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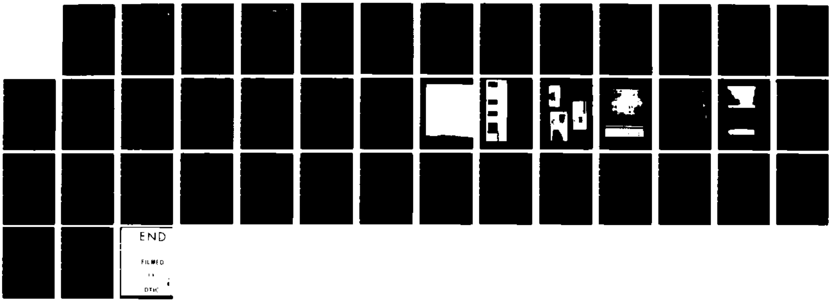

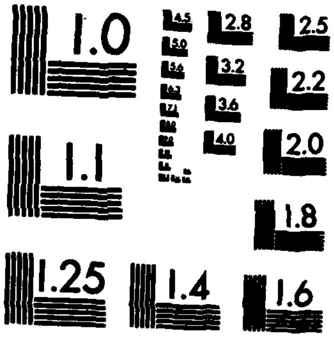
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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

RECOMMENDED PAINT SYSTEM FOR USE ON SHIP MODELS

by

Douglas S. Jenkins

and

Chao-Ho Sung

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SHIP PERFORMANCE DEPARTMENT REPORT

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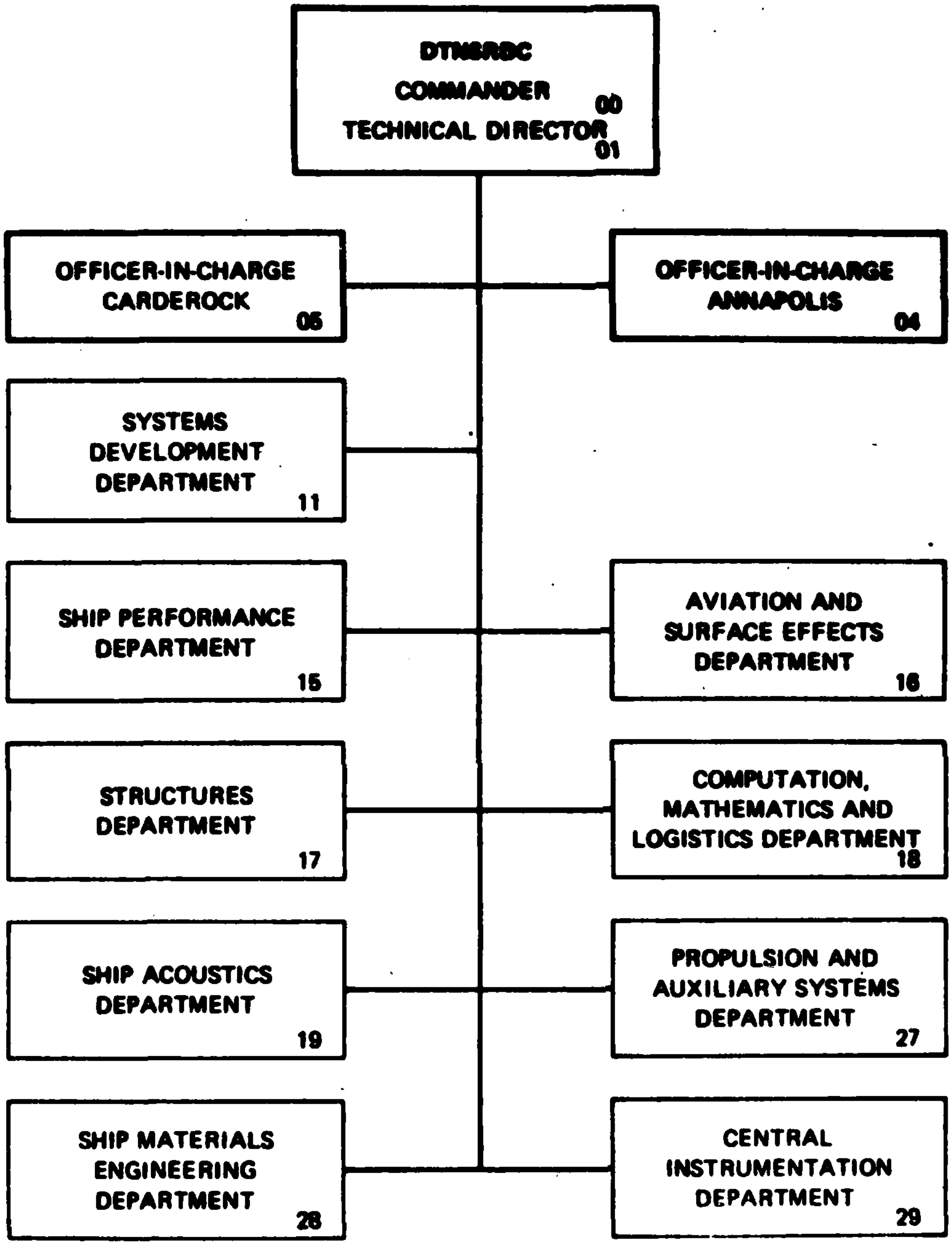

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When conducting resistance experiments on ship models in towing tanks, changes in the surface roughness are known to cause changes in the model resistance. In the past several years problems with deteriorating paint surfaces on ship models have resulted in changes in the model resistance. An investigation was undertaken to evaluate existing paint systems available at DTNSRDC for use on towing tank ship models for their ability to maintain a hydraulically smooth surface while immersed in water for a time period of up

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to three weeks. Twenty-seven specimens of fiberglass and wood were coated with combinations of paints which are currently being used at DTNSRDC. The surface roughness of each specimen was measured and observations of the amount of slime were made before, during, and after the three week period. It was found that the Seaguard Epoxy Paint System and the Balto-glaze Epoxy Paint System did maintain a smooth surface for at least three weeks. Based on this investigation, the Seaguard Epoxy paint system is recommended for use on ship models because it was found to be relatively easier to apply and more economical than the Balto-glaze paint system.

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NOMENCLATURE

		Dimension
k	Peak-to-trough roughness height	L
ks	Equivalent sandgrain roughness height	L
L	Length	L
R_n	Length Reynolds number, VL/ν	-
$R_{n_{ks}}$	Equivalent sandgrain roughness Reynolds number, $u_\tau \, ks/\nu$	-
u_τ	Friction velocity, $(\tau_o/\rho)^{1/2}$	L/T
V	Velocity	L/T
x	Distance	L
ρ	Density of fluid	M/L^3
τ_o	Wall shear stress	M/LT^2
ν	kinematic viscosity of fluid	L^2/T

SI/ENGLISH CONVERSION

1.0000 meter (m) = 3.2808 feet (ft)

1.00 micrometer (μm) = 39.37 micro-inches (μin)

1.0000 knot = 1.6878 feet per second (fps)

1.0000 meter per second (m/s) = 0.5144 knots

ABSTRACT

When conducting resistance experiments on ship models in towing tanks, changes in the surface roughness are known to cause changes in the model resistance. In the past several years problems with deteriorating paint surfaces on ship models have resulted in changes in the model resistance. An investigation was undertaken to evaluate existing paint systems available at DTNSRDC for use on towing tank ship models for their ability to maintain a hydraulically smooth surface while immersed in water for a time period of up to three weeks. Twenty-seven specimens of fiberglass and wood were coated with combinations of paints which are currently being used at DTNSRDC. The surface roughness of each specimen was measured and observations of the amount of slime were made before, during, and after the three week period. It was found that the Seaguard Epoxy Paint System and the Balto-glaze Epoxy Paint System did maintain a smooth surface for at least three weeks. Based on this investigation, the Seaguard Epoxy paint system is recommended for use on ship models because it was found to be relatively easier to apply and more economical than the Balto-glaze paint system.

ADMINISTRATIVE INFORMATION

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INTRODUCTION

Towing tank ship models are used extensively for making full scale powering predictions and for evaluating the effect of changes in hull and appendage geometry on ship resistance. At DTNSRDC, ship models are constructed of wood or fiberglass. All of the wooden models are painted with some type of sealer and then enamel or epoxy paint. Fiberglass models do not require a protective coating like wood, but they are sometimes painted, primarily for appearance and to aid flow visualization

When experiments are conducted in the towing tank, the model may be immersed in the water anywhere from several days to several weeks. As a consequence of being immersed in the water, wooden models have a tendency to swell and their shape may change. The baseline resistance of a wooden model would be obtained during the first experiment after the model had been immersed in the water for less than one day. Any subsequent resistance data would be adjusted to the baseline values that were obtained when the model had not swelled. This procedure had masked any changes in the model resistance that may have been caused by changes in surface roughness, attributable to the paint finish. Today most submerged models are built of fiberglass, and these ship models do not swell. However, some ship models do show degradation of surface finish after immersion in water over an extended time period, as illustrated in Figure 1. As a result of the surface finish degradation, the model resistance has, particularly for submarine models, increased by a measureable amount. Submarine model resistance is more sensitive to changes in surface finish than surface ship model resistance, because frictional resistance is a larger portion of the total resistance than in the case of surface ships (where wave resistance is a significant portion of the total resistance).

The problem of model resistance changing due to the surface finish is important. At the present time the model testing community is being requested to evaluate smaller differences in the powering performance of ships due to changes in geometry than in the past. If the towing tank ship-model experiments are being conducted over a period of one week or longer, any expected change in the model resistance due to changes in the geometry may be masked by changes in the model's frictional resistance caused by a deteriorating paint surface.

The effect of different paints on the resistance of ship models was shown by West[1] to be measurable. Three different paints were applied to a friction plane by West, and the resistance of the friction plane was measured over a range of speeds (Reynolds number varied from 1.45 - 5.00 x 10^7). The results showed that the drag was different for the three different paints although they were all applied to a smooth surface and the paints did not blister or peel off.

The investigation reported herein was undertaken to select and recommend a paint system that should be used on ship-models so that the surface roughness of the model does not increase with time immersed in the water. The acceptance or rejection of a specific paint system was based on the criteria of a hydraulically smooth surface at the flow conditions of typical ship models, which is based on the roughness Reynolds number.

This report describes the different paint specimens and how they were evaluated for their ability to maintain a smooth surface finish on wood and fiberglass while immersed in water.

DESCRIPTION OF EXPERIMENT

SELECTION OF PAINT SPECIMENS

The paints, sealers and surfacing compounds that were used in this study were limited to those which are currently used at DTNSRDC (See Table 1). The paints, sealers and surfacing compounds were applied to small boards made of fiberglass with epoxy resin, fiberglass with polyester resin, and pine wood. Most of the submarine models currently in use at DTNSRDC are made of fiber glass. Most of the surface ship models are made of pine wood. Twenty-seven paint specimens were prepared: nine fiberglass specimens with epoxy resin, eleven with polyester resin and seven pine wood specimens. A total of fourteen

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[1] References are listed on page 12.

different combinations of primers and top coats were applied to the twenty-seven speciments, as shown in Table 2.

PREPARATION OF SPECIMENS

Each specimen was prepared in the same manner as the surface of ship models. After the model material was selected, a sealer (for the wood specimens) and/or a surface putty was applied to the surface. The surface putty was intended to help smooth out the surface. After the sealer and/or surface putty had dried, the specimen was sanded smooth. Three light coats of primer were then applied, allowing several hours of drying time between coats. The primer coats were sanded lightly before one coat of finish paint was applied. Before immersing the specimens in water, they were allowed to dry for one to five days, depending on the paint manufacturer's recommendations.

All of the sealers, primers and finish coats of paint are applied to the surface of a model with a compressed air type spray gun. In preparing the specimens, the air pressure supplied to the spray gun, the amount of paint, and paint thinner used for each coat were provided in the same manner as during model preparation. In some of the painted surfaces of the specimens, it was discovered that small particles of dried paint were imbedded in the surface. This occurred primarily with some of the epoxy type paints. This problem was eliminated by making sure that the spray gun nozzle was properly cleaned before its use.

IMMERSION TESTS

After the paint specimens were prepared and allowed to dry, they were submerged in the towing tank. Figure 2 shows ten of the fiberglass specimens mounted on a strut. The wooden specimens were submerged in the towing tank with the aid of ballast weights. All of the wooden specimens and most of the fiberglass specimens were submerged in the towing tank without being towed under the carriage. However, seven of the fiberglass specimens were towed in water for four days on a vertical strut in the low speed basin while ship model resistance experiments were being conducted.

EVALUATION OF SURFACE FINISH

Each paint specimen was evaluated for its property to maintain a smooth surface finish and resist the growth of slime while immersed in the water. Prior to submerging the specimens in the water, their surface roughness was measured to establish an initial roughness.

A Federal Surf-Indicator surface analyser (shown in Figure 3) was used to measure the peak-to-trough roughness height. The output could be displayed on the analog meter provided in the instrument box, on a digital voltmeter or on a strip chart recorder. The roughness probe of the analyzer was calibrated with a standard block, having a sandgrain roughness height of 3.2 μm (125 μin). For roughness heights exceeding the limits of the instrumentation (76 μm (3000 μin)), a depth gage was used. The surface roughness probe could be moved along the surface either manually or with the traversing arm, shown in Figure 3. The speed of movement of the traversing arm is 0.32cm/s (0.125 in/s). The accuracy of the surface roughness gage and the interpretation of the output signal is considered to be ±1.0 μm (±40 μin).

During the time that the paint specimens were immersed, they were removed periodically to determine the amount of slime growth and to measure the surface roughness. Although it is possible to measure the thickness of the slime layer (cf. Belt and Smith[2]), this was not done for these experiments.

Instead, the degree of the growth of slime was judged visually and was described as no slime, little slime or slimey.

In addition to determining the amount of slime and the roughness height, an attempt was made to determine the distribution of the roughness. This was done using the technique of "gravestone etching". A sheet of paper is laid over the surface and the area is shaded with a pencil or a china marker. The blisters show up as dark spots. Figures 4 and 5 show paint specimen No. 3 after twelve days in the water. Figure 4 shows paint degradation in the form of blisters and Figure 5 shows the corresponding distribution of blisters using the technique of "gravestone etching".

A complete description of each specimen and the results of the slime observations and roughness measurements are given in Appendix A. The fourteen combinations of paints were given a PASS or FAIL rating for their ability to resist the growth of slime and to maintain a smooth surface finish for the total immersion time (22-24 days). If the surface roughness measurements were less than 12 μm (475 μin) for the entire immersion period on all of the specimens with the same paint combination, then the paint combination was considered to be acceptable and it was given a passing rating. The value of 12 μm (475 μin) was chosen as an acceptable roughness height, based on typical flow conditions in towing tanks on ship models. This will be further discussed in the next section of the report. The paint combination was considered acceptable in terms of its property to resist the growth of slime, if slime was not observed on any of the specimens for the entire immersion time. The results of the rating on the fourteen paint combinations for both slime and blisters are shown in Table 2.

DISCUSSION OF RESULTS

The two criteria used to judge whether one paint specimen was better than another were: (1) resistance to the growth of slime and (2) resistance to paint degradation in the form of blisters.

Typically, a ship model is only in motion for 3 to 4 hours during any 8 hour testing period. When seven of the paint specimens were towed in this manner, no differences were observed from those that were not towed, regarding the surface degradation.

Sealers and surface putty provide a smooth surface, but they do not appear to have any noticeable effect on the resistance to the growth of slime or increase in the surface roughness of painted surfaces.

The present standard paint system, Dupont preparacote primer and Dupont dulux enamel, showed consistently poor resistance to paint degradation on both wood and fiberglass. The main problem with this paint system is the primer. Paint specimen No. 21 (wooden) was painted with Devoe epoxy primer on one side and with Dupont preparacote primer on the other. Dupont dulux grey enamel was then painted over the entire specimen. After 21 days of immersion, the side with Dupont preparacote primer had blisters whose height was 12.7-17.8 μm (500-700 μin), as shown in Figure 6. The side with the Devoe epoxy primer did not have any change in its roughness height as shown in Figure 7. Dupont preparacote primer and Dupont dulux grey enamel was also used on fiberglass specimens Nos. 3 and 13. Blisters started appearing on these specimens after 6 and 9 days respectively for speciments Nos. 3 and 13; and after 22 and 24 days, the surface roughness had increased from an initial roughness of 0.5-1.0 μm (20-40 μin) to values as high as 165 μm (6500μin).

Paint specimen No. 17, which was painted with Balto-glaze primer and white finish on top of Dupont preparacote primer and Dupont dulux yellow, also showed an increase in surface roughness while immersed in water. However, paint specimen Nos. 6, 16, and 22, painted with only Balto-glaze primer and white finish, were excellent in terms of resisting the growth of slime and blisters. Based on paint specimen Nos. 6, 16, and 22, the Balto-glaze primer and white finish is acceptable for use on ship models in towing tanks. However, this paint system is more expensive than other epoxy and enamel paints. In addition, special care is required when using Balto-glaze products. The additives must be precisely proportioned and the surface to be painted must be prewashed more carefully than for other paints.

The Seaguard Epoxy paint system is strongly recommended for use on towing tank ship-models, based on the two criteria mentioned earlier, low cost, and ease of application. Paint specimens 10A, 18A, 19 and 23 were painted with this three coat epoxy paint system. For periods up to 24 days, this paint system maintained a smooth surfce finish on both fiberglass and wood. Also, there was no observable slime growth throughout the immersion period. The cost of this paint is comparable to the cost of enamel paints and it did not require special care in its application.

In addition to the Seaguard and the Balto-glaze epoxy paint systems, the combination of the Devoe epoxy primer and Rustoleum white epoxy were found to be good, as indicated by the results of the immersion tests on paint specimens Nos. 1, 11, and 24.

Quantifying the roughness of a surface is not a trivial task. The randomness of surface roughness makes the interpretation of roughness measurements difficult. However, in order to make some judgement on the paint specimen roughness measurements, an estimate was made of the maximum roughness height allowable under typical ship model flow conditions. From Reference 3, the roughness Reynolds number can be defined as,

$$R_{n_{ks}} = \frac{(ks)u_\tau}{\nu}$$

where ks = equivalent sandgrain roughness height

$u_\tau = (\tau_o / \rho)^{\frac{1}{2}}$ = friction velocity

τ_o = wall shear stress

ν = kinematic viscosity

From extensive measurements of turbulent boundary layer flows through pipes with sandgrain roughness, it is known that if $R_{n_{ks}} \leq 5$, then the surface is considered hydraulically smooth. A surface is considered hydraulically smooth if the protrusions do not exceed the height of the laminar sublayer.[3] This result is applicable to flat plates with an irregular distribution of roughness, provided the roughness height, k, can be appropriately converted to an equivalent sandgrain roughnes, ks.

To apply the above result to a ship model, both ks and u_τ must be estimated. A typical ship model has a speed range of 1.5 to 4.6 m/s (3 to 15 knots) and the area where the surface roughness affects the wall shear stress is near the bow of the model where the boundary layer is relatively thin. The highest model speed and the region just downstream of the tripwire will be considered. The speed of V = 7.7 m/s (15 knots) and a distance x = 0.3 m (1.0 ft) from the bow of the model were chosen for calculating u_τ. It is assumed that the flow is laminar upstream of and turbulent downstream of the tripwire which, for a 4.9 m

(16.0 ft) long model, would be located at 0.24 m (0.80 ft) aft of the bow. Under this assumption, the thickness of the boundary layer has an abrupt jump at the location of the tripwire due to an increase in momentum induced by the tripwire. In order to predict the friction velocity at the location of the tripwire, the concept of the virtual origin of the turbulent boundary layer (cf. McCarthy[4]) is introduced. It is assumed that the virtual origin is located at $x = 0$, and the flow is turbulent from $x = 0.3$ m (1.0 ft). From the 1/7th power law for turbulent flow, the friction velocity can be computed to be $u_\tau = 0.30$ m/s (1.0 fps). For the surface to be hydraulically smooth, $R_{n_{ks}} \leq 5$. Solving for ks, the maximum height of equivalent sandgrain roughness for a hydraulically smooth surface should be less than ks = 17 μm (670 μin). This value was calculated assuming fresh water at a temperature of 19°C (66°F).

From Figure 3 and 4 it can be seen that the paint blisters resemble densely packed spherical segments. Using Figure 20.24 of Reference 2, roughness pattern No. 11 was chosen to convert ks to k. Using this pattern, the maximum allowable roughness height in order to maintain a hydraulically smooth surface is k = 12 μm (475 μin). Those specimens which had a surface roughness height close to or greater than 12 μm (475 μin) after the total immersion time were given a "FAIL" rating in terms of their ability to maintain a smooth surface finish. These ratings are shown in Table 2 for the fourteen combinations of paints that were applied to the paint specimens.

CONCLUSIONS

1. The standard paint system, Dupont preparacote primer and dulux enamel was found to be unacceptable in terms of maintaining a smooth surface finish and resisting the growth of slime on both fiberglass and wood while immersed in water.

2. The Seaguard Epoxy Paint system is recommended for use on ship models that are used in towing tanks. This three-coat epoxy paint system is easier to apply to the surface than other epoxy paint systems, and the cost is comparable to enamel paints. On both fiberglass and wood, this paint system maintained a smooth surface finish and resisted the growth of slime, when immersed in water for as long as three weeks.

3. The Balto-glaze epoxy primer and white finish coat was also acceptable in maintaining a smooth surface finish and resisting the growth of slime. However, this paint system costs significantly more than enamel paints and requires greater care in its application.

4. For typical ship model flow conditions, calculations indicate that the surface roughness of the standard paint system, after immersion in water, was hydraulically rough. The surface painted with either the Seaguard Epoxy Paint System or the Balto-glaze Paint System was hydraulically smooth.

ACKNOWLEDGMENT

The authors wish to thank Mr. Stanley Gross, retired model surfacer and finisher, for his excellent work in preparing all of the specimens.

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2. Belt, G. G and N.A. Smith, "Drag of Slimes on Rough and Smooth Surfaces as Measured by a Rotating Disk", DTNSRDC/SPD-0865-01 (July 1979).

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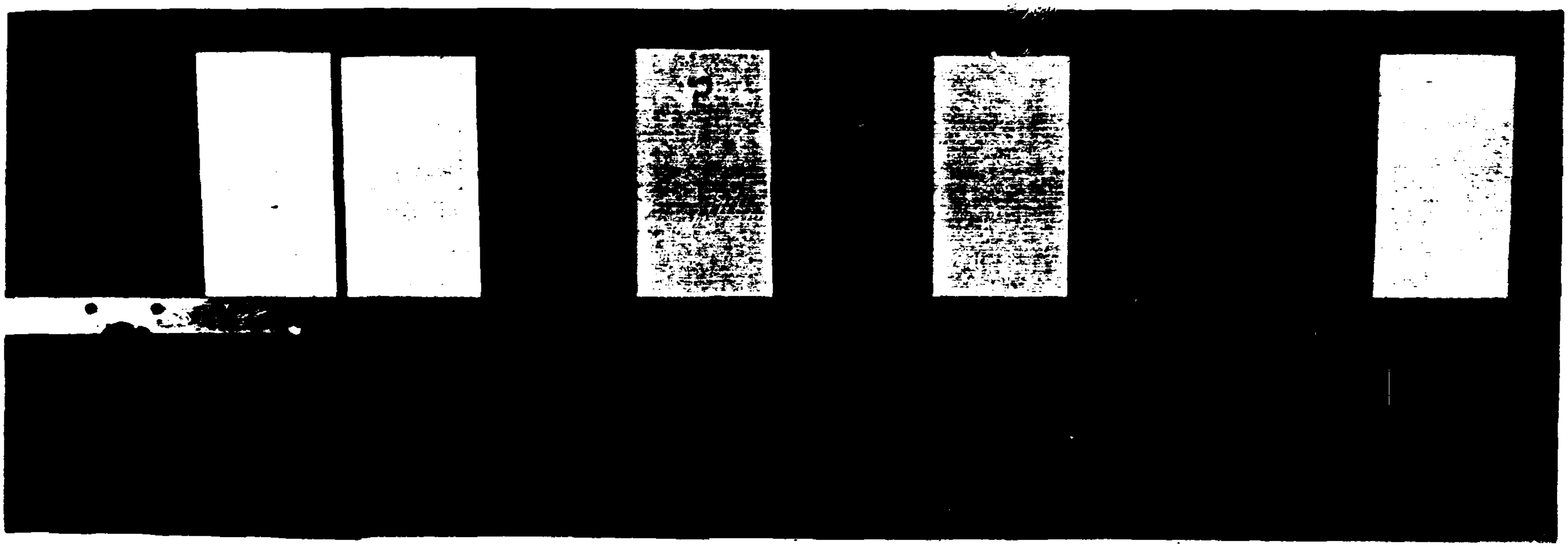
4. McCarthy, J.H., et al., "The Roles of Flow Transition, Laminar Separation and Turbulence Stimulation in the Analysis of Axisymmetric Body Drag", Eleventh Symposium on Naval Hydrodynamics, London, England (1976).

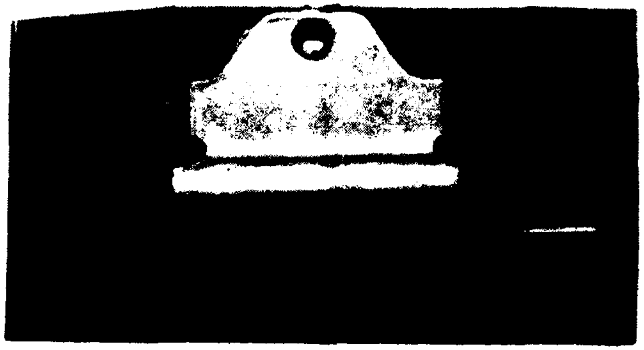
Figure 1 - Ship Model with Standard Paint System After Ten Days of Immersion [Surface Roughness Height was 5-381 μm (200-15,000 μin)]



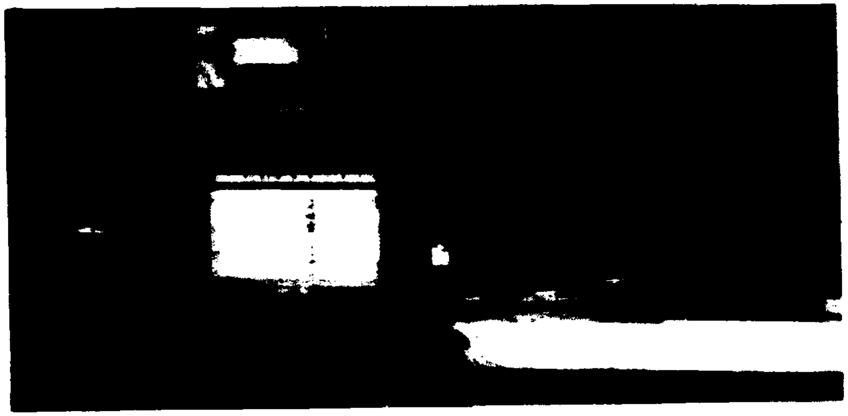
From left to right, Paint Specimens 12, 11, 10A, 8, 7, 5, 4, 3, 2, 1

Figure 2 - Ten Paint Specimens Mounted on Strut

Setup for measuring the surface roughness
of ship model



Close-up view of surface roughness probe



Setup for measuring roughness of paint specimens, with traversing mechanism

Figure 3 - Setup of Surface Roughness Measurement System

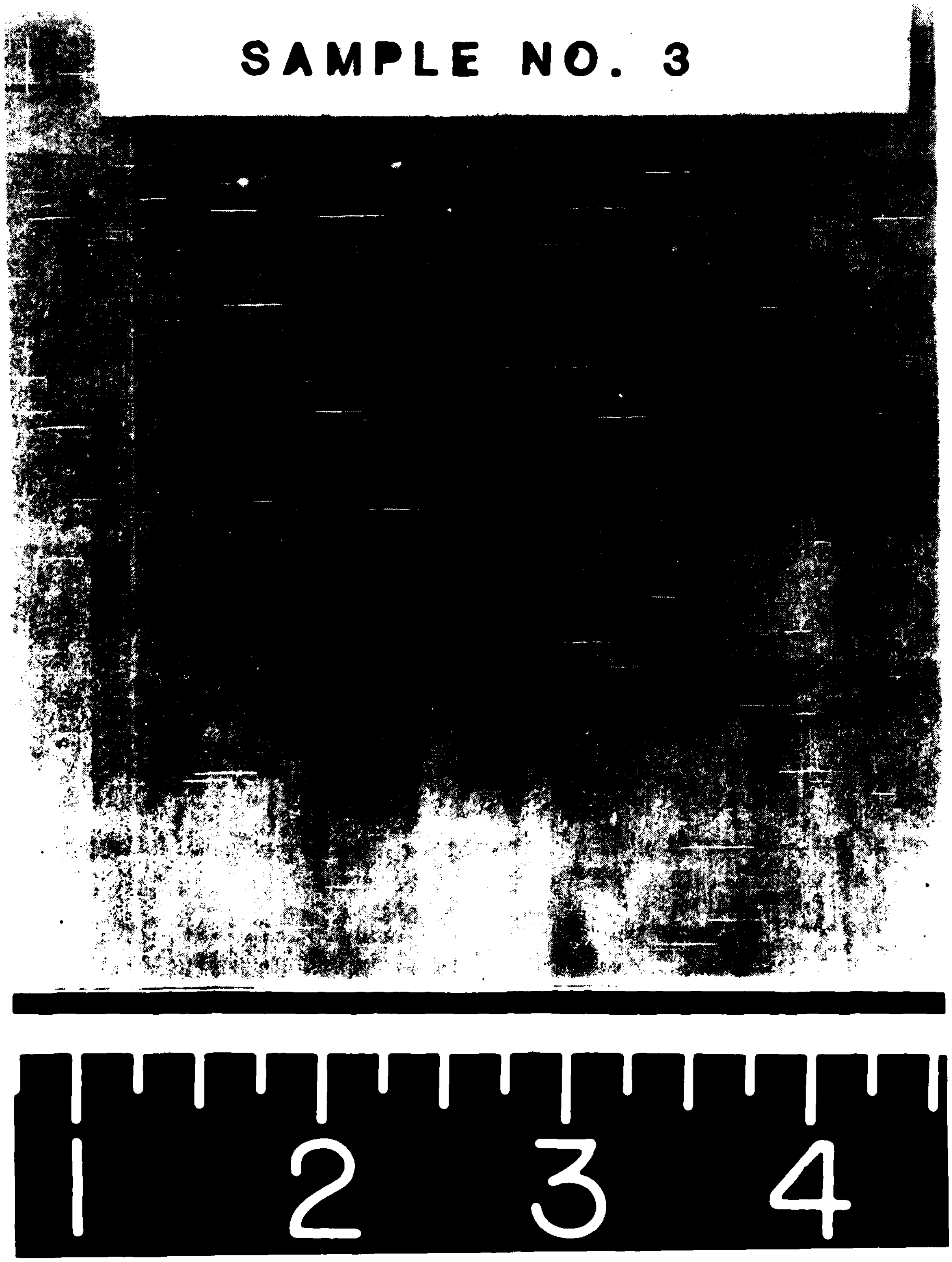


Figure 4 - Paint Specimen No. 3 After Twelve Days of Immersion
(Showing Paint Degradation in the Form of Blisters)

Figure 5 - "Gravestone Etching" of Paint Specimen No. 3 After Twelve Days of Immersion (Showing the Distribution of Blisters)

Figure 6 - The Half Board of Paint Specimen No. 21 with Dupont Preparacote Primer after Twenty-one Days of Immersion

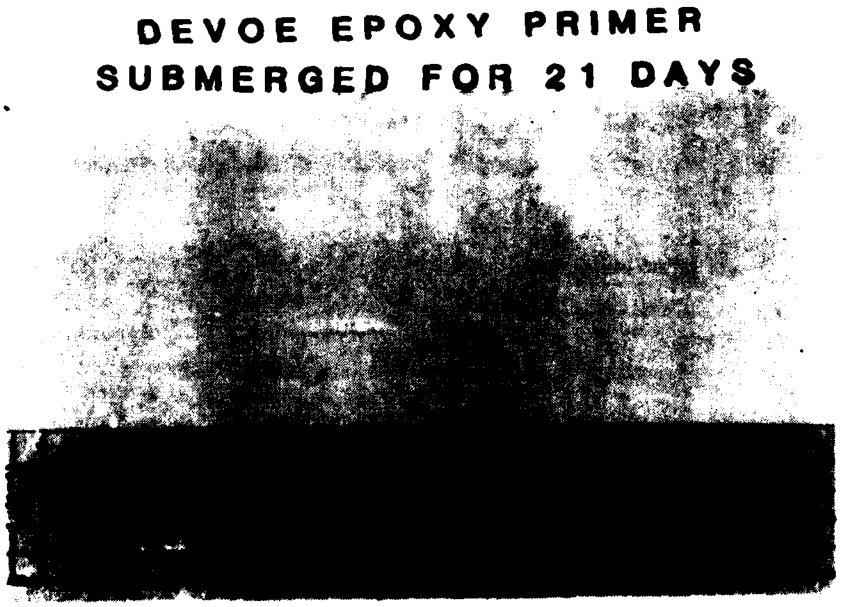


Figure 7 - The Half Board of Paint Specimen No. 21 with Devoe Epoxy Primer After Twenty-one Days of Immersion

TABLE 1 - MODEL AND PAINT MATERIALS USED AT DTNSRDC

Model Material	- fiberglass with polyester resin
	- fiberglass with epoxy resin
	- pine wood
Sealer	- Dupont Duco (clear)
Surface Putty	- Duratite
	- Dulux and Dulux-glazing
Primer	- Dupont preparacote
	- Devoe epoxy green
	- Seaguard epoxy green
	- Rustoleum orange
	- Balto-glaze
	enamel
Finish Coat	- Dupont dulux yellow
	- Dupont dulux grey
	- Dupont dulux white
	- Rustoleum yellow
	epoxy
	- Rustoleum white
	- Seaguard grey and white
	- Balto-glaze

TABLE 2 - RATING OF PAINT COMBINATIONS USED ON SPECIMENS

PAINT COMBINATION	SPECIMEN NUMBER			RATINGS (F-Fail, P-Pass)	
	FIBERGLASS		WOOD	SLIME	BLISTERS
	Polyester Resin	Epoxy Resin			
1. Dupont preparacote primer Dupont dulux yellow enamel	5	15		F	F
2. Rustoleum orange primer Rustoleum white epoxy	4	14		P	F
3. Balto-glaze primer Balto-glaze white finish	6	16	22	P	P
4. Seaguard Epoxy Paint System green primer grey finish white finish	10A	18A	19 23	P	P
5. Devoe epoxy primer Dupont dulux yellow (or white) enamel	12	20	25	F	F
6. Devoe epoxy primer Dupont dulux grey enamel	3	13	21	F	F
7. Devoe epoxy primer Rustoleum white epoxy	1	11	24	P	P
8. Devoe epoxy primer Rustoleum yellow enamel	2			F	F
9. Dupont preparacote primer Dupont dulux yellow enamel Rustoleum white epoxy	7			F	F
10. Devoe epoxy primer Dupont preparacote primer Dupont dulux grey enamel			21	P	F
11. Rustoleum orange primer Rustoleum white epoxy Dupont dulux grey enamel	8			F	F
12. Dupont preparacote primer Dupont dulux yellow enamel Balto-glaze primer Balto-glaze white finish	9	17		P	F
13. Devoe epoxy primer Rustoleum white epoxy Balto-glaze primer Balto-glaze white finish	10			P	P
14. Balto-glaze primer Balto-glaze white finish Dupont preparacote primer Dupont dulux yellow enamel		18		F	P/F

APPENDIX A
DESCRIPTION OF PAINT SPECIMENS

Paint Specimen No. 1

Material: Fiberglass with polyester resin

Paint: Duratite surface putty
Devoe epoxy green primer (3 coats)
Rustoleum white epoxy finish

Initial Roughness: The average height is 0.8 - 1.3 µm (30-50 µin) in the smooth area. There are small areas of blisters with heights of 3.8-6.4µm (150-250 µin).

After 6 days: There is no slime nor paint degradation.

After 12 days: There is very little slime and no paint degradation is observed.

After 22 days: The same as it was after 12 days.

Rating on Blisters: Excellent
Rating on Slime: Excellent

Paint Specimen No. 2

Material: Fiberglass with polyester resin

Paint: Dulux-glazing surface putty
Devoe epoxy green primer (3 coats)
Rustoleum yellow enamel

Initital Roughness: The average height is 0.8-1.8µm (30-70 µin) in the smooth area. There are three areas of small blisters with a height of 2.0 µm (80 µin). The fiberglass is bumpy.

After 6 days: The surface is slimy but there is no degradation. The roughness height of the three areas of small blisters remains approximately the same.

After 12 days: The surface is slimy. No degradation is observed in the formerly smooth area but the roughness heights of the three areas of small blisters have increased to 3.8-7.6µm (150-300 µin).

After 22 days: The same as it was after 12 days but the roughness height of the rough areas has increased to 5.1-15.2 µm (200-600 µin).

Rating on Blisters: Fair
Rating on Slime: Fair

Remark: Poor initial surface roughness

Paint Specimen No. 3

Material: Fiberglass with surface resin
Paint: Duratite surface putty
Devoe epoxy green primer (3 coats)
Dupont dulux gray enamel

Initial Roughness: The average height is 0.8-1.8 μm (30-70 μm) in the smooth area. In the area where the cloth is exposed, the surface roughness is as high as 3.8μm (150 μin).

After 6 days: It is very slimy. There is degradation in the form of densely packed small blisters, the roughness varies from 2.5 to 7.6 μm (100 to 300 μin).

After 12 days: It is less slimy but the roughness heights of the densely packed small blisters have increased to 2.5-19.1 μm(100-750 μin) with an average of 6.4 μm (250 μin)

After 22 days: There is no slime but small blisters with 3.8-10.2 μm (150-400 μin) are all over the surface. There are three areas of large blisters with heights of 16.5-22.9 μm (650-900 μin).

Rating on Blisters: Poor
Rating on Slime: Fair

Remark: Poor initial roughness; inconsistent slime observations

Paint Specimen No. 4

Material: Fiberglass with polyester resin
Paint: Rustoleum orange primer (3 coats)
Rustoleum white epoxy finish

Initial Roughness: The average roughness is 0.8-1.5 μm (30-60 μin). The surface finishing is good.

After 6 days: There is no slime nor surface degradation.

After 12 days: There is no slime. The surface remains smooth with the exception of 5 or 6 blisters with 5.1 μm (200 μin) roughness height.

After 22 days: Some slime appears. The blisters grow in four small areas with a roughness height of 25.4-38.1 μm (1000-1500 μin).

Rating on Blisters: Poor
Rating on Slime: Good

Paint Specimen No. 5

Material: Fiberglass with polyester resin
Paint: Dulux-glazing surface putty
Dupont preparacote primer (3 coats)
Dupont dulux yellow enamel

Initial Roughness: The average height of roughness is 0.8-1.8µm (30-70 µin).

After 6 days: It is slimy. Some large blisters of height 38.1 µm (1500 µin) with water moisture inside appear.

After 12 days: It is slimy. Both the number and the size of the blisters have increased. The 50 or 60 blisters have a diameter of approximately 0.32 cm(1/8 in)and have a roughness height of 45.7 µm (1800 µin).

After 22 days: It remains slimy. The number of the blisters has increased to approximately 100, the diameter has increased to 0.48 cm (3/16 in) and the roughness height varies from 15.2 µm (600 µin) to as much as 300 to 450 µm (12,000 to 18,000 µin). There is water moisture inside the blisters.

Rating on Blisters: Poor
Ration on Slime: Fair

Paint Specimen No. 6

Material: Fiberglass with polyester resin
Paint: Balto-glazing primer
Balto-glazing white finish

Initial Roughness: The average height is 0.3-1.3 µm (10-50 µin). The surface has a high gloss finish.

After 6 days: The surface is very clean: there is no slime nor blisters.

After 13 days: There is no slime nor surface degradation.

After 23 days: There is still no slime nor surface degradation. The roughness height is approximately 0.8-1.3 µm (30-50 µin).

Rating on Blisters: Excellent
Rating on Slime: Excellent

Remark: Good surface finish

Paint Specimen No. 7

Material: Fiberglass with polyester resin
Paint: Dulux surface putty
Dupont preparcote primer (3 coats)
Dupont dulux yellow enamel
Rustoleum white epoxy finish

Initial Roughness: The average height is 1.0-1.8μm (40-70 μin). The surface has a good finish.

After 6 days: There is no slime nor blisters.

After 12 days: There is no slime but there are areas of small blisters with heights of 3.8-10.2 μm (150-400 μin)

After 22 days: There is a small amount of slime. The blisters have grown into some (100) large ones with heights of 38.1-305 μm (1500-12000 μin) and some smaller ones with heights of 2.0-3.8 μm (80-150 μin).

Rating on Blisters: Poor
Rating on Slime: Good

Remark: Good Surface finish

Paint Specimen No. 8

Material: Fiberglass with polyester resin
Paint: Duratite surface putty
Rustoleum orange primer (3 coats)
Dupont dulux grey enamel
Rustoleum white epoxy finish

Initial Roughness: The average height is 0.5-1.3 μm (20-50 μin).

After 6 days: The surface is slimy and one small area of blisters with heights of 3.8-5.1 μm (150-200 μin) appears.

After 12 days: The surface remains slimy but the number of small areas of blisters has increased to four. The blisters are small in diameters and range in heights from 5.1 to 1.27 μm (from 200 to 500 μin).

After 22 days: The surface is still slimy. The number of small areas of blisters is now ten, but the roughness height has no noticeable increase.

Rating on Blisters: Fair
Rating on Slime: Fair

Paint Specimen No. 9

Material: Fiberglass with polyester resin
Paint: Dupont preparacote primer (3 coats)
Balto-glaze primer
Balto-glaze white finish

Initial Roughness: The average height is 0.3-1.3 μm (10-50 μin).

After 9 days: There is no slime nor paint degradation.

After 13 days: The same as after 9 days.

After 20 days: There is no slime but there are some blisters that have a diameter of 0.32 cm(1/8in)and a height of 2.0-2.8 μm (80-110 μin).

After 24 days: There is no slime. The diameter of the blisters appeared after 20 days remains approximately the same but the height has increased to 2.5-5.1 μm (100-200 μin).

Rating on Blisters: Fair
Rating on Slime: Excellent

Paint Specimen No. 10

Material: Fiberglass with polyester resin
Paint: Devoe epoxy green primer (3 coats)
Rustoleum epoxy white finish
Balto-glaze primer
Balto-glaze white finish

Initial Roughness: The average height is 0.3-1.3 μm (10-50 μin).

After 9 days (4 days on Carriage 1): There is no slime nor paint degradation.

After 14 days: There is no slime. Two areas of small blisters appear. The diameter of these blisters is small and the height is approximately 2.5 -6.4 μm (100-250 μin).

After 24 days: The condition is about the same as after 21 days.

Rating on Blisters: Fair
Rating on Slime: Excellent

Remark: the finish is glossy and very hard.

Paint Specimen No. 10A

Material: Fiberglass with polyester resin
Paint: Dulux surface putty
Seaguard green primer (3 coats)
Seaguard grey finish } Seaguard Epoxy System
Seaguard white finish

Initial Roughness: The average height is 0.8-1.8 μm (30-70 μin). There are a few particles as high as 3.8 μm (150 μin)

After 6 days: There is no slime nor paint degradation.

After 12 days: The same as after 6 days.

After 22 days: It still remains almost the same as after 6 days.

Rating on Blisters: Excellent
Rating on Slime: Excellent

Remark: Despite the fact that there are a few particles in the paint, this is a smooth fiberglass job.

Paint Specimen No. 11

Material: Fiberglass with epoxy resin
Paint: Dulux-glazing surface putty
Devoe epoxy green primer
Rustoleum epoxy white finish

Initial Roughness: The average height is 1.0-2.5 μm (40-100 μin). There are small particles in the paint. This is a poor fiberglass job.

After 6 days: There is no slime nor paint degradation.

After 12 days: The same as after 6 days.

After 22 days: A small amount of slime has accumulated but there is still no paint degradation.

Rating on Blisters: Excellent
Rating on Slime: Excellent

Remark: Despite poor initial roughness conditions, the paint is excellent in resisting the growth of both slime and blisters.

Paint Specimen No. 12

Material: Fiberglass with epoxy resin
Paint: Duratite surface putty
Dulux-glazing surface putty
Devoe-epoxy green primer (3 coats)
Dupont dulux yellow enamel

Initial Roughness: In smooth areas, the roughness height is 0.3-0.8 μm (10-30 μin). Otherwise, the roughness height is 0.8-1.8 μm (30-70 μin) with some peaks to 3.8 μm (150 μin). This is a poor fiberglass job.

After 6 days: There is a layer of thick slime. After wiping off the slime, the roughness height is 1.0-1.8 μm (40-70 μin).

After 12 days: It is slimy. There are blisters all over, with roughness heights of 2.5-3.8 μm (100-150 μin) and some as high as 12.7 μm (500 μin).

After 22 days: The slime situation is about the same as after 12 days, but both the number and the roughness height of the small blisters have increased. The roughness height varies from 2.5 to 10.2 μm (100 to 400 μin).

Rating on Blisters: Poor
Rating on Slime: Poor

Remark: Poor initial roughness.

Paint Specimen No. 13

Material: Fiberglass with epoxy resin
Paint: Dulux-glazing surface putty
Devoe epoxy green primer (3 coats)
Dupont dulux grey enamel

Initial Roughness: The average height is 0.5-1.0 μm (20-40 μin). There are some bumps with a height of 3.8 μm (150 μin) and some very tiny blisters.

After 9 days: (4 days on Carriage 1). There is a small amount of slime. The small-diameter blisters in the lower portion of the paint plate appear to be higher (3.8-7.6 μm, i.e. 150-300 μin) than those appear in the middle portion of the plate (3.8 μm, i.e. 150 μin).

After 14 days: The slime situation is the same as after 9 days but the small-diameter blisters are now almost everywhere. There is no significant increase in the roughness height of these blisters.

After 24 days: There is some slime. The roughness height has increased somewhat to 2.5-7.6 μm (100-300 μin) with peaks to 16.5 μm (650 μin).

Rating on Blisters: Poor
Rating on Slime: Fair

Remark: Poor initial roughness condition

Paint Specimen No. 14

Material: Fiberglass with epoxy resin
Paint: Duratite surface putty
Dulux-glazing surface putty
Rustoleum orange primer (3 coats)
Rustoleum white epoxy finish

Initial Roughness: The roughness height is 1.0-1.5 μm (40-60 μin) in smooth areas. There are areas where the cloth is exposed and areas where the bumps have roughness heights with peaks as high as 6.4 μm (250 μin).

After 9 days: (4 days on Carriage 1) There is no slime nor paint degradation.

After 14 days: There is no paint degradation, but a small amount of slime appears.

After 24 days: There is no slime nor paint degradation

Rating on Blisters: Excellent
Rating on Slime: Excellent

Remark: Despite poor initial roughness condition, the resistance to both slime and paint degradation is good.

Paint Specimen No. 15

Material: Fiberglass with epoxy resin
Paint: Duratite surface putty
Dulux-glazing surface putty
Dupont preparacote primer (3 coats)
Dupont dulux yellow enamel

Initial Roughness: In smooth areas, the roughness height is 0.5-1.0 μm (20-40 μin). There are a few small indentations and small blisters with peaks as high as 3.8 μm (150 μin).

After 9 days: (4 days on Carriage 1) It is slimy. Some scattered blisters with heights of 12.7 μm (500 μin) appear.

After 14 days: Slimy. Additional large-diameter blisters with roughness heights of 17.8-22.9 μm (700-900 μin) appear in one area.

After 21 days: It is slimy. The blisters continue to grow in number and have covered most of the area.

Rating on Blisters: Poor
Rating on Slime: Poor

Remark: Poor initial roughness condition

Paint Specimen No. 16

Material: Fiberglass with epoxy resin
Paint: Balto-glaze primer
Balto-glaze white finish

Initial Roughness: The average is 10-25 μin. It is a high quality glass finish.

After 9 days: (4 days on Carriage 1) There is no slime nor deterioration.

After 14 days: The same as after 9 days.

After 24 days: There is no slime. The surface essentially did not deteriorate although a few particles with roughness height of 80-100 μin appear in the paint.

Rating on Blisters: Excellent
Rating on Slime: Excellent

Paint Specimen No. 17

Material: Fiberglass with epoxy resin
Paint: Dulux-glazing surface putty
Dupont preparacote primer (3 coats)
Dupont dulux yellow enamel
Balto-glaze primer
Balto-glaze white finish

Initial Roughness: The average height is 0.3-0.8 μm (10-30 μin). There are particle in the paint with roughness heights as much as 2.0 μm (80 μin).

After 9 days: (4 days on Carriage 1) There is no slime nor paint degradation.

After 14 days: There is no slime. A few blisters have grown to roughness heights of 2.0-2.5 μm (80-100 μin).

After 24 days: There is no slime but a few blisters with a diameter 0.24-0.32 cm (3/32-1/8in) and a roughness height of 3.8-7.6μm (150-300 μin) appear

Remark: The entire paint coating peels off easily. This is probably because the bottom coat (Dupont preparacote) is damp and soft.

Rating on Blisters: Poor (paint peeled off)
Rating on Slime: Excellent

Paint Specimen No. 18

Material: Fiberglass with epoxy resin
Paint: Balto-glaze primer
Balto-glaze white finish
Dupont preparacote primer
Dupont dulux yellow enamel

Initial Roughness: The average height is 0.3-0.8 μm (10-30 μin) with some particles as much as 2.0μm (80 μin) in the paint.

After 9 days: It is slimy. Blisters with heights of 3.8-5.1 μm (150-200 μin) appear in a small area. These blisters mostly grew out of the particles in the paint.

After 14 days: About the same as after 9 days.

After 24 days; About the same as after 9 days.

Rating on Blisters: Fair
Rating on Slime: Poor

Remark: Poor initial roughness condition.

Paint Specimen No. 18A

Material: Fiberglass with epoxy resin
Paint: Dulux surface putty
Seaguard green primer (3 coats)
Seaguard grey finish } Seaguard Epoxy System
Seaguard white finish

Initial Roughness: The average height is 1.0-1.5 μm (40-60 μin) with occasional peaks to 3.8 μm (150 μin).

After 9 days: (4 days on Carriage 1). There is no slime nor paint degradation

After 14 days: The same as after 9 days.

After 24 days: The same as after 9 days.

Rating on Blisters: Excellent
Rating on Slime: Excellent

Remark: Good finish on fiberglass

Paint Specimen No. 19

Material: Pine Wood (5cm x 15cm x 30cm, or 2in x 6in x 12in)
Paint Sealer (2 coats)
Seaguard green primer (3 coats)
Seaguard grey finish } Seaguard Epoxy System
Seaguard white finish

Initial Roughness: The roughness height varied from 0.8 to 1.8μm (30 to 70 μin) with peaks to 3.0 μm (120 μin). These peak roughness bumps are mostly due to particles in the paint.

After 5 days: There is no slime nor paint degradation.

After 11 days: The same as after 5 days.

After 21 days: The same as after 5 days.

Rating on Blisters: Excellent
Rating on Slime: Excellent

Remark: Despite poor initial roughness condition, the resistance to both slime and paint degradation is good.

Paint Specimen No. 20

Material: Pine Wood (5cm x 15cm x 30cm, or 2in x 6in x 12in)
Paint: Sealer (2 coats)
Devoe epoxy green primer (3 coats)
Dupont dulux yellow enamel

Initial Roughness: The average height is 1.3-1.8 μm (50-70 μ in) with peaks to 3.8μm (150 μin).

After 5 days: It is slimy but there is no paint degradation.

After 11 days: About the same as after 5 days.

After 21 days: Some slime. There are small blisters in the center and near the edges. The 5 cm x 30 cm (2in x 12in) surface is fairly clean with a roughness height of 0.8-1.6μm (30-60 μin). There are small blisters on the 15 cm x 30 cm (6in x 12in) surface which are 2.5-5.1 μm (100-200 μin) high with peaks as high as 10.2 μm (400 μin).

Rating on Blisters: Fair
Rating on Slime: Poor

Paint Specimen No. 21

Material: Pine Wood (5cm x 15cm x 30cm, or 2in x 6in x 12in)
Paint: Sealer (2 coats)
Devoe epoxy primer (painted all over)
Dupont preparacote primer (painted on one half of the board only)
Dupont dulux grey enamel

Initial Roughness: The average height on the half which was painted with Dupont preparacote primer is 5.1 - 7.6 μm (200-300 μin), the other half painted only with Devoe epoxy primer is 2.5-5.1 μm (100-200 μin).

After 8 days: There is no slime on the whole board. There are no blisters on the Devoe epoxy half but some small blisters appear on the Dupont preparacote half.

After 21 days: There is no slime on the whole board and no blisters on the Devoe epoxy half. The blisters on the Dupont preparacote half have grown to 12.7 - 17.8μm (500-700 μin) in roughness height.

Rating on Blisters: Excellent on the half of the board with Devoe epoxy primer but poor on the half board with Dupont preparacote primer.

Rating on Slime: Excellent

Paint Specimen: No. 22

Material: Pine Wood (5cm x 15cm x 30cm, or 2in x 6in x 12in) The 15 cm (6in) side is made up of 5 laminated sections of 5 cm x 30 cm (2in x 12in) pine wood which were glued together.

Paint: Balto-glaze primer
Balto-glaze white finish

Initial Roughness: The average height is 0.5-2.0μm (20-80 μ in) with peaks as high as 3.8 μm (150 μin).

After 9 days: There is no slime nor paint degradation

After 14 days: There is no slime nor paint degradation but the board is coming apart because a press was not used when the glue was curing.

After 24 days: There is no slime nor paint degradation

Rating on Blisters: Excellent
Rating on Slime: Excellent

Remark: Debris in the paint contribute to the 3.8μm (150 μ in) peaks in the initial roughness condition.

imen No. 23

Pine Wood (5cm x 15cm x 30cm, or 2in x 6in x 12in). The 15 cm (6in) side is made up of 6 laminated sections of (2in x 10in) pine wood which were glued together.

Seaguard green primer
Seaguard grey finish } Seaguard Epoxy System
Seaguard white finish

ughness: Not measured

ys: There is no slime nor paint degradation

ays: A small amount of slime has accumulated but there is no paint degradation. End boards came apart.

ays: There is no slime nor paint degradation.

ays: The same as after 18 days.

Blisters: Excellent
Slime: Excellent

imen No. 24

Pine Wood (5cm x 15cm x 30cm, or 2in x6in x 12in). Not laminated.
Sealer (2 coats)
Devoe epoxy green primer (2 coats)
Rustoleum epoxy white finish

ughness: The average roughness is 0.8-1.8 μm (30-70 μin) on all sides.

ys: There is no paint degradation but it is slightly slimy.

ays: There is no slime nor paint degradation.

ays: The same as after 11 days.

Blisters: Excellent
Slime: Excellent

Paint Specimen No. 25

Material; Pine Wood (5cm x 15cm x 30cm, or 2in x 6in x 10in). Not laminated
Paint: Sealer (2 coats)
Devoe epoxy green primer (3 coats)
Dupont dulux white enamel

Initial Roughness: The average height is 1.5-3.8 μm (60-150 μin) with peaks as high as 6.4 μm (250 μin). These peak roughness elements are due to particules in the paint.

After 5 days: It is slightly slimy but there are no blisters.

After 11 days: The condition is about the same as after 5 days.

After 21 days: There is a small amount of slime. The roughness height of small blisters is about 2.5-6.4 μm (100-250 μin) and in smooth areas it is about 1.0-2.0 μm (40-80 μin).

Rating on Blisters: Good
Rating on Slime: Fair

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