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FINAL REPORT

PROJECT NO. 167-111

DEVELOPMENT OF AN EXTERIOR HOUSE
PAINT BASED ON PLIOLITE S-5

Prepared for the
CHEMICAL PRODUCTS DEVELOPMENT DIVISION
of the
GOODYEAR TIRE AND RUBBER COMPANY

By

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I. SUMMARY

An experimental investigation was made of the use of Pliolite S-5 as the primary vehicle-constituent in exterior house paints for application over wood. Evaluations were made by exterior 45°-south exposure of modified Pliolite-base paints applied over southern yellow pine. In the variations studied, the Pliolite S-5 vehicle was mixed with such modifying agents as Pliolite S-7, plasticizers and plasticizer blends, reactive and nonreactive pigments, antioxidants and antacids. Also studied were the effects of PVC variation on exposure endurance, the use of various modifying agents in clear Pliolite vehicles and the modification of Pliolite S-5 with maleic anhydride.

In general, the Pliolite paints exhibited good color retention and collected less dirt than the oil paint controls. They also exhibited good leveling characteristics but, because of the solvents involved, were troublesome from the standpoint of brush pull, particularly in applying a second coat. Also, undue sagging occurred with coating thicknesses greater than one mil. None of the experimental Pliolite systems evaluated approached the quality of a good oil paint. Failures generally were due to peeling and flaking, indicating a need for increased extensibility and better adhesion. The major portion of this investigation was aimed to improve these properties.

PVC has considerable effect upon Pliolite paint durability. For the formulation studied, best performance was obtained at approximately 30 per cent PVC with 40 per cent plasticizer in the nonvolatile vehicle.

Vehicles containing Santicizer B-16 (butyl phthalyl butyl glycolate) performed slightly better than those containing the other plasticizers which were investigated. Plasticizers generally tended to improve flaking but not enough to make Pliolite paint comparable to oil paints. ~~Most-improvement was obtained by using Pliolite S-7 as a nonvolatile plasticizer.~~

Of the pigmentations studied, basic carbonate white lead was slightly preferable to zinc oxide for increasing endurance when substituted on an equal basis; addition of 10 per cent water-ground mica was ineffectual.

Among the materials investigated as antioxidants and antacids, none effectively increased the exposure life of the Pliolite paint film; Wingstay S was observed to act as a grinding aid for the Pliolite vehicle.

The inclusion of a small amount of tung oil in the Pliolite vehicle contributed to better adhesion over the spring growth of the southern yellow pine but not over the summer growth. Consequently, its use did not improve the general performance of the paint.

A single attempt to increase the adhesion of Pliolite S-5 vehicle to wood by modifying the S-5 with maleic anhydride was unsuccessful because the modified resin jelled when it was pigmented. This approach, however, appears to have some merit and perhaps should be investigated further.

A general correlation between exposure performance of Pliolite paints in a weatherometer and exposure on a 45° outdoor fence could not be made. There is evidence of good correlation with regard to chalking only.

II. INTRODUCTION

The ready acceptance that Pliolite S-5 has achieved in the paint industry for applications as floor enamels, machinery enamels, cement and stucco paints, asphalt shingle paints, road marking paints, etc., provided an excellent incentive to further broaden the base of applications in the paint industry into the field of exterior house paints for application to wood. Research on this subject was initiated at the Georgia Tech Engineering Experiment Station by the Chemical Products Development Division of the Goodyear Tire and Rubber Company.

The original plan of investigation on this program was outlined in a letter of November 2, 1950, from Dr. Fred W. Cox to Mr. M. J. DeFrance of Goodyear. In a second letter, dated June 8, 1951, the program was modified, based on findings to that date. Subject to necessary restrictions in the scope of the work and to modifications necessitated by current findings, the experimental work as outlined in the TABLE OF CONTENTS of this report is in compliance with the submitted and approved plan of investigation.

The suggestions and guidance of Messrs. W. A. Abernethy and Joe O'Neil of Goodyear are gratefully acknowledged.

III. EXPERIMENTAL WORK

A. Preliminary Studies

1. Solvency

Measurement of the Kauri-Butanol values of the solvents that were considered for use in these studies was undertaken to insure that adequate solvency was maintained in all formulations. Determinations were made with Standardized Kauri-Butanol Solution obtained from American Gum Importers Laboratories, Inc.

	<u>Kauri-Butanol Values</u>
Benzene	123
Toluene	114
Xylene	103
Shell TS28R	74
Turpentine	71
Mineral Spirits	38

This information was used in the design of all solvent mixtures so that a minimum Kauri-Butanol value of 60 would be obtained.

2. Preparation of Pliolite Solutions

Solutions of Pliolite S-5 were prepared by milling the resin with solvent in a pebble mill, using only a few pebbles to assist in mixing. The maximum practical working concentration was found to be 50 per cent Pliolite S-5 in xylene. This solution had a viscosity of 25. Pliolite S-7-30, as received, had a viscosity of 24-25.

3. Film Properties

To evaluate film hardness of Pliolite materials compared to that of conventional oil paints and to obtain an indication of drying time and

solvent retention properties, a study of hardness as measured by the Sward Rocker was undertaken. Films of clear Pliolite S-5 and S-7 in several combinations were prepared. Two pigmented Pliolite paints designated N-491 (white enamel) and S-108-100 (cement and stucco) were also included. Finally, an oil paint, 1700 E (temporary housing specification), was used for comparison. Films of these materials were cast on clean plate glass with a Baker Film Applicator set at 5 mils. Wet-film thickness was checked with an Interchemical Gage. The hardness of the cast films was checked at 1, 4 and 7 days' drying in the laboratory. The clarity of the unpigmented films was also noted.

The results of the studies are shown in Table I below. The first five samples are the unpigmented Pliolite compositions prepared from xylene solutions of Pliolite S-5 and S-7 at 25 per cent solids. These were blended together to produce the series of compositions which are designated in the following table in terms of per cent Pliolite S-5 content.

TABLE I
FILM HARDNESS
(Measured by Sward Rocker)

Film Type	100% S-5	75% S-5	50% S-5	25% S-5	0% S-5	N-491	S-108-100	1700E
Wet-Film Thickness (mils)	3.1	3.0	3.1	2.8	3.4	3.4	4.0	3.0
Drying Time (days):								
1	32	30	26	24	18	10	10	0
4	32	26	22	22	18	12	12	2
7	30	24	24	22	16	26	18	2
Film Clarity	C*	SH**	SH	C	C	0***	0	0

* C - clear
 ** SH - slight haze
 *** 0 - opaque

Since dry-film thickness was not controlled, the results justify only qualitative evaluation. The following points are believed to be significant:

1. Pliolite compositions, even when modified and pigmented, dry much harder and more rapidly than an oil-paint composition as tested up to seven days drying in the laboratory.
2. Pliolite S-5, unmodified, produces a hard and comparatively brittle film, while Pliolite S-7 produces a pliable but tougher film. Blends of the two materials have intermediate hardness properties.
3. The slight haziness of blends of 50 per cent and 75 per cent Pliolite S-5 and S-7 indicates some incompatibility in this range.

B. Exposure Studies--Blends of S-5 and S-7

1. Plan of Investigation--Formulations

This work was initially planned to evaluate the effects of P.V.C. and of a vehicle variation in a series of 16 Pliolite paints. The formulations of these 16 paints, together with seven others added later, are shown in Table II, COMPOSITION AND PROPERTIES OF PLIOLITE FORMULATIONS, on page 6. The first 16 paints were formulated with TiO_2 --magnesium silicate pigmentation at 30, 40, 50 and 60 P.V.C. in vehicles composed solely of blends of Pliolite S-5 and S-7 solutions in combinations containing 15.8, 35, 70, and 100 per cent Pliolite S-7 in the nonvolatile vehicle. It was believed that from this series of paints optimum ranges of P.V.C. and Pliolite-blend ratios might be discovered.

Later, after conferring with Mr. Joe O'Neil of Goodyear, it was decided to include several additional formulations in this study. Numbers 17 and 18 are clear unpigmented Pliolite solutions which were proposed for use as sealers under both one and two coats of Pliolite and oil-base paints.

TABLE II
COMPOSITION AND PROPERTIES OF FLIOLITE FORMULATIONS

	Formulation Numbers																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Pigment (Total Weight Per Cent)	27.0	34.4	41.4	47.6	23.7	31.0	37.8	45.5	20.0	27.5	33.8	40.4	18.5	24.5	30.0	37.6	Clear	30.3					
Titanox A-MD	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	Solutions	38.4					
Magnesium Silicate	61.6	61.6	61.6	61.6	61.6	61.6	61.6	61.6	61.6	61.6	61.6	61.6	61.6	61.6	61.6	61.6			61.6				
Vehicle (Total Weight Per Cent)	73.0	65.6	58.6	52.4	76.3	69.0	62.2	54.5	80.0	72.5	66.2	59.6	81.5	75.5	70.0	62.4	100.0	100.0	69.7	100.0	100.0	100.0	100.0
Fliolite S-5, 50 Per Cent Xylene	47.4	43.2	38.8	33.3	30.8	28.9	25.8	23.6	11.5	11.1	10.0	8.9	—	—	—	—	25.0	—	12.7	50.0	37.5	12.5	—
Fliolite S-5-30	14.7	13.4	12.1	10.4	27.1	25.0	22.6	20.8	43.5	42.2	37.8	33.7	56.4	51.7	45.3	42.8	41.6	100.0	48.3	—	20.8	62.4	83.4
T3-28-R (Solvent)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	29.3	—	—	—	—
Xylene	9.5	13.4	18.1	23.3	7.9	11.5	12.5	17.2	6.4	9.7	13.0	17.4	2.9	2.5	12.0	17.0	33.4	—	—	50.0	41.7	25.1	16.6
Mineral Spirite	28.4	30.0	31.0	33.0	34.2	34.6	39.1	38.4	38.6	37.0	39.2	40.0	40.7	45.8	42.7	40.2	—	—	9.7	—	—	—	—
Per Cent S-7 in Nonvolatile Vehicle	15.8	15.8	15.8	15.8	35.0	35.0	35.0	35.0	70.0	70.0	70.0	70.0	100.0	100.0	100.0	100.0	50.0	100.0	70.0	—	25.0	75.0	100.0
P.V.C.	30.0	40.0	50.0	60.0	30.0	40.0	50.0	60.0	30.0	40.0	50.0	60.0	30.0	40.0	50.0	60.0	—	—	40.0	—	—	—	—
Pounds per Gallon	8.9	9.6	10.3	11.0	8.8	9.2	9.8	10.6	8.4	9.0	9.5	10.2	8.2	8.6	9.2	9.9	—	—	9.1	—	—	—	—
Consistency (K. U.)	88.0	87.0	88.0	85.0	89.0	88.0	80.0	81.0	85.0	89.0	85.0	88.0	86.0	86.0	84.0	88.0	—	—	89.0	—	—	—	—
Grind (W.S.S.)	3.0	2.5	2.5	2.5	3.0	3.5	3.5	2.5	3.0	2.5	3.0	2.0	2.5	3.0	2.5	2.0	—	—	3.0	—	—	—	—
Total Solids (Weight Per Cent)	47.4	53.1	53.6	59.3	44.8	48.2	51.4	55.5	36.8	43.2	49.4	52.2	31.8	36.9	41.2	46.4	—	—	44.2	—	—	—	—

Number 19 is a pigmented formulation in which the active solvent is Shell TS20R in place of xylene. It was thought that the slower evaporating aromatic solvent would retain solvency better during the drying period and thus produce a better film. Finally, Numbers 20, 21, 22 and 23 were included to complete the S-7- and S-5-blend ratios in clear solutions.

Oil-base paints were prepared as controls and for use in combined systems as primer or topcoat. The oil primer, P1, is a TT-P-25-type formulation while the oil topcoat, T1, is a TT-P-40, Type I, Class A formulation.

The plan for exposure evaluation of paint systems involved both weatherometer studies and exterior 45°-south exposures of identical systems. This procedure was designed to determine the utility of the weatherometer for accelerated testing of this type of paint system. The first 16 paints and Formulation No. 19 were studied both as a two-coat self-primed system and as a primer with an oil-base topcoat. The clear solutions were studied as primers in two types of three-coat systems, the first with two coats of Fliolite paint, and the second with two coats of oil-base paint. The results of weatherometer and exterior exposures were recorded and correlated.

2. Weatherometer Studies

a. Preparation of Panels. It was necessary to limit the size of weatherometer panels to the practical maximum of 3" x 9-1/2". The non-uniformity of southern yellow pine would be most objectionable for panels of this size; therefore, white pine panels were used for this work. All paint films were applied by brushing. The weight of paint applied to the panel was controlled carefully to obtain a quantity calculated to produce a dry-film thickness of 2 mils for each coat.

b. Paint Systems Exposed. It was further necessary to limit the number of panels exposed in the weatherometer to a total of 24 panels which occupied all the available space. The 24 paint systems exposed were carefully selected to provide the maximum of information from a restricted number of panels. This will explain the obvious omissions in the series of weatherometer exposures. The accelerated weathering machine used was the National X1A Weatherometer operating in accordance with A.S.T.M. Specification D822-46T. The painted panels were examined carefully before being placed in the weatherometer. After every 20 hours of weathering, the paints were examined summarily, and after each 100 hours the panels were removed from the machine and detailed evaluations were recorded. Table III shows the paint systems that were exposed and their initial appearance properties.

c. Discussion of Results. Attention is first directed to the Initial Appearance properties of the systems recorded in Table III. It will be noted that gloss decreases progressively with increasing P.V.C. and that none of the Pliolite paints are as glossy initially as the oil paint. Leveling was excellent for all the Pliolite paints but only fair for the oil paint. It was also noted that wet edge and brush pull were not entirely satisfactory in the case of the Pliolite paints. Brush pull on application of a second coat of Pliolite paint was a major difficulty. Attempts to paint over oil primers with Pliolite topcoats were abandoned because of the solubilizing effects of the solvents in the Pliolite paint on the dried oil-paint film, i.e., blisters were observed in the film within a few minutes after application of the Pliolite topcoat.

TABLE III
WEATHEROMETER SYSTEMS

System Number	Primer* Number	Second* Coat Number	Third* Coat Number	Initial Appearance	
				Gloss	Leveling
W1	2	2		Very slight	Excellent
W2	5	5		Slight	Excellent
W3	6	6		Very slight	Excellent
W4	7	7		Flat	Excellent
W5	8	8		Flat	Excellent
W6	9	9		Slight	Excellent
W7	10	10		Very slight	Excellent
W8	11	11		Flat	Excellent
W9	12	12		Flat	Excellent
W10	13	13		Slight	Excellent
W11	14	14		Very slight	Excellent
W12	15	15		Flat	Excellent
W13	16	16		Flat	Excellent
W14	17	10	10	Very slight	Excellent
W15	18	10	10	Very slight	Excellent
W16	17	10		Very slight	Excellent
W17	17	T1	T1	Moderate	Fair
W18	18	T1	T1	Moderate	Fair
W19	2	T1		Moderate	Fair
W20	5	T1		Moderate	Fair
W21	6	T1		Moderate	Fair
W22	7	T1		Moderate	Fair
W23	8	T1		Very slight	Fair
W24	P1	T1		Moderate	Fair

* All coats applied at approximately 2 mil dry film thickness.

While a complete record of the performance of each panel was maintained as the test progressed, the complete presentation of all of this data would be superfluous. It is sufficient to simply indicate the time when various failures begin to occur.

In general, for all-Fluolite systems:

Chalking began at about 100 hours, became heavy at 200 hours.

Cracking began at about 200 hours, became marked at 400 hours.

Checking occurred on 30 and 40 P.V.C. Fluolite formulations only, beginning at 100 hours and progressing up to 300 hours.

Peeling, when it occurred, began at 100 hours and progressed uniformly.

Color reached maximum depth at 100 hours, then improved as chalking progressed.

For oil-topcoated systems:

Chalking began at 300 hours, had progressed only slightly at 400 hours.

Cracking, where it occurred, progressed gradually from 100 to 400 hours.

Checking did not occur.

Peeling, when it occurred, began at 100 hours and progressed uniformly.

Color development was not appreciable.

To clarify the presentation of final results, Table IV, WEATHEROMETER SYSTEM TYPES, page 11, describes each system in terms of the main variables involved with the systems grouped in logical order. Figure 1, Final Weatherometer Exposure Results, page 12, is a graphical presentation of results

TABLE IV

WEATHEROMETER SYSTEM TYPES

System		Primer		Second Coat		Third Coat	System		Primer		Second Coat		Third Coat	
Number	% S-7	% PVC	% S-7	% PVC	Number		% S-7	% PVC	% S-7	% PVC	% S-7	% PVC	% S-7	% PVC
W-1	16	40	16	40	—	W-14	Clear Pliolite # 17	70	40	70	40	70	40	
W-2	35	30	35	30	—	W-15	Clear Pliolite # 18	70	40	70	40	70	40	
W-3	35	40	35	40	—	W-16	Clear Pliolite # 17	70	40	—	—	—	—	
W-4	35	50	35	50	—	W-17	Clear Pliolite # 17	Oil Base		Oil Base		Oil Base		
W-5	35	60	35	60	—	W-18	Clear Pliolite # 18	Oil Base		Oil Base		Oil Base		
W-6	70	30	70	30	—	W-19	16	40	Oil Base		—	—	—	
W-7	70	40	70	40	—	W-20	35	30	Oil Base		—	—	—	
W-8	70	50	70	50	—	W-21	35	40	Oil Base		—	—	—	
W-9	70	60	70	60	—	W-22	35	50	Oil Base		—	—	—	
W-10	100	30	100	30	—	W-23	35	60	Oil Base		—	—	—	
W-11	100	40	100	40	—	W-24	Oil Base		Oil Base		—	—	—	
W-12	100	50	100	50	—									
W-13	100	60	100	60	—									

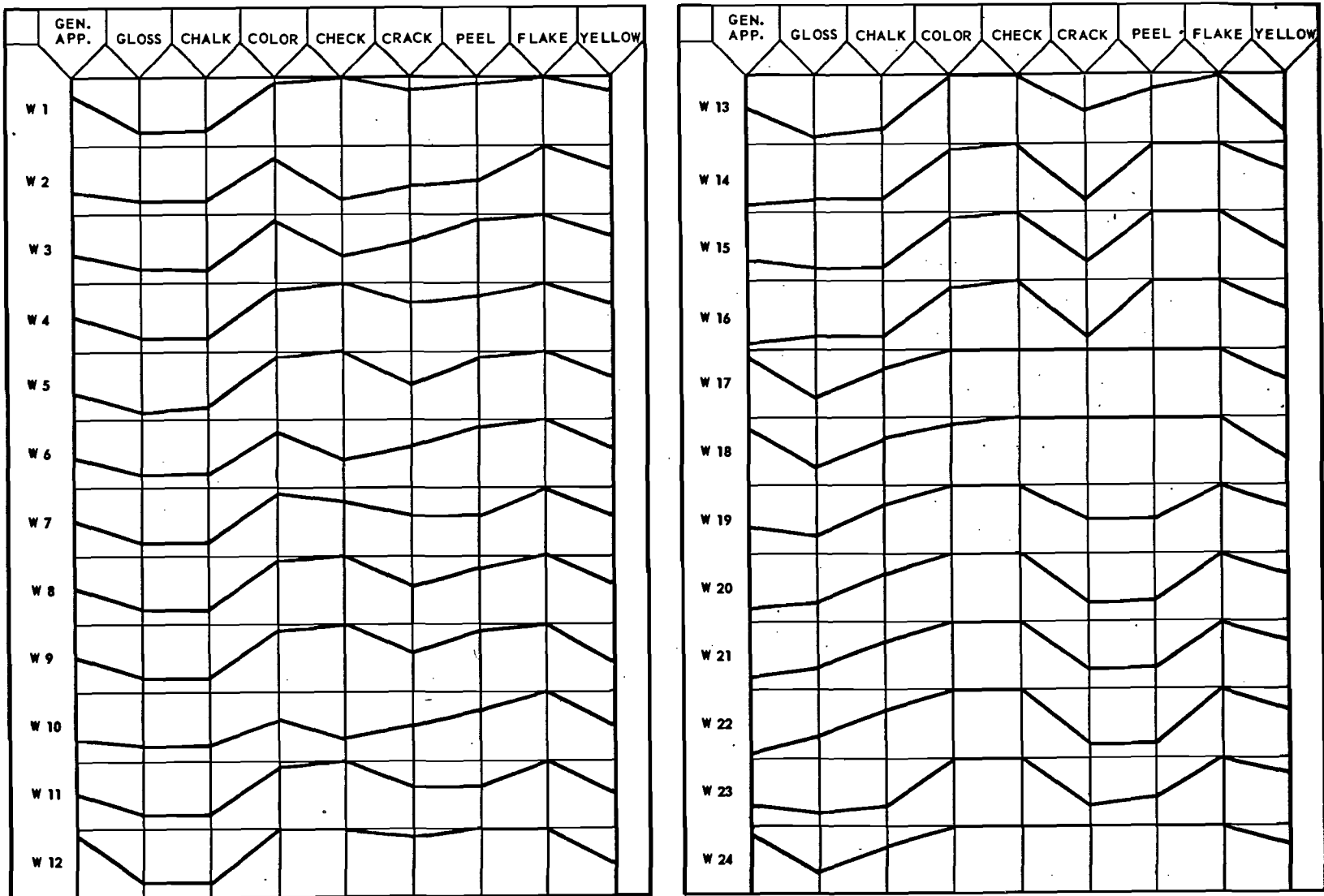


Figure 1. Final Weatherometer Exposure Results (402.1 Hours).

in the form of "profile" plots. When possible, these evaluations and all evaluations throughout this program were obtained using the Exposure Standards Manual of the Federation of Paint and Varnish Production Clubs with numerical units of 0-10 for ratings. These units comprise the ordinate for each system on the graph, while on the abscissa the types of film failures are indicated. A "profile" rather than a bar graph was used for simplicity. The comparative performance of the systems will be seen to stand out clearly in this presentation. Figure 2, Weatherometer Panels After 402.1 Hours' Exposure, page 14, is a photograph of the panels after completion of the tests.

d. Weatherometer Test Observations and Conclusions. As previously noted, because of space limitations, the series of Pliolite paints containing 16 per cent S-7 in the nonvolatile vehicle was exposed at 40 per cent P.V.C. only. Likewise, the primer-topcoat variations (W14 through W23) were condensed in scope. From examination of the results, however, it may be concluded that a more intensive investigation of the type of formulations here studied would not have been worthwhile. Significant observations are summarized as follows:

- (1) The oil-base control system (W24) was superior to all of the Pliolite systems studied.
- (2) A three-coat system (W17) involving a clear Pliolite primer followed by two coats of oil-base topcoat paint was almost equivalent in performance to the control system.
- (3) Among the all-Pliolite systems, W1 (16 per cent S-7, 84 per cent S-5, 40 per cent P.V.C.) and W12 (100 per cent S-7, 50 per cent P.V.C.) were outstanding in performance.

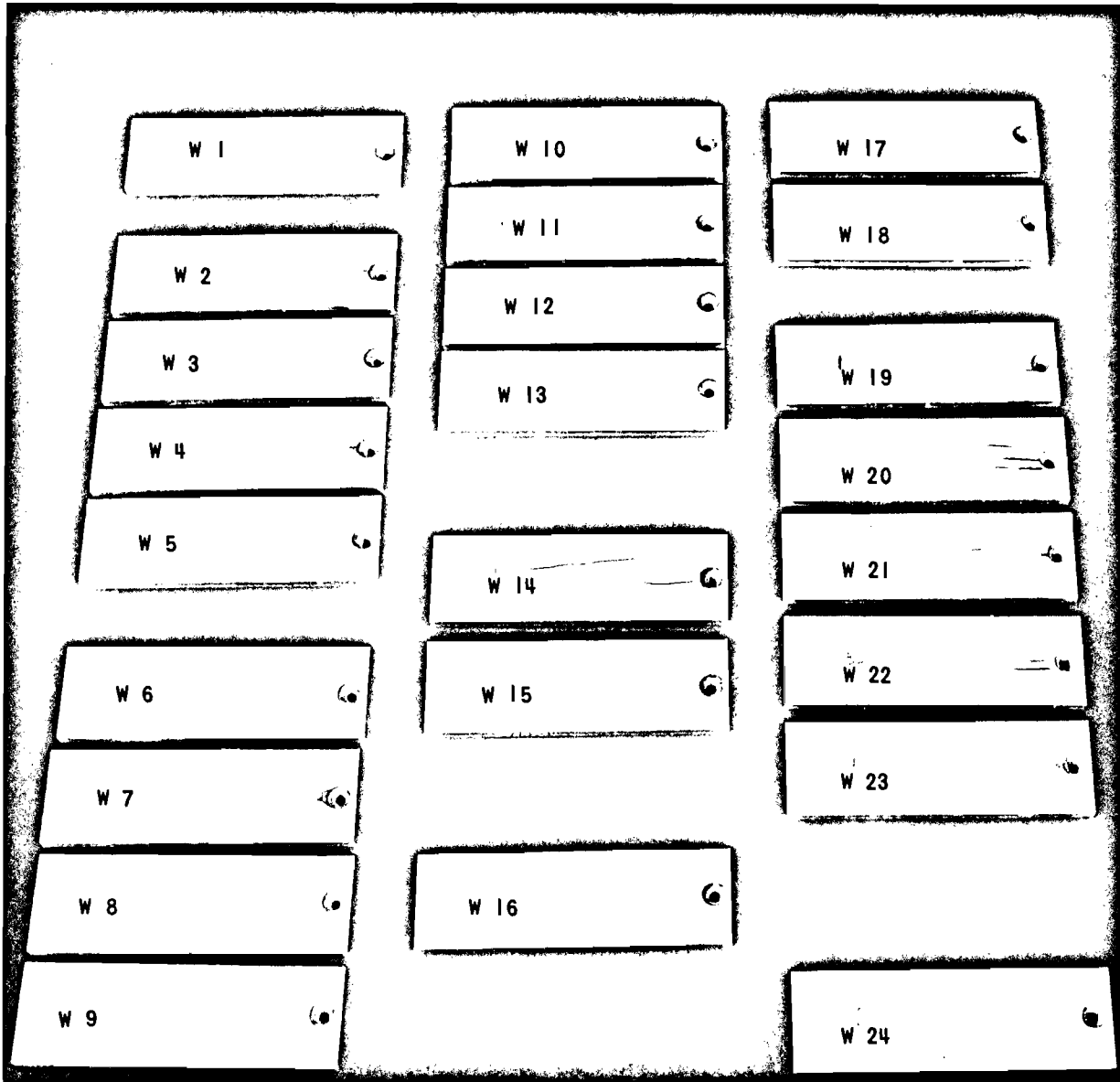


Figure 2. Weatherometer Panels After 402.1 Hours' Exposure.

- (4) A periodicity of film properties of all-Pliolite systems was observed for the three series of four systems each (W2 through W13). In general, 50 per cent P.V.C. compositions were superior for Pliolite paints, and 100 per cent S-7 vehicles were superior at all P.V.C.'s.
- (5) Pliolite paint failures were primarily checking and cracking; however, chalking was excessive in all cases.
- (6) All Pliolite paints retained satisfactory whiteness on irradiated areas but yellowed to various degrees on protected panel areas. This yellowness increased with increasing P.V.C. and Pliolite S-7 and was most pronounced at 100 per cent S-7, 60 per cent P.V.C.

While no attempt was made to evaluate adhesion quantitatively, some significant observations were made regarding this property. Adhesion of the all-Pliolite systems was considerably improved at low P.V.C.'s. Furthermore, adhesion of the systems involving a clear Pliolite primer with a pigmented Pliolite topcoat (W14, W15, W16) was excellent. The same excellent adhesion was obtained from clear Pliolite primers topcoated with oil paint. In contrast to this observation, the pigmented Pliolite primers topcoated with oil paint (W19 through W23) and the pigmented all-Pliolite systems, particularly those with high P.V.C.'s, were noticeably inferior in adhesion.

Based on these observations, the following general conclusions were drawn.

- (1) The failures of weatherometer-exposed systems by checking, cracking and peeling indicate that improved permanent distensibility

and adhesion is required to produce paints equivalent to good oil paints for application to exterior wood.

- (2) Adhesion of Pliolite paints to wood may be improved by using a clear Pliolite primer or possibly a very low-P.V.C. primer.
- (3) Excessive chalking characteristics were not shown to be related to P.V.C. or Pliolite type.

3. Exterior 45°-South Exposures

a. Preparation of Panels. Panels were assembled from three-foot lengths of No. 105 pattern southern yellow pine lumber, kiln dried. Three paint systems each one foot wide were applied to each board. On all boards, the leftmost system was the Pl-Tl oil-paint type, while the other two systems were experimental types. As in the case of the weatherometer panels, all paints were applied in weighed quantities calculated to produce a dry-film thickness of two mils. The assembly of the painted panels is shown in the photograph of Figure 3, Panels After One-Month 45°-South Exposure, on page 17.

b. Systems Exposed. Each of the sixteen pigmented Pliolite paints involving systematic variations were exposed both as a two-coat self-primed system and as a primer under the oil-base control topcoat 1700E (T1). Formulation No. 19 which involved the TS2ER solvent was exposed similarly. The remainder of the formulations, the unpigmented types, were studied as primers under one and two coats of Formulation No. 10 and of oil-topcoat T1. These systems were placed on 45°-exterior-south exposure on March 1, 1951.

c. Results. The working properties and initial appearance of these paints were discussed in connection with the weatherometer systems and need not be discussed here since the observations were identical.

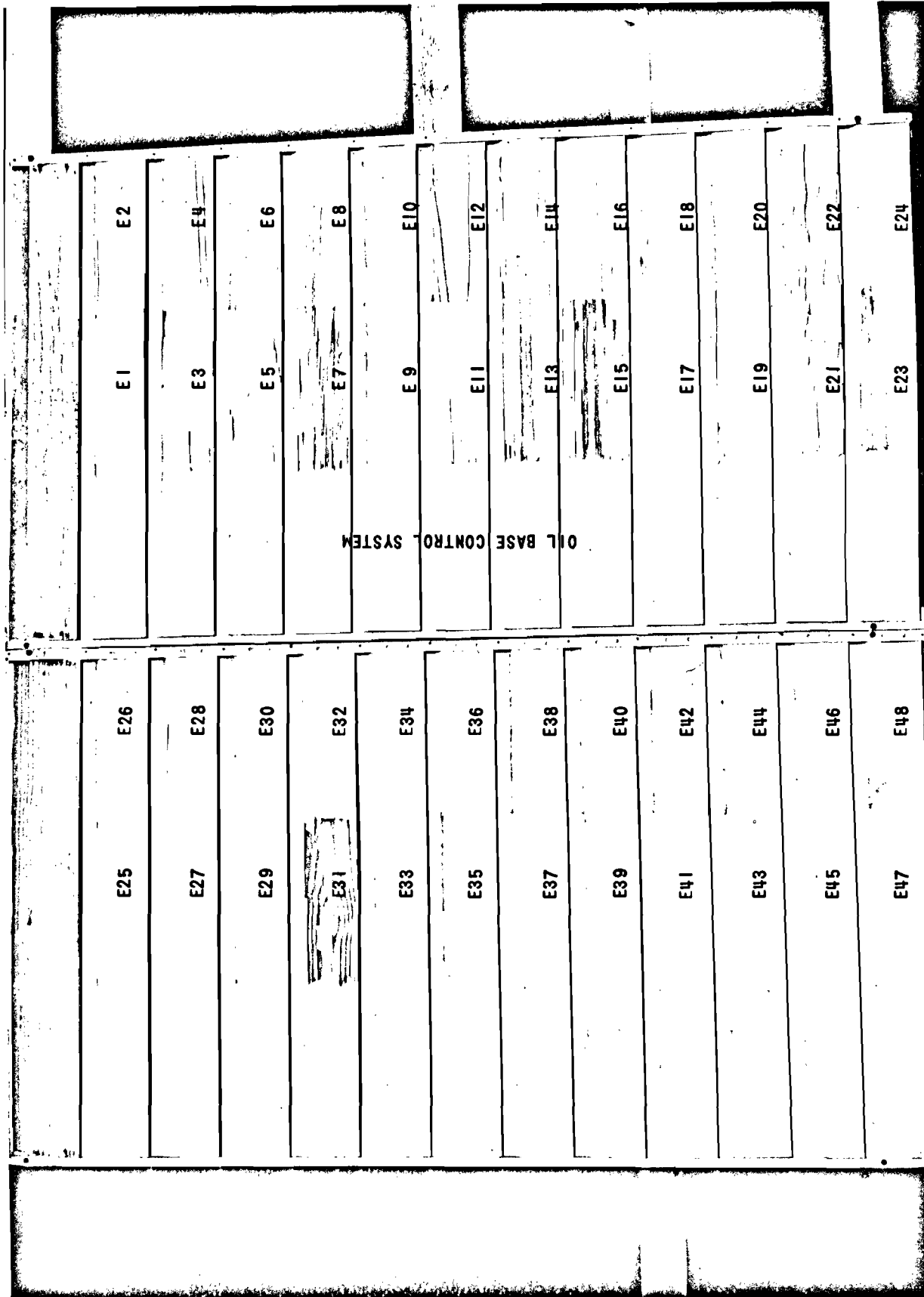


Figure 3. Panels after One-Month 45°-South Exposure.

The exposed panels were first examined for weathering effects at 11 days' exposure. Thereafter, examinations were made at intervals of one month up to a total period of eight months' exposure. Here again, a complete presentation of all data would be unnecessarily cumbersome. By far, the most significant type of film failure of the Pliolite paints was peeling which rapidly developed into a flaking failure. The progress of this condition is recorded in Table V, FLAKING FAILURES OF EXTERIOR SYSTEMS. This table also serves as a key to the paints applied, as identified by system numbers. The photograph previously referred to, Figure 3, Panels After One-Month 45°-South Exposure, further indicates the nature of the flaking failures.

FLAKING FAILURES OF EXTERIOR SYSTEMS

System Number*	Sequence**	Condition After Exposure***				System Number*	Sequence**	Condition After Exposure***			
		11 days	1 mo.	4 mos.	8 mos.			11 days	1 mo.	4 mos.	8 mos.
E-1	1-1	7	6	0	0	E-25	13-13	10	8	4	0
F-2	1-T1	9	6	0	0	E-26	13-T1	10	10	4	0
E-3	2-2	5	2	0	0	E-27	14-14	10	7	0	0
F-4	2-T1	8	2	0	0	E-28	14-T1	10	8	0	0
E-5	3-3	5	2	0	0	E-29	15-15	7	6	0	0
E-6	3-T1	8	2	0	0	E-30	15-T1	10	8	0	0
F-7	4-4	0	0	0	0	E-31	16-16	2	0	0	0
E-8	4-T1	4	1	0	0	E-32	16-T1	10	10	7	5
E-9	5-5	7	5	0	0	E-33	17-10	10	8	6	4
E-10	5-T1	9	6	0	0	E-34	17-10-10	10	10	7	4
F-11	6-6	7	4	0	0	E-35	17-T1-T1	10	10	10	6
E-12	6-T1	8	4	0	0	E-36	18-10	10	10	7	4
E-13	7-7	2	0	0	0	E-37	10-10-10	10	10	6	3
E-14	7-T1	5	1	0	0	E-38	18-T1-T1	10	10	9	6
E-15	8-8	0	0	0	0	E-39	19-19	10	7	2	0
F-16	8-T1	6	3	2	0	E-40	19-T1	10	10	0	0
E-17	9-9	10	10	2	0	E-41	20-10-10	10	10	5	4
F-18	9-T1	10	10	2	0	E-42	20-T1-T1	10	10	10	9
E-19	10-10	5	4	0	0	E-43	21-10-10	10	10	6	4
F-20	10-T1	10	4	0	0	E-44	21-T1-T1	10	10	10	8
E-21	11-11	0	0	0	0	E-45	22-10-10	10	10	8	6
F-22	11-T1	0	0	0	0	E-46	22-T1-T1	10	10	9	4
E-23	12-12	0	0	0	0	E-47	23-10-10	10	10	10	6
F-24	12-T1	10	10	3	0	E-48	23-T1-T1	10	10	10	8
						Oil Control		10	10	10	10

* These numbers refer to paint systems subjected to 45°-south exterior exposure.

** These numbers refer to the sequence in which various combinations were applied for each system.

*** These numbers denote degrees of cracking, flaking and/or peeling after certain periods of exposure.

The addition of information on dirt collection and chalking is adequate to characterize the performance of the films. These properties are very similar among all the Pliolite-topcoat systems and for all oil-base-topcoat systems. Results as averages are tabulated below.

TABLE VI

DIRT COLLECTION AND CHALKING OF EXTERIOR SYSTEMS

	<u>11 Days</u>	<u>1 Month</u>	<u>4 Months</u>	<u>8 Months</u>
Pliolite Systems				
Dirt Collection	8.0	7.5	9.0	7.5
Chalking	9.7	7.4	3.0	4.4
Oil-Base Systems				
Dirt Collection	5.8	4.3	3.4	6.0
Chalking	10.0	10.0	7.6	2.0

d. Exterior Exposure Observations and Conclusions. Based on the results for the first sixteen Pliolite paints applied as two-coat oil-primed systems, it appeared worthwhile to plot the performance of these systems in terms of Pliolite S-7 content and P.V.C. versus the degree of cracking, flaking, or peeling. The plots were taken from the data after eleven days' exposure since for these systems (odd numbers E1 through E11) the trends were well-developed at that time. From the plots shown in Figure 4, Effects of Pliolite S-7 Content, and Figure 5, Effects of Pigment Volume Concentration, the comparative performance of the sixteen compositions is well-illustrated. These plots indicate that 100 per cent S-7 vehicles with 30 per cent P.V.C.'s show superior performance among this series. It is further noted that paints formulated at 100 per cent S-7 vehicles were considered perfect at 30, 40, and 50 per cent P.V.C., while paints at 30 per cent

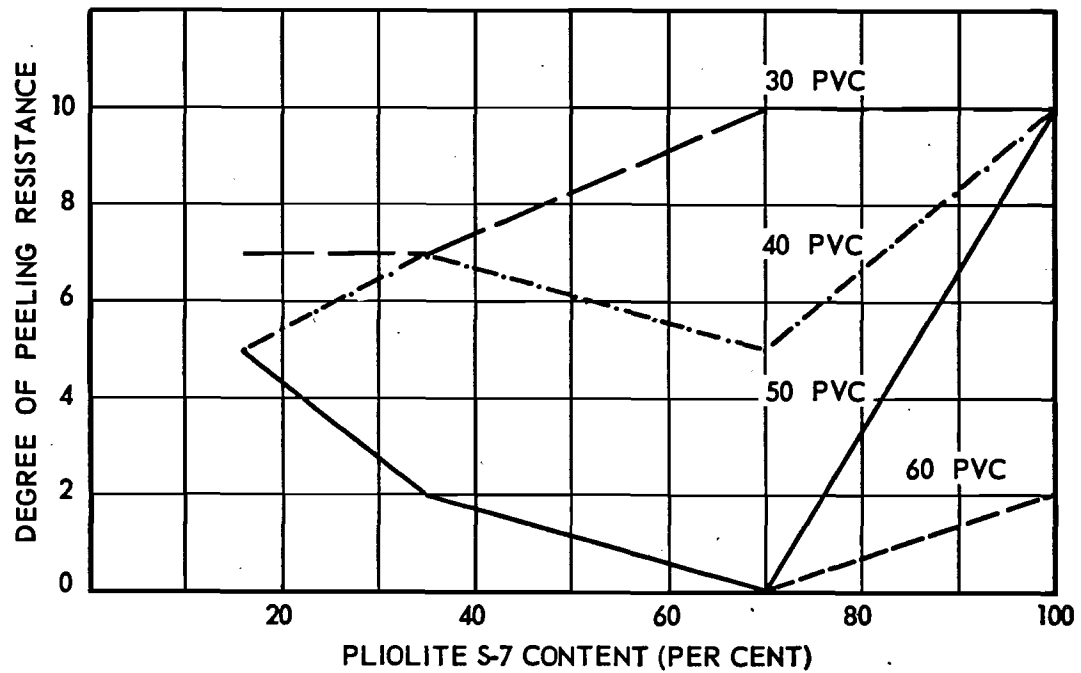


Figure 4. Effects of Pliolite S-7 Content.

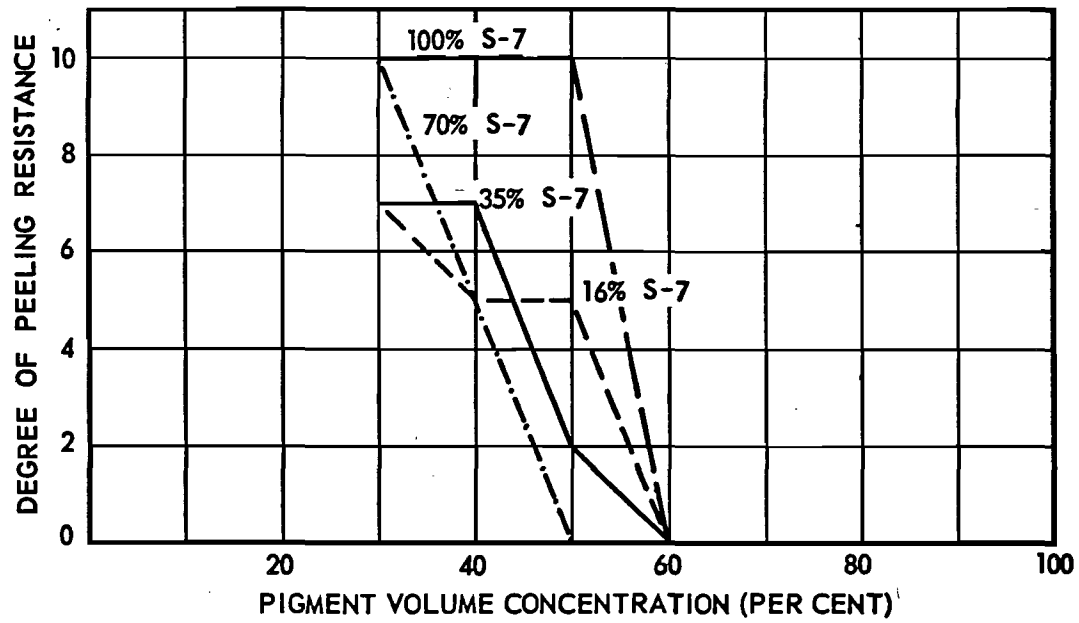


Figure 5. Effects of Pigment Volume Concentration.

P.V.C. were rated perfect at both 70 and 100 per cent Pliolite S-7 content. Weathering for a longer period of time clearly indicated that System No. E25, two coats of pigmented Pliolite at 100 per cent S-7 and 30 per cent P.V.C., was the best of this group and that System No. E17 at 70 per cent S-7 and 30 per cent P.V.C. was next in performance.

The study of a variation in solvent type (TETRA replacing xylene) is exemplified in System No. E39, two coats at 70 per cent S-7, 40 per cent P.V.C., which is analogous to System No. E19 in the series. The use of the slower-evaporating aromatic solvent definitely improved the performance of this paint.

Evaluation of oil topcoats over the pigmented Pliolite primers (even-numbered systems E2 through E32 plus E40) shows, in general, somewhat superior performance for these systems, compared to their all-Pliolite counterparts, with respect to flaking failure. Chalking properties of oil topcoats were also more satisfactory than Pliolite topcoats. A significant observation in favor of the Pliolite topcoats concerned dirt collection. The oil-base topcoats were much dirtier even at only eleven days exposure than were Pliolite topcoats. The greater film hardness of Pliolite paints was probably responsible for this condition since chalking had not yet occurred when distinct differences in dirt collection were first evident.

The performance of systems utilizing clear Pliolite sealers was somewhat more encouraging. These studies involved Systems Nos. E33 through E43, excluding E39 and E40. The selection of Formulation No. 10 as the Pliolite topcoat was unfortunate since it was not the best of the Pliolite paints. Most of the systems studied were three-coat types since a single topcoat over a clear sealer did not supply completely adequate hiding.

Nevertheless, Systems E33 and E36 which had only a single application of Pliolite topcoat compared favorably in performance to their counterparts E34 and E37 having two topcoats of Pliolite paint.

Relating the performance of the clear sealers to their composition, it will be seen that under Pliolite topcoats, Formulation Nos. 22 (75 per cent S-7) and 23 (100 per cent S-7) were superior. Under oil topcoats Formulation Nos. 20 (0 per cent S-7), 21 (25 per cent S-7), and 23 (100 per cent S-7) were best in performance. Presumably, Formulation No. 23 (100 per cent S-7) was the best all-around clear sealer of the group. Conversely, Formulation Nos. 17 (50 per cent S-7) and 18 (100 per cent S-7-30 unreduced) were comparatively poor in performance. It is of further interest to note that Formulation No. 22 performed better under the Pliolite topcoats than under oil topcoats. This was a reversal of the performance of the other sealers.

The lack of precision of evaluation and the limited data obtained do not permit an attempt to tentatively explain the observations made on the clear primer systems. A comparison of Formulation No. 18 (100 per cent S-7-30 unreduced) with Formulation No. 23 (100 per cent S-7 reduced with xylene) appears to indicate clearly that a reduction in concentration and viscosity of the Pliolite S-7 solution yields improved performance as a clear primer. It is possible that the generally poor performance of S-7 - S-5 blends, notably Formulation No. 17 (50 per cent S-7), is related to a slight incompatibility of blends observed and noted earlier in this report.

The most significant observations are summarized as follows:

1. The oil-base control system was generally superior to all the Pliolite systems studied.

2. System No. E42 (clear Pliolite S-5 primer with 2 coats of oil-base topcoat) was almost equivalent in performance to the control system.

3. Among the all-Pliolite two-coat systems, E25 (100 per cent S-7, 30 per cent P.V.C.) was outstanding.

4. The systematic series of all-Pliolite systems (odd-numbered E1 through E31) showed a periodicity of film properties. In all cases, performance improved as P.V.C. decreased and/or as Pliolite S-7 content increased.

5. Pliolite film failures were by cracking and flaking; chalking was excessive in all cases.

6. No serious color changes were observed.

7. Dirt collection was much greater on the oil-paint film than on Pliolite-paint films.

8. Improved performance of Pliolite paint was achieved by replacing xylene with a slower aromatic solvent.

As in the case of weatherometer exposures, it was observed that adhesion was improved when low-P.V.C. Pliolite primers were used. Adhesion was still better when clear Pliolite primers were used, even in a two-coat system (E33, E36).

General conclusions from these observations are as follows:

1. It is indicated that Pliolite binders require modification to improve distensibility and adhesion to wood if a satisfactory house paint is to be achieved.

2. Comparatively low P.V.C.'s are indicated for Pliolite paints for exterior wood application.

3. Excessive chalking is a problem that appears to be unrelated to P.V.C. or Pliolite type.

4. Solvent variations significantly affect film properties of Pliolite paints.

4. Correlation of Weatherometer--Exterior Studies.

a. Discussion. From an examination of the exposure data, it appeared evident that for chalking failures a fair degree of correlation might be obtainable between the weatherometer-exposed and the exterior-exposed identical systems. Conversely, it was apparent also that correlations for cracking, flaking, and peeling would be rather poor. To indicate the degree of correlation without undertaking lengthy mathematical operations, a series of plots was prepared to compare weatherometer-versus exterior-exposure results. These plots in Figure 6, Chalking Correlations, and Figure 7, Integrity Correlations, are shown on pages 27 and 28, respectively. Each dot on these scatter plots represents a paint system. A dot is located on the abscissa by the exterior performance, and on the ordinate by the weatherometer performance of the system represented. Perfect correlation would be obtained if all dots should fall on the diagonal straight line shown in each plot. Beneath each plot, the exposure period for the weatherometer and exterior systems under consideration are indicated.

At 100 hours versus 11 days, weatherometer chalking is seen to be more advanced than exterior chalking. At 100 hours versus 1 month, points are somewhat scattered, but correlation is fairly good. When 200 hours' versus 2 months' exposure is examined, characteristic trends are seen to have developed, and the weatherometer is found to be leading again in chalkiness. At 200 hours versus 4 months, good correlation occurs. Four hundred versus 4 months places the weatherometer slightly ahead again, and finally, 400 hours versus 6 months shows good correlation.

Integrity, as referred to in the charts on page 28, means the condition of the system with respect to cracking, flaking, or peeling--whichever

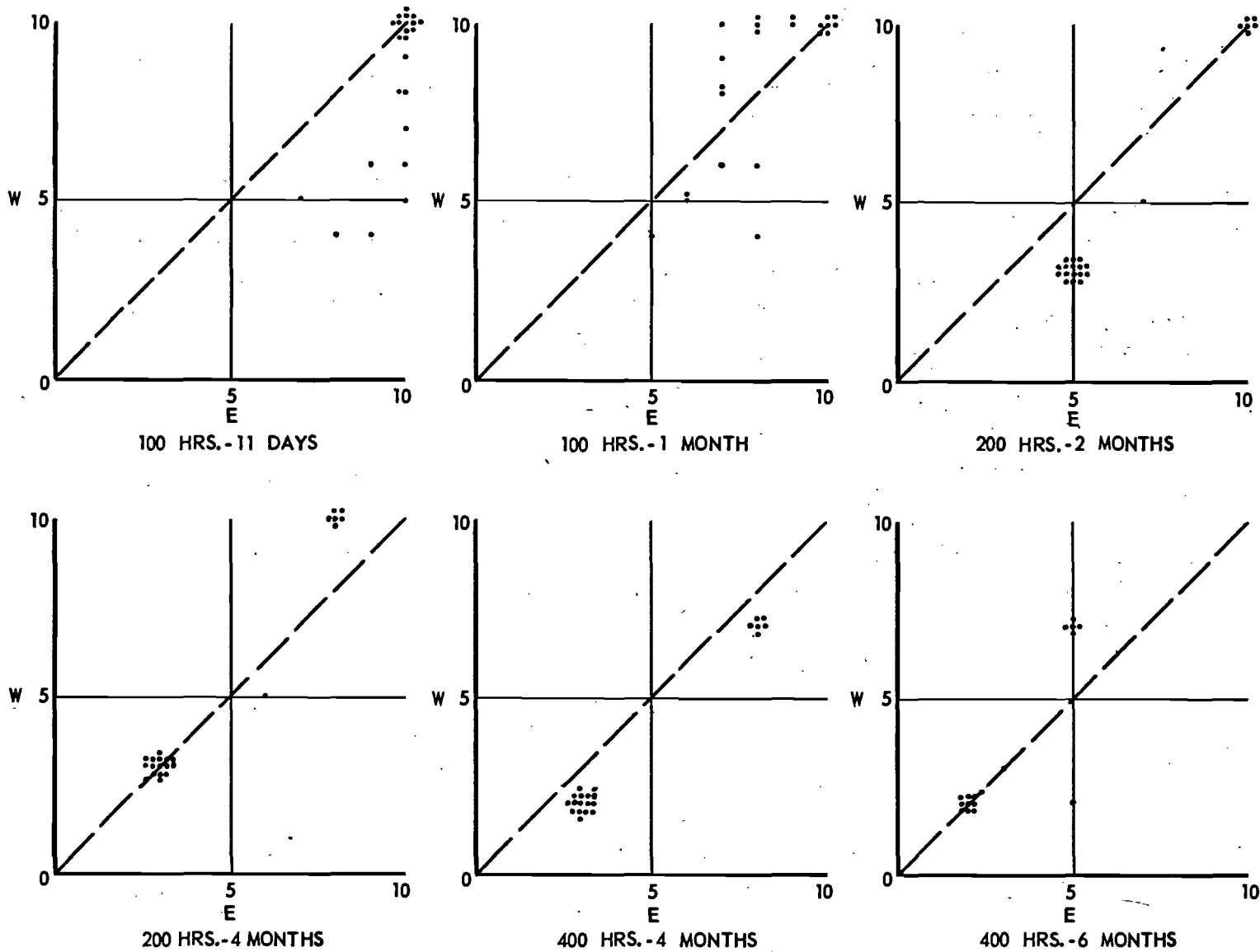


Figure 6. Chalking Correlations.

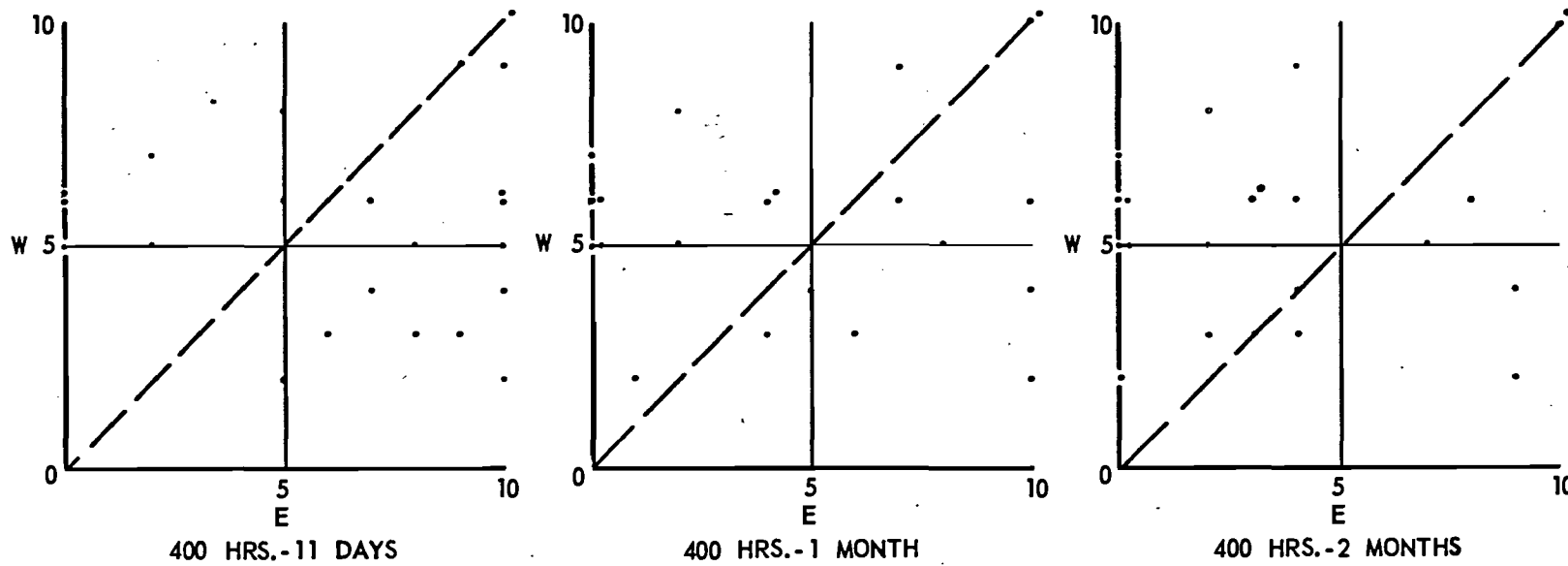


Figure 7. Integrity Correlations.

is the poorest. From an examination of the raw data, it appeared obvious that practically no correlation existed between weatherometer and exterior performance with respect to integrity failures. Nevertheless, three scatter plots were prepared to illustrate the degree of correlation. The first of these, 400 hours versus 11 days, shows wide dispersion but also indicates that weatherometer aging is more advanced than exterior aging. The second plot, 400 hours versus 1 month, also shows wide dispersion but does indicate that, in general, the degree of aging is about the same. The third plot, 400 hours versus 2 months, retains the wide dispersion and clearly shows greater aging for 2 months' exterior exposure than for 400 hours in the weatherometer.

b. Conclusions. For accelerated evaluation of the chalking tendencies of pigmented Pliolite and oil-based paints, the following approximate equivalence has been established.

<u>Weatherometer</u>	<u>Exterior 45°</u>
100 hours	1 month
200 hours	4 months
400 hours	6 months

For accelerated evaluation of integrity failures, no useful correlation of weatherometer versus exterior 45°-exposure performance was determined.

C. Plasticizers With Pliolite S-5 Paints

1. Plan of Investigation--Formulations

It was decided that formulation efforts should be concentrated on modifications of Pliolite S-5 since the work to this point had indicated that Pliolite S-7 does not provide sufficient permanent plasticity, even when used as the sole binder material. Furthermore, Pliolite S-7 was not

available in the more desirable form of a solid resin. Thus, all subsequent work was devoted to the study of compositions based on Pliolite S-5 as the primary vehicle constituent.

The previous work clearly showed the need for additional plasticization; however, the quantity and type of plasticizer required was, as yet, undetermined. The purpose of the study here described was to obtain this information. By a systematic study of plasticizer variations in a single Base Formulation, the approximate plasticizer requirements for Pliolite S-5 vehicles was determined.

The Base Formulation selected for this work was as follows:

BASE FORMULATION

	<u>Per Cent by Weight</u>
Rutile TiO ₂	12.1
Zinc Oxide	7.7
Magnesium Silicate	10.7
Pliolite S-5 + Plasticizer	20.3
Shell T328R	30.4
Mineral Spirits	<u>18.8</u>
	100.0

P.V.C. - 30 per cent

Solvent K-B - 60

Consistency = 85-90 K.U.

The percentages by weight as listed above were necessarily varied slightly depending upon the amounts and types of additives used, but the P.V.C., Solvent K-B, and consistency were held constant. It may be noted

that this formulation does not depart very much from the N-491 Gloss White Enamel tested on Project No. M-142. The Rutile TiO_2 was selected to supply the necessary hiding, and possibly to improve chalk resistance. Zinc Oxide provided ultraviolet opacity to inhibit degradation of the Pliolite binder. Magnesium Silicate served as an extender and possibly reinforced the film mechanically. Shell T328R provided the aromatic content for the solvent, and had a volatility approximately equivalent to the mineral spirits diluent.

The following plasticizers were selected for this study:

- (1) Chlorowax 40
- (2) Santicizer B-16 (butyl phthalyl butyl glycolate)
- (3) Tung Oil
- (4) Paraplex G-60 (polyester-type plasticizer)
- (5) Arcolor 1254

Each of these materials was used in the base formulation, replacing Pliolite S-5 at the rate of 5, 10, 20, 30, and 40 per cent of the total solids in the vehicle. The actual formulations used are shown in Table VII, PLASTICIZED PLIOLITE FORMULATIONS, on pages 32 and 33.

2. Test Procedure

All of the paints were prepared by pebble-milling the ingredients with a 30 per cent solution of Pliolite S-5 in the mixed T328R-mineral spirits solvent. Milling required about 15-20 hours. Consistency was adjusted by subsequent addition of mixed solvent as shown in the formulations. About one quart of each type of paint was prepared.

Test panels were constructed from three-foot lengths of No. 105 pattern southern yellow pine lumber, kiln dried. Two boards were used for

TABLE VII

PLASTICIZED PHTHALATE FORMULATIONS

	Formulation Numbers												
	100	101	102	103	104	105	106	107	108	109	110	111	112
Pigment (Total Weight Per Cent)	31.0	32.0	32.0	33.0	35.0	36.0	32.0	32.0	34.0	34.0	38.0	32.0	33.0
Titanox RA-NC	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6
ZrO	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Pig. Sil.	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4
Vehicle (Total Weight Per Cent)	69.0	68.0	68.0	67.0	65.0	64.0	68.0	68.0	66.0	64.0	62.0	68.0	67.0
Phtalite S-5 (30 Per Cent in Solvent)	96.9	94.3	90.7	86.0	82.8	76.8	93.6	90.8	88.6	84.0	80.5	93.6	91.7
Tung Oil	--	--	--	--	--	--	--	--	--	--	--	1.5	3.1
Chlorowax-40	--	1.5	3.0	6.4	15.6	15.4	--	--	--	--	--	--	--
Santicizer E-16	--	--	--	--	--	--	1.5	2.9	6.7	10.9	16.1	--	--
Paraplex C-60	--	--	--	--	--	--	--	--	--	--	--	--	--
Aroclor #1254	--	--	--	--	--	--	--	--	--	--	--	--	--
Added Solvent	3.1	4.2	6.3	7.6	6.6	7.8	4.9	6.3	4.7	5.1	3.4	4.9	5.2
Plasticizer Content of Nonvolatile Vehicle (%)	0	5.0	10.0	20.0	30.0	40.0	5.0	10.0	20.0	30.0	40.0	5.0	10.0
Pounds Per Gallon	9.6	9.7	9.8	9.9	10.2	10.4	9.7	9.8	10.0	10.2	10.4	9.6	9.7
Grind (N.S.S.)	4.5	4.5	3.5	4.5	4.0	4.0	4.0	5.0	4.5	4.5	4.0	4.0	5.0
Consistency (K.U.)	80.0	80.0	80.0	85.0	88.0	85.0	85.0	83.0	89.0	85.0	87.0	88.0	85.0

(Continued)

TABLE VII (Continued)

PLASTICIZED PLIOLITE FORMULATIONS

	Formulation Numbers												
	<u>113</u>	<u>114</u>	<u>115</u>	<u>116</u>	<u>117</u>	<u>118</u>	<u>119</u>	<u>120</u>	<u>121</u>	<u>122</u>	<u>123</u>	<u>124</u>	<u>125</u>
Pigment (Total Weight Per Cent)	35.0	37.0	40.0	32.0	33.0	34.0	37.0	38.0	32.0	32.0	--	34.0	35.0
Titanox RA-NC	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6
ZnO	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Mg.Sil.	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4
Vehicle (Total Weight Per Cent)	65.0	63.0	60.0	68.0	67.0	66.0	63.0	62.0	68.0	68.0	--	66.0	65.0
Pliolite S-5 (30 Per Cent in Solvent)	87.2	84.1	77.6	94.2	93.2	88.3	83.3	77.1	95.0	94.1	89.6	85.8	78.8
Tung Oil	6.8	10.7	15.6	--	--	--	--	--	--	--	--	--	--
Chlorowax-40	--	--	--	--	--	--	--	--	--	--	--	--	--
Santicizer E-16	--	--	--	--	--	--	--	--	--	--	--	--	--
Paraplex G-60	--	--	--	1.5	3.1	6.6	11.0	15.4	--	--	--	--	--
Aroclor #1254	--	--	--	--	--	--	--	--	1.6	3.0	6.7	11.0	16.0
Added Solvent	4.0	5.2	6.8	4.3	3.7	5.1	5.7	7.5	3.4	2.9	3.7	3.2	5.2
Plasticizer Content of Nonvolatile Vehicle (%)	20.0	30.0	40.0	5.0	10.0	20.0	30.0	40.0	5.0	10.0	20.0	30.0	40.0
Pounds Per Gallon	9.7	10.2	10.3	9.6	9.7	10.2	10.2	10.3	9.7	9.8	10.0	10.3	10.5
Grind (N.S.S.)	2.5	4.0	5.0	4.5	4.0	4.0	3.5	5.0	4.0	4.0	4.0	3.0	3.0
Consistency (K.U.)	83.0	88.0	80.0	84.0	84.0	88.0	89.0	83.0	84.0	88.0	86.0	89.0	89.0

each test system. All boards were back-primed with a heavy coat of aluminum paint. A one-foot length of each board was primed with an oil-base TT-P-25 formulation, while the remaining two feet were primed with the test paint. Then, after 24 hours' drying, the whole board was topcoated with the test paint. Paints were applied to the panels in weighed quantities calculated to produce a dry-film thickness of one mil for each coat. Several panels of a system of TT-P-25 - TT-P-40 oil-base paints at normal film thicknesses were also included in the study.

The test panels were mounted on frames which held six panels each. Altogether, five frames were used for this series of studies. These frames were mounted on a 45°-south test fence located on the roof of the Georgia Tech Research Building on January 14, 1952.

3. Test Results

a. Application Properties. It was necessary to apply Pliolite paints to the panels in quantities equivalent to only one mil dry-film thickness, since greater quantities of paint caused severe sagging of the wet film. Pliolite paints brushed satisfactorily as primers and as topcoats over the oil primer, but they were difficult to brush as self-primed topcoats. Brushing properties varied considerably, however, with the degree and type of modification of the Pliolite paints. Brush-drag in the application of Pliolite topcoats over Pliolite primers was undoubtedly due to a resolubility of the primer in the topcoat solvent. At the same time, it was encouraging to note that no "lifting" of oil-base primer was experienced upon application of this series of Pliolite paints as topcoats over the oil-base primer. All the Pliolite paints dried to

touch in a few hours' time, and the systems provided adequate hiding despite the low film thicknesses attained.

b. Exposure Observations. After ten days of 45°-south exposure, the panels were examined. All of the Fliolite paints applied over oil-based primer were unchanged, but, among the two-coat Fliolite applications, definite trends were already apparent. In all cases, performance improved directly with increasing plasticizer concentration. All formulations at 30 per cent and 40 per cent plasticizer concentrations were perfect, but the paints containing lower plasticizer concentrations were beginning to fail. The softer films of the 40 per cent plasticizer paints showed slightly greater dirt collection than paints with less plasticizer, but they were still no dirtier than a conventional oil-paint control system.

All of the observed film failures originated with cracking which rapidly developed into a flaking condition. Therefore, the progress of the weathering process can be adequately described in terms of flaking. The results of these observations over a six-month period are presented graphically in Figure 8, Flaking of Two-Coat Fliolite Systems, on page 36, and in Figure 9, Flaking of Oil-Primer, Fliolite-Topcoat Systems, on page 37. (Exposed systems are designated by the Formulation No. of the Fliolite paint used with the suffixes P or O to represent two coats of Fliolite paint or oil-primer Fliolite-topcoat systems, respectively.) Unfortunately, even the best of these experimental systems was inferior to the two-coat oil-base control system which was rated 9-flaking at the end of six months.

Positive accomplishments were not entirely lacking, however. The 40 per cent Santicizer B-16 modification was seen to be decidedly superior

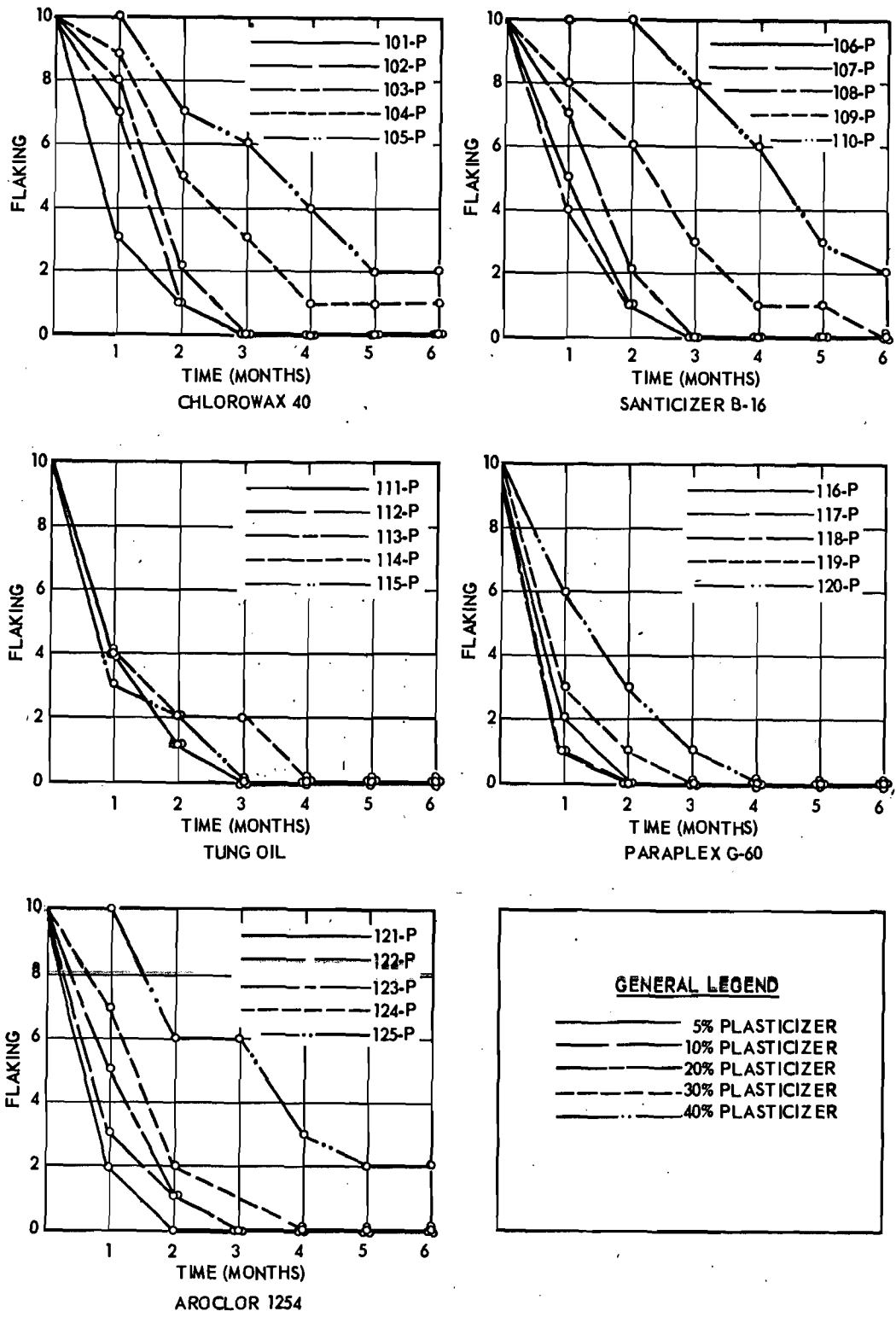


Figure 8. Flaking of Two-Coat Pliolite Systems.

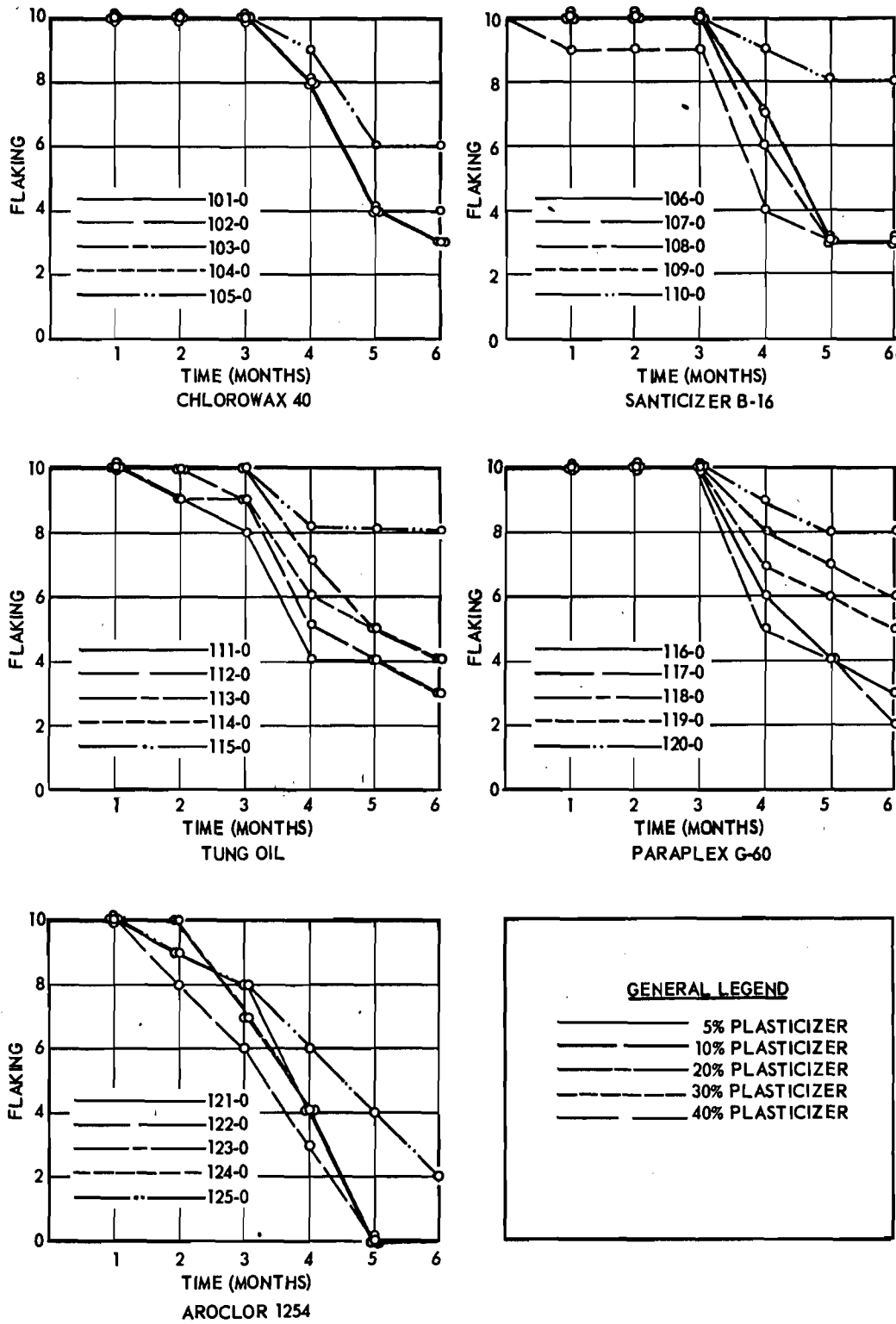


Figure 9. Flaking of Oil-Primer Pliolite-Topcoat Systems.

to any previous Pliolite formulation. Chalking was not objectionable in this series of formulations but actually followed very closely the chalking performance of the oil control. Finally, despite the slightly softened film produced by 40 per cent plasticizer modification, dirt collection of the Pliolite films was still slightly less than the oil-paint film.

4. Conclusions

The results of this study indicate that improvements in the film properties of Pliolite paints were accomplished in this work. Nevertheless, the flaking character of the film failures demonstrated again that more permanent film flexibility and adhesion must be achieved if the performance of oil-based paints is to be approached. Specific conclusions from this work are as follows:

a. Plasticizer concentrations of 40 per cent based on the nonvolatile vehicle are most effective in the paints studied.

b. Santicizer B-16 was definitely superior among the plasticizers tested. The order of performance was:

- (1) Santicizer B-16
- (2) Chlorowax 40
- (3) Aroclor 1254
- (4) Paraplex G-60
- (5) Tung Oil

c. Systems of Pliolite topcoats over oil primers were definitely superior to all-Pliolite systems with respect to weathering properties.

d. Excessive chalking was corrected in this work, but brushing properties and exterior weathering properties were not sufficiently improved to make these types of Pliolite paints worthy of consideration as exterior wood finishes.

D. Study of Plasticizer Blends

1. Introduction--Formulations

After preliminary observations on the results of the individual plasticizer studies, it was thought that certain blends of plasticizers in Pliolite paints might produce enhanced weathering performance. Accordingly, a series of exposure studies was devised to test this idea. The same Base Formulation as described in Section C was used in this work. Actual composition data for the blends are shown in Table VIII, PLASTICIZER BLEND FORMULATIONS, on page 40. The plasticizer concentration in all cases was 40 per cent of the nonvolatile vehicle. The plasticizers used were the same as in Section C, and they were blended in the following manner:

- a. Two-thirds Chlorowax 40 with one-third of each of the other plasticizers.
- b. Two-thirds Santicizer B-16 with one-third each of the other plasticizers.

2. Test Procedure

This series of paints was prepared by simply blending the paints prepared in the previous work, described in Section C, in accordance with the composition requirements for this study. Panel design and painting followed the same plan that was described for the individual plasticizer studies. The completed frames were mounted on a 45°-south test fence located on the roof of the Georgia Tech Research Building on April 1, 1952.

3. Test Results

a. Application Properties. As in the case of previous Pliolite paints, a dry-film thickness of only one mil per coat could be attained

TABLE VIII

PLASTICIZER BLEND FORMULATIONS

	Formulation Numbers							
	128	129	130	131	132	133	134	135
Pigment (Total Weight Per Cent)	37.0	36.0	37.0	36.0	37.0	38.0	37.0	37.0
Titanox RA-NC	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6
ZnO	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
MgCO ₃	—	—	—	—	—	—	—	—
Diphos	—	—	—	—	—	—	—	—
Hg.Sil.	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4
Vehicle (Total Weight Per Cent)	63.0	64.0	63.0	64.0	63.0	62.0	63.0	63.0
Fliolite S-5, 30 Per Cent Solution	78.1	77.0	77.0	77.6	79.3	79.5	79.3	80.0
Chlorowax 40	10.2	10.2	10.2	10.2	5.1	—	—	—
Santicizer B-16	5.4	—	—	—	10.7	10.7	10.7	10.7
Tung Oil	—	5.3	—	—	—	5.2	—	—
Paraplex C-60	—	—	5.1	—	—	—	5.2	—
Aroclor #1254	—	—	—	5.3	—	—	—	5.3
Solvent	6.3	7.5	7.7	6.9	4.9	4.6	4.8	4.0

-40-

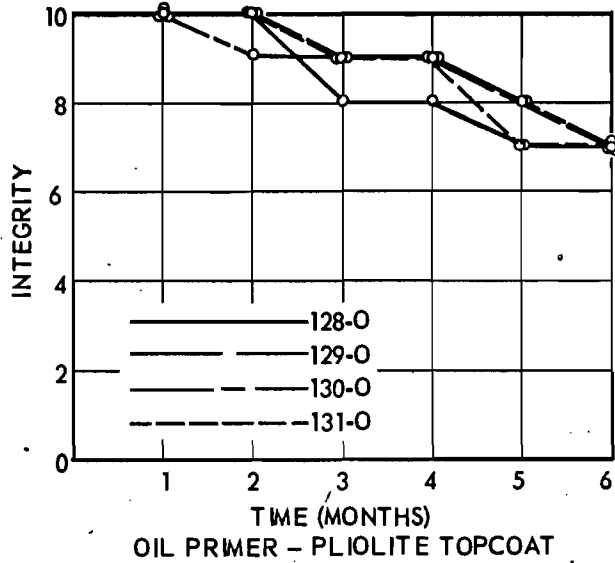
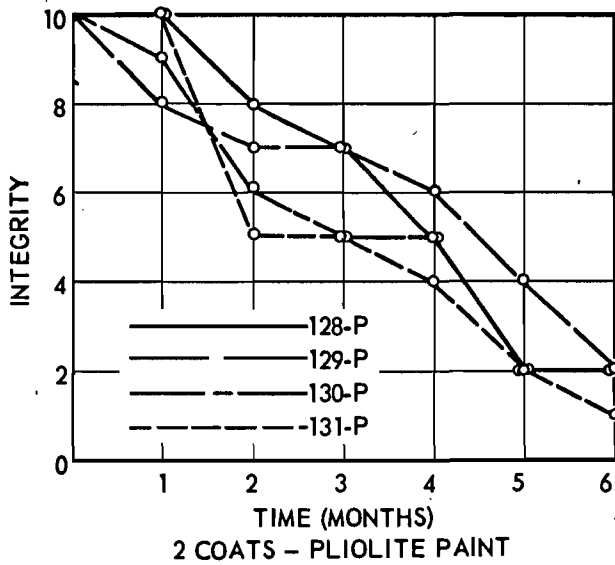
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without the occurrence of sagging. The problem of brush-drag over Pliolite primers also recurred. Application properties were substantially identical to the previous individual plasticizer studies.

b. Exposure Observations. As a group, this series of formulations demonstrated the improved durability that had previously been observed in compositions containing 40 per cent plasticizer. Dirt collection and chalking followed very closely the performance of the oil-base control system in all cases. Integrity failures began to appear after about two months' exposure. Actual performance data are shown in Figure 10, Integrity of Two Coats of Pliolite Paints Containing Plasticizer Blends, on page 42. The rating for integrity refers to the cracking or flaking failures, whichever is worse for any particular system at the time a reading is made. In general, failures began with cracking which rapidly developed into flaking. As in previous work, the best of the experimental systems was still inferior to oil-base systems, and Pliolite paints over oil primers were better than two-coat Pliolite systems. Distinctions in performance among the various plasticizer systems were not clearly drawn. Modifications of Chlorowax 40 and Santicizer B-16 with one-third tung oil appeared to produce a slight improvement, while similar modification with Aroclor 1254 may have been slightly inferior to the other systems. However, these observations cannot be regarded as conclusive, since differences in evaluations were very slight among this whole series of two-coat Pliolite systems.

Paint-film failures on southern yellow pine always begin over the summerwood portions of the panel. In the case of the Pliolite paints that have been studied, the film over the summerwood reaches an advanced stage of deterioration before the film over the springwood begins to fail. In other words, evaluations are largely based on the performance of the

SYSTEMS PLASTICIZED WITH TWO-THIRDS CHLOROWAX 40



SYSTEMS PLASTICIZED WITH TWO-THIRDS SANTICIZER B-16

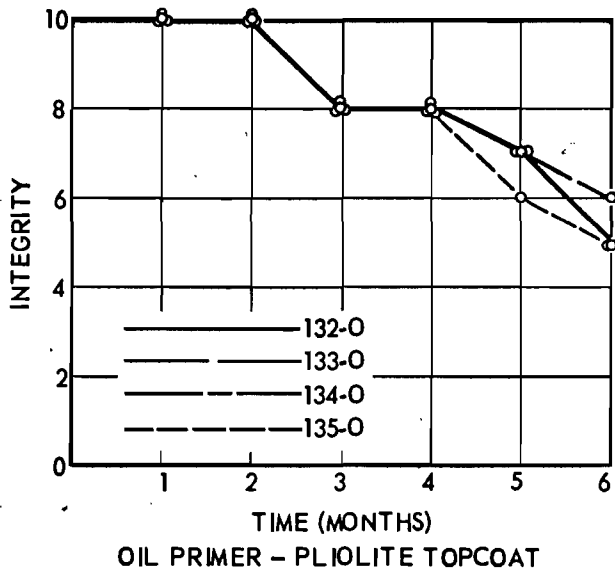
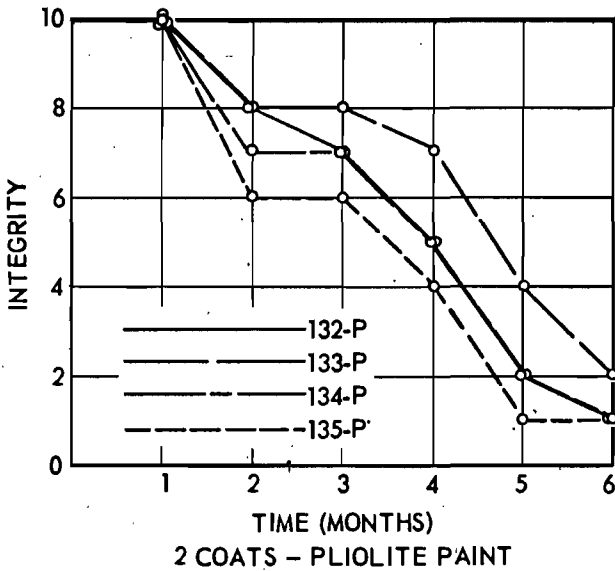


Figure 10. Integrity of Two Coats of Pliolite Containing Plasticizer Blends.

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paint over the harder summerwood. Thus, a paint may show gross failures over summerwood and be rated very low, yet its durability over springwood might be comparatively good. Now, while the performance of these paints specifically over the springwood was not numerically rated, it was observed that after ten months' exposure the two-coat Pliolite systems modified with tung oil (129-P and 133-P) were in much better condition over the springwood than the other systems studied. For the purposes of the present work, this observation is not highly significant, since adhesion over summerwood must be attained if a satisfactory paint for southern yellow pine is to be achieved. Nevertheless, this observation may be useful in formulation work aimed at the development of Pliolite paints for use over substrates other than southern yellow pine.

4. Conclusions

No significant improvement in the performance of plasticized Pliolite paints on southern yellow pine was achieved by using blends of plasticizers in these paints.

E. Reactive Pigments--Vehicle Acidity

1. Introduction--Formulations

The contributions of reactive pigments, notably basic carbonate white lead (BCWL) and zinc oxide (ZnO), to the durability of exterior oil-based house paints has long been recognized. It is known that these basic pigments form soaps with the fatty acids in the vehicle, and these soaps are believed to be largely responsible for the improved properties that are developed. Since Pliolite vehicles contain no fatty acids, there is no opportunity for formation of reinforcing metallic soaps with basic pigments in such paints. Therefore, reactive pigments

should be expected to display no particular merits in Pliolite paints except insofar as their physical properties are helpful. On the other hand, if fatty acids were introduced into the Pliolite vehicle as an additive, the desirable soaps would be formed in the Pliolite paints containing reactive pigments, and the properties of these paints might be improved.

Preliminary work with clear films indicated that small quantities of linseed fatty acids could be added to Pliolite vehicles without producing incompatibility. Accordingly, it was decided to test the theory. Six formulations were prepared for this work. They were designed around the Base Formulation described in Section C. In all cases, the vehicle contained 40 per cent of Santicizer B-16. The composition of these paints is detailed in Table IX, REACTIVE FORMULATIONS, on page 45. In the first four of these formulations, BCWL was substituted for ZnO on an equal volume basis, and vehicle acidity was adjusted to acid numbers of 0, 5, 10, and 15 with linseed fatty acids. The last two formulations were returned to the original pigmentation with ZnO, and vehicle acidities of 0 and 10 acid numbers were used.

2. Test Procedure

The preparation of paints, panel design, and paint application was done exactly in accordance with the procedure described in Section C. The panels were placed on 45°-south vertical exposure on April 1, 1952.

3. Test Results

a. Application Properties. At the time of application of the paints containing linseed fatty acids, a "streaking" was noted along the inside walls of the paint cans above the liquid level of the paint. This

TABLE IX
REACTIVE FORMULATIONS

	Formulation Numbers					
	<u>138</u>	<u>139</u>	<u>140</u>	<u>141</u>	<u>142</u>	<u>143</u>
Pigment (Total Weight Per Cent)	41.0	42.0	45.0	43.0	38.0	38.0
Basic Lead Carbonate	50.0	50.0	50.0	50.0	--	--
Titanox RA-80	20.6	20.0	20.0	20.0	39.6	39.6
ZnO	--	--	--	--	25.0	25.0
Hg.Sil.	30.0	30.0	30.0	30.0	35.4	35.4
Vehicle (Total Weight Per Cent)	59.0	58.0	55.0	57.0	62.0	62.0
Phiolite S-5 (30 Per Cent In Solvent)	79.9	78.4	77.5	76.6	80.5	79.1
Santicizer B-16	15.4	15.7	15.5	15.2	16.1	15.9
Linseed Fatty Acid	--	1.0	2.1	3.2	--	2.2
Solvent	4.7	4.9	4.9	5.0	3.4	2.8
Acid Number	--	5.0	10.0	15.0	--	10.0
Pounds Per Gallon	11.4	11.3	11.3	11.4	10.4	--
Grind (M.S.S.)	3.0	3.5	3.0	3.0	4.0	--
Consistency (K.U.)	86.0	86.0	86.0	86.0	87.0	--

effect suggested that pigment agglomeration may have occurred. To check this, the grind was measured and it was found to be 1 or less in each case, although a minimum value of 3 had been obtained at the time of manufacture. Despite this agglomeration, the application properties of these paints did not appear to be affected by this phenomenon.

The use of BCWL in the pigmentation was observed to produce a difference in application properties. Lead appeared to impart a "stringiness" and somewhat poorer brushing properties to the product.

b. Exposure Observations. The effects of reactive pigment and acid number variations at six months' exposure are shown in Table X below.

TABLE X

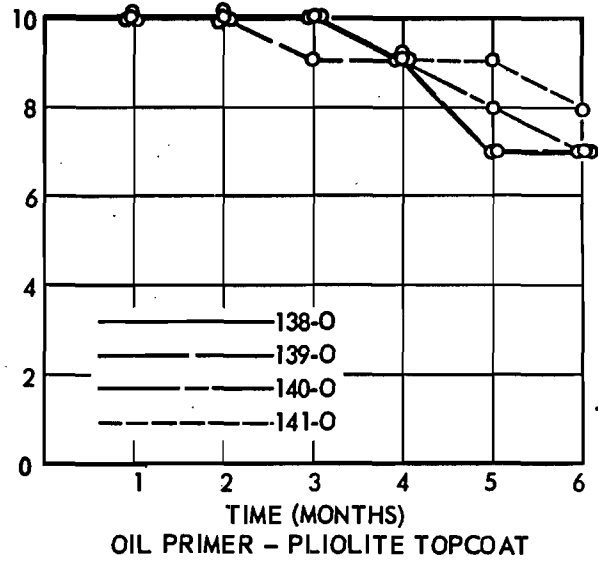
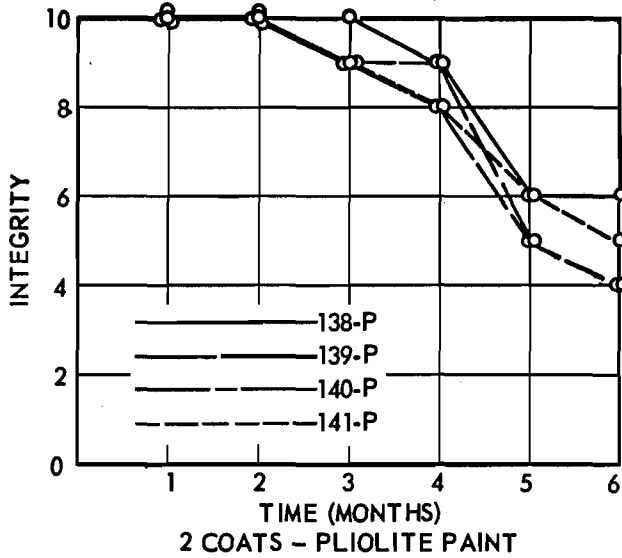
DIRT COLLECTION AND CHALKING OF REACTIVE SYSTEMS AT SIX MONTHS' EXPOSURE

	Lead Systems				Zinc Systems	
	0	5	10	15	0	10
System Number	138	139	140	141	142	143
Dirt Collection						
2 Coats Pliolite	4	4	4	4	6	6
Oil Primer--Pl. T.C.	6	6	6	6	8	8
Chalking						
2 Coats Pliolite	9	9	9	8	7	7
Oil Primer--Pl. T.C.	8	8	8	8	7	7

The lead systems show slightly greater dirt collection and less chalking than the zinc systems. No significant relation between vehicle acidity and dirt collection or chalking tendencies is shown.

Paint-film-integrity effects are plotted for these systems in Figure 11, Integrity of Reactive Systems from Zero to Six Months, on page 47. For two-coat paints the integrity of lead-containing systems was definitely

LEAD SYSTEMS



ZINC SYSTEMS

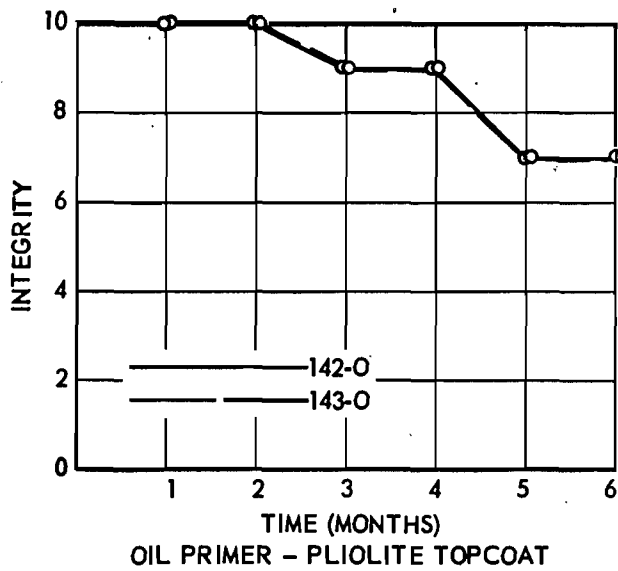
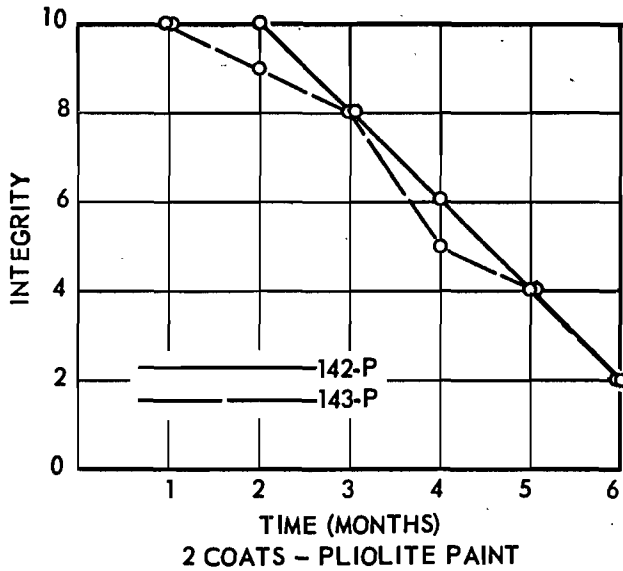


Figure 11. Integrity of Reactive Systems from Zero to Six Months.

better than zinc-containing systems. Acidity in the vehicle was not helpful and actually appeared to be detrimental in the lead systems.

4. Conclusions

For the systems studied, paints based on basic carbonate white lead were superior in weathering performance to paints based on zinc oxide.

Additions of linseed fatty acids to these systems did not improve performance.

F. Antioxidants and Antacids

1. Introduction--Formulations

In order to retard any possible oxidative deterioration in Pliolite paints, antioxidants and antacids were studied as additives in the system. As in previous studies, the Base Formulation plasticized with 40 per cent Santicizer B-16 was used as the basis for this work. The antioxidants studied were Wingstay S (Goodyear) and Santivar A (Monsanto). Diphos (National Lead) was investigated as an antacid. Formulation details are shown in Table XI, PLIOLITE PAINTS WITH ANTIOXIDANTS AND ANTACIDS, on page 49.

2. Test Procedure

The preparation of paints, panel design, and paint application was done exactly in accordance with the procedure described in Section C. Systems E154 and E155 were prepared by blending from the other formulations. The panels were placed on 45°-south vertical exposure on April 25, 1952.

3. Test Results

a. Dispersion Properties. It was noted that the formulations prepared with Wingstay S (E144-146) had a much shorter grinding time than

TABLE XI

PLIOLITE PAINTS WITH ANTIOXIDANTS AND ANTACIDS

	Formulation Numbers											
	<u>144</u>	<u>145</u>	<u>146</u>	<u>147</u>	<u>148</u>	<u>149</u>	<u>150</u>	<u>151</u>	<u>152</u>	<u>153</u>	<u>154</u>	<u>155</u>
Pigment (Total Weight Per Cent)	38.0	38.0	38.0	—	38.0	38.0	38.0	38.0	39.0	39.0	39.0	39.0
Basic Lead Carbonate	—	—	—	—	—	—	—	—	—	—	—	—
Titanox RA-NC	39.6	39.6	39.6	39.6	39.6	39.6	39.6	37.9	36.7	34.8	37.2	37.2
ZnO	25.0	25.0	25.0	25.0	25.0	25.0	25.0	24.5	23.9	22.6	23.8	23.8
Diphos	—	—	—	—	—	—	—	2.6	5.1	9.9	5.0	5.0
Mica	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.0	34.3	32.7	34.0	34.0
Vehicle (Total Weight Per Cent)	62.0	62.0	62.0	—	62.0	62.0	62.0	62.0	61.0	61.0	61.0	61.0
Pliolite S-5	80.9	80.9	80.9	80.7	80.6	80.6	80.3	80.9	81.0	81.0	81.0	81.0
Santicizer B-16	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.2	16.2	16.2	16.2	16.2
Wingstay S	0.2	0.4	0.8	—	—	—	—	—	—	—	0.4	—
Santovar "A"	—	—	—	0.2	0.4	0.8	—	—	—	—	—	0.4
Solvent	2.8	2.6	2.2	3.0	2.9	2.8	3.0	2.6	2.8	2.8	2.4	2.4

all other paints studied. Furthermore, somewhat less solvent was required to obtain proper viscosity in this system.

b. Application Properties. These formulations were substantially identical in properties to the same formulation without the additives, e. g., E142.

c. Exposure Observations. Dirt collection and chalking properties were unchanged by the addition of antioxidants and the antacid. Integrity, as a function of exposure time, is plotted in Figure 12, Antioxidants in Pliolite Paints, on page 51, and in Figure 13, Diphos in Pliolite Paints, on page 52.

4. Conclusions

It was indicated that Wingstay S acts as a grinding aid in Pliolite paints. Otherwise, no modifying effects were observed to occur by inclusion of these additives.

G. P.V.C. and Pigment Variations

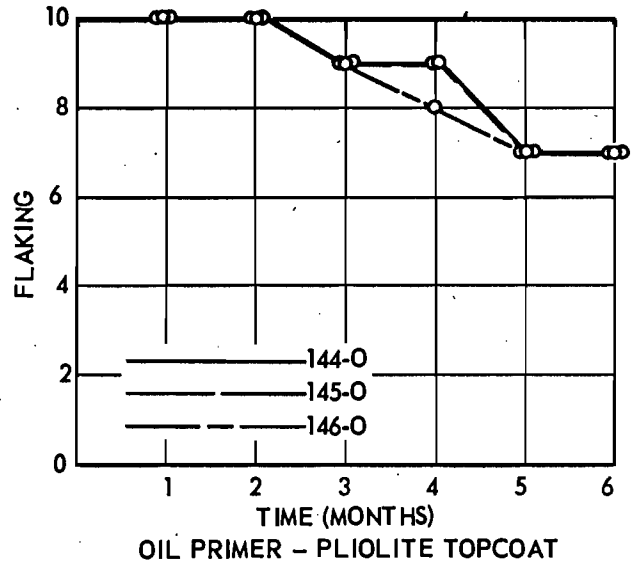
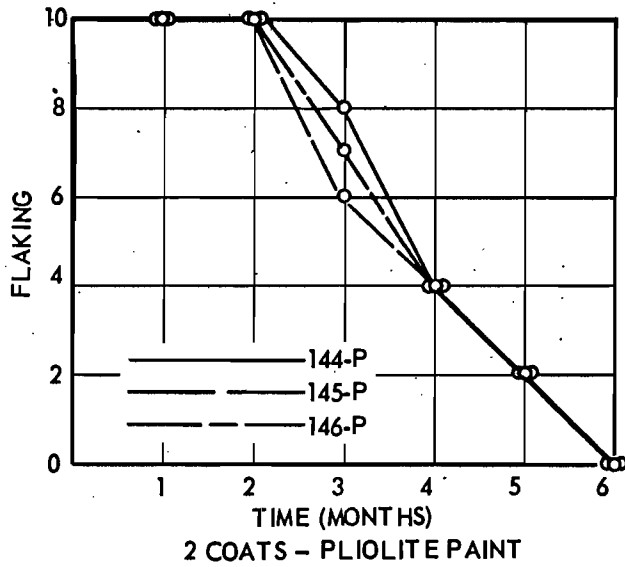
1. Introduction--Formulations

Previous work in Section B had indicated that clear sealers might be useful as primers for Pliolite paints. It appeared to follow from this that lower-P.V.C. paints might also have some merit. Accordingly, paints at 20 P.V.C. with zinc and with lead in the pigmentation were prepared. Along with this study, a formulation containing 10 per cent of water-ground mica in the pigmentation at 30 P.V.C. was included. The possibility of gaining a reinforcing effect from the mica was contemplated. Formulation details are shown in Table XII, PLIOLITE PAINTS WITH P.V.C. AND PIGMENT VARIATIONS, on page 53.

2. Test Procedure

The previously described procedure in Section C was followed in detail. The panels were placed on 45°-south vertical exposure on June 30, 1952.

WINGSTAY S



SANTOVAR A

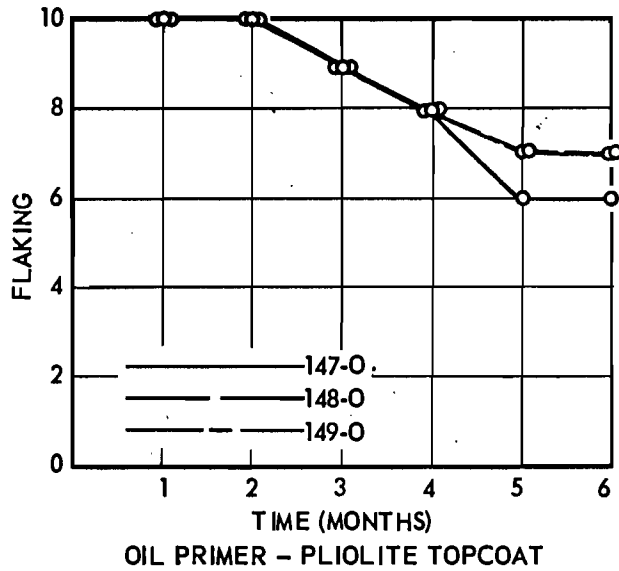
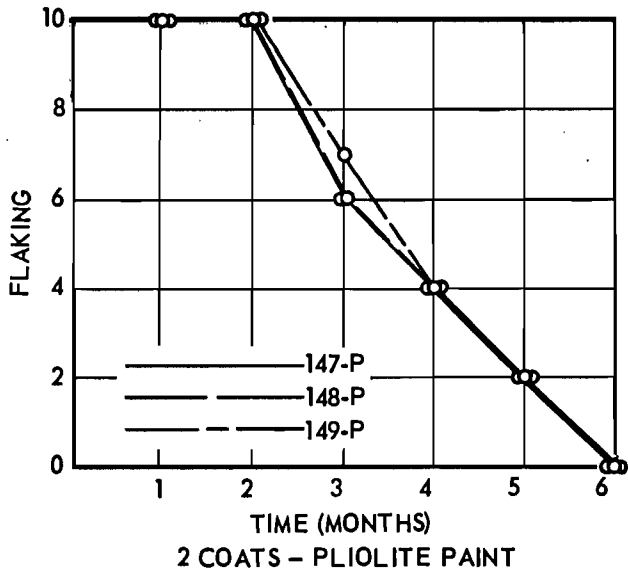
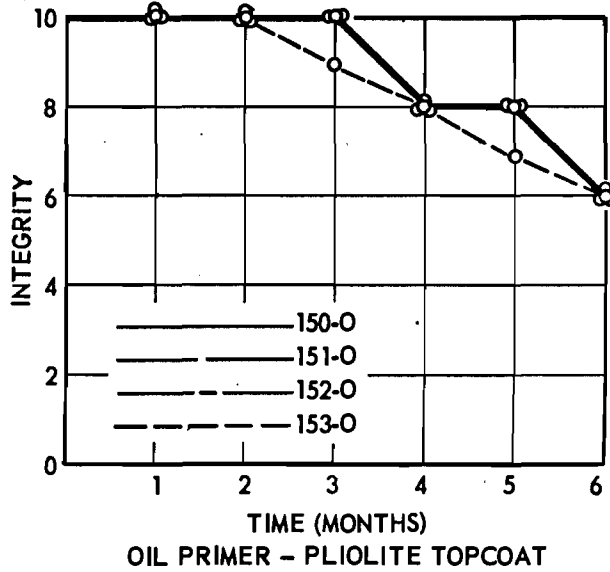
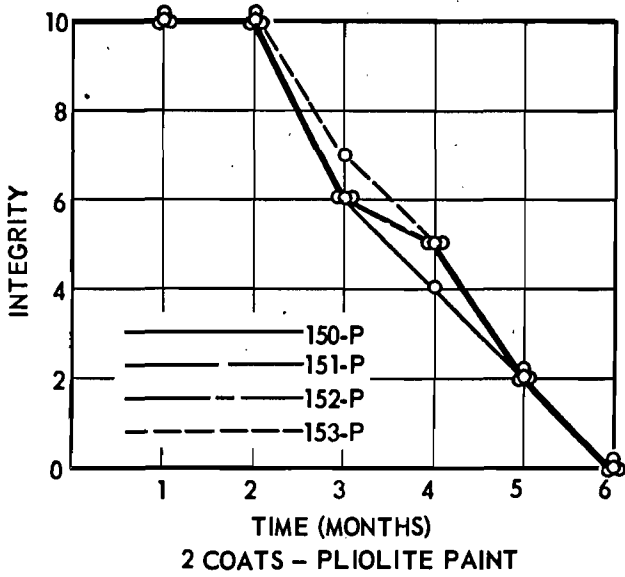


Figure 12. Antioxidants in Pliolite Paints.

DIPHOS



DIPHOS, WINGSTAY S, AND SANTOVAR A

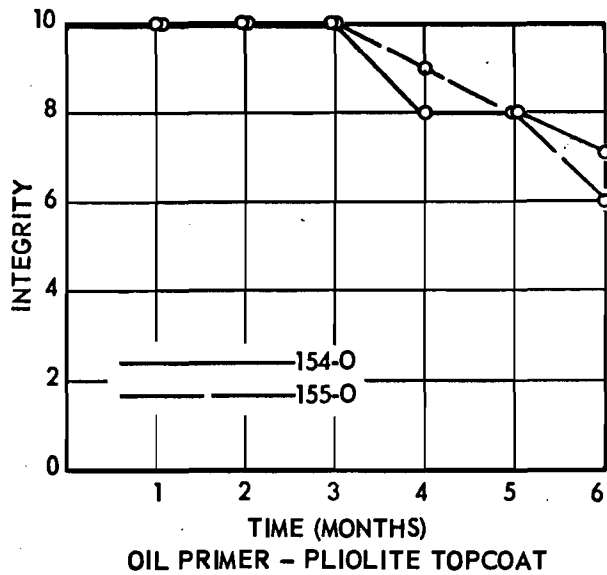
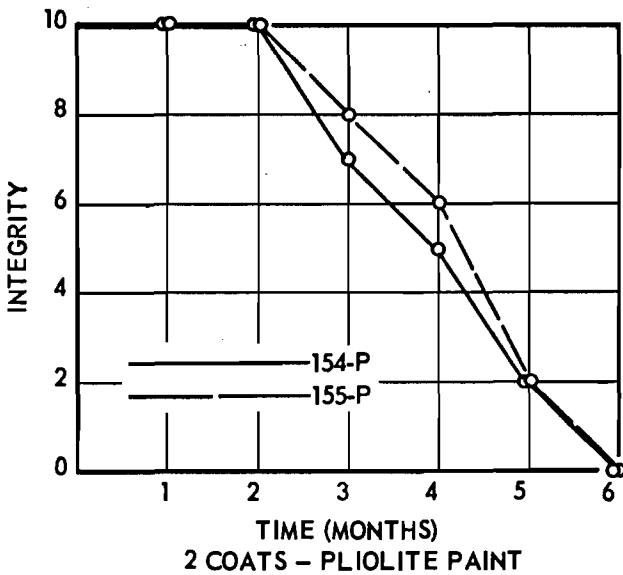


Figure 13. Diphos in Pliolite Paints.

TABLE XIX

PLIOLITE PAINTS WITH P.V.C. AND PIGMENT VARIATIONS

	Formulation Numbers			
	<u>156</u>	<u>157</u>	<u>158</u>	<u>159</u>
Pigment (Total Weight Per Cent)	38.0	27.0	37.0	29.0
Basic Carbonate White Lead	--	--	--	50.0
Titanox RA-NC	39.6	39.6	38.0	20.0
ZnO	25.0	25.0	24.0	--
Mica	--	--	4.0	--
Mg. Sil.	35.4	35.4	34.0	30.0
Vehicle (Total Weight Per Cent)	62.0	73.0	63.0	71.0
Pliolite S-5	79.5	80.7	79.8	81.0
Santizer B-16	15.9	16.1	16.0	15.6
Solvent	4.6	3.2	4.2	3.4
P.V.C.	30.0	20.0	30.0	20.0

3. Test Results

a. Application Properties. The variations studied here did not significantly affect brushing properties. The lead formulation again displayed a slight "stringiness" in brushing.

b. Exposure Observations. The variations studied here did not significantly affect the chalking properties of Pliolite paints. Slightly greater dirt collection occurred for paints at 20 P.V.C. (157 and 159), and, of these two paints, the one containing lead pigmentation (159) displayed the greater dirt collection. Definite checking was also observed to occur on these same two paints at 20 P.V.C. The zinc-containing formulation 157 was the poorer in this respect. Checking occurred only on two-coat Pliolite applications. It was not observed in the oil primer-Pliolite topcoat systems.

The integrity performance of the systems over a six months' exposure period is presented in Figure 14, Integrity of Systems with P.V.C. and Pigmentation Variations, on page 55. Distinctions in the performance of these systems were very slight. In the two-coat applications of Pliolite paints, the lead-containing system (157-P) demonstrated a slight superiority throughout the exposure period. Over the oil primer, distinctions in the performance of Pliolite topcoats were insignificant.

4. Conclusions

For the Pliolite paints studied, the following conclusions were drawn:

a. Reduction of P.V.C. to 20 per cent does not improve the performance of the paint on southern yellow pine.

b. Inclusion of 10 per cent water-ground mica in the pigmentation of the Pliolite paint does not improve performance.

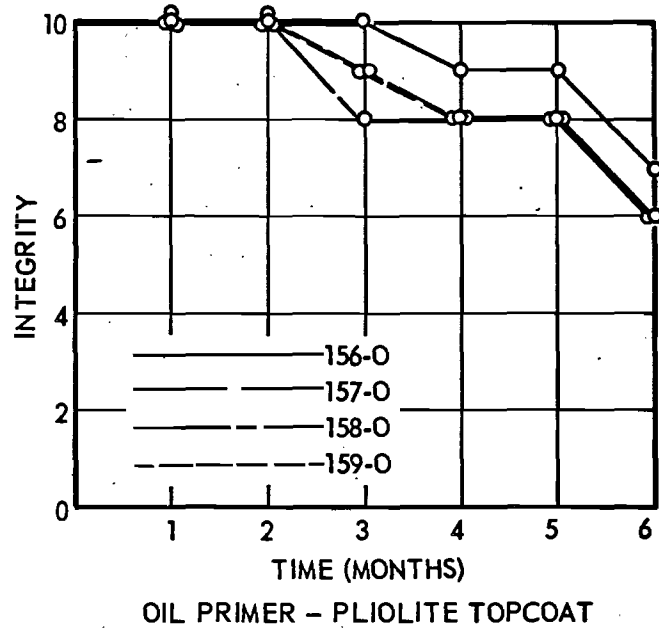
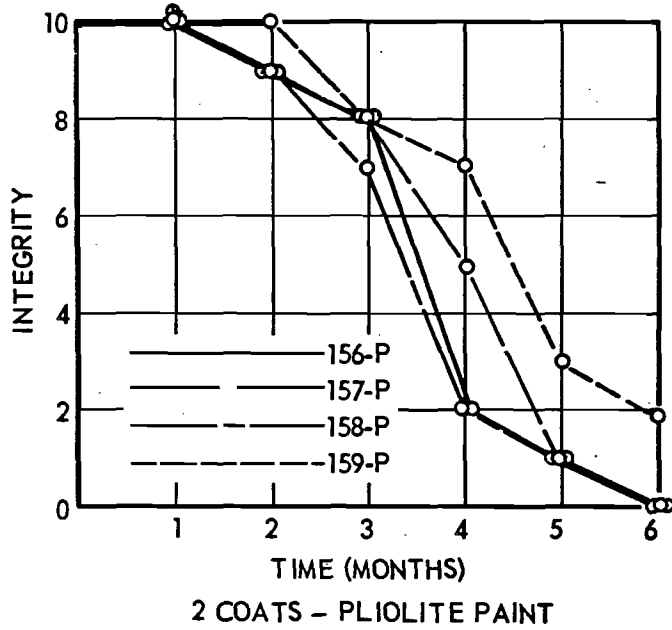


Figure 14. Integrity of Systems with P.V.C. and Pigmentation Variations.

c. Substitution of DCWL for ZnO in the Pliolite paint at 20 per cent P.V.C. improves the integrity of the paint slightly.

II. Study of Clear Vehicles

1. Introduction

While the plasticizers that were evaluated were observed to promote adhesion and film integrity to some extent, it was believed possible that some other additive may produce more specific effects. Since it was desirable to "screen" many materials as rapidly as possible, and since the problem was believed to involve principally the design of the vehicle, evaluations were made with unpigmented films.

2. Preparation Procedure

A quantity of a 30 per cent Pliolite S-5 solution in a 60 K-B blend of TS28R and mineral spirits was prepared as a stock solution. Portions of this stock solution were mixed with plasticizers and additives according to the following general formulas, Base Vehicle Nos. 1 and 2.

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BASE VEHICLE NO. 1

	<u>Grams</u>
30 Per Cent Pliolite Solution	47.
Aroclor 1254	6
Additive	4

The following additives were evaluated in Base Vehicle No. 1:

<u>Exposure No.</u>	<u>Additive</u>	<u>Supplier</u>
SF4	30% Pliolite Solution (Control)	(1)
SF5	Wood Rosin	(2)
SF6	Abalyn	(2)
SF7	Hydrolyn A	(2)
SF8	Staybelite #3	(2)
SF9	Pentalyn A	(2)
SF10	Abietic Acid	(2)
SF11	Piccolastic C-5	(3)
SF12	Piccolastic C-50	(3)
SF13	Morpholine	(4)
SF14	Tetraethylene pentamine	(4)
SF15	Monoethanolamine	(4)
SF16	Propylene Diamine	(4)
SF17	Diethylene Triamine	(4)
SF18	Dibutyl Sebacate	(5)
SF19	Piccolyte (65% S115 in Min. Sp.)	(3)
SF20	Oleic Acid	(6)
SF21	Linseed Fatty Acids	(6)
SF22	Petropon 2138	(7)
SF23	Butyl Stearate	(5)
SF24	Santicizer 107	(8)
SF25	Santicizer M-17	(8)
SF26	Allyl Starch	(9)
SF27	Silicone Resin XR 129 G	(10)
SF28	Chlorovax 70	(11)

BASE VEHICLE NO. 2

	<u>Grams</u>
30 Per Cent Pliolite Solution	47
Principal Plasticizer	6
Secondary Plasticizer	4

The following plasticizers or additives were evaluated in the combinations indicated in Base Vehicle No. 2.

<u>Principal Plasticizer</u>	<u>Secondary Plasticizer</u>	<u>Supplier</u>
<u>Santacizer B-16</u>	<u>Hydrolyn A</u>	
<u>Exposure No.</u>	<u>Exposure No.</u>	
SF29	SF41	Santacizer B-16 (8)
SF30	SF42	Hydrolyn A (2)
SF31	SF43	Chlorowax 70 (11)
SF32	SF44	Rosin (1)
SF33	SF45	Oleic Acid (6)
SF34	SF46	Baker's P-10 (12)
SF35	SF47	Flexricin (12)
SF36	SF48	Linseed Fatty Acids (6)
SF37	SF49	Staybelite Ester #3 (2)
SF38	SF50	Allyl Starch (9)
SF39	SF51	Abalyn (2)
SF40	SF52	Tung Oil (6)

Suppliers

- (1) Newport Industries
- (2) Hercules Powder Co.
- (3) Pennsylvania Industrial Chemical Corp.
- (4) Carbide and Carbon
- (5) Commercial Solvents Corp.
- (6) Archer-Daniels-Midland Co.
- (7) American Mineral Spirits Co.
- (8) Monsanto Chemical Company
- (9) General Mills, Inc.
- (10) Dow Corning Corp.
- (11) Diamond Alkali Corp.
- (12) Baker Castor Oil Co.

3. Applications

These compositions were applied in two coats to one-foot lengths of No. 105 pattern southern yellow pine lumber and exposed 45° south. The first series with Base Vehicle No. 1 was exposed on February 29, 1952. The second series with Base Vehicle No. 2 was exposed on April 1, 1952.

4. Observations

With few exceptions these clear films failed very rapidly. Exposure results are recorded in Table XIII on page 60. Film failures were largely by disintegration and erosion. While the integrity of SF29, plasticized with Santicizer B-16 alone, was good at two months' exposure, the film was still very soft and had collected a great deal of dirt.

5. Conclusions

None of the additives studied were found to merit further investigation in pigmented systems. The superior contribution of Santicizer B-16 to the integrity of Pliolite vehicles was confirmed. Of the secondary additives studied, only tung oil in combination with Santicizer B-16 (SF40) approached the performance of Santicizer B-16 alone.

I. Maleic-Treated Pliolite S-5

1. Introduction

It has been indicated that lack of adhesion is one of the principal problems to be overcome in attempting to formulate suitable exterior house paints with Pliolite S-5 for application to wood exteriors. Adhesion of polymers to various substrates is believed to be influenced by the degree of polarity of the polymer molecule. Since Pliolite S-5 is a polymer with very slight polarity, it was thought that the introduction

TABLE XIII
CLEAR FILM EXPOSURE RESULTS

<u>Exposure Number</u>	<u>Integrity One Month</u>	<u>Integrity Two Months</u>	<u>Exposure Number</u>	<u>Integrity One Month</u>	<u>Integrity Two Months</u>
SF4	5	0	SF29	10	10
SF5	5	0	SF30	10	0
SF6	5	3	SF31	8	0
SF7	8	6	SF32	8	0
SF8	6	3	SF33	8	7
SF9	5	0	SF34	10	7
SF10	2	0	SF35	10	5
SF11	5	0	SF36	10	5
SF12	6	0	SF37	10	0
SF13	6	0	SF38	6	0
SF14	3	0	SF39	0	0
SF15	3	0	SF40	8	9
SF16	2	0	SF41	10	0
SF17	1	0	SF42	1	0
SF18	4	0	SF43	1	0
SF19	5	0	SF44	2	0
SF20	9	5	SF45	2	0
SF21	5	0	SF46	1	0
SF22	5	0	SF47	1	0
SF23	4	0	SF48	1	0
SF24	8	4	SF49	1	0
SF25	5	0	SF50	1	0
SF26	6	0	SF51	1	0
SF27	2	0	SF52	2	0
SF28	8	4			

of some material into the molecule to increase polarity might produce a product with improved adhesion properties. It is known that a small amount of maleic anhydride is used in the preparation of Vinylite VMCH to promote adhesion of the polymer. It was thought that a similar treatment might be effective with Pliolite S-5. While maleic anhydride will react most readily at conjugated double bonds in a molecule to form an adduct, it is also capable of reacting with isolated double bonds at higher temperatures, and it is under these conditions that it was believed a reaction with Pliolite S-5 might be achieved.

2. Preparation Procedure

The reaction was carried out in a 2000-ml. glass resin kettle equipped with an automatic stirrer, a reflux condenser, and a thermometer. The kettle was heated with an electric heating mantle. It was believed to be desirable to carry out the reaction in the presence of a liquid plasticizer in order to provide a liquid medium at the beginning of the heat and to reduce the viscosity of the mass so that better mixing would be obtained during the reaction period and a liquid produce would result. The kettle was charged as follows.

	<u>Grams</u>
Pliolite S-5, milled	294
Maleic Anhydride	6
Santicizer B-16	<u>200</u>
	500

The contents were heated according to the following schedule:

Time (minutes)	0	30	60	60+
Temperature (°C)	26	160	230	240 max.

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At the end of a one-hour heating period the kettle was cut off and allowed to cool to room temperature. The resulting amber-colored resin was poured into a glass jar and capped. The yield was 462 grams.

3. Properties of the Resin

a. Color. The resin was diluted with aromatic solvent and its color determined as follows:

	<u>Grams</u>	<u>Per Cent</u>
Maleic Resin	462	54
Shell TS28R	395	46
	857	100

Gardner Color = 6

b. Acid Number. Two types of acid number determinations were made. The first was a conventional type of determination, and the second was a water-extraction procedure designed to indicate the amount of extractable unreacted maleic acid remaining in the final resin.

Duplicate acid number determinations were made on the maleic resin using the procedure of ASTM D 555-47 Paragraph 5 with the following results:

Ave. Acid Number = 13.9

Duplicate determinations of "water-extractable" or "free" acid number were made as follows:

Free-Acid-Number Procedure

- (1) Accurately weigh 5-10 g of sample into 300 ml flask.
- (2) Add 50 ml benzene, and dissolve sample completely.
- (3) Add 100 ml water, and shake 3 minutes.
- (4) Add 10 ml ethyl alcohol, and separate water phase into another flask.
- (5) Add 50 ml of water to benzene phase, shake 3 minutes and separate phases adding the water phase to the previously separated water phase of step (4).
- (6) Repeat step (5).
- (7) Titrate the combined water phases as in ASTM D 555-47.

Average Free Acid Number = 3.1

The theoretical total acid number of the maleic resin is calculated as follows:

$$\begin{aligned}\text{Theo. Acid No.} &= \frac{\text{wt. maleic anhydride}}{\text{wt. total sample}} \times \frac{\text{equiv. wt. KOH}}{\text{equiv. wt. M.A.}} \times 1000 \\ &= \frac{6.0}{500} \times \frac{56.1}{49.03} \times 1000 \\ &= 13.7\end{aligned}$$

The maleic anhydride was assumed to be 100 per cent pure. The manufacturer (Carbide and Carbon) specifies a minimum purity of 99 per cent.

The purpose of these acid number determinations was twofold: (1) to ascertain the paint formulation limitations of the resin and (2) to obtain an indication of the amount of maleic anhydride that had combined in the reaction. The acid number of the resin was very high if the resin were to be used in formulations of the type that have been studied previously in this work. Considerable reactivity with either lead or zinc pigmentations would be expected. The determination of Free Acid Number at 3.1 is interpreted to indicate that a considerable part of the maleic anhydride in the original mixture had reacted with the resin and was thus bound so that it would not be extracted by water. Further work aimed at characterization of the resin was not attempted, since such studies were not regarded as being within the scope of the present work.

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c. Paint Formulation Properties. Two types of paints were prepared from the maleic resin according to the formulations shown below:

Formulations with maleic resin:

	<u>F-63</u>	<u>F-64</u>
PIGMENT (Per Cent of Paint)	27.4	34.0
Rutile TiO ₂	39.6	48.6
ZnO	25.0	
Mg. Sil.	35.4	51.4
VEHICLE (Per Cent of Paint)	72.6	66.0
Maleic Resin (54% solids)	47.2	70.4
Mineral Spirits	13.1	20.0
Added Solvent (60 K-B)	40.7	9.6
Yield (g)	424	353
Grind (IBS)	3.0	4.0
P.V.C. (%)	30	30

These paints were prepared by pebble milling for about 16 hours.

The Added Solvent was introduced at the end of the grinding period.

Formulation F-63 gelled in the mill during the grinding period. The excessive solvent shown in the formulation was used in an effort to dissolve the gel. This effort was unsuccessful, and the paint was completely unusable. Formulation F-64 was prepared successfully; however, after several days' storage in a paint can, it also gelled and was unusable.

4. Conclusions

A mixture of Pliolite 8-5, Santicizer B-16, and maleic anhydride may be reacted to form a viscous liquid product having a satisfactory color. The acid number of this product is approximately equivalent to the acid in the added maleic anhydride. As prepared in this work, the reactivity of the maleic resin was too great to make the product useful as the primary vehicle in paints of the type studied here.

IV. FINAL CONCLUSIONS

1. The durability of oil-based exterior house paints has not been equaled or approached with formulations based on Pliolite S-5.
2. Weatherometer studies were found to be unsatisfactory for Pliolite paint evaluation.
3. The durability of Pliolite S-5 formulations is enhanced by the addition of plasticizers; 40 per cent of Santicizer B-16 in the nonvolatile vehicle represents the best composition that was studied.
4. P.V.C.'s of 20 to 30 per cent yield the best performance for Pliolite paints on exterior wood.
5. In the formulations studied, the replacement of ZnO with BCWL on a volume basis was found to produce a slightly more durable paint film.
6. The addition of fatty acids to the vehicle of the Pliolite paints studied was not beneficial.
7. Antioxidants and antacids were ineffective with respect to durability. Wingstay S was observed to act as a grinding aid.
8. Study of a variety of vehicle additives in clear plasticized Pliolite S-5 films did not indicate utility for any additive except possibly tung oil. In pigmented systems, the tung oil additive was shown to enhance adhesion over spring wood, although it did not improve general performance.
9. Maleic-treated Pliolite S-5 was unsuccessful as a paint vehicle; the pigmented system gelled. This was presumed to be caused by the high acidity of the vehicle.

V. RECOMMENDATIONS

1. Further formulation studies of the type conducted in this work with Pliolite S-5 are not recommended, except possibly for special work with additives that may be expected to have particular merit.

Based on the results of this study, it would appear that the properties of Pliolite S-5 are not well suited for application as a vehicle in exterior paints for wood. None of the additives or plasticizers studied was found to be capable of modifying the properties of the Pliolite sufficiently to produce the required characteristics of adhesion, film flexibility, and strength. Another serious limitation is in the fact that Pliolite paints are essentially lacquer-type systems. Because of the high volatile content that must be carried by a Pliolite paint at 30 per cent P.V.C., when this paint is applied at a reasonable wet-film thickness, only about one-half of the dry-film thickness of a comparable oil paint of similar P.V.C. and wet-film thickness can be attained. On a film-thickness basis, this would mean that a Pliolite paint should be capable of outperforming an oil-base paint two to one if it is to be capable of competing with the conventional product. At this time it does not appear likely that such performance will be achieved.

2. A more complete study of the maleic treatment of Pliolite S-5 is recommended.

The studies of maleic treatment conducted in this work were limited to a single experimental run and were therefore very inconclusive. Nevertheless, it was very definitely indicated that vehicle-pigment reactivity could be achieved by this means, and additional studies using lower maleic concentrations might develop modifications of Pliolite S-5 having superior properties. This product might have applications in exterior house paints,

but would by no means be confined to this field. The characteristics of such a resin should include better adhesion because of the polarity of the molecule and stronger films because of the film reinforcing effect resulting from pigment-vehicle reactivity.

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