
420				100			30	B
429			25		50		30	B
431	12.5			12.5	75		30	B

* A = 50% Mica, 50% Zinc Chromate

B = 50% Mica, 50% Zinc Oxide

TABLE IV

Panel Service Test #6Panels of Low Rating - Below 5 after Three Months

Panel No.	Resinous Composition of Primer						Pigmentation	
	Bodied Linseed	Linseed F. A.	Ester Gum	W. W. Rosin	Mn. Linoleate	RCI	P/V%	Type*
83	100						20	A
84	50	50					20	A
85	50		50				20	A
86	50			50			20	A
87		100					20	A
99	37.5	37.5			25		20	A
101	25		25		50		20	A
102	37.5	37.5			25		20	A
104	25			25	50		20	A
108		75			25		20	A
110		25	25		50		20	A
111		37.5	37.5		25		20	A
115			25		75		20	A
167	50		50				30	A
168	50			50			30	A
190		75			25		30	A
197			25		75		30	A
136	40				40	20	20	A
138	10	10			60	20	20	A
149		60			20	20	20	A
150		10	10		60	20	20	A
210		80				20	30	A
221	20	20			40	20	30	A
372	40		40			20	30	B
466	10		10		60	20	30	B

TABLE V
 Panel Service Test No. 6
 SUMMARY OF PANEL RATINGS AFTER 7 MONTHS' EXPOSURE

Vehicle No.	Vehicle Composition %					Summary of Monthly Ratings									
	0% RCI		Mn Lino- leate	Linseed Oil	Linseed F. A.	Ester Gum	W. W. Rosin	0% RCI				20% RCI			
	0% RCI	20% RCI						A Pigmentation		B Pigmentation		A Pigmentation		B Pigmentation	
							20%P/V	30%P/V	20%P/V	30%P/V	20%P/V	30%P/V	20%P/V	30%P/V	
1	42		100				16	63	69	51	39	34	58	42	
2	43		50	50			23	54	-	-	41	59	67	43	
3	44		50		50		31	50	65	66	52	63	35	42	
4	45		50			50	19	50	50	67	50	62	69	43	
5	46				100		37	57	-	-	40	31	64	49	
6	47				50	50	54	57	-	52	53	55	45	57	
7	48				50		55	55	-	69	41	43	65	55	
8	49					100	50	58	50	63	59	65	40	54	
9	50					50	40	60	50	65	63	65	51	68	
10	51					100	37	42	56	69	26	43	68	69	
11	52	100					Incompatible								
12	53	75	25				45	36	48	57	35	36	37	53	
13	54	50	50				46	35	62	56	24	39	27	41	
14	55	25	75				56	42	52	70	57	41	46	36	
15	56	75	12.5	12.5			40	45	47	70	33	41	46	36	
16	57	50	25.0	25.0			38	-	-	-	30	30	38	34	
17	58	25	37.5	37.5			21	21	-	-	-	28	47	-	
18	59	75	12.5		12.5		28	38	-	-	33	36	44	41	
19	60	50	25.0		25.0		19	42	69	69	38	49	46	49	
20	61	25	37.5		37.5		14	48	-	55	-	48	46	69	
21	62	75	12.5			12.5	30	46	70	69	39	33	63	43	
22	63	50	25.0			25.0	36	38	70	53	40	42	55	43	
23	64	25	37.5			37.5	34	53	58	54	58	67	69	63	
24	65	75		25			42	60	-	-	41	33	69	52	
25	66	50		50			39	42	-	-	-	45	65	56	
26	67	25		75			22	14	-	-	19	34	70	70	
27	68	75	12.5	12.5		12.5	58	70	68	54	37	37	46	68	
28	69	50	25.0	25.0		25.0	34	44	-	-	42	-	53	43	
29	70	25	37.5	37.5		37.5	23	56	-	-	46	57	57	65	
30	71	75	12.5	12.5		12.5	42	43	63	33	40	67	43	41	
31	72	50	25.0	25.0		25.0	44	-	-	-	49	70	46	68	
32	73	25	37.5	37.5		37.5	47	-	68	-	61	-	70	70	
33	74	75			25		25	24	64	-	37	36	45	-	
34	75	50			50		44	55	68	-	44	50	43	-	
35	76	25			75		55	63	55	58	60	52	61	64	
36	77	75			12.5	12.5	37	47	55	70	36	43	43	41	
37	78	50	25.0	25.0		25.0	32	44	65	58	39	41	48	67	
38	79	25	37.5	37.5		37.5	48	53	65	55	57	55	70	57	
39	80	75				25	51	62	54	52	35	52	46	62	
40	81	50				50	51	43	58	57	30	52	46	52	
41	82	25				75	44	60	61	65	51	60	66	65	

TABLE VI

List of Formulations with Summary Rating Above 55 (70=Perfect)

<u>Panel No.</u>	<u>Linseed Oil</u>	<u>Linseed F.A.</u>	<u>Ester Gum</u>	<u>W. W. Rosin</u>	<u>Mn. Linoleate</u>
132			40	40	20
134					80
155		30	30		20
158			60		20
207	40	40			
208	40		40		
209	40			40	
213			80		
214			40	40	
228	30			30	20
235		10		10	60
236		20		20	40
246				60	20
371	40	40			
373	40			40	
374		80			
376		40		40	
279				80	
390	10			10	60
392	30			30	20
393		20			60
394		40			40
395		60			20
401		30		30	20
404			60		20
407			30	30	20
410				60	20
460			40	40	
461				80	
471	30		30		20
474	30			30	20
477		60			20
478		10	10		60
480		30	30		20
482		20		20	40
488			20	20	40
490				20	60
492				60	20
89		50		50	
96	75				25
109		12.5	12.5		75
450				50	50
451				75	25

TABLE VI (continued)

117			75		25
165	100				
169		100			
170		50	50		
171		50		50	
172			100		
173			50	50	
188		25			75
191		12.5	12.5		75
193		37.5	37.5		25
198			50		50
199			75		25
201			25	25	50
202			37.5	37.5	25
205				75	25
329	100				
331	50		50		
338			100		
341	50				50
347	25		25		50
349	12.5			12.5	
350	25			25	
351	37.5			37.5	25
355		12.5	12.5		75
358		12.5		12.5	75
360		37.5		37.5	75
362			50		50
363			75		25
364			12.5	12.5	75
365			25	25	50
366			37.5	37.5	25
368				50	50
369				75	25
413	50		50		
414	50			50	
417		50		50	
418			100		
419			50	50	
420				100	
422	25				75
423	50				50
424	75				25
425	12.5	12.5			75
429	25		25		50
430	37.5		37.5		25
431	12.5			12.5	75
445			75		25
446			12.5	12.5	75
447			25	25	50
448			37.5	37.5	25

CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

25. While the data resulting from this study proves somewhat disappointing in providing information leading to the formulation of improved matrices, a strong case has been prepared for the use of zinc oxide in preference to zinc chromate when both are used in combination with mica as pigments for anti-corrosive primers.

26. The data indicate that pliolite does not add materially to the life of an anti-corrosive primer.

27. No conclusions may be made concerning the composition of primer matrices based on the data of this report, other than no apparent advantage results from the inclusion of pliolite.

B. Recommendations

28. It is recommended that additional studies be authorized to further establish the merits of zinc oxide relative to zinc chromate as an ingredient in under-water primers to be used under anti-fouling paint. This study might include the use of additional toughening agents in lieu of pliolite.

29. Adequate interpretation of results obtained from small panels in considerable quantity does not appear to be satisfactory as a means of conducting a study of this nature. In future investigations it is recommended that the variables be limited and duplicate panels prepared on a larger scale in order to afford a more accurate basis for evaluation.

ACKNOWLEDGMENT

30. The cooperation of the staff of the Woods Hole Oceanographic Institution is greatly appreciated for exposing the panels, preparing the kodachrome slides, and the tables of data of the appendix.

APPENDIX A

Panel Service Test No. 6

- I. Objective: To evaluate the effect of fatty acids and soaps in contributing to the adhesion of protective coatings to steel in complete seawater immersion.
 - A. Vehicle Quality
 - (1) Determine the difference in adhesion between linseed fatty acids and rosin, and the glycerides of those acids.
 - (2) Determine the effect of adding manganese linoleate, a metallic soap, to the glycerides and acids.
 - (3) Determine the effect of toughening the above combinations by the addition of a small proportion of chlorinated rubber, preferably synthetic rubber.
 - B. Pigment Quality
 - (1) Determine the difference between zinc chromate and zinc oxide in corrosion inhibition.
 - C. Pigment Quantity
 - (1) Determine the effect of varying the quantity of pigment from 10% to 30% P.V.

II. Vehicle Combinations

	<u>Bodied Linseed Oil</u>	<u>Linseed Fatty Acids</u>	<u>Ester Gum</u>	<u>W. W. Rosin</u>	<u>Manganese Linoleate</u>	<u>Chlorinated Rubber</u>
(1)	100	0	0	0	0	0
(2)	50	50	0	0	0	0
(3)	50	0	50	0	0	0
(4)	50	0	0	50	0	0
(5)	0	100	0	0	0	0
(6)	0	50	50	0	0	0
(7)	0	50	0	50	0	0
(8)	0	0	100	0	0	0
(9)	0	0	50	50	0	0
(10)	0	0	0	100	0	0
(11)	0	0	0	0	100	0
(12)	25	0	0	0	75	0
(13)	50	0	0	0	50	0
(14)	75	0	0	0	25	0
(15)	12.5	12.5	0	0	75	0
(16)	25	25	0	0	50	0
(17)	37.5	37.5	0	0	25	0
(18)	12.5	0	12.5	0	75	0
(19)	25	0	25	0	50	0
(20)	37.5	0	37.5	0	25	0
(21)	12.5	0	0	12.5	75	0
(22)	25	0	0	25	50	0
(23)	37.5	0	0	37.5	25	0
(24)	0	25	0	0	75	0
(25)	0	50	0	0	50	0
(26)	0	75	0	0	25	0
(27)	0	12.5	12.5	0	75	0
(28)	0	25	25	0	50	0
(29)	0	37.5	37.5	0	25	0
(30)	0	12.5	0	12.5	75	0
(31)	0	25	0	25	50	0
(32)	0	37.5	0	37.5	25	0
(33)	0	0	25	0	75	0
(34)	0	0	50	0	50	0
(35)	0	0	75	0	25	0
(36)	0	0	12.5	12.5	75	0
(37)	0	0	25	25	50	0
(38)	0	0	37.5	37.5	25	0
(39)	0	0	0	25	75	0
(40)	0	0	0	50	50	0
(41)	0	0	0	75	25	0
(42)	80	0	0	0	0	20
(43)	40	40	0	0	0	20
(44)	40	0	40	0	0	20
(45)	40	0	0	40	0	20

	<u>Bodied Linseed Oil</u>	<u>Linseed Fatty Acids</u>	<u>Ester Gum</u>	<u>W. W. Rosin</u>	<u>Manganese Linoleate</u>	<u>Chlorinated Rubber</u>
(46)	0	80	0	0	0	20
(47)	0	40	40	0	0	20
(48)	0	40	0	40	0	20
(49)	0	0	80	0	0	20
(50)	0	0	40	40	0	20
(51)	0	0	0	80	0	20
(52)	0	0	0	0	80	20
(53)	20	0	0	0	60	20
(54)	40	0	0	0	40	20
(55)	60	0	0	0	20	20
(56)	10	10	0	0	60	20
(57)	20	20	0	0	40	20
(58)	30	30	0	0	20	20
(59)	10	0	10	0	60	20
(60)	20	0	20	0	40	20
(61)	30	0	30	0	20	20
(62)	10	0	0	10	60	20
(63)	20	0	0	20	40	20
(64)	30	0	0	30	20	20
(65)	0	20	0	0	60	20
(66)	0	40	0	0	40	20
(67)	0	60	0	0	20	20
(68)	0	10	10	0	60	20
(69)	0	20	20	0	40	20
(70)	0	30	30	0	20	20
(71)	0	10	0	10	60	20
(72)	0	20	0	20	40	20
(73)	0	30	0	30	20	20
(74)	0	0	20	0	60	20
(75)	0	0	40	0	40	20
(76)	0	0	60	0	20	20
(77)	0	0	10	10	60	20
(78)	0	0	20	20	40	20
(79)	0	0	30	30	20	20
(80)	0	0	0	20	60	20
(81)	0	0	0	40	40	20
(82)	0	0	0	60	20	20

III. Pigmentations (Parts by wt.)

	<u>A</u>	<u>B</u>
Zinc Chromate	50	
Zinc Oxide		50
Mica	50	

IV. Preparation of Base Paints at 30% P.V.

- a. Pigmentation A in Bodied Linseed Oil solution
- b. Pigmentation B in Bodied Linseed Oil solution
- c. Pigmentation A in Linseed Fatty Acids solution
- d. Pigmentation B in Linseed Fatty Acids solution
- e. Pigmentation A in Ester Gum solution
- f. Pigmentation B in Ester Gum solution
- g. Pigmentation A in W. W. Rosin solution
- h. Pigmentation B in W. W. Rosin solution
- i. Pigmentation A in Manganese Linoleate solution
- j. Pigmentation B in Manganese Linoleate solution
- k. Pigmentation A in Chlorinated Rubber solution
- l. Pigmentation B in Chlorinated Rubber solution

V. Preparation of Test Paints

Mix base paints with unpigmented vehicles in proportions to obtain the combinations listed in Table VI.

VI. Table of Test Paints - Panel Numbers

Vehicle Combina- tions	20%		30%		: Vehicle : Combina- : tions	20%		30%	
	Pigment Vol.		Pigment Vol.			Pigment Vol.		Pigment Vol.	
	A	B	A	B		A	B	A	B
(1)	83	329	165	411	(42)	124	370	206	452
(2)	84	330	166	412	(43)	125	371	207	453
(3)	85	331	167	413	(44)	126	372	208	454
(4)	86	332	168	414	(45)	127	373	209	455
(5)	87	333	169	415	(46)	128	374	210	456
(6)	88	334	170	416	(47)	129	375	211	457
(7)	89	335	171	417	(48)	130	376	212	458
(8)	90	336	172	418	(49)	131	377	213	459
(9)	91	337	173	419	(50)	132	378	214	460
(10)	92	338	174	420	(51)	133	379	215	461
(11)	93	339	175	421	(52)	134	380	216	462
(12)	94	340	176	422	(53)	135	381	217	463
(13)	95	341	177	423	(54)	136	382	218	464
(14)	96	342	178	424	(55)	137	383	219	465
(15)	97	343	179	425	(56)	138	384	220	466
(16)	98	344	180	426	(57)	139	385	221	467
(17)	99	345	181	427	(58)	140	386	222	468
(18)	100	346	182	428	(59)	141	387	223	469
(19)	101	347	183	429	(60)	142	388	224	470
(20)	102	348	184	430	(61)	143	389	225	471
(21)	103	349	185	431	(62)	144	390	226	472
(22)	104	350	186	432	(63)	145	391	227	473
(23)	105	351	187	433	(64)	146	392	228	474
(24)	106	352	188	434	(65)	147	393	229	475
(25)	107	353	189	435	(66)	148	394	230	476
(26)	108	354	190	436	(67)	149	395	231	477
(27)	109	355	191	437	(68)	150	396	232	478
(28)	110	356	192	438	(69)	151	397	233	479
(29)	111	357	193	439	(70)	152	398	234	480
(30)	112	358	194	440	(71)	153	399	235	481
(31)	113	359	195	441	(72)	154	400	236	482
(32)	114	360	196	442	(73)	155	401	237	483
(33)	115	361	197	443	(74)	156	402	238	484
(34)	116	362	198	444	(75)	157	403	239	485
(35)	117	363	199	445	(76)	158	404	240	486
(36)	118	364	200	446	(77)	159	405	241	487
(37)	119	365	201	447	(78)	160	406	242	488
(38)	120	366	202	448	(79)	161	407	243	489
(39)	121	367	203	449	(80)	162	408	244	490
(40)	122	368	204	450	(81)	163	409	245	491
(41)	123	369	205	451	(82)	164	410	246	492

VII. Exposure of Test Paints

Apply to small steel panels at approximately equal film thicknesses. Drying time should not exceed twenty-four hours before application of AF coat. Apply thin films of Formula 143 to all panels at approximately equal film thicknesses. Coat panel edges with ceresin wax, preferably before application of AF paint. Duplicate panels are not necessary in this test.

Arrange with Woods Hole Oceanographic Institution for exposure by complete immersion at Woods Hole.

Inspect and photograph in 35 mm. Kodachrome after each month of exposure.

APPENDIX B

The comments of the Woods Hole Oceanographic Institution's investigation on the condition of the panels at each inspection are contained in the following tables. The condition of most panels was quite good at the end of the first month and no comments were included for the first reading. A considerable number of panels had failed almost completely (ratings of 3 or less). They were removed after six (6) months and are thus omitted from Table VI.

TABLE I

SECOND MONTHLY INSPECTION

The backs of these panels are fouling with hydroids and streamers of these hydroids may have lain across the face of some of the panels. The AF surfaces are completely unfouled. Blisters were noticed on the following panels:

104	174	229	465
107	176	231	466
110	182	232	468
111	210	241	469
147	221	405	
162	223	449	

and spots of paraffin dropped on the following panels

219	232	235	238	341
231	234	237	236	406

have resulted in bright red spots which will show up in the pictures. Many of the panels show black marks on the edges or bottoms where they have rubbed against the racks.

TABLE II

THIRD MONTHLY INSPECTION

Panel 143 was lost overboard during the first monthly photographing. This month, panel 144 was accidentally set above number 143 of the identifying numbers, and panel 145 appears above identifying number 144. Panel 145 then reappears above its proper number in the next picture.

Blisters which may not have photographed were observed on panels:

84	119	150	210	237	395	464
87	120	151	212	238	397	465
98	123	153	217	241	399	466
99	133	156	219	244	400	469
100	135	159	221	364	402	472
104	136	162	222	372	403	473
108	138	163	223	377	405	475
110	139	174	226	381	411	476
111	141	176	227	383	440	479
112	142	197	229	384	449	481
114	144	200	231	386	455	487
115	145	206	232	389	463	491

Spots of paraffin (most of them very small) on the AF surfaces will probably show bright red in the photographs. They were observed on panels:

206	232	239	392	398	401	459
219	234	245	393	399	433	461
231	236	341	394	400	437	488

Panel 172 had hydroids growing on paraffin spots on its AF surface. Fading of the entire AF surface to a tan color was noted on panels:

133	206	215	363	398	402	449
173	208	351	391	399	403	472
174	213	358	394	400	404	473
191	214	360	397	401	410	492

Cracking, which may not show in the photographs, was present on panels:

108	133	173	174	217	221	389
-----	-----	-----	-----	-----	-----	-----

Corrosion eruptions, which probably will not be visible in the Kodacolors, were present on panels 106, 190, and 397.

The paint film of panel 90 was still intact, but was loosened from the steel except under the paraffin edge-trim.

TABLE II (Continued)

Purple granules the color of potassium permanganate crystals were found in abundance on panel 190 and a single spot of the same color was found near the bottom of panel 404.

Panel 102 has extensive damage to the AF film and undercoats which was caused by adherence to the waxed paper in which it was shipped. When it was unwrapped, considerable areas of the paint were removed on the paper. Many of the panels show black marks on their sides and/or bottom edges where they rub on the racks.

TABLE III

FOURTH MONTHLY INSPECTION

84	Blisters
86	Blisters
87	Blisters
89	Fading
90	Wrinkling
92	Blisters, fading
94	AF surface fouled with hydroids
95	AF surface fouled with hydroids
96	AF surface fouled with hydroids
97	Hairline cracks
101	Fouled by hydroids
102	Fouled by hydroids
104	Blistering, chipping
105	Blistering
106	Blistering, cracking
107	Hairline cracks
108	Blisters
109	Hairline cracks
110	Hairline cracks, blisters
112	Blisters
114	Fouled by hydroids
115	Fouled by hydroids
121	Wrinkling, blistering
122	Fouled by hydroids
123	Fouled by hydroids
124	Fouled by hydroids, blisters
125	Fouled by hydroids, blisters
126	Fouled by hydroids
127	Fouled by hydroids
128	Fouled by hydroids, blisters, fading
129	Fouled by hydroids
130	Fouled by hydroids
131	Fouled by hydroids, fading
132	Fouled by hydroids, fading
133	Blisters, fading
134	Fouled by hydroids
135	Fouled by hydroids, blisters, hairline cracks
136	Hairline cracks
138	Fouled by hydroids
139	Fouled by hydroids, blisters, hairline cracks
141	Fouled by hydroids, blisters, cracking
142	Fouled by hydroids, half surface loosened from panel
144	Fouled by hydroids, blisters
145	Fouled by hydroids, blisters
146	Fouled by hydroids
147	Blisters, hairline cracks
150	Blisters, fouled by hydroids, cracking
151	Blisters, fouled by hydroids
152	Fouled by hydroids

TABLE III (continued)

211	Fading
212	Fading, fouled by hydroids, blisters
213	Fading, fouled by hydroids
214	Fading, fouled by hydroids
215	Fading, fouled by hydroids
216	Fading, fouled by hydroids
217	Fouled by hydroids
218	Fouled by hydroids, blisters
219	Fouled by hydroids, blisters, cracking along edge-trim
221	Blisters, hairline cracks
224	Hairline cracks
225	Hairline cracks
226	Blisters
227	Blisters, hairline cracks
228	Fouled by hydroids, hairline cracks
229	Blisters, hairline cracks
230	Corrosion eruptions
231	Blisters
232	Blisters
236	Fading
237	Fading, blisters, lost after photographing
238	Blisters
239	Blisters
244	Blisters
331	Fouled by hydroids
342	Wrinkling
343	Hairline cracks
347	Fouled by hydroids
349	Fouled by hydroids, wrinkling
350	Wrinkling
351	Fading
355	Fading, alligatoring
358	Fading
360	Fading
362	Wrinkling
363	Wrinkling, fading, fouled by hydroids
364	Blistering, fading
365	Wrinkling, fading
367	Wrinkling, fading, alligatoring
371	Hairline cracks
373	Hairline cracks
374	Fading
375	Blisters, hairline cracks, fading
378	Wrinkling
381	Hairline cracks, blisters, fading
383	Hairline cracks
384	Blisters
385	Hairline cracks
386	Hairline cracks
387	Hairline cracks, blisters

TABLE III (continued)

388	Hairline cracks
389	Hairline cracks
391	Blisters
393	Hairline cracks
396	Blisters
399	Blisters
400	Blisters
402	Blisters
403	Blisters
405	Blisters
408	Blisters
409	Blisters, Fading
411	Blisters, fading
413	Blisters, fading, hairline cracks
416	Blisters
417	Hairline cracks
424	Blisters
430	Blisters
432	Blisters
437	Blisters
440	Blisters
445	Blisters, purple spots near bottom
446	Hairline cracks
447	Hairline cracks
449	Hairline cracks
450	Hairline cracks
451	Hairline cracks
452	Hairline cracks, fading, blisters
453	Hairline cracks
454	Blisters
455	Blisters, hairline cracks
456	Hairline cracks
457	Hairline cracks
458	Hairline cracks, blisters
459	Hairline cracks, blisters
460	Hairline cracks
463	Hairline cracks, blisters
464	Hairline cracks, blisters
465	Hairline cracks, blisters
466	Hairline cracks, blisters
468	Hairline cracks, blisters
469	Hairline cracks, blisters
470	Hairline cracks, blisters
471	Hairline cracks
472	Hairline cracks, blisters
473	Hairline cracks, blisters
474	Hairline cracks
475	Hairline cracks, blisters
476	Hairline cracks, blisters

TABLE III (continued)

477	Hairline cracks
479	Hairline cracks, blisters
480	Hairline cracks
481	Blisters
486	Hairline cracks
487	Blisters
490	Hairline cracks
491	Hairline cracks, blisters
492	Blisters

TABLE IV

84	Blistering
85	Blistering
86	Blistering
87	Blistering and hairline cracks
89	Hairline cracks
90	Corrosion eruption
92	Blistering
94	Blistering and hairline cracks
95	Blistering and hairline cracks
96	Half the film loosened
97	Hairline cracks and blistering
101	Half the film loosened and hairline cracks
102	Paper ring surrounds a barnacle which has dug under the entire system-5 ml. barnacle.
104	Blistering and corrosion eruptions
105	Blistering
106	Blistering and corrosion eruptions
107	Blistering and corrosion eruptions and hairline cracks
109	Hairline cracks and corrosion eruptions
112	Hairline cracks, blistering, and corrosion eruptions
114	Many purple spots on bottom half
115	Hairline cracks
117	Blistering
118	Blistering
119	Blistering
120	Blistering
121	Blistering
122	Blistering
123	Blistering
124	Blistering and hairline cracks
125	Blistering
128	Blistering
130	Blistering
133	Blistering and corrosion eruptions
134	Hairline cracks--otherwise perfect
135	Blisters
136	Blisters
137	Hairline cracks and blisters along edges
138	Blisters
139	Blisters
141	Blisters
142	Blisters
144	Blisters
145	Blisters
146	Hairline cracks--otherwise perfect
147	Blisters
149	Anti-corrosive coat which shows is blistered
150	Blisters
151	Wrinkling, hairline cracks, and blisters
152	Blisters
153	Blisters

TABLE IV (continued)

154	Hairline cracks
155	Cracking along edge-trim
156	Blisters and corrosion eruptions
157	Hairline cracks--otherwise perfect
158	Hairline cracks
159	Blisters and hairline cracks
160	Blisters and hairline cracks
161	Hairline cracks
162	Blisters and corrosion eruptions
163	Blisters and hairline cracks
164	Hairline cracks and corrosion eruptions
165	Black marks due to mud settling against panel
169	Hairline cracks
171	Several purple spots on bottom half of panel
174	Blisters and hairline cracks
176	Blisters, corrosion eruptions, and purple spots on bottom half of panel
177	Blisters
178	Cracking along edge-trim
179	Blisters, corrosion eruptions and cracking along edge-trim
182	Blisters and cracking along edge-trim
183	Blisters and cracking along edge-trim
184	Many purple spots
185	Blisters, hairline cracks, corrosion eruption and cracking along edge-trim
186	Blisters and cracking along edge-trim
189	Blisters, corrosion eruptions
191	Corrosion eruptions and purple spots
192	Blisters and cracking along edge-trim
193	Cracking along edge-trim
194	Purple spots and blisters
197	Blisters
200	Blisters
201	Blisters
202	Wrinkling and corrosion eruptions
204	Blisters and corrosion eruptions and wrinkling
206	Blisters and hairline cracks
209	Corrosion eruptions
210	Blisters
212	Blisters
215	Blisters
217	Blisters
218	Blisters
219	Blisters
221	Blisters
223	Blisters
224	Blisters
225	Blisters
226	Blisters
227	Blisters

TABLE IV (continued)

228	Hairline cracks
229	Blisters and hairline cracks
230	Blisters
231	Blisters
232	Blisters and hairline cracks
234	Cracking along edge-trim
238	Blisters
239	Blisters and hairline cracks
241	Blisters and hairline cracks
242	Blisters and hairline cracks
244	Blisters
245	Blisters, hairline cracks and tube worm
246	Blisters
329	Wrinkling
331	One corrosion eruption--otherwise excellent
337	Corrosion eruptions
340	Blisters and hairline cracks
341	Blisters and hairline cracks
342	Wrinkling and cracking along edge-trim
343	Wrinkling, hairline cracks, and cracking along edge-trim
347	Wrinkling, cracking along edge-trim--otherwise excellent
349	Wrinkling--otherwise perfect
350	Wrinkling, four hairline cracks--otherwise perfect
355	Wrinkling and cracking along edge-trim
358	Blisters and hairline cracks
362	Wrinkling and hairline cracks
363	Hairline cracks, cracking along edge-trim and blisters
364	Blisters
365	Wrinkling and hairline cracks
366	wrinkling and hairline cracks
367	Wrinkling and checking
368	Hairline cracks
369	Hairline cracks and blisters
371	Hairline cracks and wrinkling
372	Cracking along edge-trim
373	Hairline cracks
375	Blisters and hairline cracks
376	Hairline cracks
377	Blisters
378	Wrinkling and blisters
379	Fading--otherwise perfect
381	Blisters
383	Blisters and hairline cracks
384	Blisters
385	Blisters
386	Blisters and hairline cracks
387	Blisters
388	Blisters
389	Blisters and hairline cracks

TABLE IV (continued)

390	Blisters and hairline cracks
391	Blisters
392	Hairline cracks
393	Hairline cracks--otherwise perfect
396	Blisters
397	Blisters
398	Blisters and hairline cracks
399	Blisters
400	Blisters
401	Hairline cracks
402	Blisters
403	Blisters and hairline cracks
405	Blisters
406	Blisters
407	Hairline cracks
408	Blisters
410	Hairline cracks
411	Hairline cracks and blisters
413	Hairline cracks
414	Hairline cracks
416	Hairline cracks and blisters
417	Hairline cracks
419	Hairline cracks
420	Hairline cracks
422	Hairline cracks
423	Blisters and hairline cracks
424	Blisters
425	Fading--otherwise perfect
429	Hairline cracks
430	Blisters
431	Hairline cracks
432	Blisters and hairline cracks
433	Blisters
437	Blisters
440	Blisters and hairline cracks
445	Blisters
447	Blisters and hairline cracks
449	Blisters and hairline cracks
450	Blisters and hairline cracks
451	Hairline cracks
452	Blisters and hairline cracks
453	Blisters and hairline cracks
454	Blisters
455	Blisters and hairline cracks
456	Blisters and hairline cracks
457	Blisters and hairline cracks
458	Blisters and hairline cracks
459	Blisters
460	Hairline cracks
463	Blisters and hairline cracks
466	Blisters and hairline cracks
468	Blisters
469	Blisters and hairline cracks

TABLE IV (continued)

470	Blisters
471	Hairline cracks
472	Blisters
473	Blisters
474	Hairline cracks
475	Blisters
479	Blisters
480	Hairline cracks
481	Blisters
486	Hairline cracks
487	Blisters
490	Hairline cracks
491	Hairline cracks and blisters

TABLE V - SIXTH MONTHLY INSPECTION

4	Blisters	158	1 Blister near edge-trim
5	Blisters	160	Blisters
7	Blisters	161	Corrosion eruptions
8	Cracked along the edge-trim	162	Blisters
9	Blisters	163	Blisters
0	Wrinkling	166	Blisters
1	Wrinkling	171	Corrosion eruptions
2	Blisters	172	Wrinkling
5	Entire film loose	173	Wrinkling
6	Blisters	174	Blisters
8	Blisters	176	Blisters - corrosion eruptions
04	Blisters	182	Blisters
05	Blisters	186	Blisters
06	Blisters	188	1 small blister along edge-trim, otherwise perfect
07	Blisters	189	Blisters
09	Blisters	191	Perfect
12	Blisters	193	Overboard
13	Blisters	194	Blisters
14	Blisters - purple spots	197	Blisters
15	Blisters	198	Blisters
16	Blisters	199	Wrinkling
17	Blisters	200	Blisters
18	Blisters	201	Blisters
19	Blisters	202	Wrinkling
21	Blisters	203	Wrinkling
22	Blisters	205	Wrinkling
23	Blisters	210	Blisters
25	Blisters	211	Blisters
27	Blisters	212	Blisters
28	Blisters	214	Blisters
30	Blisters	215	Blisters
31	Blisters	221	Blisters
34	Blisters - checking	223	Blisters
35	Blisters	224	Blisters
37	Cracks along edge-trim otherwise perfect	225	Blisters
138	Blisters	226	Blisters
142	Blisters - cracks along edge-trim	227	Blisters
144	Blisters	228	Checking otherwise perfect
145	Blisters	229	Blisters
146	Cracked and blistered along edge-trim	230	Blisters
147	Blisters	231	Blisters
150	Blisters - corrosion eruptions	232	Blisters
151	Blisters	234	Blisters
152	Blisters	236	Perfect
153	Blisters	238	Blisters
154	Blisters	239	Blisters
157	Blisters	241	Small blisters
		242	Blisters
		244	Blisters
		245	Blisters
		246	Blisters

TABLE V (continued)

9	Wrinkling	414	Checking otherwise perfect
8	Blisters	416	Blisters
0	Blisters	417	Checking otherwise perfect
1	Blisters	419	Blisters
2	Wrinkling	420	Checking otherwise perfect
7	Wrinkling otherwise perfect	422	One blister along edge-trim, otherwise perfect
9	Wrinkling otherwise perfect		
0	Wrinkling, one check, otherwise perfect	423	Blisters
		424	Blisters
5	Two blisters at edge-trim	425	Checking, otherwise perfect
8	Blisters	429	1 Blister along edge-trim
0	Wrinkling and checking	430	Blisters
2	Wrinkling and checking	431	One Blister
3	Blisters, checking	432	Blisters
4	Blisters	433	Blisters
5	Wrinkling, checking	437	Blisters
6	Wrinkling, checking	440	Entire film loose
7	Wrinkling, checking, 1 blister	445	Blisters
0	Blisters	446	One blister beside edge-trim otherwise perfect
1	Wrinkling, blisters		
3	checking	447	Blisters
4	Blisters	449	Blisters
5	Blisters	450	Blisters
6	Blisters	451	Checking otherwise perfect
8	Blisters	452	Blisters
9	Blisters	453	Blisters
3	Blisters	454	Blisters
4	Blisters	455	Blisters
5	Blisters	456	Blisters
6	Blisters	457	Blisters
7	Blisters	458	Blisters
8	Blisters	461	1/4 film loose
9	Blisters	463	Blisters
0	Blisters	464	Blisters
1	Blisters	465	Blisters
2	Checking otherwise perfect	466	Blisters
3	Checking otherwise perfect	468	Blisters
4	Blisters	470	Blisters
5	Perfect	471	Blisters
6	Blisters	472	Blisters
7	Blisters	473	Blisters
8	Blisters	474	Blisters
9	Blisters	475	Blisters
0	Blisters	476	Blisters
1	Perfect	477	Perfect
2	Blisters	478	Small blisters
3	Blisters	479	Blisters
4	Corrosion eruptions	480	Blisters
5	Blisters	481	Blisters
6	Blisters	482	Blisters
7	Checking otherwise perfect	483	Perfect
8	Blisters	488	Blisters along edge-trim
9	Whole film loose	490	Blisters
0	Checking otherwise perfect	491	Blisters
1	Blisters	492	Checking otherwise perfect
3	Checking otherwise perfect		

TABLE VI

SEVENTH MONTHLY INSPECTION

88	Cracked along edge-trim
89	Blistered along edge-trim
90	Wrinkling, corrosion eruptions, 1 blister
91	1 blister
96	Chipping, cracking, blistering
106	Blisters
112	Blisters, cracked along edge-trim
114	Blisters
116	Wrinkling, cracking, corrosion eruptions
121	Blisters
122	Blisters, wrinkling, corrosion eruptions
123	Blisters, corrosion eruptions
126	Corrosion eruptions
127	1/3 film loose
129	Checking, otherwise perfect
131	1 small blister
132	Blisters
134	Blisters
137	Chipped by rock along edge-trim, otherwise perfect
143	Lost while consolidating after removing panels on 9/24/45
146	4/5 film loose
154	Chipping, blistering
155	Blisters
158	Blisters
165	Checking, otherwise perfect
167	Checking, otherwise perfect
168	Checking, otherwise perfect
170	Checking, otherwise perfect
171	Corrosion eruptions
172	Mottled, chipping
173	Corrosion eruptions
184	Corrosion eruptions, cracked along edge-trim
187	Blisters
188	3 Blisters, otherwise perfect
191	Brown spots at top, otherwise perfect
193	Lost
198	Blisters
199	Corrosion eruptions
201	Wrinkling, blisters
202	Corrosion eruptions
203	Wrinkling
204	Blisters
205	Corrosion eruptions
207	1/2 film loose
208	Blisters
209	1/3 film loose, corrosion eruptions
211	Blistered at bottom
213	Checking, otherwise perfect
214	Cracking
216	Checking, otherwise perfect
228	Checking, otherwise perfect

TABLE VI (continued)

234	Blisters
235	Lost while photographing
236	Perfect
237	Lost while consolidating after removal of panels on 9/24/45
239	Blisters
241	Blisters
245	Blisters
246	Wrinkling, Blisters
329	2 cracks along edge-trim
331	Checking, otherwise perfect
332	Corrosion eruptions
336	Corrosion eruptions
337	Corrosion eruptions
338	1 blister
341	Blisters
343	Blisters
347	Peeling
349	Wrinkling, otherwise perfect
350	Wrinkling, otherwise perfect
351	3 blisters along edge-trim
355	Peeling
358	Blisters
360	Checking, otherwise perfect
362	Wrinkling, otherwise perfect
363	Blisters
364	Blisters
365	Wrinkling, otherwise perfect
367	Cracking
369	Corrosion eruptions
370	Blisters
371	Blisters
373	Checking, otherwise perfect
374	Blisters
376	Blisters
378	Corrosion eruptions
379	Blisters
386	Blisters
390	Blisters
391	Blisters
392	Checking, otherwise perfect
393	Perfect
394	Blisters
395	1 corrosion eruption, otherwise perfect
397	Blisters
398	Blisters
400	Blisters
401	Blisters
404	Blisters
407	Checking, otherwise perfect
411	Blisters
413	Checking, otherwise perfect
416	Blisters

TABLE VI (continued)

417	Wearing, otherwise perfect
419	Blisters
422	Checking, otherwise perfect
423	Blisters
424	Blisters
425	Perfect
428	Blisters
430	Blisters
431	Blisters
432	Blisters
433	Blisters
437	Blisters
445	Blisters
446	Blisters
447	Blisters
448	Corrosion eruptions
449	Blisters
450	Blisters
451	Blisters
457	Blisters
458	Blisters
459	Cracking
460	Checking, otherwise perfect
461	Blisters
463	Blisters
468	Blisters
469	Blisters
470	Blisters
471	Checking, otherwise perfect
474	Blisters
475	Blisters
476	Blisters
477	wearing, otherwise perfect
478	Blisters
480	Blisters
482	Blisters
483	Checking, otherwise perfect
486	Checking, otherwise perfect
488	Blisters
490	Blisters
491	Blisters
492	Checking, otherwise perfect

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