UNIVERSITY OF CALIFORNIA, SAN DIEGO
SCRIPPS INSTITUTION OF OCEANOGRAPHY
VISIBILITY LABORATORY
SAN DIEGO, CALIFORNIA 92152

THE PERMANENCE OF REFLECTANCE PROPERTIES OF SUBMARINE CONCEALMENT PAINTS

Roswell W. Austin

SIO Ref. 73-35

October 1973

Contract No. N00024-68-C-1100
Technical Report
August 1968 – January 1970

U. S. Naval Ship Systems Command
Department of the Navy
Washington, D. C. 20360

Approved:

Seibert Q. Duntley, Director
Visibility Laboratory

Approved for Distribution:

George G. Shor, Jr., Acting Director
Scripps Institution of Oceanography

SUMMARY

A study of the reflectance properties of submarine concealment paints was undertaken by the Visibility Laboratory as part of its effort under Contract N00024-68-C-1100. The study extended over a period of 17 months from August 1968 to December 1969 during which reflectances of submarines from Submarine Flotilla One were repeatedly measured at intervals of approximately 1 month.

The results of the study showed that the vinyl alkyd paints 122-$R_0$1.8 and 122-$R_0$3.6 specified by the "Submarine Concealment Camouflage Manual"* provided coatings that were stable and generally acceptable from a concealment viewpoint, except for low initial values of submerged reflectance on the 122-$R_0$3.6 paints. Devran epoxy paints showed greater variations in reflectance with time. Furthermore, it was necessary to mix Devran 219-3 and 219-7 paints to obtain the required submerged reflectance for application to the vertical surfaces, and the resultant reflectances frequently missed the desired value. For these reasons plus their higher gloss, the epoxies are less desirable from a concealment viewpoint than the vinyl alkyds. However, other factors may outweigh these considerations.

It is recommended that, if such paints are to be used, they be procured from the manufacturer with the proper reflectance characteristics, i.e., gloss and submerged reflectance similar to that obtained with the vinyl alkyds. It is further recommended that a portable reflectometer be available at the squadron level to assist in maintaining the quality of submarine camouflage.

* NAVSHIPS 0919-002-7010, 1 March 1968.

TABLE OF CONTENTS

THE PERMANENCE OF REFLECTANCE PROPERTIES OF SUBMARINE CONCEALMENT PAINTS

1. INTRODUCTION

The permanence of the reflectance properties of concealment paints used on submarine topsides is a matter of prime importance in attempting to determine the visibility of submarines under operational or deployment conditions. The mission of the attack submarine requires that it be able to operate near the surface without visual detection from aircraft or surface vessels. The probability of such detection depends upon the excellence of the match between the reflectance of the submarine hull and the reflectance of the surrounding water.

Studies of the reflectance of various ocean waters in which operations may occur have resulted in recommendations for specific concealment painting measures. They are described in the "Submarine Concealment Camouflage Manual."* Adherence to the recommendations contained in this manual should minimize the probability of visual detection when operating in most types of ocean water. This presumes, of course, that the submerged reflectance of the paint remains essentially unaltered during a deployment. Considerable detailed information has been obtained on the submerged reflectance properties of several types of freshly applied submarine paints under various lighting conditions, and some data exist on the permanence of these reflectance properties under artificial weathering conditions. Little or no quantitative data existed, however, on how these important properties might vary with time under actual operating conditions.

It was to this end that in August of 1968 the Visibility Laboratory undertook a study in San Diego of the extent to which fading, chalking, and fouling of topside, camouflage paints changed the submerged reflectance and, hence, the probability of visual detection.

---

* NAVSHIPS 0919-002-7010, 1 March 1968

2. PROCEDURE

Permission was obtained from the commanders of Submarine Squadrons 3 and 5 of Submarine Flotilla 1 to make routine, periodic measurements of the submerged reflectance of selected areas on the hulls of available submarines in their commands. An attempt was made to measure each submarine at approximately 1-month intervals. Two horizontal and two vertical surface areas were selected on each hull for the repeated measurements. The locations were accurately noted in order to assure that the same areas would be repetitively measured. The areas were chosen as representative of exposed but not heavily trafficked or abraided surfaces. Special attention to upkeep of those areas was neither required nor desired.

As each submarine was incorporated into the program, a measurement was made of the reflectances of the existing topside paints and the approximate date of last painting. The type of paint used was also established, along with the number of hours of submerged operation since painting. Thereafter, as the submarines were repainted either by the ship's force or by a shipyard, 4-inch square primed metal plates were painted with the same paints used on the horizontal and vertical surfaces of the hull. These sample plates were forwarded to the Visibility Laboratory for measurement on a precision laboratory reflectometer and were retained as a control to aid in monitoring any change. Detailed information was requested regarding the type of paint used, formula number, manufacturer, batch number, packaging date, and any special information such as mixing proportions or unusual circumstances. At the time of each onboard monthly repeat measurement, the number of hours of submerged operation since the last painting was recorded.

The onboard reflectance measurements were made by technicians from the Visibility Laboratory using a specially modified Gardner portable reflectometer. A description of this instrument, as modified, and the method of its use in the field are given in Appendix A.

When requested, assistance was supplied to the ship's force in recommending proper mixes of the available paints to achieve the submerged reflectances required by the Concealment Manual. No effort was made to recommend or suggest painting procedures to the crews unless they were specifically requested, as the purpose of the tests was to determine the reflectances and changes in reflectance which occured under typical operational situations.

3. DISCUSSION

The measurement program continued until the end of December 1969, a period of about 17 months. Thirty-three submarines from SUBFLOT ONE participated to some extent in the program. There were numerous instances where it was possible to obtain only one or two measurements before the hull was repainted or the ship became unavailable through deployment or decommissioning, and these measurements were not included in compiling the statistics of the stability of the paints. They did help, however, in providing statistics on the initial submerged reflectances of operational submarines when painted in accordance with current practices.

Histories of the reflectances of 21 submarines were obtained, and in some instances, the same submarine was involved in the program for more than one repainting cycle. In all, 92 hull areas were repetitively measured. Of these, 47 were painted with a vinyl-alkyd formulation, 33 with Devran, a proprietary epoxy formulation, and the remaining 12 with either Brolite, a polyamide epoxy formulation being tested by the Paint Laboratory of the San Francisco Bay Naval Shipyard, or other paints that did not fit the above classifications. A total of 275 measurements were made and separately recorded for the 92 hull areas. Each of these areas was considered independently. Even though two areas on a single submarine were painted with the same paint, differences in application and exposure resulted in some differences being observed in the variation of reflectance with time. Each record was given a seven-character code symbol for identification. The code identified the year and month the hull area was painted, the type of paint used, the submarine involved, and the location of the measurement area. Table I provides the key to the code. The two-letter submarine designators will not be identified in this report.

One of the difficulties encountered in the program was obtaining data over sufficiently long periods of time. This resulted from the repainting cycle which is determined by factors other than the submerged appearance of the camouflage coating. Thus deterioration in the appearance of the dry hull due to excessive wear in areas of heavy traffic, chalking, fading, or any other of a large number of causes would be sufficient reason to repaint for cosmetic purposes alone in an elite service that prides itself on its appearance. As a consequence, the interval over which a hull could be observed between repaintingswas determined by such factors as the amount and type of upkeep work taking place alongside the tender, the frequency of inspections, the amount of time at sea versus in port, and a forthcoming deployment. The average period between paintings while the ships were involved in the study was 98 days. The longest period over which the reflectances were monitored between paintings was 197 days, 25 of which were submerged. The longest period of submerged operation for a submarine involved in the study was 74 days. In this case the interval between paintings was 143 days. On one hull our records show that 226 days elapsed between paintings; however, our period of observation of the reflectance was only 97 days due to the submarine's deployment.

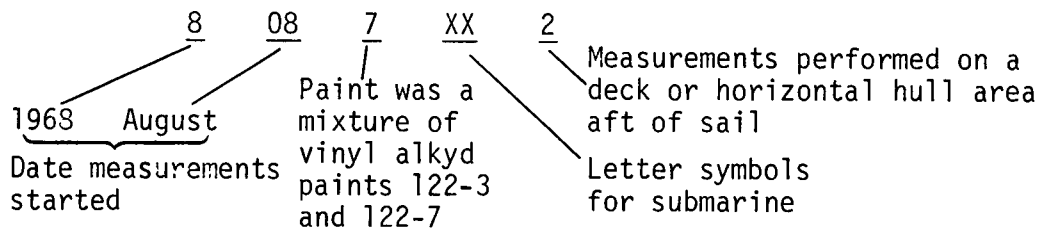
TABLE I

SYMBOL CODE FOR PAINT TEST RECORDS

The paints in this test were identified by a seven-character code as follows:

Character No.	Meaning
1	Last digit of year in which sample was first measured, i.e., 8 = 1968, or 9 = 1969
2 & 3	Month in which sample was first measured, e.g., 09 = Sept, 11 = Nov
4	Paint Code: Symbol / Formulation / Type 1 — 122-R_o1.8 — Vinyl Alkyd 2 — 122-R_o3.6 — Vinyl Alkyd 3 — 122-3 — Vinyl Alkyd 4 — 122-7 — Vinyl Alkyd 5 — 219-3 — Devran Epoxy 6 — 219-7 — Devran Epoxy 7 — 122-3&-7 (Mixed) — Vinyl Alkyd 8 — 219-3&-7 (Mixed) — Devran Epoxy 9 — All Other — Special Experimental Paints
5 & 6	Ship Code: Two-letter ship designator assigned arbitrarily by Visibility Laboratory for record purposes
7	Location Code: Symbol / Location 1 — Hull Forward 2 — Hull Aft 3 — Sail Forward 4 — Sail Aft 5 — Test Plaque (Laboratory)

Example: 8087XX2



One motivation for the study issued from anecdotal information about the marked changes in the submerged appearance of some submarines after extended deployments in warm tropical waters. These changes were mostly attributable to the growth of grasses, algae, tubeworms, barnacles, etc. on the topside paints and not to reflectance changes in the paints themselves.*

Because the waters in the operating areas around San Diego are relatively cool and not conducive to the rapid growth of fouling organisms of the type mentioned above, we did not have the opportunity to obtain quantitative measurements of the reflectance changes which such organisms cause. Neither was the effect of the growth of algae or "grass" around the waterline area which frequently occurs in port included in the study. The location of the algae makes their measurement difficult and hazardous. Also, because of the generally low reflectance of these organisms and their distance from the water surface (as compared to, say, the distance from the surface to the top of the sail), the attenuation of the intervening water tends to diminish the importance of this type of waterline fouling to the concealment of the submarine.

---

* As a result of these instances of fouling of the topside paints and the resulting major compromise to security from visual detection, strong recommendations have been made for an aggressive program to develop antifouling topside paints.

4. RESULTS

The results of the study are presented in the following four sections. In each section a table summarizes the findings. Additionally, complete data are presented in Appendix B on the submerged and dry reflectances of the 92 hull areas which were repeatedly measured to obtain the variation of these values with time. In that appendix the reflectance data grouped into seven categories of paints have been individually tabulated. The reflectance determinations for each sample area plotted as a function of time are presented in the curves following the tables.

In Section 4.1, all valid measurements of freshly painted submarine hulls have been compiled to obtain the statistics on the initial submerged reflectance of the submarines under observation. Where it was not possible to authenticate the type of paint applied, the data were not used in this compilation. It was possible, however, to use a number of initial reflectance measurements obtained on submarines which, for one reason or another, were not available for repeated measurements. For these reasons, the data base for the statistics in Section 4.1 is different from that used in Section 4.2.

In Section 4.2, the study results of the permanence of the submerged reflectance of seven paint categories is discussed. This section summarizes the submerged reflectance data presented in Appendix B. The bases for compiling a series of measurements in a particular category were the paint formulation data supplied by the ship, the location of the hull area in question (horizontal or vertical), and/or the initial reflectance. Some accommodation was permitted where an apparent mistake had been made in the original recording of the paint can label information or where appreciable simplification in the presentation could be obtained without compromising the validity of the result. Section 4.2, then, presents information pertinent to the durability of the significant reflectance characteristics of the camouflage coatings.

One fact that became obvious early in the study was that, when not on a deployment, the repainting schedule of submarine topsides is more likely to be determined by cosmetic considerations while in port than by the effectiveness of the paint in providing submerged concealment. Thus, routine measurements of the dry reflectances of the sample areas were initiated soon after the program began. Section 4.3 summarizes these results.

In Section 4.4, data is presented on the stability of the submerged and dry reflectances of sample 4-inch square paint control plaques prepared at the time the submarines were painted.

4.1 INITIAL SUBMERGED REFLECTANCES

A total of 140 measurements of the submerged reflectance of freshly painted submarines were compiled and analyzed to obtain statistics on the initial

reflectance values. These data were based on the four paints and the mixtures of these paints (a total of five categories) which were most frequently used in SUBFLOT 1. The results of these observations are summarized in Table II.

The vinyl alkyd Formula No. 122-R 1.8 paint is intended for use on decks and all horizontal surfaces (0 to 60 degrees from horizontal). It has a nominal submerged reflectance of 1.8 percent (0.0180 in the decimal reflectance units used in this report). The military specification MIL-E-24306 (SHIPS) under which it is purchased allows this reflectance to be in the range between 0.0180 and 0.0146 and still be acceptable. The average of the 26 submerged reflectance measurements of areas verified to have been recently painted with this paint was 0.0182 with a standard deviation of 0.0019. Thus, although the reflectances were slightly higher than the prescribed range, they were rather tightly grouped about the mean, and all would excellently serve their intended concealment purpose.

The vinyl alkyd Formula No. 122-$R_0$3.6 paint is most frequently used on vertical surfaces (60 to 90 degrees from the horizontal) and has a nominal submerged reflectance of 0.0360. Its specification, MIL-E-24292 (SHIPS), permits this reflectance to be between 0.0360 and 0.0312. The average of the 24 measurements of submerged reflectance of areas verified to have been recently painted with this paint was 0.0288 with a standard deviation of 0.0056. In the group of 24, only four areas measured had a reflectance within the range specified in MIL-E-24292 (SHIPS). The major effect of these low values is to make the sail appear too dark against the water background when submerged. It could require as much as 75 feet of clear ocean water to attenuate the contrast (optical signal) this average reflectance mismatch would generate. Thus, while the change in reflectance is seemingly small, its effect on the quality of the concealment can be significant. It might also be pointed out that under sunny conditions even with the proper paint on the vertical surfaces, those surfaces that are in shadow could provide an even higher negative contrast than that which resulted from the reflectance mismatch. However, proper painting is still important in order to reduce the probability of detection when the submarine is viewed from above with the sun behind the observer--generally the best viewing situation.

Seemingly, the problem with the 122-$R_0$3.6 paint is quality control but one that is easily amenable to correction, as the paints are apparently not meeting their specifications.

The Devran proprietary epoxy paint, 219-3, was not made to a specification requiring control of the reflectance. It was intended, however, for use as a coating for decks and other horizontal surfaces. Its submerged reflectance should fall in the same range, therefore, as that of the vinyl alkyd 122-$R_0$1.8 if it is to be acceptable from the concealment viewpoint. The average submerged reflectance of the 20 hull areas recently painted with this paint was 0.0165 with a standard deviation of 0.0015. This paint had the tightest grouping of initial submerged reflectances of the five evaluated, and the spread of

TABLE II

SUMMARY OF OBSERVATIONS

INITIAL VALUES OF SUBMERGED REFLECTANCE OF CONCEALMENT PAINTS

Observation \ Paint Type	122-R_o1.8 Vinyl Alkyd (Paint Code 1)	122-R_o3.6 Vinyl Alkyd (Paint Code 2)	219-3 Devran (Epoxy) (Paint Code 3)	219-3 & -7 Mixed Devran (Epoxy) (Paint Code 8) Horizontal	219-3 & -7 Mixed Devran (Epoxy) (Paint Code 8) Vertical
Nominal Submerged Reflectance, R_o	.0180	.0360	.0180	.0180	.0360
Variation in R_o Permitted by Applicable Paint Specifications	-.0034	-.0048	N/A	N/A	N/A
Mean of R_o Determinations, $\overline{R}_o$	.0182	.0288	.0165	.0274	.0415
Standard Deviation of R_o Determinations, σ	.0019	.0056	.0015	.0100	.0130
Number of Hull Areas Measured (1)	26	24	20	34	36

(1) In most cases two areas were measured on each submarine. Reflectances of these two areas were usually but not always close to the same value.

the reflectances was well within the range permitted in the specification for the 122-$R_0$1.8. If this sample is representative of the typical reflectance for the Devran 219-3 paint, we find on the basis of the initial submerged reflectance criteria that this paint is preferable, by a slight margin, to the vinyl alkyd 122-$R_0$1.8. There are other important considerations, however, including 1) the fact that the Devran is not procured with a specification requiring a control on the submerged reflectance and as a consequence could conceivably depart from values found in this study (this could be easily remedied), and 2) the significantly higher gloss of the Devran epoxy paints (apparently not so easily remedied).

The remaining two categories of paints included in Table II are mixtures of Devran 219-3 and 219-7 paints applied to horizontal and vertical surfaces. In our analysis of these findings we assumed that the intent was to obtain submerged reflectances of 0.0180 and 0.0360 respectively for the two classes of painted areas (i.e., horizontal and vertical). It is possible that some of the paintings were intended to achieve the "lignt" as opposed to the "dark" measure, that is, 0.0360 submerged reflectance on the horizontal and 0.060 on the vertical surfaces, although this is a measure intended for use only under special and very limited circumstances.

A major finding from the analysis of the measurements of these two paint groups is that the initial submerged reflectance of paints blended by the ship's force varies over a significantly wider range than does that of the commercially mixed paints. Of 34 horizontal surfaces measured, the submerged reflectance ranged from a low of 0.0155 to a high of 0.0470 with a mean of 0.0274 and a standard deviation of 0.0100. Of 36 vertical areas measured, the minimum was 0.0190, the maximum 0.0660, the mean of reflectances 0.0415, and the standard deviation 0.0130.

Apparently some of the paints were mixed in a predetermined ratio of 219-3 to 219-7 without comparing the result to control plaques having the required reflectance. In some cases the reflectance variation may have resulted from inadequate instruction in proper mixing procedures or a lack of understanding of the relationship between proper reflectance of topside coatings and the effectiveness of the submarine concealment from visual detection. Whatever the reason, the results were generally less than optimum although better than previously obtained using the 219-7 on the vertical surfaces.*

---

* The 219-7 was the darkest of the Devran epoxy coatings used on the vertical surfaces prior to instituting the new concealment measures in 1967 and 1968. This paint has a submerged reflectance of about 0.090 and is definitely too light for concealment use in submerged operations.

4.2 STABILITY OF SUBMERGED REFLECTANCE

Data on the variations in submerged reflectance were first obtained from 92 sample hull areas. Each sample area was then remeasured after an interval of 30 days or more, depending on ship scheduling, and measured again as many subsequent times as possible until the ship was repainted or was no longer available. In all, 183 repeat measurements were obtained after the initial 92. Each of these reflectance values (275 in all) is entered in Tables B-I through B-VII in Appendix B. The time elapsed since painting is entered next to each reflectance value, and the total time of submerged operation (in days) is entered in the right-hand column. Following each table these same reflectance data are plotted as a function of time. The bar (dotted) at the bottom of the graphs shows total submerged time, when available.

Table III summarizes the information from Appendix B in a manner that facilitates a comparison of the seven paint categories. Reference to Table III shows that for the majority (viz. 60 percent) of all the 183 repeat measurements of 92 different hull areas the change in submerged reflectance was less than ±0.002 decimal units. Changes less than this amount were felt to be of little practical significance considering the overall accuracy of the field measurements and the uncertainty of the water reflectance of the ocean in operating areas. Of the remaining 40 percent, 24 percent increased more than 0.002, and 16 percent decreased more than 0.002 submerged reflectance units from the initial measurements.

It should be further noted that the results of the measurements on surfaces coated with the vinyl alkyd paints procured under the current military specifications showed these paints to be superior to the epoxy formulations with respect to changes in submerged reflectance. Thus, 79 percent of the 122-$R_0$1.8 paint areas showed no significant change in 53 repeat measurements, and 71 percent of the 122-$R_0$3.6 had no significant change in 38 measurements. Combining all vinyl alkyd data including that for paints manufactured prior to the issue of the new specifications, we found that for 99 repeat measurements, 75 percent showed no significant change, 17 percent increased, and 8 percent decreased in submerged reflectance.

By contrast, the Devran epoxy paints used singly or mixed to achieve submerged reflectances of 1.8 percent or 3.6 percent showed no significant change in only 55 percent of the 62 repeat measurements, while 24 percent increased and 21 percent decreased.

The two remaining paint types listed in Table III are Devran 219-7 (paint code 6) and the miscellaneous experimental paints grouped under paint code 9. The results of measurements on these paints were included in the summary statistics for all measurements given above. These paints were not as stable as the other categories. Of the combined 22 repeat measurements on 14 hull areas, only one measurement (i.e., 5 percent) showed no significant change, while 55

TABLE III

SUMMARY OF OBSERVATIONS
STABILITY OF SUBMERGED REFLECTANCE, R_o, OF SUBMARINE CONCEALMENT PAINTS

Observation \ Paint Type →	122-R_o1.8 Vinyl Alkyd (Paint Code 1)	219-3 Devran (Epoxy) (Paint Code 5)	122-R_o3.6 Vinyl Alkyd (Paint Code 2)	122-3 & -7 Mixed Vinyl Alkyd (Paint Code 7)	219-3 & -7 Mixed Devran (Epoxy) (Paint Code 8)	219-7 Devran (Epoxy) (Paint Code 6)	All Other Paints (Paint Code 9)
Nominal Submerged Reflectance, R_o	0.0180	0.0180	0.0360	0.0360	0.0360	N/A	N/A
Mean of Initial R_o Determinations	0.0176	0.0193	0.0283	0.0301	0.0376	0.0915	N/A
Range of Initial R_o Determinations: Max	0.0225	0.0277	0.0370	0.0330	0.0472	0.091	N/A
Min	0.0155	0.0172	0.0200	0.0260	0.0330	0.090	
Number of Different Hull Areas Measured	24	14	19	4	17	2	12
Total Number of Measurements	77	45	57	12	48	8	28
Changes in Reflectance from Initial Value							
Increases in R_o: Number	9	10	6	2	5	1	11
Maximum Increase	0.0060	0.0136	0.0140	0.0105	0.0050	0.0040	0.0178
Mean Increase	0.0039	0.0053	0.0066	0.0077	0.0034	0.0040	0.0089
Decreases in R_o: Number	2	5	5	1	8	5	4
Maximum Decrease	0.0043	0.0092	0.0068	0.0039	0.0083	0.0065	0.007
Mean Decrease	0.0036	0.0046	0.0043	0.0039	0.0053	0.0038	0.0048
No Significant Change: Number (i.e., $\Delta R_o < \pm 0.002$)	42	16	27	5	18	0	1
Appendix Table Number	B-I	B-III	B-II	B-V	B-VI	B-IV	B-VII

percent showed an increase and 40 percent a decrease. As these paints are not normally used when painting in accordance with the camouflage manual, the statistics obtained without their inclusion is a better indicator of the performance of topside concealment paints during the test interval. Combining the measurements of all vinyl-alkyd and Devran epoxy coatings having nominal submerged reflectances of 1.8 or 3.6 percent (i.e., the first five columns in Table III), we find that of 161 repeat measurements of 78 areas, 67 percent had no significant change, 20 percent showed an increase in excess of 0.002 reflectance units, and 13 percent decreased in excess of 0.002 units.

Thus far, the statistics presented have been based on the number of repeat measurements which showed a change from the initial reflectance value in excess of the tolerance limits of ±0.002 reflectance units. While these represent significant changes in the concealment of the submarine, it is also useful to compare the range of the repeat measured reflectance values with the range of initial values for the paints in the first five columns. Of the combined 99 repeat measurements for the vinyl alkyd paints, only 4 drifted outside the range of initial values (all 4 became lighter). Of the 62 repeat measurements for the two categories of Devran epoxy, 6 became lighter than the maximum initial reflectance and 15 had reflectances below the minimum of the initial reflectances.

Based on the statistics presented above which were obtained during the 17-month period of the test program, the vinyl alkyd system of topside paints is superior with respect to stability or permanence of submerged reflectance. Reference to the curves in Appendix B confirms also a greater variability in the submerged reflectance of the Devran epoxies than for the vinyl alkyds. This is not to say that all the Devran epoxies are unsatisfactory, but they are, as a group, less stable.

4.3 STABILITY OF DRY REFLECTANCE

The tables and graphs in Appendix B show the data obtained on the dry reflectance of the selected hull areas. Inspection of the curves shows a generally greater variability in the dry than in the submerged reflectance values. Table IV summarizes the findings. Of 140 repeat measurements on 65 areas, only 14, or 10 percent, showed a change less than ±0.002 reflectance units. Of the remaining observations, 70, or 50 percent, increased and 56, or 40 percent, decreased. Again, as found for the submerged reflectance, the vinyl alkyd paints showed smaller changes in dry reflectance with time than did the Devran epoxy paints.

TABLE IV

SUMMARY OF OBSERVATIONS

STABILITY OF DRY REFLECTANCE, R_{dry}, OF SUBMARINE CONCEALMENT PAINTS

Observation \ Paint Type →	122-R_o1.8 Vinyl Alkyd (Paint Code 1)	219-3 Devran (Epoxy) (Paint Code 5)	219-3 & -7 Mixed Devran (Epoxy) (Paint Code 8)	122-R_o3.6 Vinyl Alkyd (Paint Code 2)
Mean of Initial R_{dry} Determinations	0.0240	0.0300	0.0370	0.0470
Number of Different Hull Areas Involved	24	12	12	17
Total Number of Measurements	79	39	34	52
Changes in Reflectance from Initial Value				
Increases in R_{dry}: Number	26	18	12	14
Maximum Increase	0.0165	0.0230	0.0120	0.0090
Mean Increase	0.0052	0.0094	0.0074	0.0041
Decreases in R_{dry}: Number	21	8	8	19
Maximum Decrease	0.0090	0.0130	0.0150	0.0150
Mean Decrease	0.0032	0.0078	0.0055	0.0041
No Significant Change: Number	8	1	2	3

4.4 CONTROL PLAQUES

In the course of the measurement program, 16 4-inch-square metal plaques were painted at the time of and with the paints used for painting the submarines. These plaques were turned over to the Visibility Laboratory where their dry and submerged reflectances were measured with a precision Laboratory reflectometer. This served as an additional check on the initial reflectance properties of the paints being applied and also provided a control which could be referred to during the course of the field measurements. Not all submarines involved in the program were able to provide these plaques; however, the absence of a complete set did not affect the findings. All controls were stored in a closed, dark container. At the end of the program, the reflectances were again determined. Most of the final readings were identical or essentially so, with the original determinations; we do not attribute any particular significance to the two readings which changed by more than 0.002 units except to note that, again, both paints were Devran epoxies. Table VI is a summary of these measurements.

5. CONCLUSIONS AND RECOMMENDATIONS

There was a tendency on the part of some of the crews to consider all paints used in the present prescribed submarine camouflage measures as equally "black". Consequently, there was an insensitivity to the effects of applying paints with improper reflectance on the concealment of the submarine when operating near the surface. Furthermore, without an instrument to measure the reflectance of the paints when mixing two colors, if that was necessary, or after application to the paint at the build, was difficult for the responsible members of the ship's force to determine, in fact, the proper reflectance values had been obtained. In considering these factors, we must conclude that the concealment painting of the units involved in the program was generally well done and effective. However, it is recommended that significant improvements in the excellence of the concealment could be obtained by having available at the squadron level a simple portable reflectometer and an individual trained in its proper use and interpretation. An individual attached to the squadron engineer's office with this as a supplemental duty could provide assistance to the ships in mixing paints to obtain proper submerged reflectance, provide a final quality control check of paints as received and applied to the submarines, assist in establishing the need to repaint and provide a means of quantitatively establishing the effectiveness of final camouflage coating in meeting concealment requirements prior to deployment.

Although the effectiveness of the camouflage is determined by the submerged reflectance, it is the dry reflectance that determines the in-port appearance and hence, to a large extent, the frequency of repainting. However, due to this procedure, the observed changes in dry reflectance were greater than the changes

TABLE V

STABILITY OF SUBMARINE PAINT CONTROL PLAQUES

Code	Type of Paint	Total Days Elapsed	R_o		R_{dry}	
			Initial	Final	Initial	Final
8111BU5	122-1.8	151	0.0175	0.0177		0.0357
9011BG5	122-1.8	88	0.012	0.012	0.0288	0.0293
8102PE5	122-3.6	161	0.0277	0.0277	0.0280	0.0280
8112BU5	122-3.6	151	0.0412	0.0400		0.0540
9012BG5	122-3.6	88	0.0361	0.0350	0.0475	0.0470
8095D15	219-3	196	0.0137	0.0137		0.0120
8105CH5	219-3	162	0.0137	0.0137	0.010	0.0096
8105SA5	219-3	162	0.0185	0.0207	0.0420	0.0420
8115SP5	219-3	149	0.0150	0.0152		0.0295
8115HA5	219-3	149	0.0095	0.0097		0.0104
8106CH5	219-7	140	0.087	0.087	0.050	0.050
8098RK5	219-3 & -7	199	0.0137	0.0137		
8108SA5	219-3 & -7	162	0.0385	0.0385	0.0500	0.0500
8118SP5	219-3 & -7	151	0.0475	0.0410		0.0488
8118HA5	219-3 & -7	149	0.0397	0.0392		0.0427
8109PE5	122-3.6&-7	176	0.0332	0.0332	0.048	0.0480

$0^{o}45^{o}$ Reflectance of 4" x 4" metal plaques prepared by submarines at the time of painting. Submerged reflectance (R_o) was determined from wet reflectance. Plaques were stored in a closed, dark container.

in submerged reflectance for the same sample areas, and they were also poorly correlated. Therefore, the use of dry reflectance as a criterion for repainting may result in more frequent painting than is required from a concealment viewpoint.

The standard vinyl alkyd paints, as procured under the military specification and when applied in accordance with the concealment manual, generally performed well with respect to the stability or permanence of their submerged reflectance. However, the vinyl alkyd 122-R_o3.6 paints as a group were too dark by a significant and unnecessarily large amount. This is a quality control problem that could be easily remedied but one that is not easily recognized unless the capability exists to measure the submerged reflectance of the paint at the time of application (see recommendation above).

From the concealment viewpoints of permanence of reflectance and low gloss, the vinyl alkyd system is to be preferred over either the Devran epoxies or the experimental Brolite epoxies involved in the program (the latter showing the poorest performance). The Devran epoxy systems had popular acceptance, however, because of difficulties experienced by some units in applying the vinyl alkyds over existing paints and obtaining satisfactory adhesion. If the use of epoxies is to continue, formulations with gloss characteristics and reflectance stability comparable to the vinyl alkyds should be developed and used. It is further recommended that they be procured from the manufacturer with the required R_o as an acceptance specification. Attempts by the crews to mix Devran 219-3 and Devran 219-7 to obtain a submerged reflectance of 3.6 percent for use on vertical surfaces showed a large variation in the values actually obtained.

6. ACKNOWLEDGMENTS

We wish to gratefully acknowledge the excellent cooperation extended by the Commander, Submarine Flotilla One, and all the units and individuals under his command. Special thanks go to the officers and crews of the submarines involved and to the squadron engineers of Squadrons One, Three, Five, and Seven for their understanding and assistance.

Measurements and data reduction were performed by D. M. Webb and A. L. Chapin of the Visibility Laboratory Staff.

APPENDIX A

TECHNIQUE FOR MEASUREMENT OF SUBMERGED REFLECTANCE OF SUBMARINE CONCEALMENT PAINTS

A-1. INTRODUCTION

The concept of reflection is a familiar one to everybody. As is so often the case, however, when it becomes necessary to quantify a concept, we find technical ramifications which must be thoroughly understood before we can define and measure a useful reflectance value for a surface. There exists a complex hierarchy of reflectances, each with different physical and geometric definitions and each providing information useful for particular lighting and viewing conditions. But no simple, single measurement can provide the reflectance information needed to completely describe the behavior of a surface under all conditions. We must accept the reality, therefore, that any single measurement will be a compromise, and we must make certain that the measurement made will be indicative of those reflectance properties significant to the problem.

The measurement of reflectance should be accomplished in a manner that (1) provides a value useful in the context of the particular application, and (2) is recognized and understood by other workers in the field. In the case here, submarine concealment paints should have their reflectances measured and specified in accordance with the operational conditions under which they are to be used. Thus, if the situation called for concealment from detection by low-flying aircraft or surface vessels while the submarine was surfaced (as was the case in World War II), then the reflectance of the dry paint would be the value needed. Present-day submarine capabilities and operational tactics, however, allow the submarine to remain submerged most of the time when concealment from visual detection is of concern, and the reflectance value needed is consequently the submerged reflectance. As the dry and submerged reflectances are significantly different and are not simply related to each other, knowledge of the dry reflectance alone will not suffice in determining the concealment performance of topside paints for current operational applications.

Fortunately, a simple technique has been devised (reported originally by Duntley in 1952*) by which the submerged reflectance can be computed from a measurement of the reflectance of the surface when wet with a thin film of water. The equipment used for this measurement can be, with only minor modifications, the conventional reflectance measuring instruments used in many laboratories and familiar to most paint manufacturers. Both the technique and equation devised by Duntley have been verified for present-day paints and equipment. No change in the original method is recommended.

---

* S. Q. Duntley, Visibility of Submerged Objects, Visibility Laboratory, M. I. T., Cambridge, Massachusetts, 1952 (Contract N4ori 07864).

A-2. REFLECTANCE MEASUREMENT

Rather complete reflectance data have been obtained by the Visibility Laboratory for both the vinyl-alkyd and proprietary epoxy topside submarine concealment paints. As a result of the study of these data, we feel that a single bidirectional reflectance measurement as described below can be related to the significant reflectance properties of the paint, provided the gloss characteristics are not changed by variations in the paint formulation, production process, or method of application.

The bidirectional reflectance measurement is performed by illuminating an area of the specimen (painted) surface with a narrow-angle cone of light having an angle θ_i to the surface normal and by viewing the surface at an angle θ_v to the normal with a receiver which has a narrow-angle cone of viewing. A commonly used set of angles is $\theta_i = 45°$ and $\theta_v = 0°$, and the resulting reflectance is frequently designated as R(45°, 0°). Thus, the detector collects the light which is reflected perpendicular to a surface when the surface is illuminated at 45 degrees (see Fig. A-1). The results of such measurements are given as a ratio of the amount of light reflected by the surface in question to the amount of light reflected by a perfectly diffuse white surface when illuminated and viewed under the same conditions. Although such diffuse white surfaces cannot be obtained in practice, laboratory methods exist for determining the departure of any real surface from the hypothetical ideal surface. Secondary standards may then be generated whose reflectance is known on scale where the perfect diffuse white surface would have a reflectance of 1.00. It should be noted that a painted surface will generally have some degree of gloss, that is, a higher reflectance when the angle of view is equal and opposite to the angle of illumination (i.e., the condition for specular or mirror-like reflection). The value of the reflectance under these conditions may easily exceed 1.00, even in cases where the 45°/0° bidirectional reflectance is very low. However, because the R(45°, 0°) values for submarine paints are representative of the reflectance values for most illuminating and viewing geometries other than those in the region of specularity and because the 45°/0° geometry approximates important situations encountered in the concealment of submerged submarines, this measurement is a reasonable choice for use in the specification of submarine concealment paints. Although the 45°/0° notation is not used elsewhere in this report, it should be understood that all measurements were made with instruments using this geometry.

The submerged reflectance, R_o, of a surface may be obtained from the relationship

$$R_o = \frac{R_w}{0.42R_w + 0.564}$$

where R_w is the reflectance of the surface measured while wet with a thin film of water. The standard submerged reflectances of the submarine topside paints are 1.8, 3.6, and 6.0 percent (or 0.018, 0.036, and 0.060 when expressed in decimal units as required by the above equation). The corresponding wet

reflectances are 0.0102, 0.0206, and 0.0347. The measurement of these very low reflectances not only requires careful attention to the details of the procedure but also requires that the measuring instrument be designed and calibrated for this range of reflectance measurement. If the accuracy of an instrument is ±1 percent of full scale, as was the case for the field instrument, and the full-scale range of the instrument is 1.00 reflectance units, the error in the measurement of the wetted submarine paints would be far greater than could be tolerated, as a 3.6 percent paint could be mistaken for a 1.8 percent paint. Also, significant changes with time in the reflectance of either paint would go undetected. However, if an instrument were calibrated to have a full-scale indication of, say, 0.10 reflectance, then the ±1 percent of full-scale instrumental error would result in an error in the R_W measurement of 0.001. Such an error in the determination of R_W would result in an error of 0.0017 in the determination of the submerged reflectance, R_O.

Three separate determinations of R_W were made of each paint area at the time of each field measurement. The average R_W was then used to further improve the precision in the computed R_O. The residual measurement error was less than the reflectance variation permitted by the military specifications under which the paints were procured and was certainly less than the variation in reflectance encountered, during the course of the study, on submarines supposedly painted with the same formulation.

A-3. DESCRIPTION OF EQUIPMENT

The instrument used for field measurement of the submarine paint reflectances was the Model 45-R-3 portable reflectometer manufactured by Gardner Laboratory, Bethesda, Maryland. It was modified at the Visibility Laboratory by the addition of an amplifier in order to provide the increased sensitivity required for the measurement of low reflectances. An electrical and optical schematic of the instrument as modified is shown in Fig. A-1. In Fig. A-2 a technician is shown calibrating the equipment against standards of reflectance while on board a submarine. The small storage battery in front of the carrying case supplies power for the lamp. The bottles contain water and a wetting agent for obtaining the thin water film required for the wet reflectance measurement. With the increased sensitivity of this instrument it is possible to obtain a full-scale response with a reflectance of 0.100. By using reflectance standards whose reflectances are close to the paints being measured, the precision of the measurement, which is now limited by the stability and resolution of the equipment, is better than ±0.001 reflectance (i.e., ±1 percent of the full-scale range of 0.100 reflectance).

The 4 x 4 inch sample plaques prepared at the time the submarine was painted were measured at the Laboratory using a precision reflectometer Gardner Model A U X-2 which on its higher sensitivity range is capable of precisions a factor of ten better than the portable instrument (i.e., ±0.0001 reflectance units). Comparison measurements made with the two instruments at the Laboratory generally agreed within the precision of the portable unit and served to provide a continual check on the performance of the portable unit.

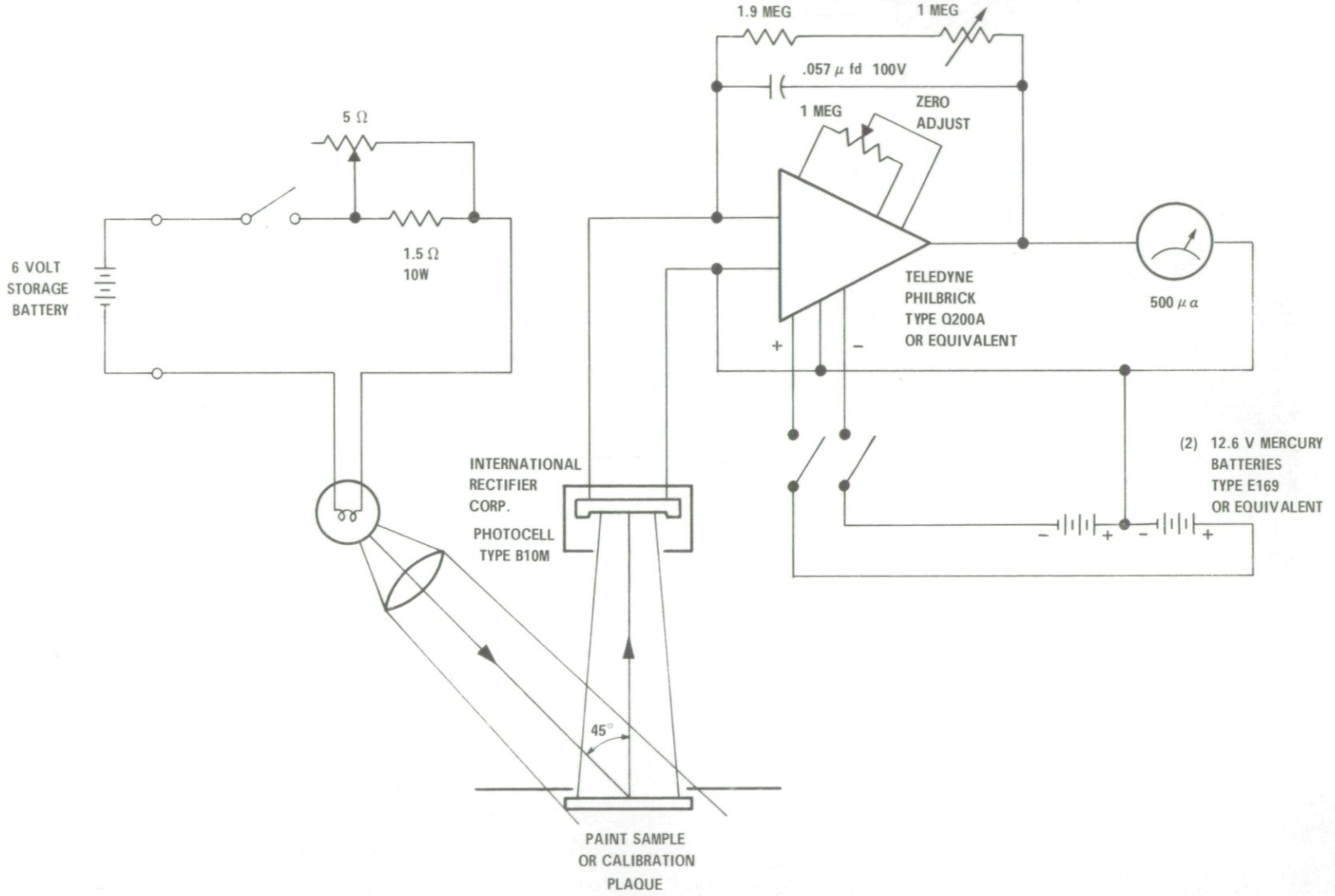


Fig. A-1. Gardner Laboratory 45°, 0° Portable Reflectometer with Visibility Laboratory Circuit Modifications Providing Increased Sensitivity for Low Reflectance Measurements.

Fig. A-1. Gardner Laboratory 45°, 0° Portable Reflectometer with Visibility Laboratory Circuit

APPENDIX B

PAINT REFLECTANCE MEASUREMENTS STATISTICS

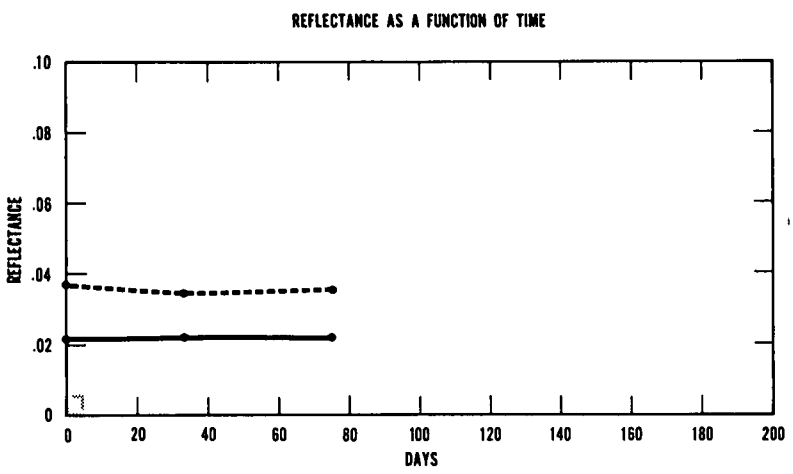
Table B I Summary Log of Paint Reflectance Measurements Vinyl Alkyd 122 R_o 1 8 Paint

Code	Initial Measurement		1st Repeat		2nd Repeat		3rd Repeat		4th Repeat		5th Repeat		Total Days Submerged
	†Reflectance	‡Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	
8111BU1*	0 0212 0 0360	1	0 0212 0 0340	33	0 0212 0 0350	75							5
8111BU2*	0 0212 0 0340	1	0 0242 0 0360	33	0 0212 0 0402	75							5
8121BA1	0 0174 0 0280	31	0 0174 0 0240	61	0 0172 0 0260	83	0 0172 0 0260	104					15
8121BA2	0 0174 0 0350	31	0 0174 0 0300	61	0 0196 0 0300	83	0 0192 0 0280	104					15
9011BG1	0 0175 0 0180	1	0 0230 0 0206	35	0 0172 0 0330	68							13
9011BG2	0 020 0 036	1	0 212 0 031	35	0 026 0 036	68							13
9021RO1*	0 019 –	16	0 0207 0 0320	56									No Data
9021RO2*	0 019	16	0 0225 0 0380	56									No Data
9031GU1	0 0172 0 0260	5	0 017 0 025	69	0 018 0 031	97							29
9031GU2	0 0172 0 0340	5	0 018 0 036	60	0 019 0 030	97							29
9041PE2*	0 0155 0 0120	1	0 0155 0 0180	30									6
9051ME1*	0 020 0 032	36	0 018 0 034	64	0 0172 0 0370	99							8
9051ME2*	0 020 0 036	36	0 020 0 032	64	0 020 0 027	99							8
9061BL1	0 021 0 028	33	0 021 0 034	89	0 0197 0 0340	134	0 0207 0 0340	145					8
9061BL2	0 021 0 025	33	0 021 0 034	89	0 0190 0 0315	134	0 019 0 030	145	0 019 0 030	173			11
9061SC1*	0 017 0 030	9	0 018 0 031	37	0 0190 0 0445	72	0 017 0 035	100	0 019 0 039	132			18
9061SC2*	0 017 0 030	9	0 017 0 028	37	0 0172 0 0330	72	0 017 0 035	100	0 017 0 034	132			18
9062CA3	0 018 0 028	4	0 022 0 028	39	0 0175 0 0340	73	} (NOTE Listed as 3 6 by ship painters Included here because of marked similarity of readings to Vinyl Alkyd 122 R_o 1 8)						8
9062CA4	0 018 0 028	4	0 022 0 028	39	0 0175 0 0340	73							8
9071CA1	0 0175 0 0180	5	0 0175 0 0345	39									8
9081GU1	0 0225 0 0420	14	0 0182 0 0370	41									4
9081GU2	0 0162 0 0365	14	0 0155 0 0330	41									4
9081RB1	0 0155 0 0225	28	0 0172 0 0330	62	0 0182 0 0345	98	0 020 0 038	126					21
9081RB2	0 0155 0 0225	28	0 0172 0 0330	62	0 0155 0 0310	98	0 0172 0 0280	126					21

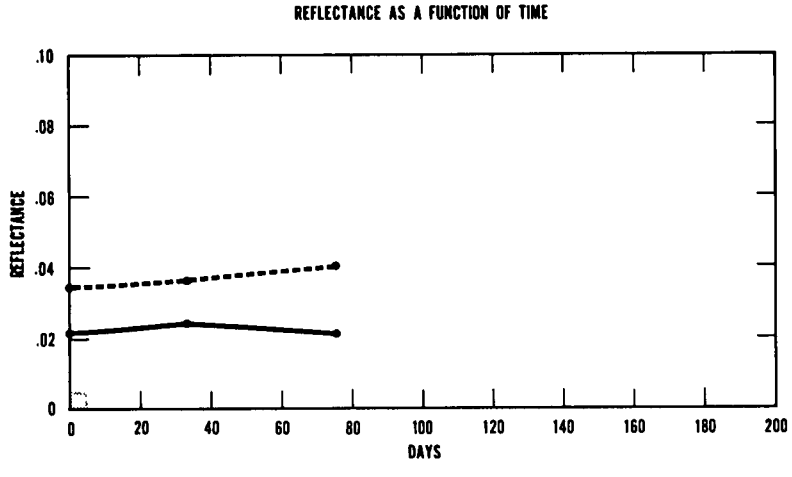
Refers to documented paint data including date of painting paint formula manufacturer date of paint manufacture and packaging batch number and special remarks

†Upper number is R_o lower number is R_{dry}

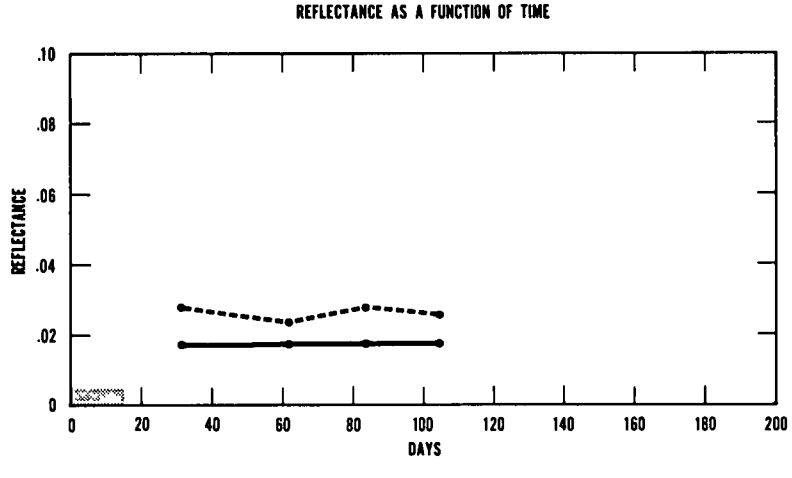
‡Days between painting and measuring



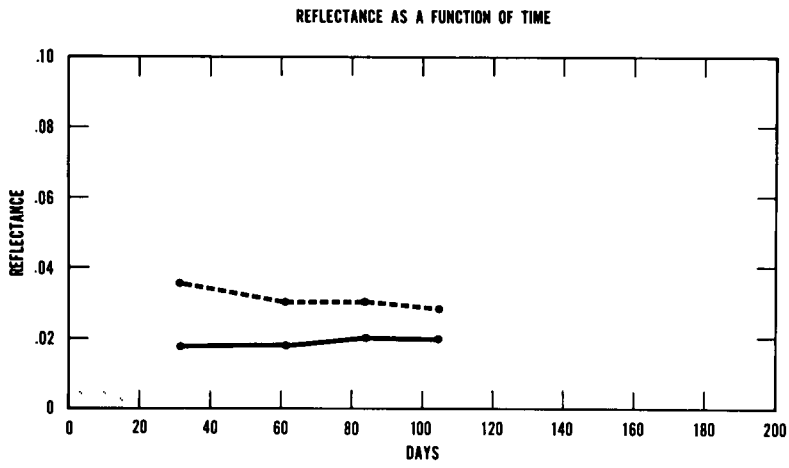
(1) Code: 8111BU1
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Fwd
Date Painted: November 1968
Paint Mfr – Devoe
Date Mfd – MD8790
Batch No. – A87145



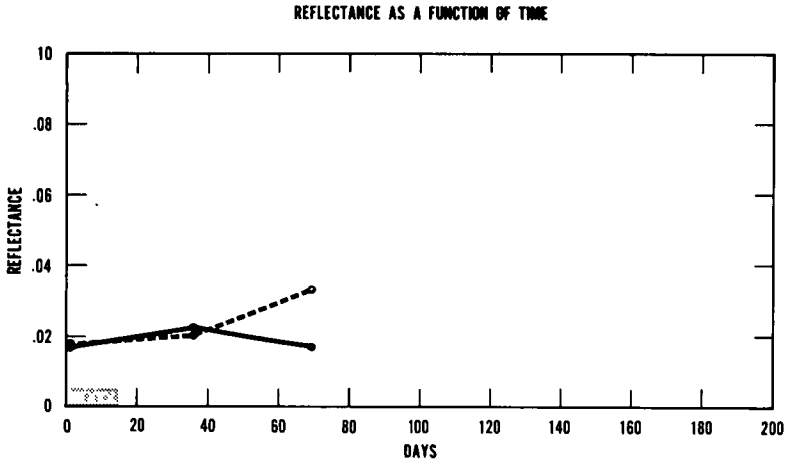
(2) Code: 8111BU2
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Aft
Date Painted: November 1968
Paint Mfr – Devoe
Date Mfd – MD8790
Batch No. – A87145



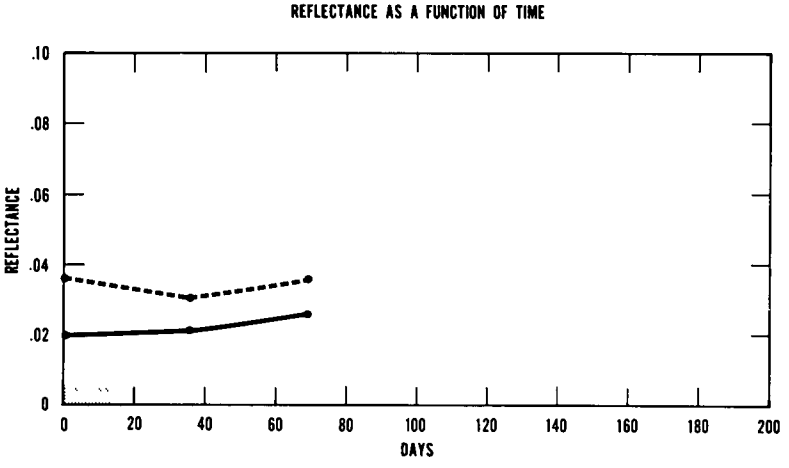
(3) Code: 8121BA1
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Fwd
Date Painted: December 1968



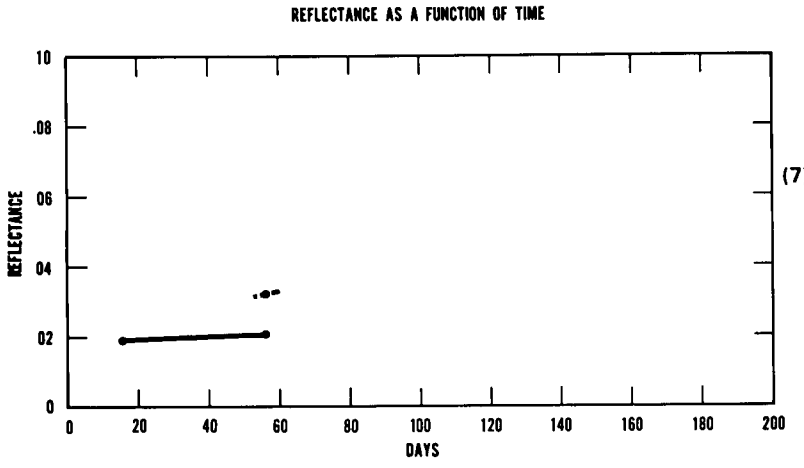
(4) Code: 8121BA2
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Aft
Date Painted: December 1968



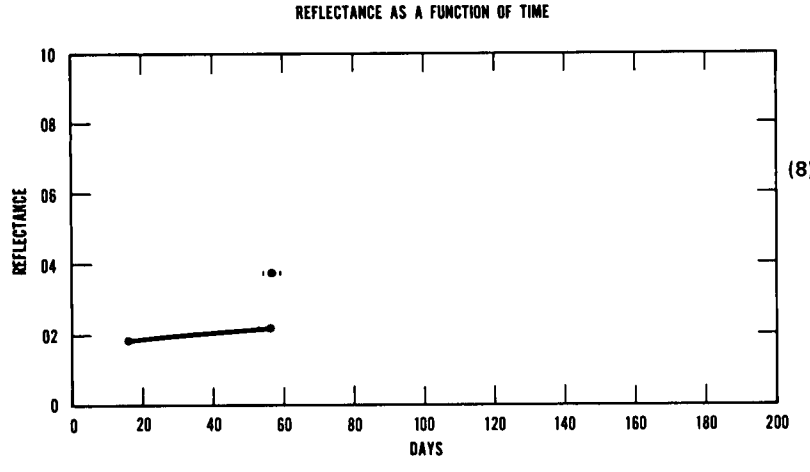
(5) Code: 9011BG1
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Fwd
Date Painted: January 1969



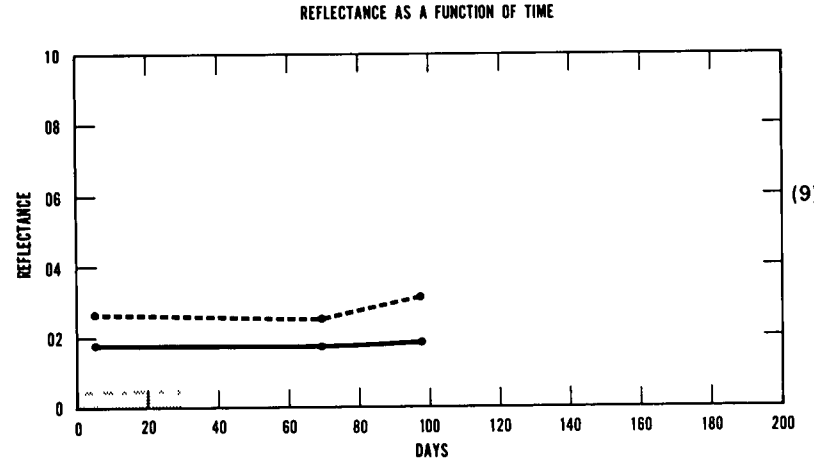
(6) Code: 9011BG2
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Aft
Date Painted: January 1969



(7) Code: 9021RO1
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Fwd
Date Painted: February 1969
Paint Mfr – De Boom

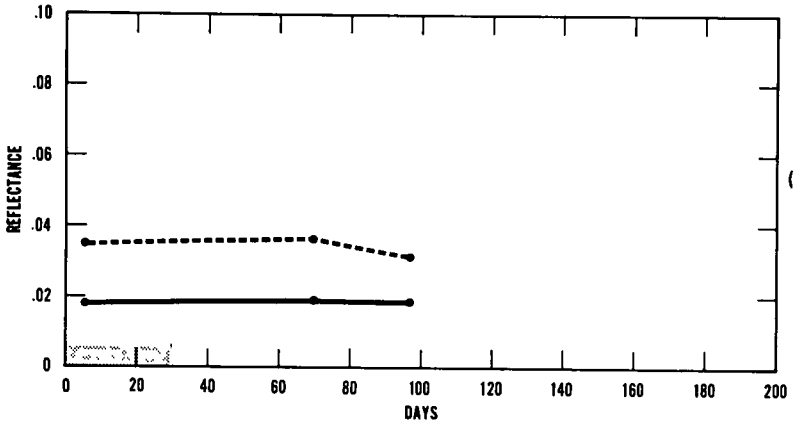


(8) Code: 9021RO2
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Aft
Date Painted: February 1969
Paint Mfr – De Boom



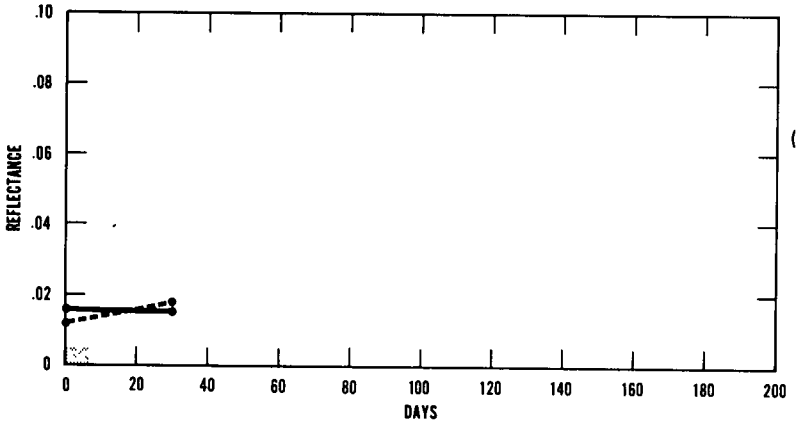
(9) Code: 9031GU1
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Fwd
Date Painted: March 1969

REFLECTANCE AS A FUNCTION OF TIME



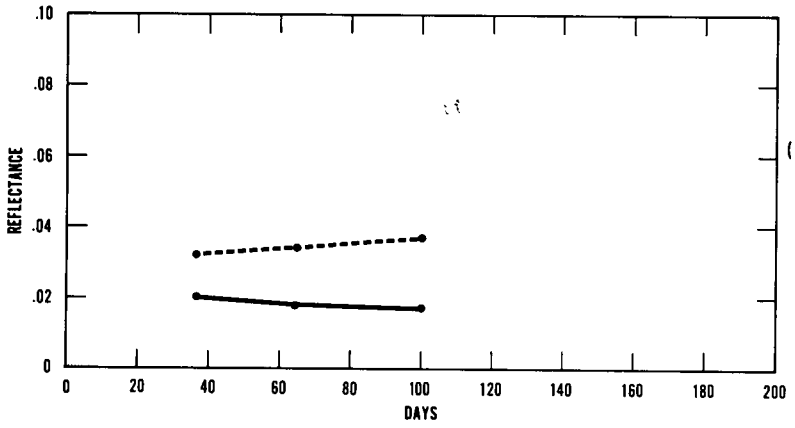
(10) Code: 9031GU2
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Aft
Date Painted: March 1969

REFLECTANCE AS A FUNCTION OF TIME

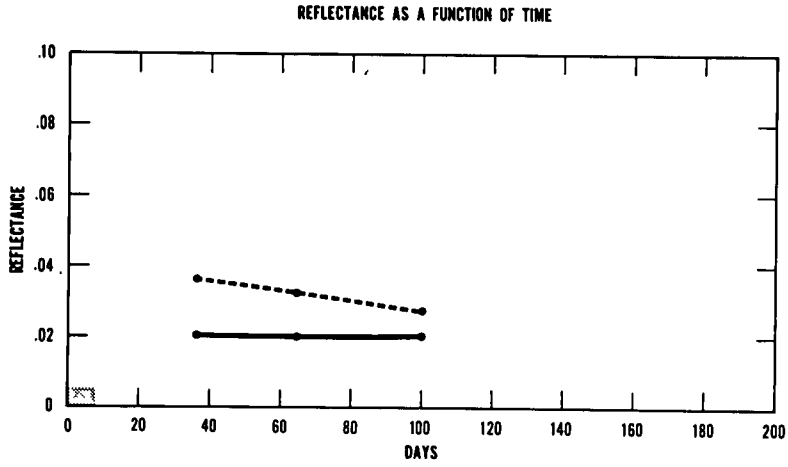


(11) Code: 9041PE2
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Aft
Date Painted: April 1969
Paint Mfr – Sentry Paint & Chem Co.
Date Mfd – June 1968
Batch No. – CG-40

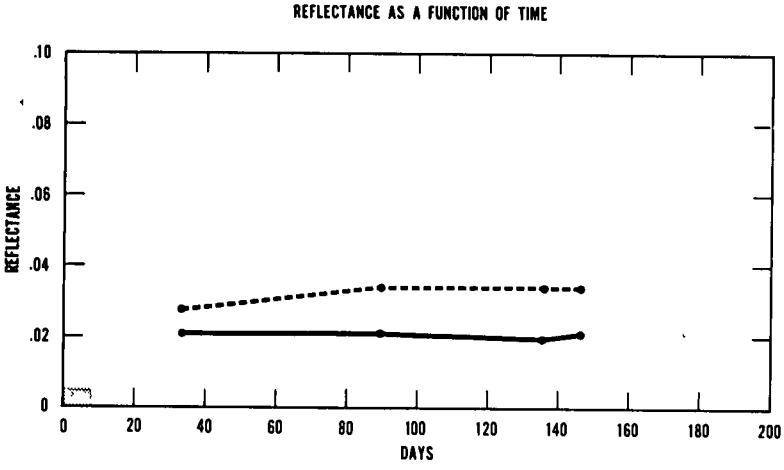
REFLECTANCE AS A FUNCTION OF TIME



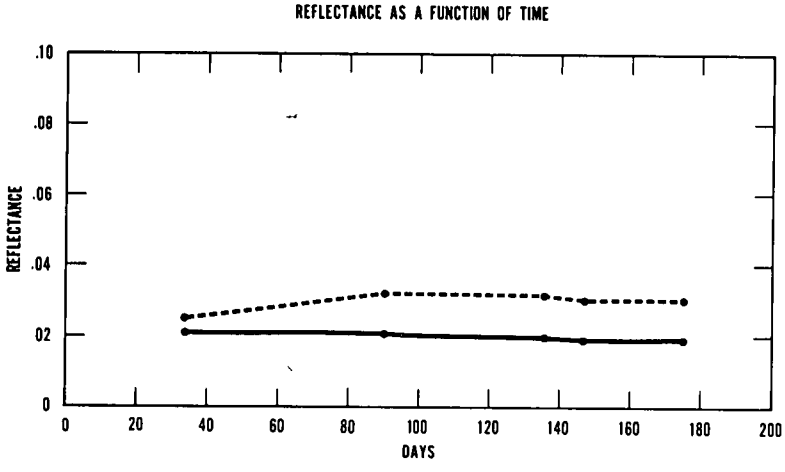
(12) Code: 9051ME1
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Fwd
Date Painted: May 1969
Paint Mfr – De Boom



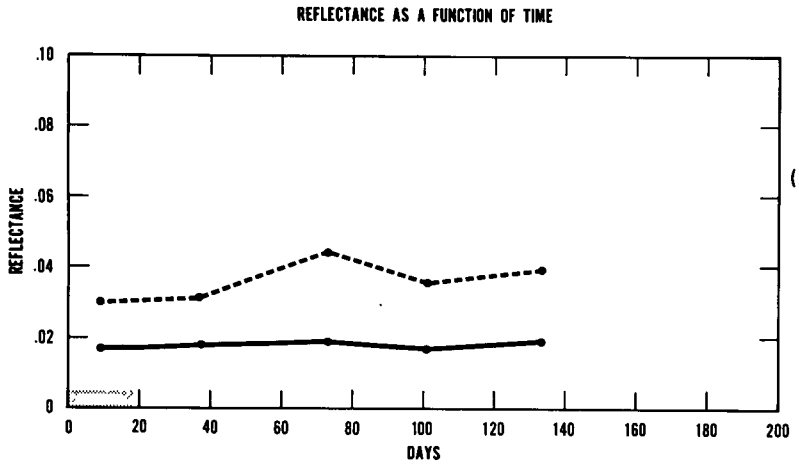
(13) Code: 9051ME2
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Aft
Date Painted: May 1969
Paint Mfr – De Boom



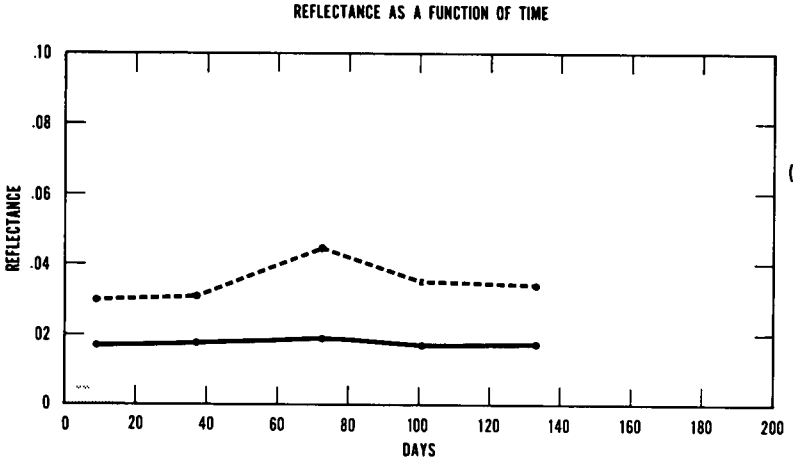
(14) Code: 9061BL1
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Fwd
Date Painted: June 1969



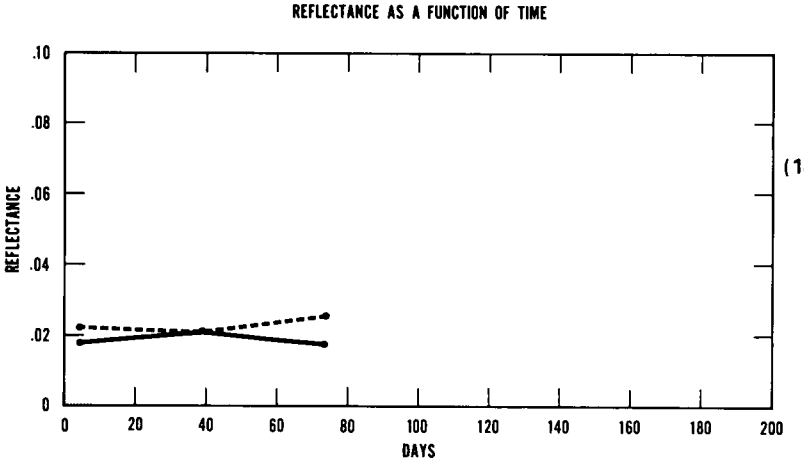
(15) Code: 9061BL2
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Aft
Date Painted: June 1969



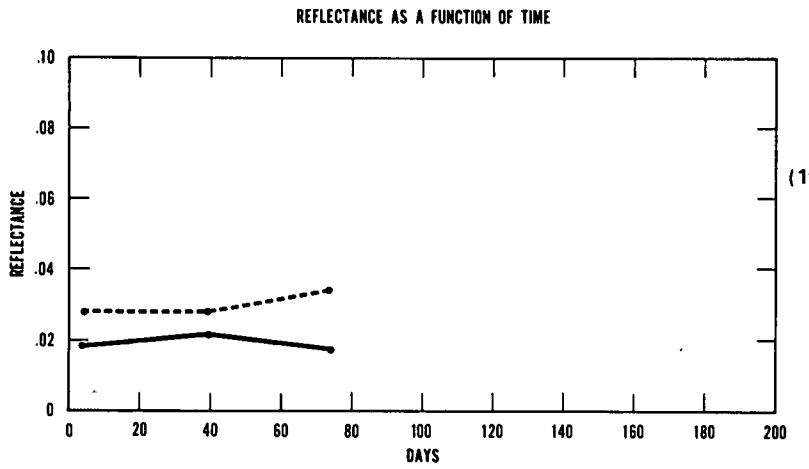
(16) Code: 9061SC1
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Fwd
Date Painted: June 1969
Paint Mfr – Reliance Chem Co.
Date Mfd – 9132
Batch No. – 69-26



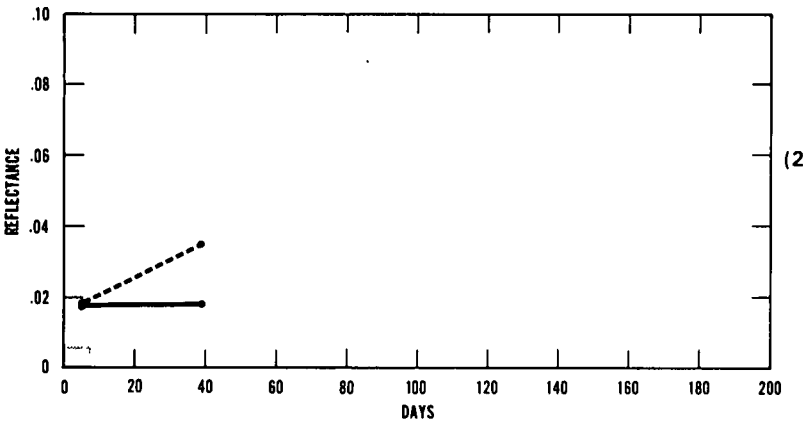
(17) Code: 9061SC2
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Aft
Date Painted: June 1969
Paint Mfr – Reliance Chem Co.
Date Mfd – 9132
Batch No. – 69-26



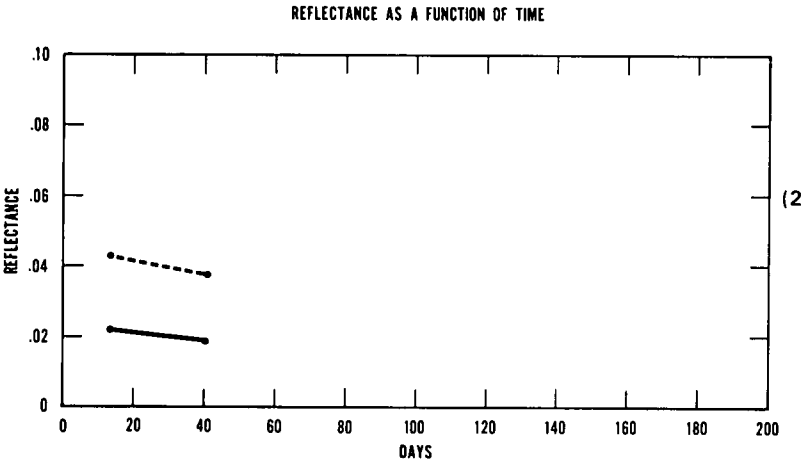
(18) Code: 9062CA3
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Fwd
Date Painted: June 1969
Paint Mfr – Sentry Paint & Chem Co.
Date Mfd – June 1968
Batch No. – CG-40



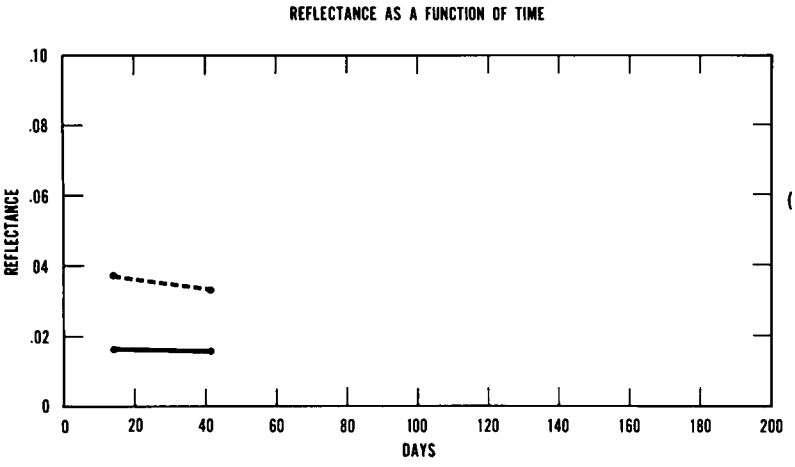
(19) Code: 9062CA4
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Aft
Date Painted: June 1969
Paint Mfr – Sentry Paint & Chem Co.
Date Mfd – June 1968
Batch No. – CG-40



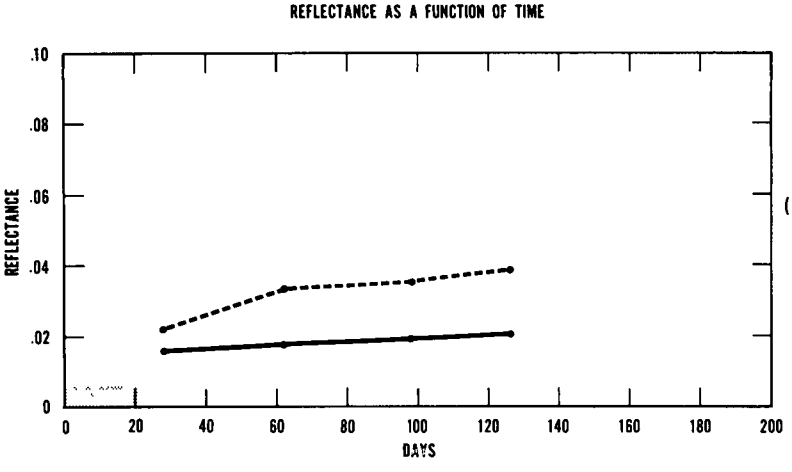
(20) Code: 9071CA1
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Fwd
Date Painted: July 1969



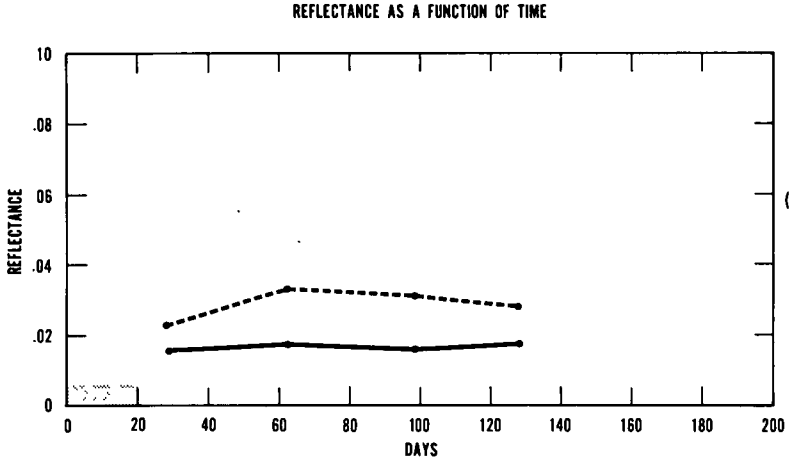
(21) Code: 9081GU1
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Fwd
Date Painted: August 1969



(22) Code: 9081GU2
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Aft
Date Painted: August 1969



(23) Code: 9081RB1
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Fwd
Date Painted: August 1969



(24) Code: 9081RB2
Type of Paint: Vinyl Alkyd 122, R_o 1.8
Type of Area: Horiz Aft
Date Painted: August 1969

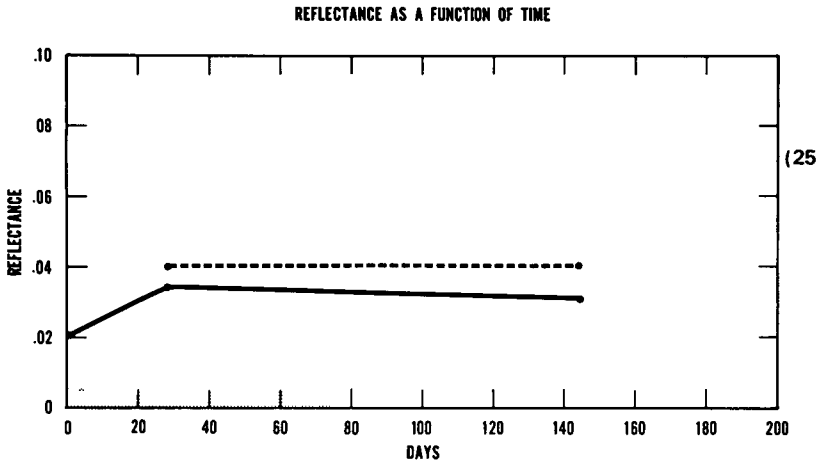
Table B-II. Summary Log of Paint Reflectance Measurements: Vinyl Alkyd 122, R_o 3.6 Paint

Code	Initial Measurement		1st Repeat		2nd Repeat		3rd Repeat		4th Repeat		5th Repeat		Total Days Submerged
	†Reflectance	‡Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	
8102PE3*	0.0207 –	1	0.0347 0.0400	28	0.0315 0.0400	143							74
8112BU3*	0.037 0.048	1	0.0352 0.0500	33	0.0352 0.0510	75							4
8112BU4*	0.0287 0.0420	1	0.0265 0.0400	33	0.0265 0.0400	75							4
8122BA3	0.0276 0.0470	31	0.026 0.032	61	0 0277 0.0350	83	0.026 0.032	104					15
8122BA4	0.026 0 038	31	0.0315 0.0360	61	0.0295 0.0370	83	0.026 0.034	104					15
9012BG3	0.035 0.044	1 1	0.0357 0.0405	35	0.0365 0.0490	68							13
9012BG4	0.035 0.048	1	0.0317 0.0404	35	0.0282 0.0420	68							13
9022RO3*	0.028 0.046	16	0.0277 0.0360	56									No Data
9022RO4*	0 026 0.046	16	0.026 0 037	56									No Data
9042PE3*	0 0332 0 0300	1	0 031 0 028	30									6
9052ME3*	0.020 0.036	36	0.020 0 032	64	0.020 0.027	99							8
9052ME4*	0 029 0.041	36	0 027 0 040	64	0.035 0 044	99							8
9062BL3*	0.035 0 040	33	0.037 0.048	89	0.0367 0 0465	134	0.0350 0 0480	145	0.030 0.047	173			11
9062BL4*	0.024 0 030	33	0.0230 0 0325	89	0.0242 0.0325	134	0.0295 0.0350	145	0.0242 0.0380	173			11
9062SC3*	0.027 0.038	9	0.026 0.036	37	0 0255 0.0450	72	0.027 0.043	100	0.026 0.044	132			17
9072CF3	0.028 0.045	51	0.028 0.044	86									9
9072CF4	0.0290 0.0455	51	0.028 0.045	86									9
9082GU3	0.0260 0 0445	14	0.0245 0 0440	41									4
9082GU4	0.0235 0.0440	14	0 0225 0 0380	41									4

*Refers to documented paint data including date of painting, paint formula, manufacturer date of paint manufacture and packaging batch number, and special remarks

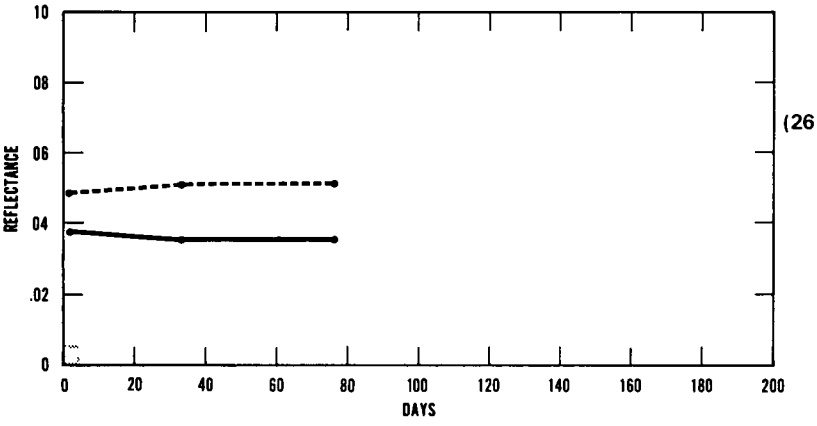
†Upper number is R_o; lower number is R_{dry}.

‡Days between painting and measuring.



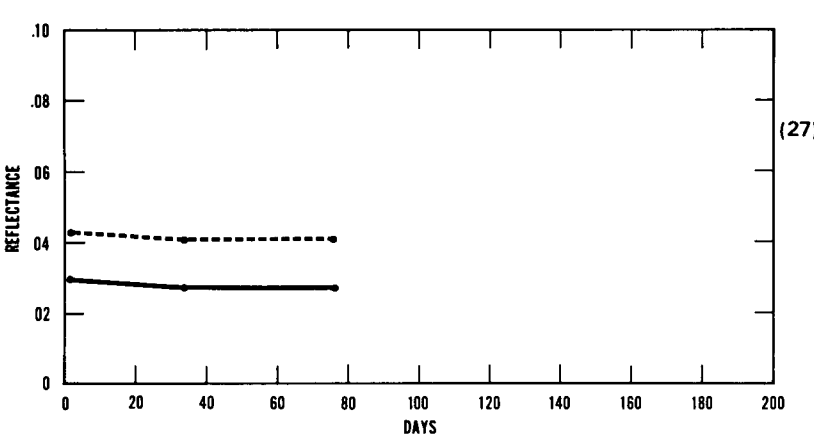
(25)

Code: 8102PE3
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Fwd
Date Painted: October 1968
Initial measurement while very fresh
Paint Mfr – Devoe



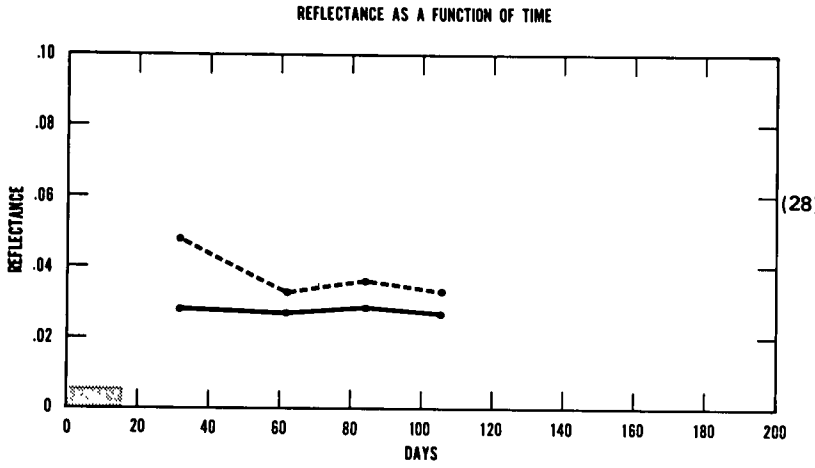
(26)

Code: 8112BU3
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Fwd
Date Painted: November 1968
Paint Mfr – Devoe
Date Mfd – MD8661
Batch No. – A8X058



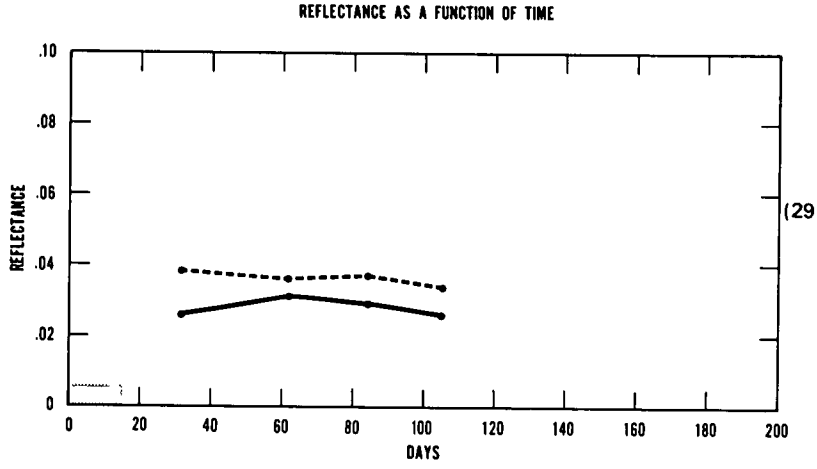
(27)

Code: 8112BU4
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Aft
Date Painted: November 1968
Paint Mfr – Devoe
Date Mfd – MD8661
Batch No. – A8X058



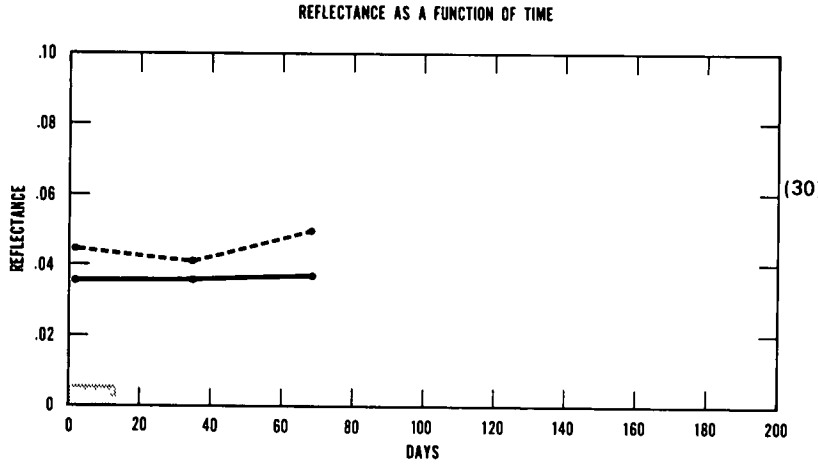
(28)

Code: 8122BA3
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Fwd
Date Painted: December 1968



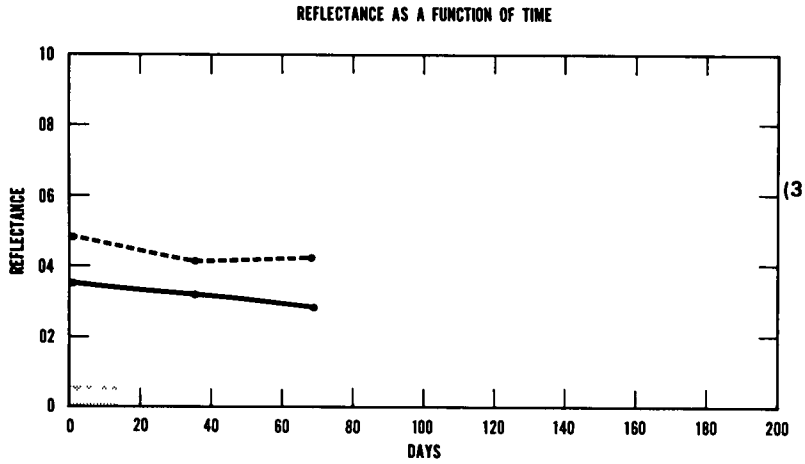
(29)

Code: 8122BA4
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Aft
Date Painted: December 1968



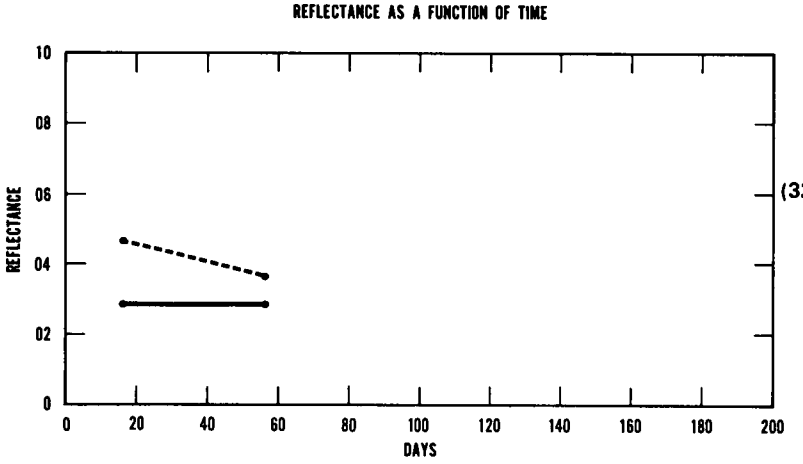
(30)

Code: 9012BG3
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Fwd
Date Painted: February 1969
Paint Mfr – De Boom



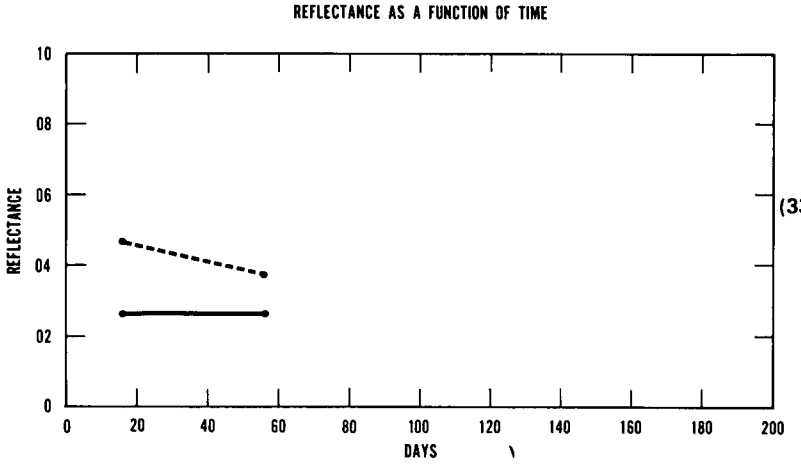
(31)

Code: 9012BG4
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Aft
Date Painted: February 1969
Paint Mfr – De Boom



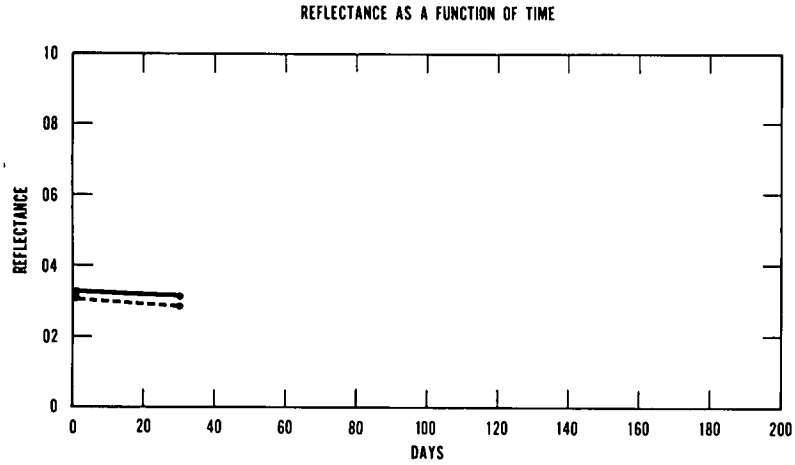
(32)

Code: 9022RO3
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Fwd
Date Painted: February 1969

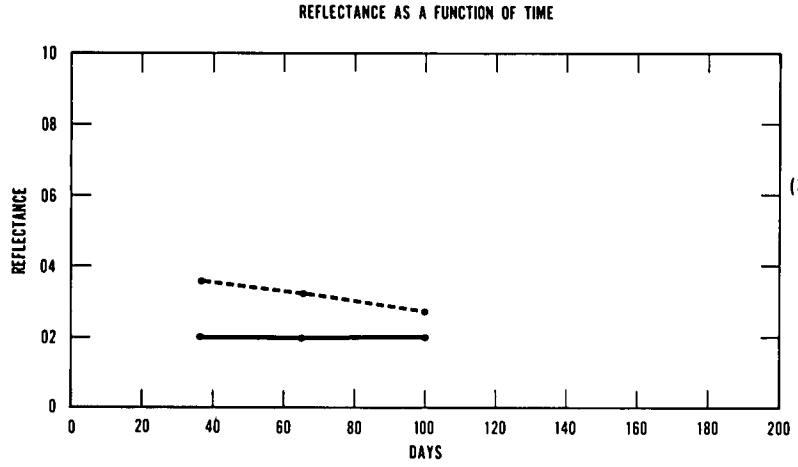


(33)

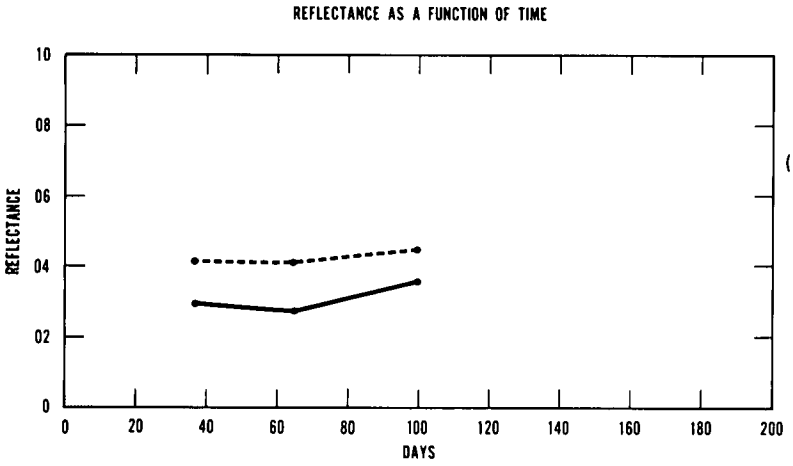
Code: 9022RO4
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Aft
Date Painted: February 1969



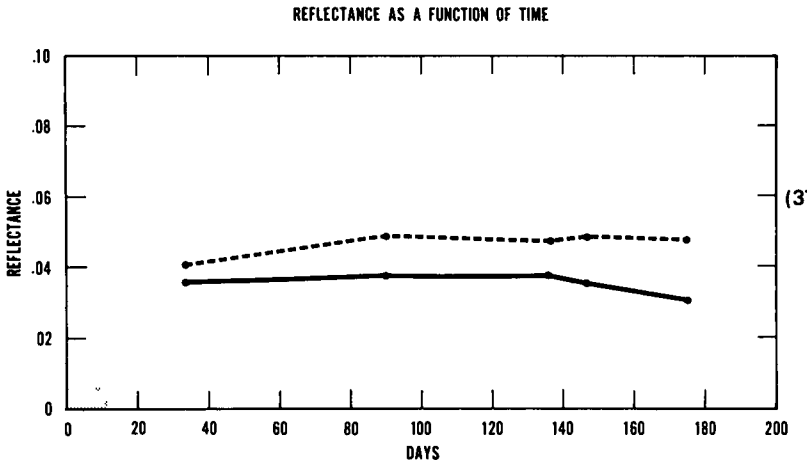
(34) Code: 9042PE3
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Fwd
Date Painted: April 1969



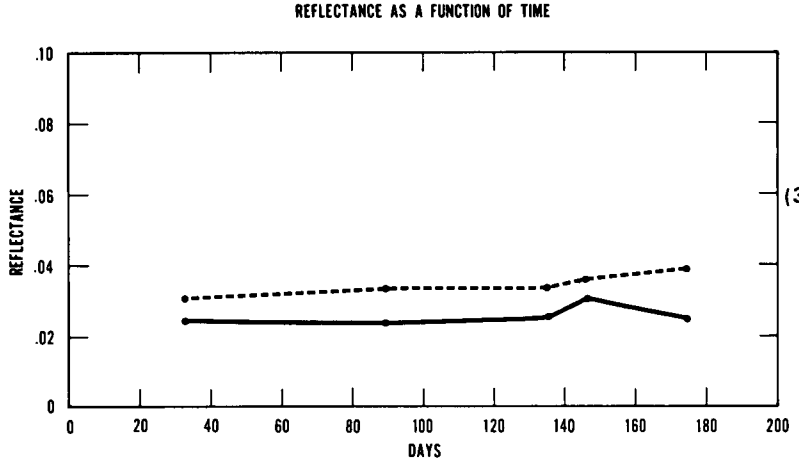
(35) Code: 9052ME3
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Fwd
Date Painted: May 1969
Paint Mfr – De Boom



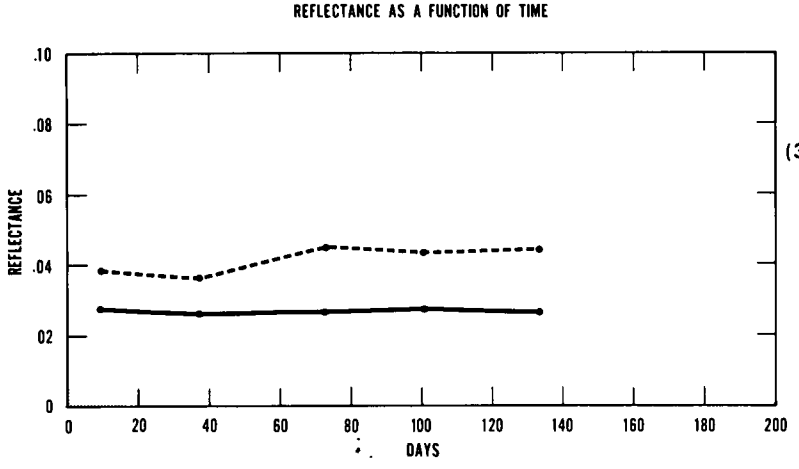
(36) Code: 9052ME4
Type of Paint. Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Aft
Date Painted· May 1969
Paint Mfr – De Boom



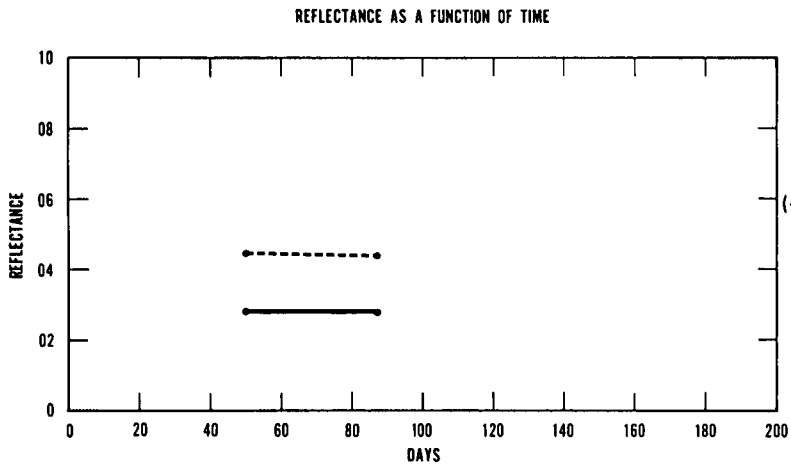
(37) Code: 9062BL3
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Fwd
Date Painted: June 1969



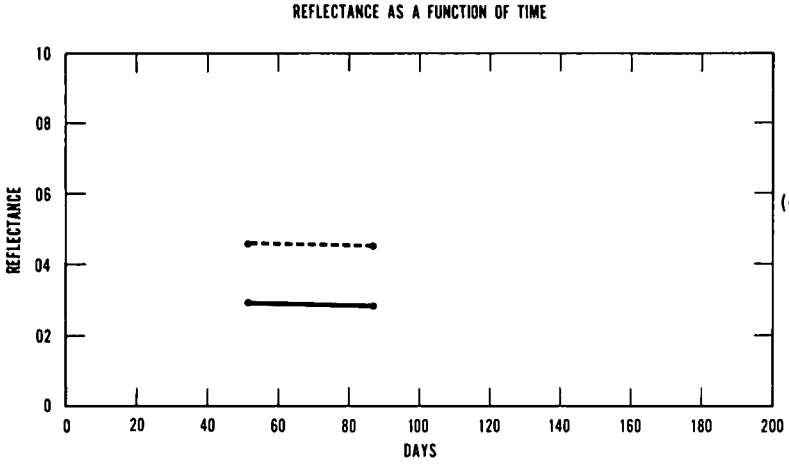
(38) Code: 9062BL4
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Aft
Date Painted: June 1969



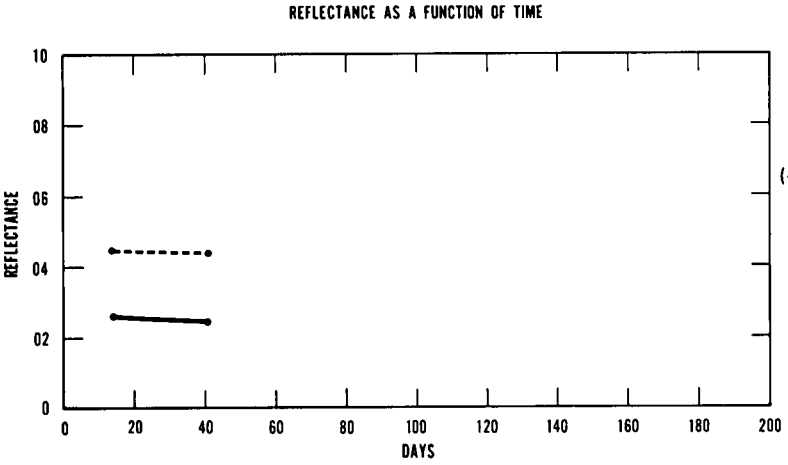
(39) Code: 9062SC3
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Fwd
Date Painted: June 1969
Paint Mfr – Sentry Paint & Chem Co.
Batch No. – CC-40



(40) Code 9072CF3
Type of Paint Vinyl Alkyd 122, R_o 3 6
Type of Area Vert Fwd
Date Painted July 1969

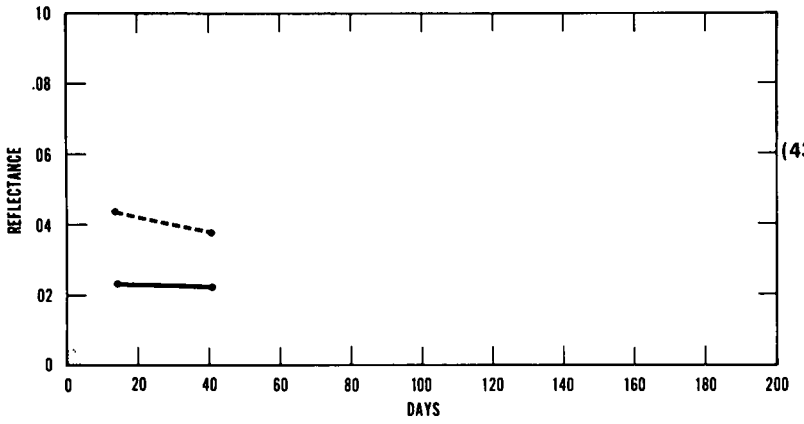


(41) Code 9072CF4
Type of Paint Vinyl Alkyd 122, R_o 3 6
Type of Area Vert Aft
Date Painted July 1969



(42) Code 9082GU3
Type of Paint Vinyl Alkyd 122, R_o 3 6
Type of Area Vert Fwd
Date Painted August 1969

REFLECTANCE AS A FUNCTION OF TIME



Code: 9082GU4
Type of Paint: Vinyl Alkyd 122, R_o 3.6
Type of Area: Vert Aft
Date Painted: August 1969

Table B-III. Summary Log of Paint Reflectance Measurements: Devran Epoxy 219-3 Paint ★

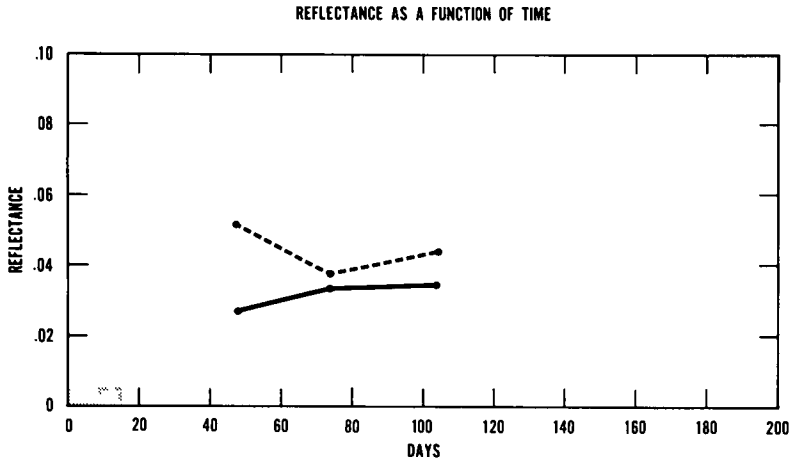
Code	Initial Measurement		1st Repeat		2nd Repeat		3rd Repeat		4th Repeat		5th Repeat		Total Days Submerged
	†Reflectance	‡Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	
8099PO1	0.0277 0.0520	47	0.0335 0.0380	73	0.035 0.044	103	Devran (UNVERIFIED)						15
8099PO2	0.0212 0.0590	47	0.012 0.038	73	0.0348 0.0460	103							15
8108SC1	0.0277 –	1	0.028 0.036	87	0.026 0.040	136 136	0.034 0.030	163					69
8108SC2	0.0275 –	1	0.026 0.015	87	0.027 0.038	136	0.034 0.034	163					69
8105CH1*	0.0175 0.0140	2	0.012 0.021	44	No Data	72	0.0177 0.0204	107	0.019 0.026	135			20
8105CH2*	0.0175 0.0150	2	0.0175 0.0270	44	0.015 0.020	72	0.0172 –	107	0.0172 0.0300	135			20
8115SN1	0.0155 0.0210	13	0.018 0.011	49	0.019 0.030	91	0.018 0.036	118					22
8115SN2	0.0172 0.0300	13	0.018 0.021	49	0.0182 0.0320	91	0.020 0.032	118					22
9048RA1	0.021 0.021	3	0.019 0.019	33									No Data
9048RA2	0.024 0.024	3	0.022 0.032	33									No Data
9078BU1	0.019 0.028	38	0.0215 0.0310	66									0
9078BU2	0.019 0.024	38	0.0190 0.0325	66									0
9095SL1	0.0172 0.0420	66	0.0172 0.0500	93	0.0162 0.0370	175							25
9095SL2	0.0172 0.0300	66	0.0172 0.0330	93	0.0162 0.0280	175							25

*Refers to documented paint data including date of painting, paint formula, manufacturer date of paint manufacture and packaging batch number, and special remarks

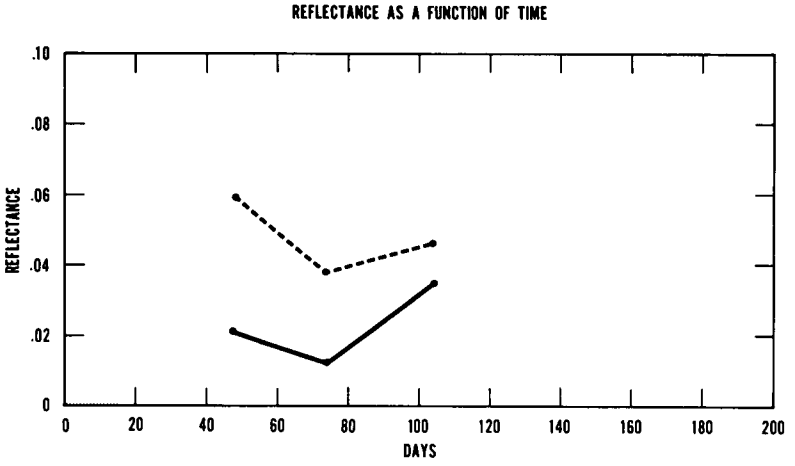
† Upper number is R_ω; lower number is R_{dry}

‡ Days between painting and measuring

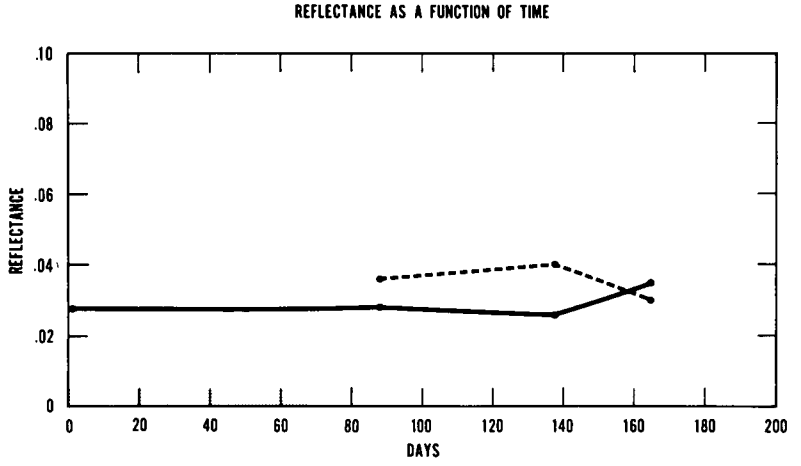
★ All surfaces painted with Devran Epoxy having $R_\omega < 0.028$.



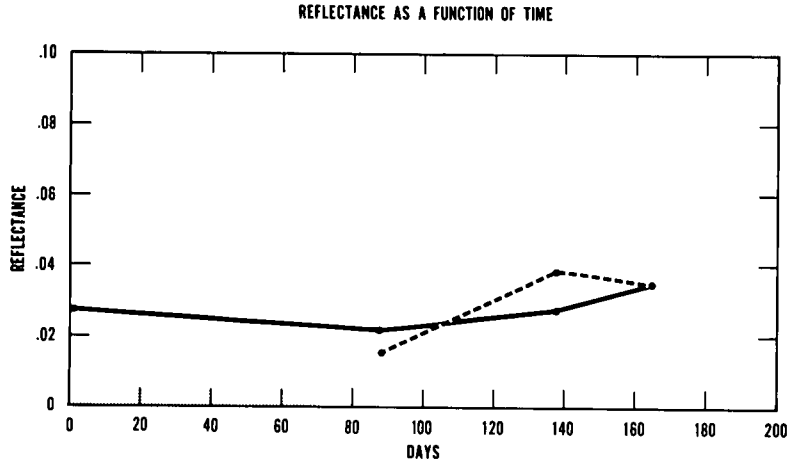
(44) Code: 8099PO1
Type of Paint: Devran Epoxy
Type of Area: Horiz Fwd
Date Painted: September 1968
Probably 219-3 & 7 mix



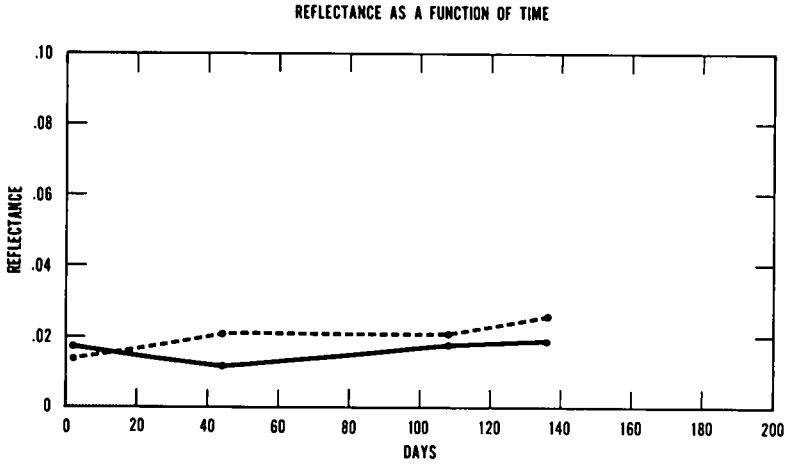
(45) Code: 8099PO2
Type of Paint: Devran Epoxy
Type of Area: Horiz Aft
Date Painted: September 1968
Probably 219-3 & 7 mix



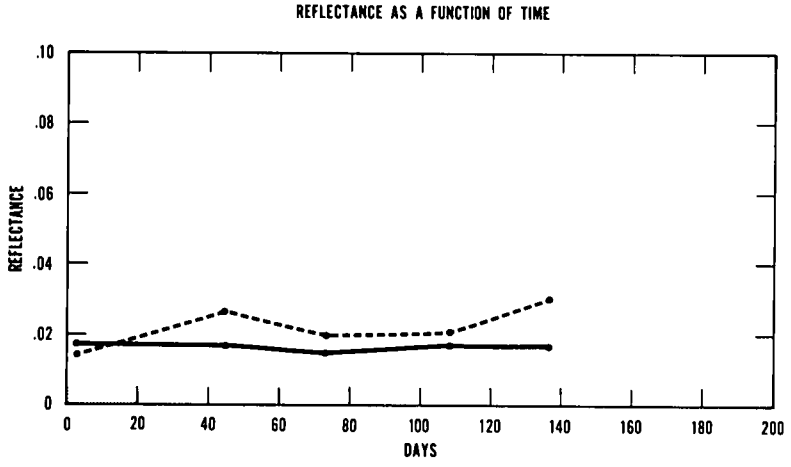
(46) Code: 8108SC1
Type of Paint: Devran Epoxy
Type of Area: Horiz Fwd
Date Painted: October 1968
Probably 219-3 & 7 mix



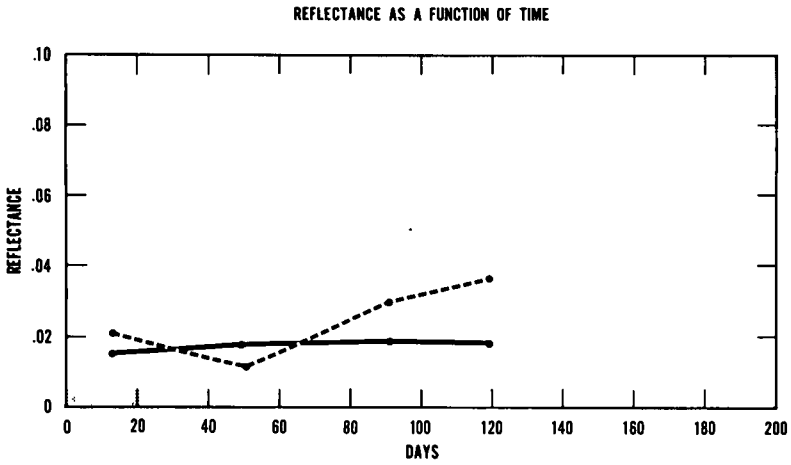
(47) Code: 8108SC2
Type of Paint: Devran Epoxy
Type of Area: Horiz Aft
Date Painted: October 1968
Probably 219-3 & 7 mix



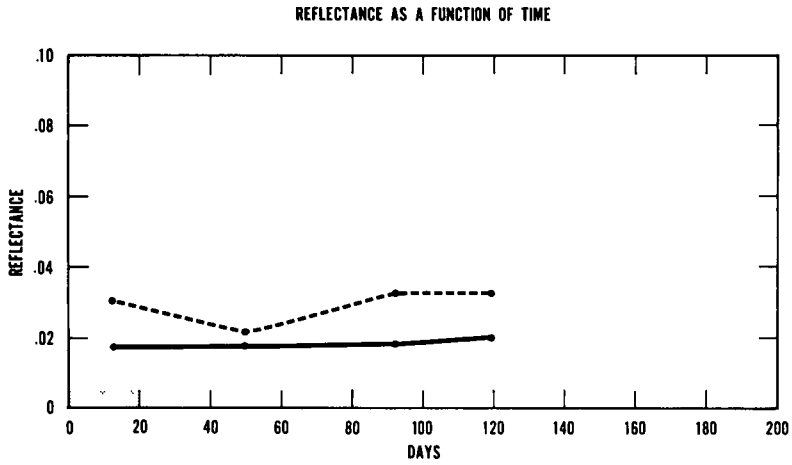
(48) Code: 8105CH1
Devran Epoxy 219-3
Type of Area: Horiz Fwd
Date Painted: October 1968



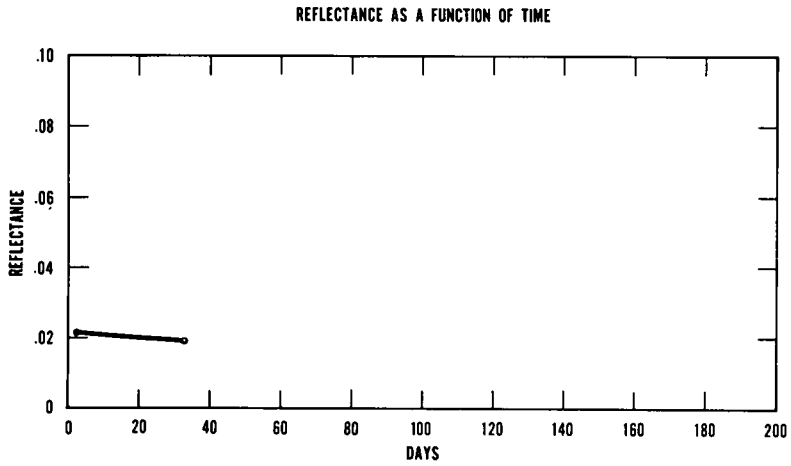
(49) Code: 8105CH2
Devran Epoxy 219-3
Type of Area: Horiz Aft
Date Painted: October 1968



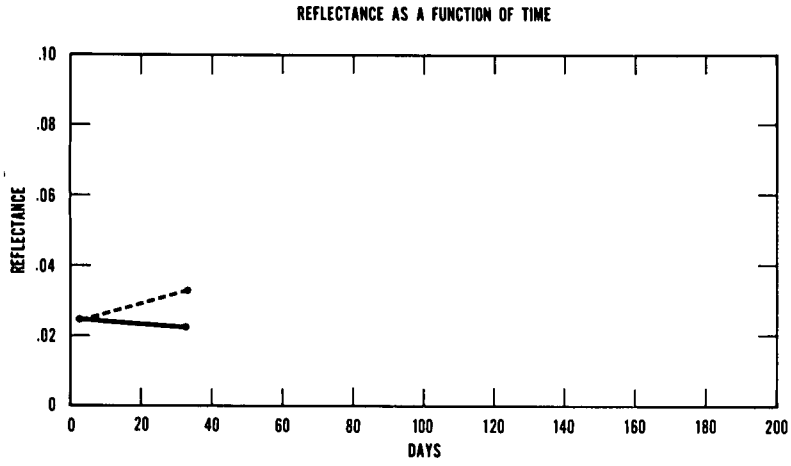
(50) Code: 8115SN1
Devran Epoxy 219-3
Type of Area: Horiz Fwd
Date Painted: November 1968



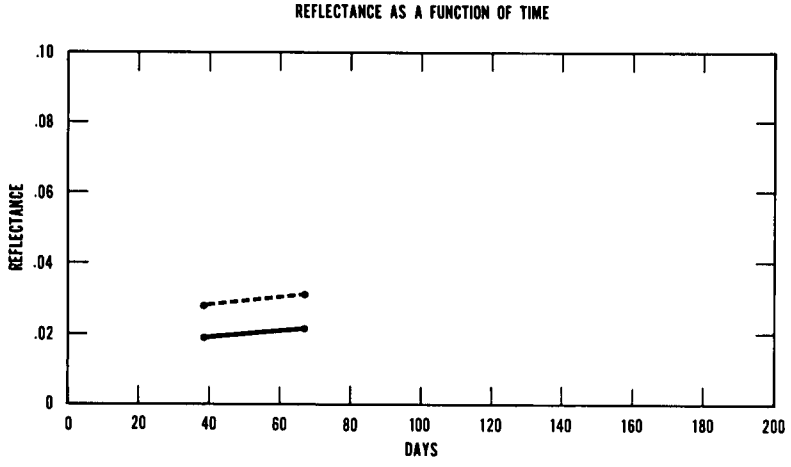
(51) Code: 8115SN2
Devran Epoxy 219-3
Type of Area: Horiz Aft
Date Painted: November 1968



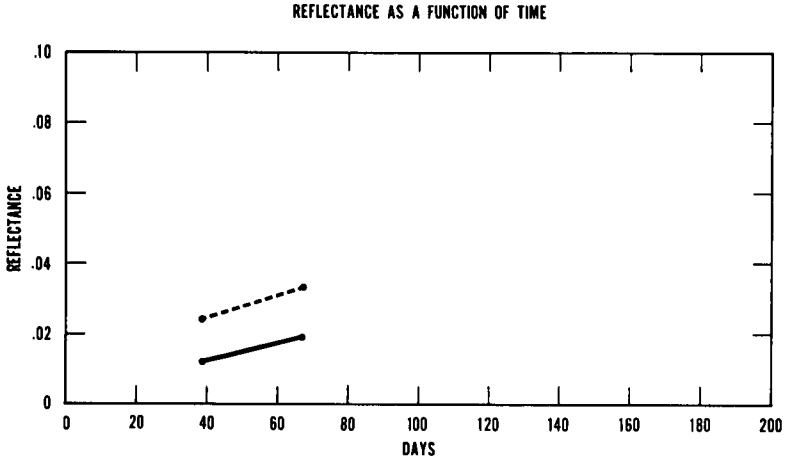
(52) Code: 9048RA1
Type of Paint: Devran Epoxy
Type of Area: Horiz Fwd
Date Painted: April 1969
Note: Dry and wet readings were the same on both occasions tested.



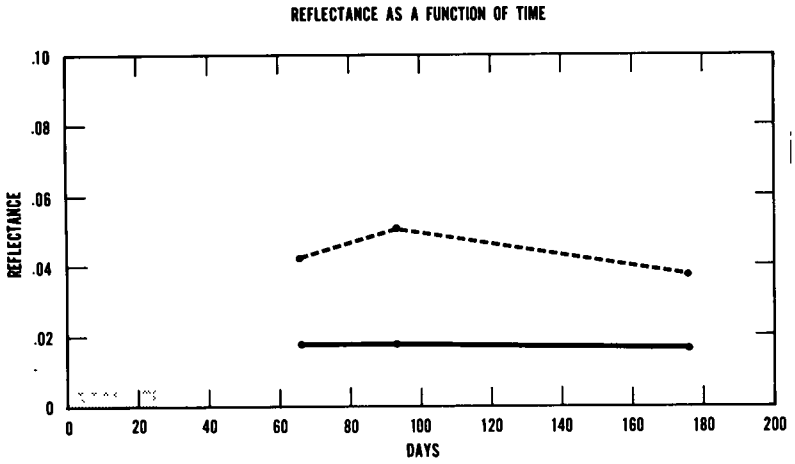
(53) Code: 9048RA2
Type of Paint: Devran Epoxy
Type of Area: Horiz Aft
Date Painted: April 1969



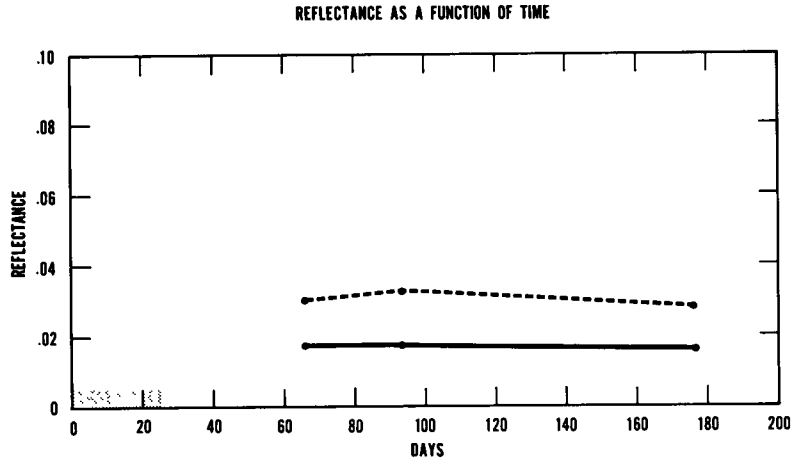
(54) Code: 9078BU1
Devran Epoxy 219-3 & 7 mix
Type of Area: Horiz Fwd
Date Painted: July 1969



(55) Code: 9078BU2
Type of Paint: Devran Epoxy
Type of Area: Horiz Aft
Date Painted: July 1969



(56) Code: 9095SL1
Devran Epoxy 219-3
Type of Area: Horiz Fwd
Date Painted: September 1969



(57) Code: 9095SL2
Devran Epoxy 219-3
Type of Area: Horiz Aft
Date Painted: September 1969

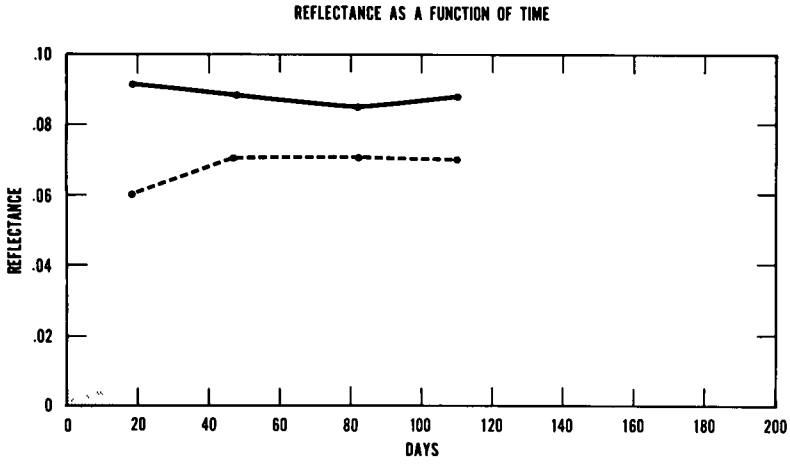
Table B-IV Summary Log of Paint Reflectance Measurements Devran Epoxy 219-7 Paint

Code	Initial Measurement		1st Repeat		2nd Repeat		3rd Repeat		4th Repeat		5th Repeat		Total Days Submerged
	†Reflectance	‡Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	
8116CH3*	0 09 0 06	19	0 087 0 070	47	0 0835 0 0700	82	0 0865 0 0690	110					13
8116CH4*	0 091 0 066	19	0 095 0 057	47	0 085 0 051	82	0 085 0 066	110					13

*Refers to documented paint data including date of painting paint formula manufacturer date of paint manufacture and packaging batch number and special remarks

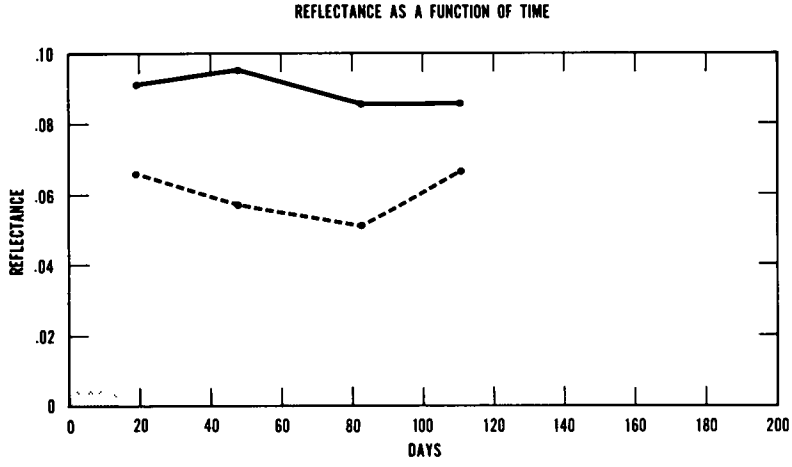
†Upper number is R_o lower number is R_{dry}

‡Days between painting and measuring



(58)

Code: 8116CH3
Type of Paint: Devran Epoxy 219-7
Type of Area: Vert Fwd
Date Painted: November 1968
Paint Mfr – Devoe
Batch No. – MD1974



(59)

Code: 8116CH4
Type of Paint: Devran Epoxy 219-7
Type of Area: Vert Aft
Date Painted: November 1968
Paint Mfr – Devoe
Batch No. – MD1974

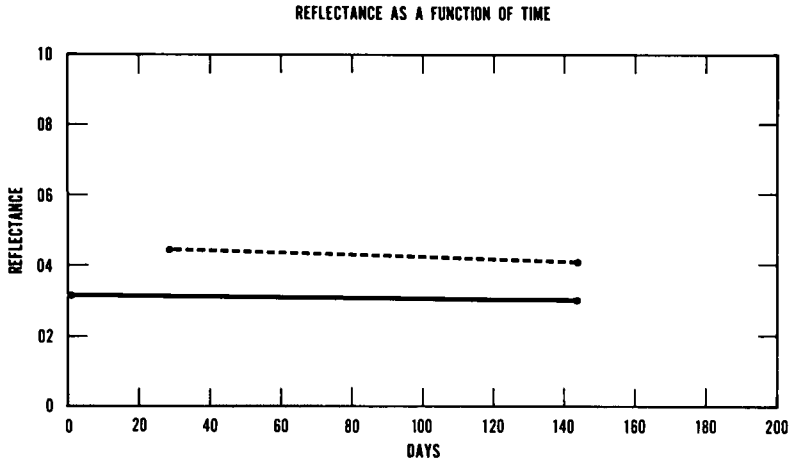
Table B-V Summary Log of Paint Reflectance Measurements Vinyl Alkyd Mixed Paint

Code	Initial Measurement		1st Repeat		2nd Repeat		3rd Repeat		4th Repeat		5th Repeat		Total Days Submerged
	†Reflectance	‡Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	
8107PE1*	0 0312 –	1	0 0312 0 0440	28	0 0295 0 0400	143							72
8107PE2*	0 0312 –	1 1	0 0312 0 0440	28	0 0277 0 0340	143							72
9037GU3	0 033 0 030	5	0 031 0 035	69	0 031 0 027	97							29
9037GU4	0 026 –	5	0 031 –	69	0 0365 –	97							29

*Refers to documented paint data including date of painting paint formula manufacturer date of paint manufacture and packaging batch number and special remarks

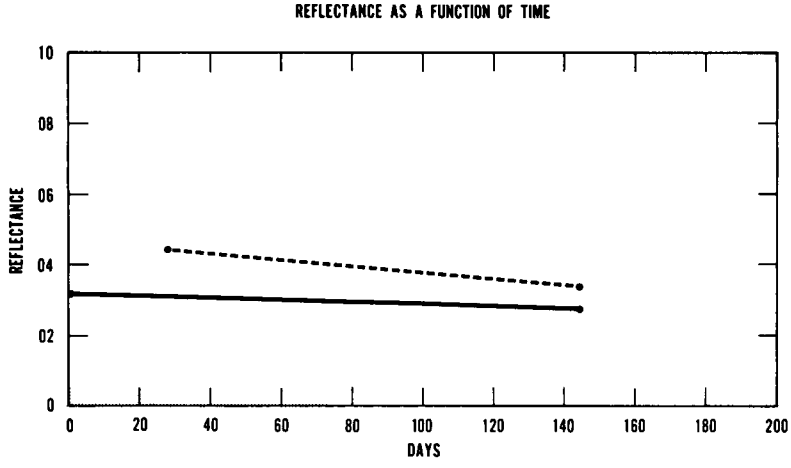
†Upper number is R_o lower number is R_{dry}

‡Days between painting and measuring



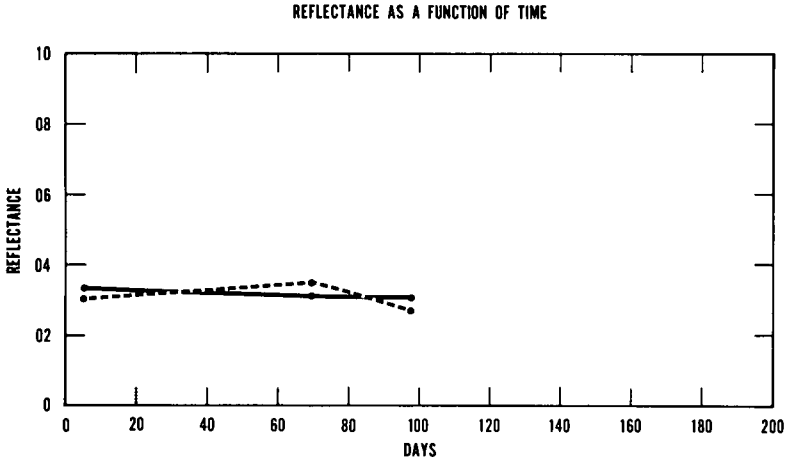
(60)

Code: 8107PE1
Type of Paint: Vinyl Alkyd Mix
122 R_o 3.6 and 7.0
Type of Area: Horiz Fwd
Date Painted: October 1968
Paint Mfr – Atlas Paint & Varnish Co.
Date Mfd – July 1967



(61)

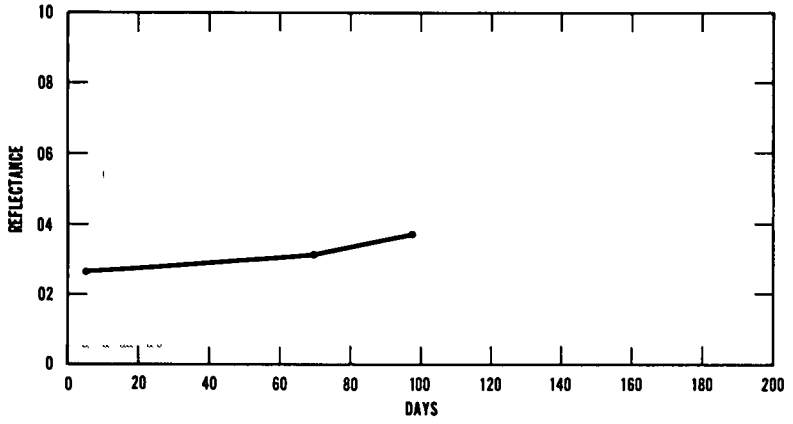
Code: 8107PE2
Type of Paint: Vinyl Alkyd Mix
122 R_o 3.6 and 7.0
Type of Area: Horiz Fwd
Date Painted: October 1968
Paint Mfr – Atlas Paint & Varnish Co.
Date Mfd – July 1967



(62)

Code 9037GU3
Type of Paint: Vinyl Alkyd Mix
122 R_o 1.8, 3.0, 3.6
Type of Area: Vert Fwd
Date Painted: March 1969

REFLECTANCE AS A FUNCTION OF TIME



(63)

Code: 9037GU4
Type of Paint: Vinyl Alkyd Mix
122 R_o 1.8, 3.0, 3.6
Type of Area: Vert Aft
Date Painted: March 1969

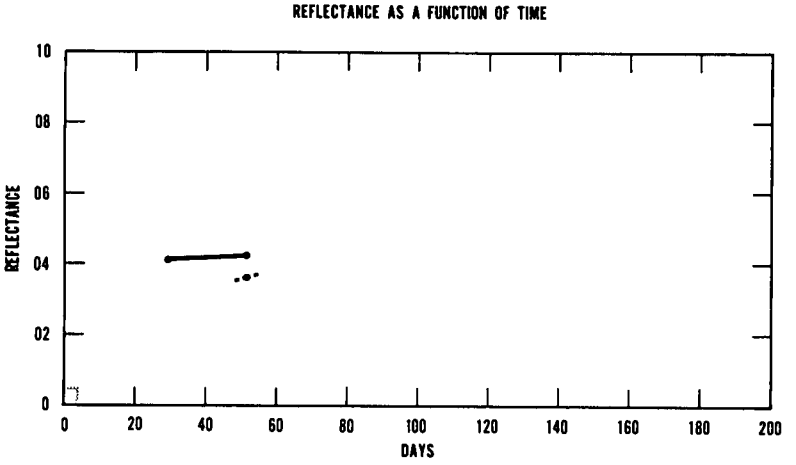
Table B-VI. Summary Log of Paint Reflectance Measurements: Devran Epoxy Mix 219-3 and 219-7 Paints

Code	Initial Measurement		1st Repeat		2nd Repeat		3rd Repeat		4th Repeat		5th Repeat		Total Days Submerged
	†Reflectance	‡Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	
8088SN1	0 041 –	29	0 042 0 036	51									4
8088SN2	0 036 –	29	0 0367 0 0318	51									4
8088SN3	0 0367 –	22	0 035 0 023	44	0 0367 0 0260	96	0 0312 0 0210	116	0 0385 0 0270	170	0 034 0 026	197	25
8088SN4	0 0405 –	22	0 035 0 032	44	0 0455 0 0360	96	0 0322 0 0210	116	0 041 0 036	170	0 035 0 032	197	25
8098SA1	0 0472 –	1	0 042 0 035	24									4
8098SA2	0 0462 –	1	0 042 0 035	24									4
8108SC3	0 033	1	0 033 0 046	87	0 0317 0 0360	136	0 035 0 044	163					69
8108SC4	0 034 –	1	0 037 0 028	87	0 0287 0 0360	136	0 0327 0 0400	163					69
9048PO4	0 035 0 041	2	0 0359 0 0530	161									1
9048RA3	0 035 0 026	3	0 035 0 026	33									No Data
9048RA4	0 035 0 026	3	0 038 0 036	33									No Data
9078BU3	0 035 0 042	38	0 0365 0 0500	66									0
9078BU4	0 035 0 036	38	0 0365 0 0470	66									0
9098SL3	0 0367 0 0500	66	0 0365 0 0500	93									25
9098SL4	0 040 0 050	66	0 0385 0 0480	93	0 0385 0 0460	64							25
9118RB3	0 0365 0 0440	0	0 0385 0 0470	36	0 039 0 047	64							8
9118RB4	0 0375 0 0465	0	0 0385 0 0390	36									8

*Refers to documented paint data including date of painting paint formula manufacturer date of paint manufacture and packaging batch number and special remarks

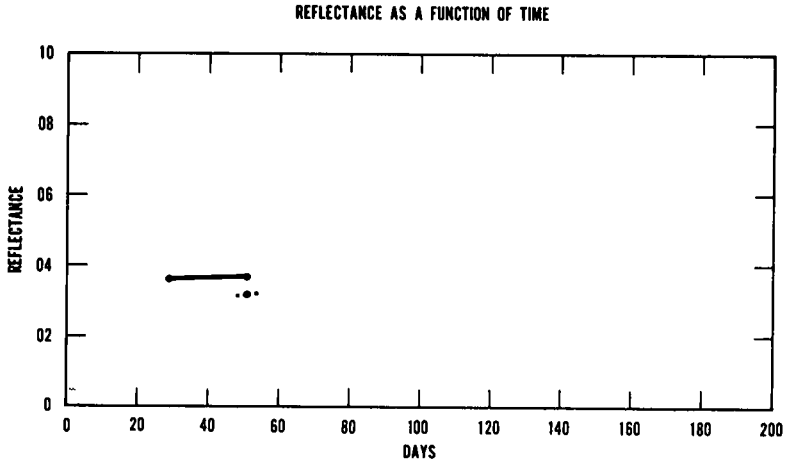
†Upper number is R_o, lower number is R_{dry}

‡Days between painting and measuring



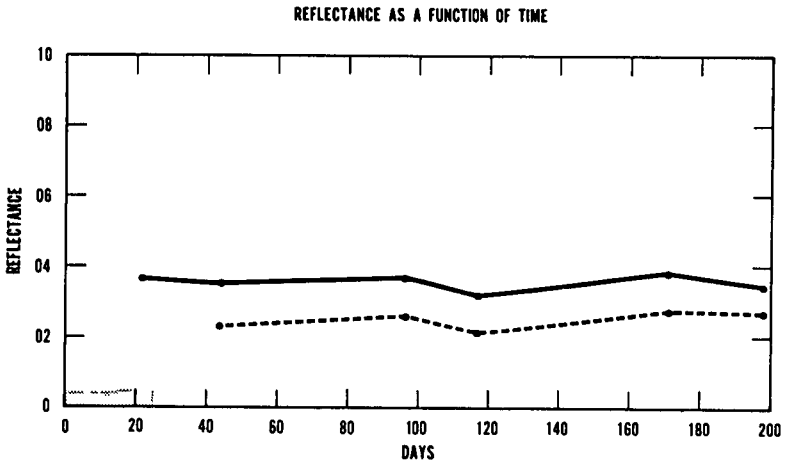
(64)

Code: 8088SN1
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Horiz Fwd
Date Painted: August 1968



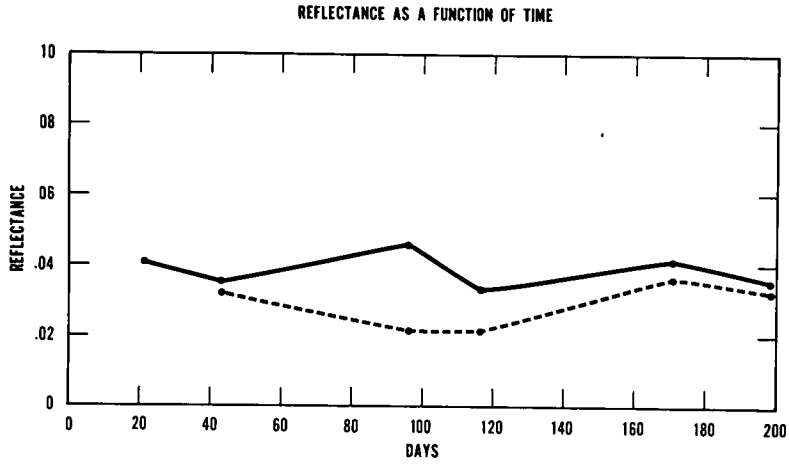
(65)

Code: 8088SN2
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Horiz Aft
Date Painted: August 1968



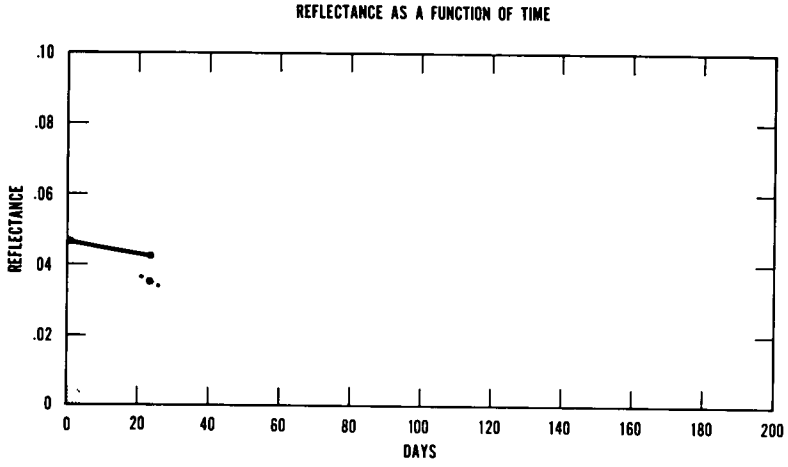
(66)

Code: 8088SN3
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Vert Fwd
Date Painted: August 1968



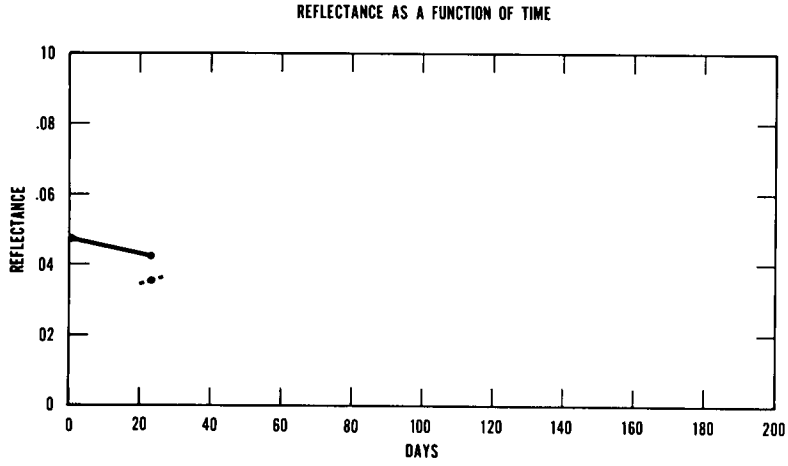
(67)

Code: 8088SN4
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Vert Aft
Date Painted: August 1968



(68)

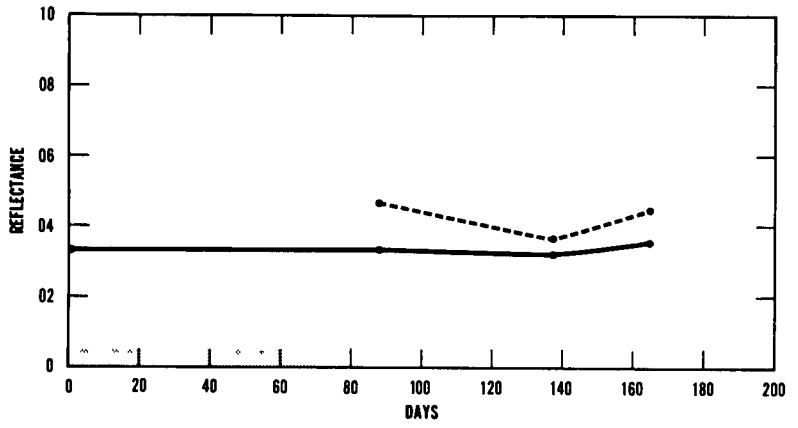
Code: 8098SA1
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Horiz Fwd
Date Painted: September 1968



(69)

Code: 8098SA2
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Horiz Aft
Date Painted: September 1968

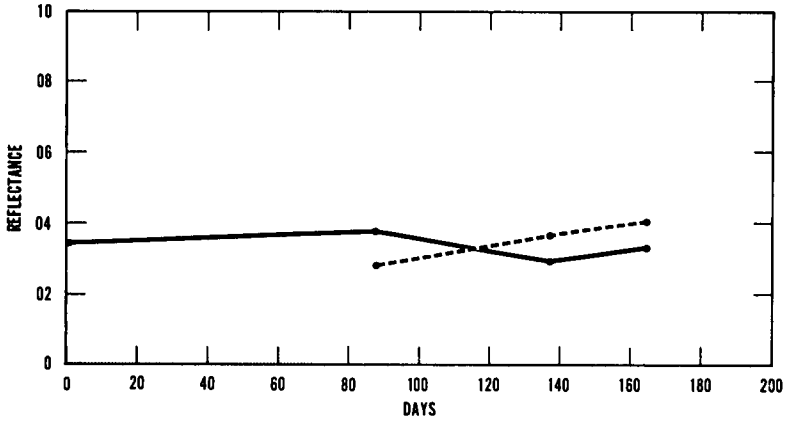
REFLECTANCE AS A FUNCTION OF TIME



(70)

Code· 8108SC3
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Vert Fwd
Date Painted: October 1968

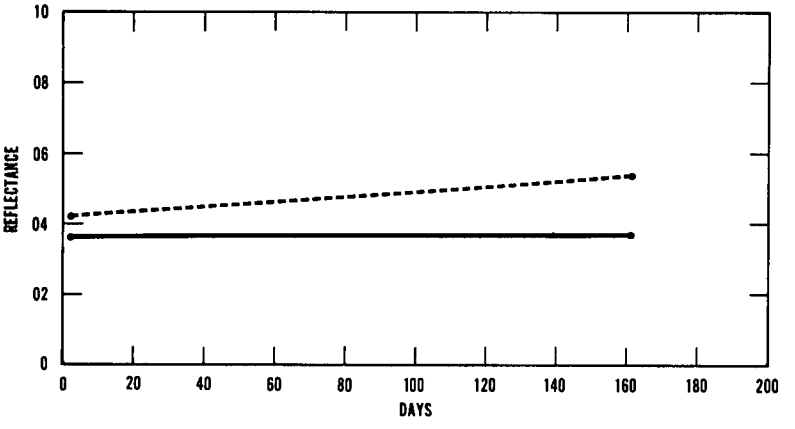
REFLECTANCE AS A FUNCTION OF TIME



(71)

Code: 8108SC4
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Vert Aft
Date Painted· October 1968

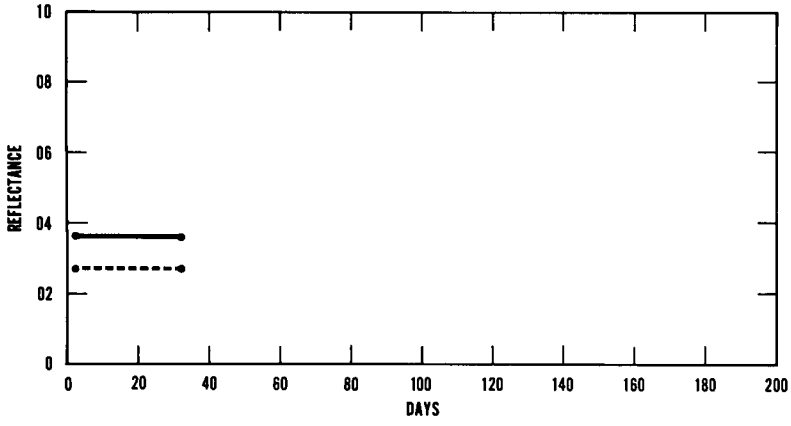
REFLECTANCE AS A FUNCTION OF TIME



(72)

Code: 9048PO4
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Vert Aft
Date Painted· April 1969

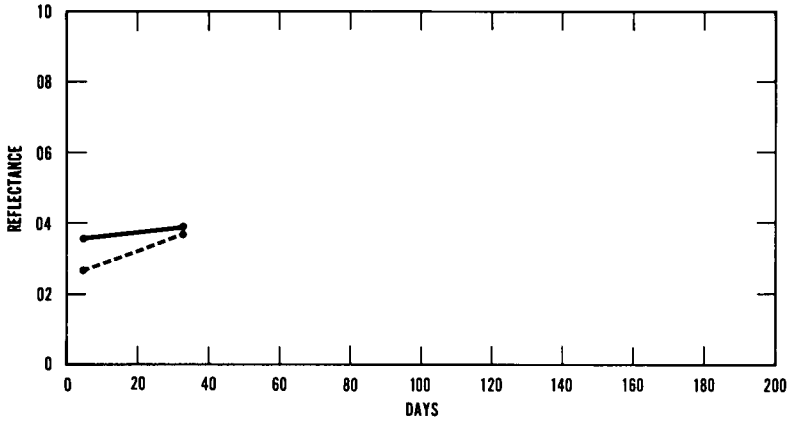
REFLECTANCE AS A FUNCTION OF TIME



(73)

Code: 9048RA3
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Vert Fwd
Date Painted: April 1969

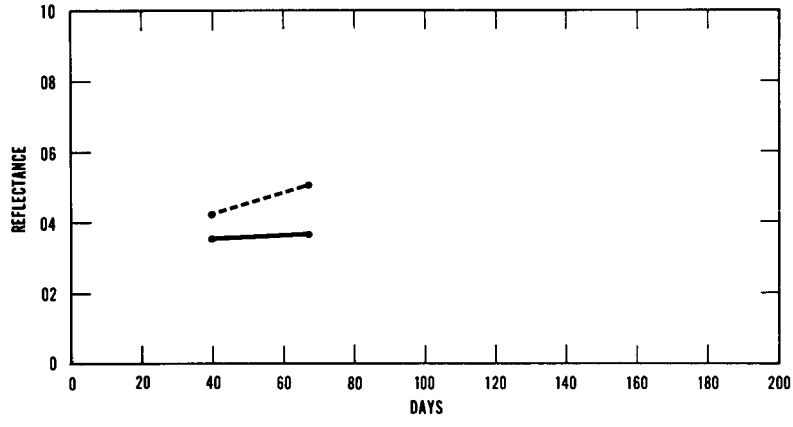
REFLECTANCE AS A FUNCTION OF TIME



(74)

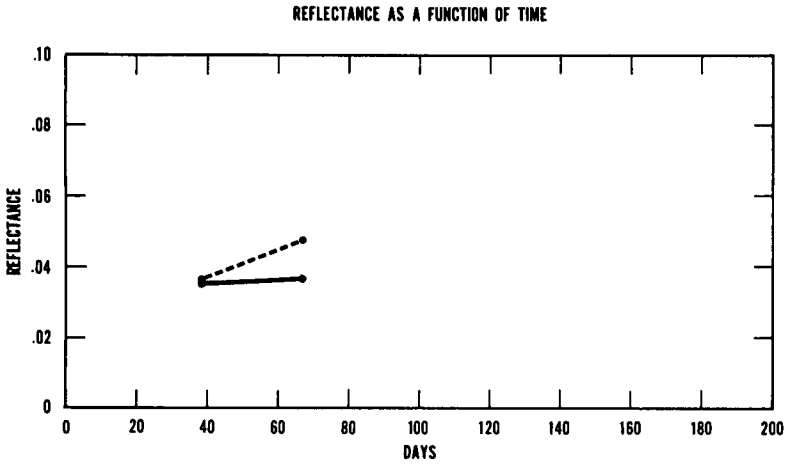
Code: 9048RA4
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Vert Aft
Date Painted: April 1969

REFLECTANCE AS A FUNCTION OF TIME



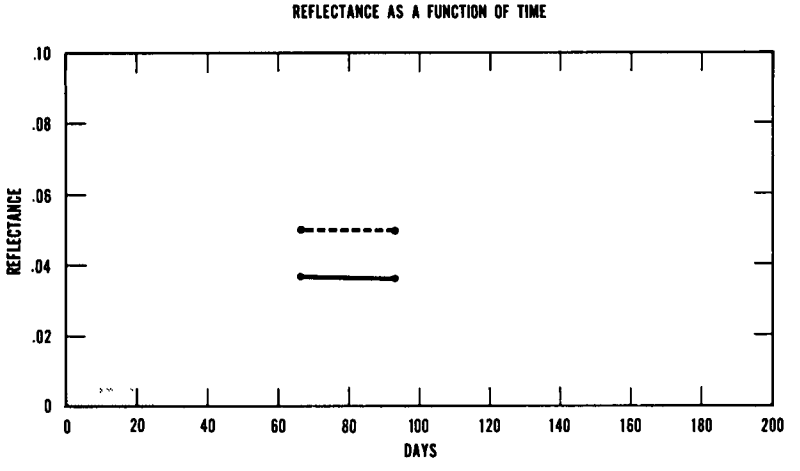
(75)

Code: 9078BU3
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Vert Fwd
Date Painted: July 1969



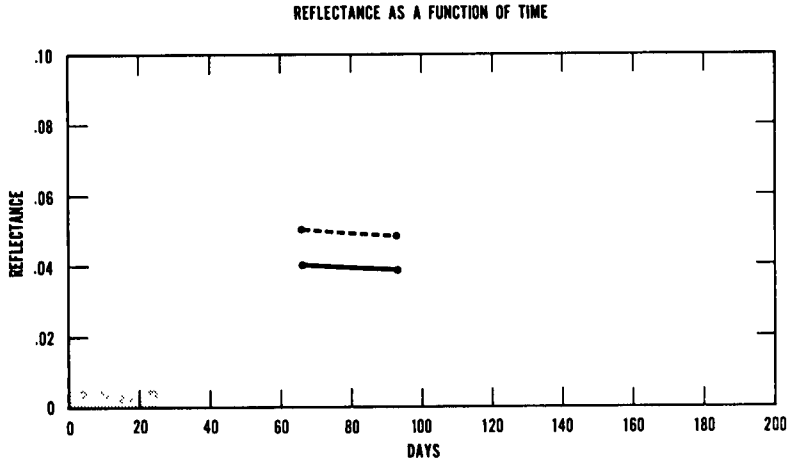
(76)

Code: 9078BU4
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Vert Aft
Date Painted: July 1969



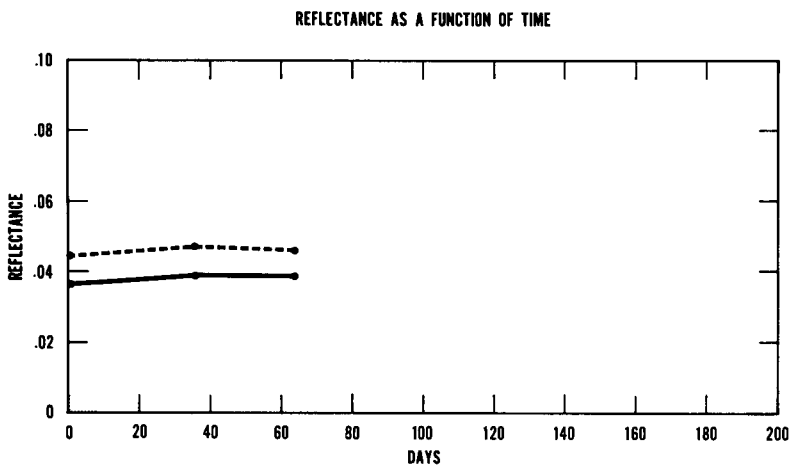
(77)

Code: 9098SL3
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Vert Fwd
Date Painted: September 1969



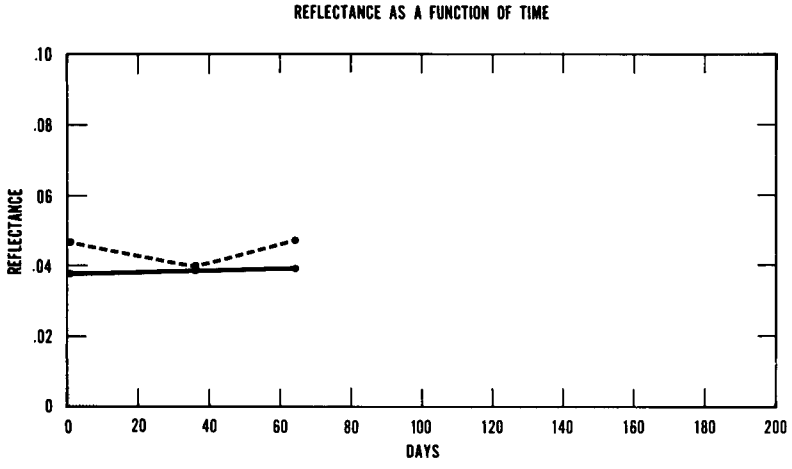
(78)

Code: 9098SL4
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Vert Aft
Date Painted: September 1969



(79)

Code: 9118RB3
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Vert Fwd
Date Painted: November 1969



(80)

Code: 9118RB4
Type of Paint: Devran Epoxy Mix 219-3 & 7
Type of Area: Vert Aft
Date Painted: November 1969

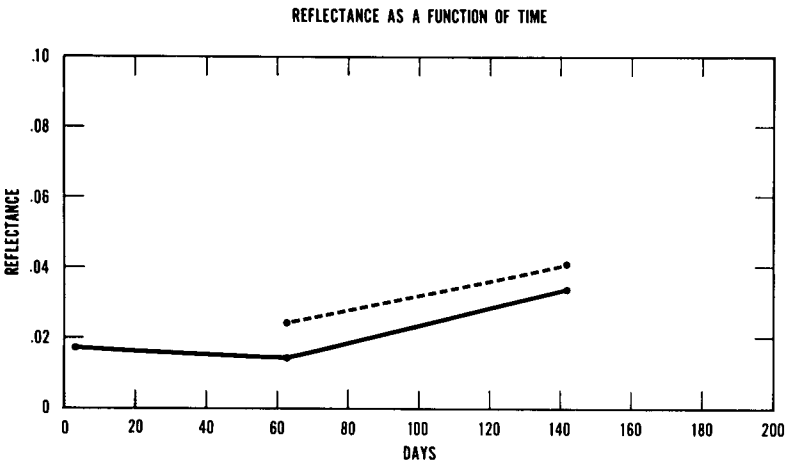
Table B-VII Summary Log of Paint Reflectance Measurements All Other Types of Paints

Code	Initial Measurement		1st Repeat		2nd Repeat		3rd Repeat		4th Repeat		5th Repeat		Total Days Submerged
	†Reflectance	‡Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	Reflectance	Days	
8099SE1	0 0172 –	3	0 014 0 024	62	0 023 0 040	139	Spec SFBNSY Paint Lab						26
8099SE2	0 0172 –	3	0 014 0 024	62	0 031 0 050	139	Spec SFBNSY Paint Lab						26
8099SE3	0 0172 –	3	0 027 0 024	62	0 035 0 051	139	Spec SFBNSY Paint Lab						26
8099SE4	0 0172 –	3	0 0197 0 0240	62	0 031 0 060	139	Spec SFBNSY Paint Lab						26
8119PO3	0 065 –	10	0 068 0 050	40									No Data
8119PO4	0 067 0 062	10	0 078 0 080	40	Devran Epoxy (Probably 219 3 & 7 Mix)								No Data
8119PT1*	0 028 0 044	1	0 0350 0 0504	97	Devran Epoxy (Probably 219 3 & 7 Mix)								17
8119PT2*	0 033 0 046	1	0 0387 0 0602	97	Brolite Polyamide Epoxy R_o 3 6								17
8119PT3*	0 060 0 048	1	0 053 0 060	97	Brolite Polyamide Epoxy R_o 3 6								17
8119PT4*	0 059 0 047	1	0 0530 0 0704	97	Brolite Polyamide Epoxy R_o 6 0								17
9069TI3	0 0472 0 0485	67	0 0472 0 0700	94	Brolite Polyamide Epoxy R_o 6 0								2
9069TI4	0 033 0 040	67	0 0402 0 0485	94	Brolite Polyamide Epoxy R_o 3 6								2
					Brolite Polyamide Epoxy R_o 3 6								

Refers to documented paint data including date of painting paint formula manufacturer date of paint manufacture and packaging batch number and special remarks

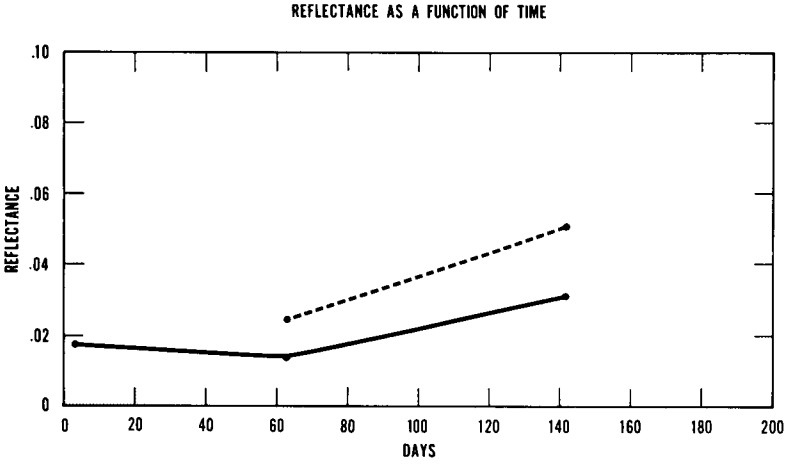
† Upper number is R_o lower number is R_{dry}

‡ Days between painting and measuring



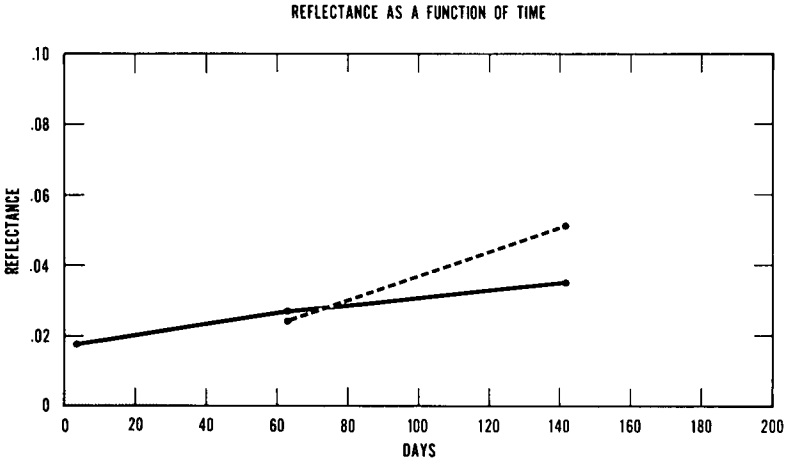
(81)

Code: 8099SE1
Type of Paint: Special dark scheme provided by SFBNSY Paint Lab
Type of Area: Horiz Fwd
Date Painted: September 1968



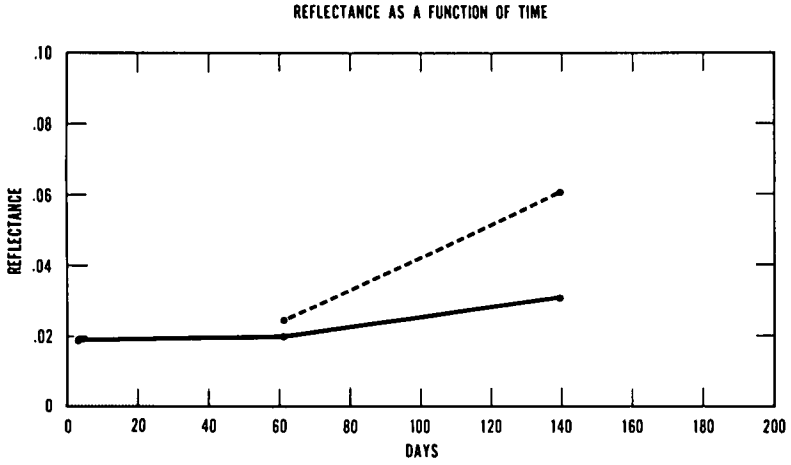
(82)

Code: 8099SE2
Type of Paint: Special dark scheme provided by SFBNSY Paint Lab
Type of Area: Horiz Aft
Date Painted: September 1968



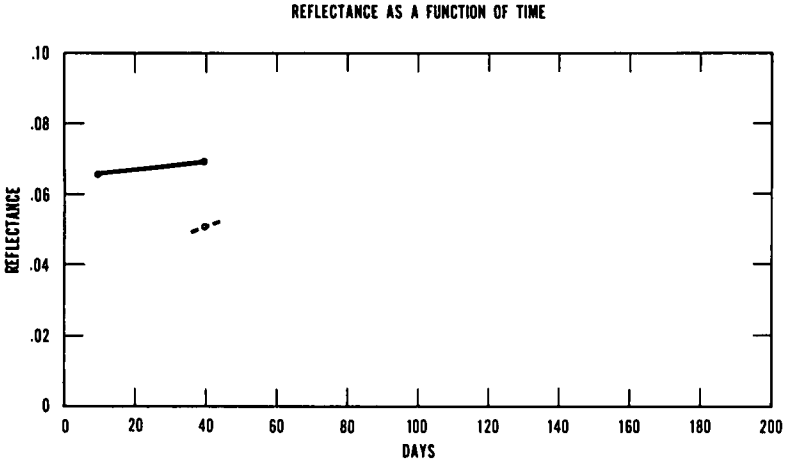
(83)

Code: 8099SE3
Type of Paint: Special dark scheme provided by SFBNSY Paint Lab
Type of Area: Vert Fwd
Date Painted: September 1968



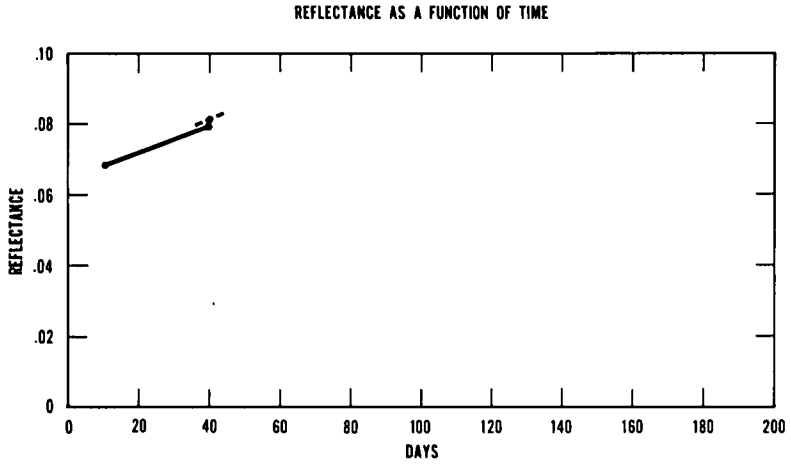
(84)

Code: 8099SE4
Type of Paint: Special dark scheme provided by SFBNSY Paint Lab
Type of Area: Vert Aft
Date Painted: September 1968



(85)

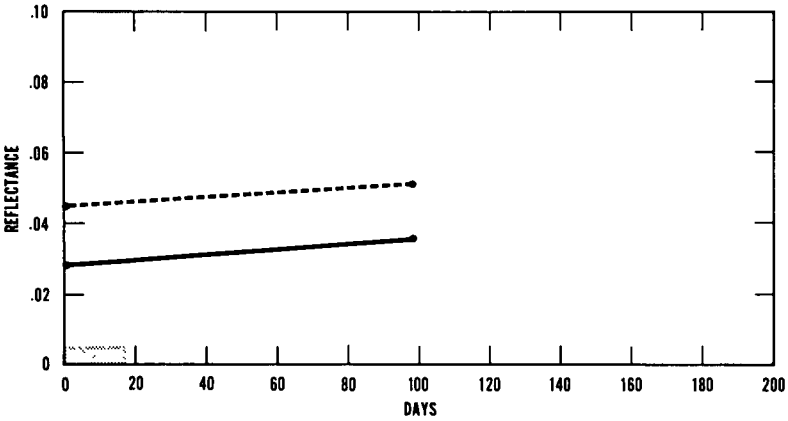
Code: 8119PO3
Type of Paint: Devran Epoxy
Type of Area: Vert Fwd
Date Painted: November 1968



(86)

Code: 8119PO4
Type of Paint: Devran Epoxy
Type of Area: Vert Aft
Date Painted: November 1968

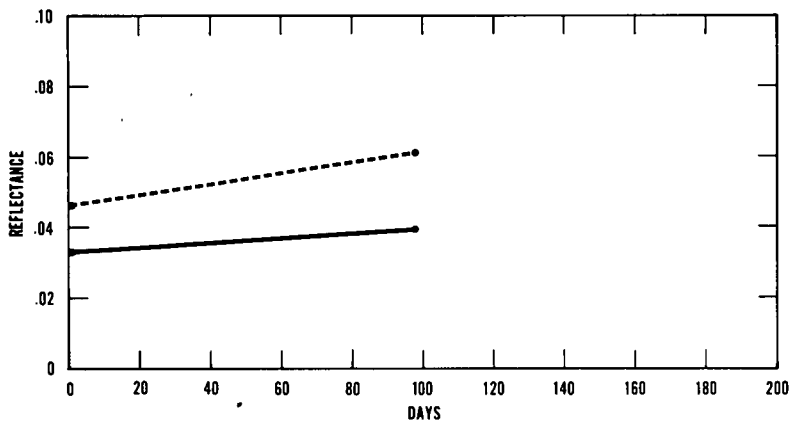
REFLECTANCE AS A FUNCTION OF TIME



(87)

Code: 8119PT1
Type of Paint: Brolite (Exp IB-32)
Type of Area: Horiz Fwd
Date Painted: November 1968
Paint Mfr – Brolite
Date Mfd – August 1968
Batch No. – 7263

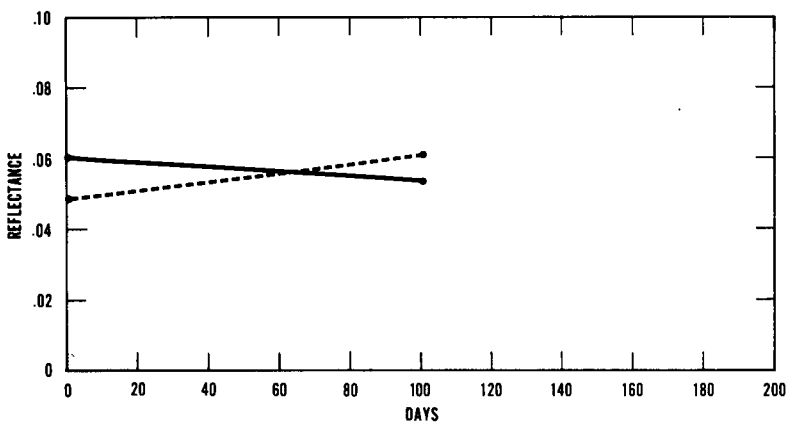
REFLECTANCE AS A FUNCTION OF TIME



(88)

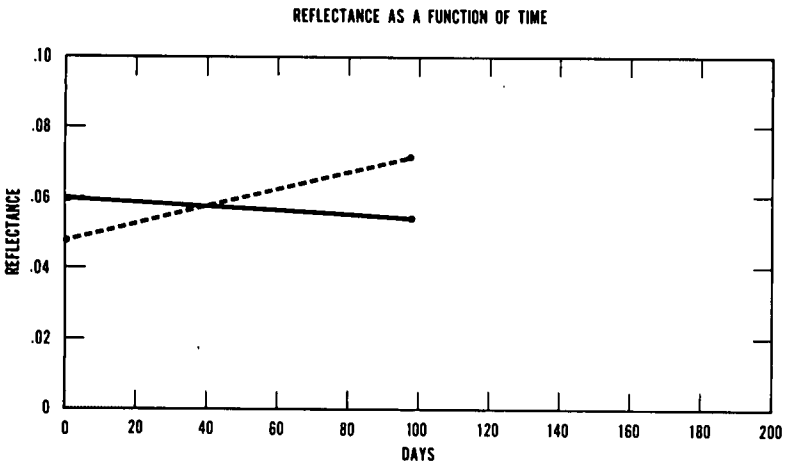
Code: 8119PT2
Type of Paint: Brolite (Exp IB-32)
Type of Area: Horiz Aft
Date Painted: November 1968
Paint Mfr – Brolite
Date Mfd – August 1968
Batch No. – 7263

REFLECTANCE AS A FUNCTION OF TIME



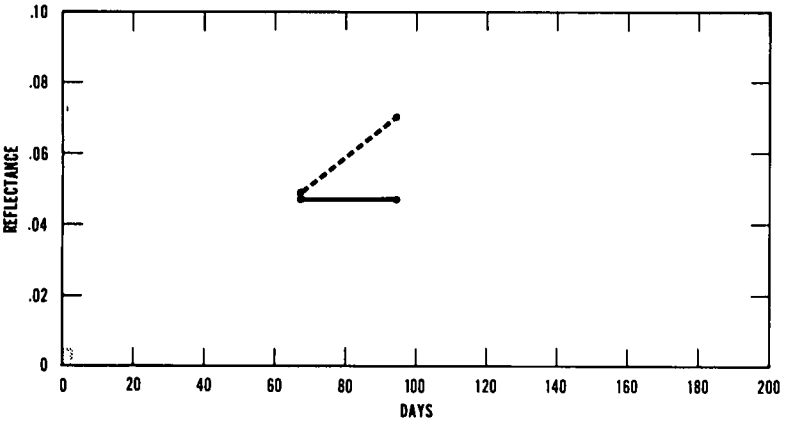
(89)

Code: 8119PT3
Type of Paint: Brolite (Exp IB-27, R_o 6.0)
Type of Area: Vert Fwd
Date Painted: November 1968
Paint Mfr – Brolite
Date Mfd – August 1968
Batch No. – 7264



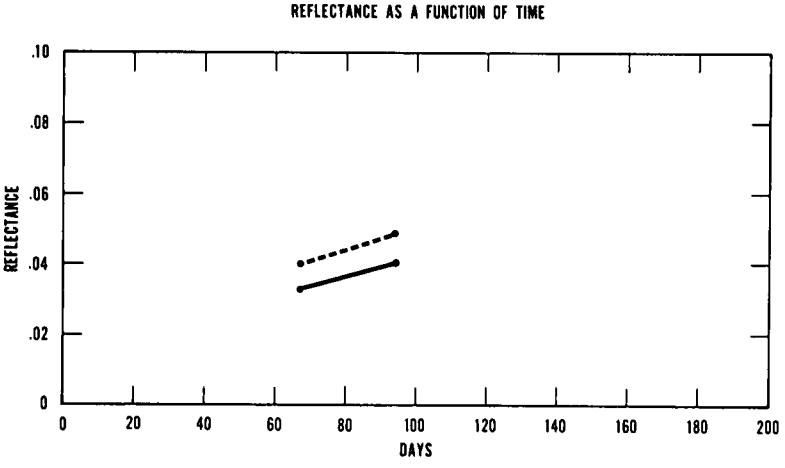
(90)

Code: 8119PT4
Type of Paint: Brolite (Exp IB-27, R_o 6.0)
Type of Area: Vert Aft
Date Painted: November 1968
Paint Mfr – Brolite
Date Mfd – August 1968
Batch No. – 7264



(91)

Code: 9069TI3
Type of Paint: Brolite (Exp IB-27)
Type of Area: Vert Fwd
Date Painted: June 1969



(92)

Code: 9069TI4
Type of Paint: Brolite (Exp IB-27)
Type of Area: Vert Aft
Date Painted: June 1969

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author)

Visibility Laboratory
University of California
San Diego, California, 92152

2a REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

2b GROUP

3 REPORT TITLE

The Permanence of Reflectance Properties of Submarine Concealment Paints

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

Technical Report August 1968 through January 1970

5 AUTHOR(S) (Last name, first name, initial)

Austin, Roswell W.

6 REPORT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
September 1972	64	1

8a CONTRACT OR GRANT NO	9a ORIGINATOR S REPORT NUMBER(S)
b N00024-68-C-1100	SIO 73-35
c	9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d	

10 AVAILABILITY/LIMITATION NOTICES

Distribution Limited to U. S. Government Agencies only; Test and Evaluation August 1968 - January 1970. Other requests for this document must be referred to Commander, Naval Ship Systems Command Department of the Navy, Washington, D. C. 20360

11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY
	U. S. Naval Ship Systems Command Department of the Navy Washington, D. C. 20360

13 ABSTRACT

A study of the reflectance properties of submarine concealment paints was undertaken by the Visibility Laboratory as part of its effort under Contract N00024-68-C-1100. The study extended over a period of 17 months from August 1968 to December 1969 during which reflectances of submarines from Submarine Flotilla One were repeatedly measured at intervals of approximately 1 month.

The results of the study showed that the vinyl alkyd paints 122-$R_0$1.8 and 122-$R_0$3.6 specified by the "Submarine Concealment Camouflage Manual"* provided coatings that were stable and generally acceptable from a concealment viewpoint, except for low initial values of submerged reflectance on the 122-$R_0$3.6 paints. Devran epoxy paints showed greater variations in reflectance with time. Furthermore, it was necessary to mix Devran 219-3 and 219-7 paints to obtain the required submerged reflectance for application to the vertical surfaces, and the resultant reflectances frequently missed the desired value. For these reasons plus their higher gloss, the epoxies are less desirable from a concealment viewpoint than the vinyl alkyds. However, other factors may outweigh these considerations.

It is recommended that, if such paints are to be used, they be procured from the manufacturer with the proper reflectance characteristics, i.e., gloss and submerged reflectance similar to that obtained with the vinyl alkyds. It is further recommended that a portable reflectometer be available at the squadron level to assist in maintaining the quality of submarine camouflage.

* NAVSHIPS 0919-002-7010, 1 March 1968.

DD FORM 1 JAN 64 1473

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE		ROLE	WT
Submarine concealment						
Camouflage paints						
Submarine paints						
Paint reflectance						
Reflectometer, portable						