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Technical Report

AIRFIELD MARKING PAINTS FOR ASPHALTIC PAVEMENTS

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INTRODUCTION

Numerous activities of the Naval Facilities Engineering Command (NAVFAC) have encountered early deterioration of airfield marking paints and damage to the asphaltic substrate underlying the markings. The occurrence of these problems at widely differing geographical locations indicates that the problem is broad in scope and not limited to any special type of environment or service, although the severity of this problem may be related to such factors. NCEL Technical Reports R-296[1] and R-296 Supplement[2] describe several different types of failure of marking paint and asphaltic substrate as found in a survey of several Naval Air Stations in the Eleventh and Twelfth Naval Districts. The reports also describe the limited testing of proprietary marking paints conducted at the Naval Air Station, Point Mugu. This test showed the importance of investigating the basic causes of these failures. Thus laboratory and small test plot studies[3-7] were performed in order to determine the causes for failure and the effects of variables in paint composition on field performance. Formulations which performed well in these studies were subsequently tested[8,9] under actual field conditions. This report covers the final laboratory and field investigations on this work and includes guidelines to be followed by field activities in order to obtain optimum performance from marking paints.

BACKGROUND

Types of Deterioration

Deterioration of marking paints and underlying substrates result from (1) deficiencies in the paint, (2) deficiencies in the pavement, (3) improper substrate preparation, (4) improper coating application, (5) environmental factors, (6) service factors, or (7) a combination of these. While the nature of the deterioration may vary somewhat, there are a number of types of deterioration that occur with great frequency.

The most frequently encountered type of failure associated with marking paints occurs on slurry-sealed asphaltic pavements. The slurry seal first cracks along the edges of the markings and then the portions under the markings peel back from the pavement to which it is relatively weakly bonded. With unslurried pavements, cracking of the paint, pavement, or both may occur. Traffic over the cracked and/or peeling paint results in loss by chipping.* Abrasion or erosion** of painted markings by the abrasive action of vehicle tires is usually insignificant on airfield runways, but may be quite appreciable on heavily trafficked roadways.

Asphalt is quite soluble in most organic solvents. Thus discoloration of markings occasionally occurs by dissolution and subsequent deposition of asphalt from the pavement by solvent. The solvent may be introduced by accidental contamination (for example, spillage of fuel or cleaner) or as a component of the paint. When excessively strong solvents are present in the paint, the discoloration (bleeding***) occurs shortly after paint application. Where there are low areas (commonly called "bird baths") in the pavement that collect rain water, asphalt from recently paved or sealed pavements may be spread by water onto painted markings. Coal tar seals are sometimes used to minimize solvent deterioration of asphaltic pavements.

In touchdown areas of runways, black tire tracks are quite common on the pavement, and the painted markings may be badly obscured. The black rubber deposits are difficult, as well as costly, to remove without causing damage to the markings, pavement, or adjacent vegetation.

Mechanism of Deterioration

Previous NCEL studies[3-6] have shown that paint deterioration and substrate degradation on asphaltic pavements proceed according to the following mechanism:

1. Marking paints contract significantly on curing and set up a stress between themselves and the substrate. Both paint and pavement continue to harden and degrade with time.

2. Daily differential expansion and contraction between painted marking (together with adhering substrate) and the substrate adjacent to the markings add to this strain. (Griffith and Puzinauskas[13] found that

* Chipping is defined in ASTM Designation D913-51[10] as "actual detachment of entire sections of the film, usually in small pieces, either from its substrate or from paint previously applied" and "is usually characterized by sharp edges and definite demarkation of the bare area."

** Abrasion or erosion condition is defined in ASTM Designation D821-47[11] as the "more or less graduation surface disappearance, thinning of the film, and exposure of the substrate because of abrasion, erosion, or combinations of both."

*** Bleeding is defined in ASTM Designation D868-48[12] as "that condition of discoloration manifested in traffic paint when applied to tar or asphaltic-type roads."

if test paints were pigmented so heavily with carbon black that they were black in color, edge cracking of sand-asphalt pavement surfaces was eliminated.)

3. Cracking of the paint occurs if the strain caused by paint contraction becomes greater than the cohesive forces in the paint. On slurry-sealed asphaltic pavements, the relatively weak bond of the slurry seal to the pavement is usually broken before paint cracking occurs or while paint cracking is occurring. Separation and curling of the slurry seal from the pavement is initiated along the cracked edges.

4. Penetration of rain water under lifted edges of paint or slurry seal promotes further loss of bonding. Collection of rain water in areas of painted markings may significantly increase the rate of chemical decomposition of the paint.

5. Reduced flexibility or increased contraction of the paint film tends to accelerate deterioration associated with marking paints because of the resultant greater strain between the paint and substrate. A buildup of several coats of paint increases the strain between the initial coat and its underlying substrate.

6. Asphalt is quite soluble in hydrocarbon and other organic solvents; therefore, variations in paint formulation that permit greater solvent action promote deterioration. Thus, high boiling range solvents (or thinners) should be avoided since they permit more time for the solvent to penetrate the asphalt before evaporating.

7. Ultraviolet radiation contributes to the deterioration of paint binders. Thus, tropical locations have the disadvantage of high ultraviolet radiation in addition to that of heavy rainfall. Remote tropical locations generally have additional problems associated with supply, storage, and proper application of marking paints.

Present Marking Paint Specifications

NAVFAC MO-110[14] lists three paints suitable for use on exterior pavements: TT-P-85,[15] TT-P-110,[16] and TT-P-115.[17] It also specifies that application must be made to a thoroughly cured and cleaned substrate. Flexible pavements should be allowed to cure as long as practicable before application of the marking paint in order to minimize the possibility of (1) bleeding of the asphalt into the marking or (2) significant softening of the asphalt by the paint solvents. NAVFAC field activities frequently specify a minimum of 21 days between laying of asphaltic pavement or slurry seal and painting of markings.

TT-P-85 is primarily used as a reflectorized paint on airfield pavements (either asphaltic or portland cement concrete). White is used on runways and yellow on taxiways and aprons.[18] The paint can also be used for marking roadways with or without reflectorization. To impart reflectorization, glass spheres are dropped onto the wet paint immediately after application. TT-P-85 specifies that the paint shall be applied at a rate of 150 ft^2, ± 5 ft^2, per gallon of paint, and the glass spheres shall be dispersed at the rate of 10 pounds per gallon of paint. This corresponds to about 7 to 8 mils* of dry paint film. At several NAVFAC field activities which have deteriorated paint markings, the paint film thickness has been in excess of 50 mils. Such thicknesses contribute greatly to internal strains.

TT-P-85 is a broad specification that does not limit the type of resin, pigment, or solvent to be used in the formulation so long as the required physical, chemical, and performance properties are met. Alkyd formulations are the ones most commonly used by marking paint suppliers, but oleoresinous phenolic varnish formulations are also used to an appreciable extent.[19] A survey[8] of field activities in Southwest Division, NAVFAC, indicates that the latter type of paint generally performed better than alkyd formulations.

TT-P-110 is a general purpose, nonreflective black paint. It is used for black markings on light pavements and for obliterating white and yellow markings that are no longer desired. TT-P-110 is available in two types: type I (vinyl toluene-butadiene) which has an appreciably longer drying time than type II (chlorinated rubber-alkyd).

TT-P-115 is a general use white or yellow marking paint that may be used with or without glass spheres for reflectorization. It is to be applied at a wet-film thickness of 15 mils which would give a dry-film thickness of about 7 to 8 mils (similar to TT-P-85). TT-P-115 is available in three types. Type I (alkyd) is the slowest drying and is used where slow drying can be tolerated and where bleeding may be a problem (for example, on bituminous pavements); type II (vinyl toluene-butadiene) is intermediate in drying time and is used where bleeding is a problem; type III (chlorinated rubber-alkyd) is the fastest drying and is used where bleeding is not a problem. It should be noted that faster drying marking paints tend to be less flexible (more brittle). Also, the tendency for a paint to exhibit bleeding is directly related to its solvent action.

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* 1 mil = 0.001 inch.

FIELD TESTING OF MARKING PAINTS

Plot Testing at CBC, Port Hueneme

A study,[6,9] initiated 4 years earlier, investigated the deterioration of 15 specially formulated or procured marking paints in test plots at CBC, Port Hueneme that received no traffic. Analyses of the paints, their formulations, and the dry-film thicknesses of the test stripes are given in Reference 6. It also presents a statistical analysis of the factors affecting lifting of the slurry seal at the time of maximum variation of lifting ratings. The 15 test paints are identified as to generic type in Table 1. Test paints 101 and 108 were replicated as 116 and 117, respectively, in order to obtain a measure of experimental error.

Table 1. Type of Coating

Test Paint No.	Resin Used	Plasticizer Used
101	medium oil alkyd	–
102	long oil alkyd	–
103	medium oil alkyd	tricresyl phosphate
104	medium oil alkyd	dibutyl phthalate
105	long oil alkyd	tricresyl phosphate
106	long oil alkyd	dibutyl phthalate
107	short oil oleoresinous	–
108	medium oil oleoresinous	–
109	long oil oleoresinous	–
110	medium oil oleoresinous	tricresyl phosphate
111	medium oil oleoresinous	dibutyl phthalate
112	long oil oleoresinous	tricresyl phosphate
113	long oil oleoresinous	dibutyl phthalate
114	water-emulsion polyvinyl acetate	–
115	vinyl toluene-butadiene	–
116	medium oil alkyd	–
117	medium oil oleoresinous	–

Periodic rating of the stripes applied at a normal and a twice normal thickness to a slurry-sealed pavement has been done since their application. Tables 2, 3, 4, and 5 show the ratings of the test stripes after 1, 2, 3, and 4 years, respectively. Ratings for the degree of lifting of paint and slurry seal from the underlying asphaltic pavement range from a high of 4 to a low of 1; the values assigned are listed below:

Condition	Rating
No appreciable lifting	4
Slight edge lifting only	3
Moderate edge lifting	2
Extensive lifting and loss of adhesion	1

Half-point ratings (for example, 3-1/2) are given when the strip condition is between two of the standards. Random placement and coding of test stripes reduced rating bias, and replication reduced differences created by variations in the substrate.

Table 2. Lifting Ratings of Paint Stripes 1 Year After Paint Application

(T_1 = single thickness;[a] T_2 = double thickness)

Test Paint No.	Plot 1		Plot 2		Plot 3		Plot 4		Totals		
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1 and T_2
101	3½	3	4	4	3½	3	3½	4	14½	14	28½
102	3½	2	4	2	4	1	4	3½	15½	8½	24
103	4	3	4	3½	4	3½	4	3	16	13	29
104	4	2½	4	1½	4	1	4	3	16	8	24
105	3	3	4	1	3	2	4	3	14	9	23
106	3	1	3½	1	3	1	4	1½	13½	4½	18
107	2	2½	3	3	3	2½	3	3	11	11	22
108	3½	3½	4	4	4	4	4	4	15½	15½	31
109	4	3½	4	4	3	3	4	4	15	14½	29½
110	3½	3½	4	3½	4	4	4	4	15½	15	30½
111	4	3½	4	3½	4	3½	4	4	16	14½	30½
112	3½	3½	4	3½	3½	3	4	3½	15	13½	28½
113	3½	3	4	3½	3½	3	3½	3½	14½	13	27½
114	4	4	4	4	4	4	4	4	16	16	32
115	4	3	4	3	4	3½	4	3½	16	13	29
116	4	3	4	4	4	4	4	4	16	15	31
117	4	4	4	4	4	3½	4	4	16	15½	31½
Subtotals	61	51½	66½	53	62½	49½	66	59½	256	213½	469½
Totals	112½		119½		112		125½		469½		

[a] Wet-film thickness of single layer stripe = 15 mils.

Table 3. Lifting Ratings of Paint Stripes 2 Years After Paint Application

(T_1 = single thickness;[a] T_2 = double thickness)

Test Paint No.	Plot 1		Plot 2		Plot 3		Plot 4		Totals		
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1 and T_2
101	3	3	3½	3½	4	3	3½	4	14	13½	27½
102	4	1½	4	2½	4	1½	4	2	16	7½	23½
103	4	3	4	3½	3	3	3½	3	14½	12½	27
104	4	1½	4	1½	4	1	4	2½	16	6½	22½
105	3	2	4	1½	4	1	4	1½	15	6	21
106	3	1	3	1	3	1	3	1	12	4	16
107	2	3	3	3	3½	3	3½	3	12	12	24
108	3½	3	3½	3½	4	3½	4	4	15	14	29
109	4	3	3½	3½	4	3½	4	4	15½	14	29½
110	3½	3½	4	3½	3½	3½	4	3½	15	14	29
111	4	3	4	3½	4	3	4	3½	16	13	29
112	3½	3½	3½	3½	3½	3	4	4	14½	14	28½
113	3½	3	3½	3	3	3	3½	3	13½	12	25½
114	4	4	4	4	4	4	4	4	16	16	32
115	4	4	4	3½	4	3½	4	4	16	15	31
116	4	3	4	4	4	4	4	4	16	15	31
117	4	4	4	4	4	3½	4	4	16	15½	31½
Subtotals	61	49	63½	52½	63½	48	65	55	253	204½	457½
Totals	110		116		111½		120		457½		

[a] Wet-film thickness of single-layer stripe = 15 mils.

From Tables 2 through 5, it can be seen that relatively little deterioration occurred during the second year of exposure, more occurred during the third year, and much more occurred during the fourth year. The order of performance, from high to low, for each of the yearly ratings is listed in Table 6. It can be seen from this table that, aside from the water-emulsion polyvinyl acetate paint (114) and the vinyl toluene-butadiene paint (115), the paints first deteriorated rather slowly and then more rapidly with additional time, while the relative order of rating totals was not greatly affected.

After 4 years, the most conspicuous aspect of the test stripes was the virtually perfect condition of the water-emulsion polyvinyl acetate paint (114) and the much better condition of the vinyl toluene-butadiene paint (115) than that of the rest of the test paints. This is directly correlated to the percent of elongation as measured by the free-film method at 7-1/2 mils dry-film thickness, approximately that of the test stripes. From Reference 6 it can be seen that paint 114 had at least 9 times and paint 115 at least 2 times such elongation as the other test paints. It should be noted that the single-thickness stripes of paint 115 showed some erosion. This was no doubt due to weathering, as there was no traffic on the test stripes.

Table 4. Lifting Ratings of Paint Stripes 3 Years After Paint Application

(T_1 = single thickness;[a] T_2 = double thickness)

Test Paint No.	Plot 1		Plot 2		Plot 3		Plot 4		Totals		
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1 and T_2
101	3	2½	3½	3	3½	3½	3	2½	13	11½	24½
102	4	1	4	2½	4	1	4	3½	16	8	24
103	3½	2	4	2	3	1½	3½	2½	14	8	22
104	4	1	4	1½	4	1	4	2½	16	6	22
105	3	1½	3½	1	3½	1	4	1½	14	5	19
106	3	1	3	1	3	1	3	1	12	4	16
107	2	3	3	3	3½	3	3½	3	12	12	24
108	3	3	3½	3	3½	3½	3½	3	13½	12½	26
109	3½	3	3½	3½	3½	3½	4	3½	14½	13½	28
110	3½	3	3	3	3½	3½	3½	3½	13½	13	26½
111	3½	2½	3½	3	3½	3	4	3½	14½	12	26½
112	3½	3	3½	3	3½	3½	3½	3½	14	13	27
113	3½	2½	3½	2½	3½	3	3½	2½	14	10½	24½
114	4	4	4	4	4	4	4	4	16	16	32
115	4	3½	3½	3	4	3½	4	3½	15½	13½	29
116	4	2½	4	4	3½	2½	4	4	15½	13	28½
117	3½	3½	4	3½	4	3	3½	3½	15	13½	28½
Subtotals	58½	42½	61	46½	61	45	62½	51	243	185	428
Totals	101		107½		106		113½		428		

[a] Wet-film thickness of single-layer stripe = 15 mils.

In almost all cases, single-thickness ratings were as great as or greater than double-thickness ratings. Poorer ratings for double-thickness stripes were especially conspicuous for the alkyd paints. Thus single-thickness stripes of two alkyd paints (102 and 104) still had maximum ratings after 3 years while the corresponding double-thickness stripes were considerably deteriorated after 1 year. As previously noted[6] on the 1-year ratings, the oleoresinous phenolic varnish ratings continued to be significantly higher overall than the corresponding alkyd ratings. This was due, however, to the lower ratings of the double-thickness alkyd stripes, as the single-thickness rating totals were quite comparable. The addition of a plasticizer had no appreciable effect on single-thickness ratings, but it appreciably lowered double-thickness alkyd rating totals after 2 and 3 years and slightly lowered long oil oleoresinous phenolic varnish double-thickness rating totals after 3 and 4 years. The alkyd paints with tricresyl phosphate as a plasticizer (103 and 105) were generally rated higher than corresponding formulations (104 and 106) with dibutyl phthalate as a plasticizer. This was also true for the long oil oleoresinous phenolic varnish formulations.

Table 5. Lifting Ratings of Painted Stripes 4 Years After Paint Application

(T_1 = single thickness;[a] T_2 = double thickness)

Test Paint No.	Plot 1		Plot 2		Plot 3		Plot 4		Totals		
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1 and T_2
101	2	1	2	1	2½	1	2½	1	9	4	13
102	2½	1	3	1½	2	1	2½	1½	10	5	15
103	2½	1	2½	1	2½	1	3½	1½	11	4½	15½
104	2½	1	2½	1	2½	1	3	1½	10½	4½	15
105	2½	1	3½	1	2	1	2½	1	10½	4	14½
106	2	1	2	1	2	1	2½	1	8½	4	12½
107	1½	2	2½	1½	2½	2	2½	2	9	7½	16½
108	2½	2½	2	2	2½	2	2½	2	9½	8½	18
109	2½	3	2	2	2	1½	3	2½	9½	9	18½
110	2½	2½	2½	2½	2½	2	2½	2	10	9	19
111	2	1½	2	1½	2	1½	2½	2	8½	6½	15
112	2½	1½	2½	1½	2½	2	2½	2	10	7	17
113	2½	2	2	1½	1½	1½	2	1	8	6	14
114	4	4	4	4	4	4	4	4	16	16	32
115	3	2½	2½	2½	4	3	4	3	13½	11	24½
116	2½	1	3	2½	2½	1	2½	2	10½	6½	17
117	2	2	2	2	2½	2	3	2½	9½	8½	18
Subtotals	41½	30½	42½	30	42	28½	47½	32½	173½	121½	295
Totals	72		72½		70½		80		295		

[a] Wet-film thickness of single-layer stripe = 15 mils.

Roadway and Runway Testing at Guam

A previous study[20] indicated that TT-P-115[17] (paint, traffic, highway, white) had a useful life of approximately 6 months in tropical environments, and, thus, NAVFAC Instruction 11012.98A[21] specifies that TT-P-85[15] (paint, traffic, reflectorized for airfield runway marking) be used for both highway and airfield marking in tropical environments. Because TT-P-85 has subsequently performed very poorly both on roads and runways at Guam, the Navy Public Works Center there requested that an NCEL paint specialist (1) inspect areas of premature marking paint failure in order to determine the causes of failure and (2) initiate a small test program to determine which marking paint formulations would perform best at Guam.

Table 6. Order of Lifting Rating Totals for Single- and Double-Thickness Stripes

Test Paint	Rating Totals
After 1 Year	
$103T_1$, $104T_1$, $111T_1$, $114T_1$, $114T_2$, $115T_1$, $116T_1$, $117T_1$	16
$102T_1$, $108T_1$, $108T_2$, $110T_1$, $117T_2$	15½
$109T_1$, $110T_2$, $112T_1$, $116T_2$	15
$101T_1$, $109T_2$, $111T_2$, $113T_1$	14½
$101T_2$, $105T_1$	14
$106T_1$, $112T_2$	13½
$103T_2$, $113T_2$, $115T_2$	13
$107T_1$, $107T_2$	11
$105T_2$	9
$102T_2$	8½
$104T_2$	8
$106T_2$	4½
After 2 Years	
$102T_1$, $104T_1$, $111T_1$, $114T_1$, $114T_2$, $115T_1$, $116T_1$, $117T_2$	16
$109T_1$, $117T_2$	15½
$105T_1$, $108T_1$, $110T_1$, $115T_2$, $116T_2$	15
$103T_1$, $112T_1$	14½
$101T_1$, $108T_2$, $109T_2$, $110T_2$, $112T_2$	14
$101T_2$, $113T_1$	13½
$111T_2$	13
$103T_2$	12½
$106T_1$, $107T_1$, $107T_2$, $113T_2$	12
$102T_2$	7½
$104T_2$	6½
$105T_2$	6
$106T_2$	4

Table 6. Continued

Test Paint	Rating Totals
After 3 Years	
$102T_1$, $104T_1$, $114T_1$, $114T_2$	16
$115T_1$, $116T_1$	15½
$117T_1$	15
$109T_1$, $111T_1$	14½
$103T_1$, $105T_1$, $112T_1$, $113T_1$	14
$108T_1$, $109T_2$, $110T_1$, $115T_2$, $117T_2$	13½
$101T_1$, $110T_2$, $112T_2$, $116T_2$	13
$108T_2$	12½
$106T_1$, $107T_1$, $107T_2$, $111T_2$	12
$101T_2$	11½
$113T_2$	10½
$102T_2$, $103T_2$	8
$104T_2$	6
$105T_2$	5
$106T_2$	4
After 4 Years	
$114T_1$, $114T_2$	16
$115T_1$	13½
$103T_1$, $115T_2$	11
$104T_1$, $105T_1$, $116T_1$	10½
$102T_1$, $110T_1$, $112T_1$	10
$108T_1$, $109T_1$, $117T_1$	9½
$101T_1$, $107T_1$, $109T_2$, $110T_2$	9
$106T_1$, $108T_2$, $111T_1$, $117T_2$	8½
$113T_1$	8
$107T_2$	7½
$112T_2$	7
$111T_2$, $116T_2$	6½
$113T_2$	6
$102T_2$	5
$103T_2$, $104T_2$	4½
$101T_2$, $105T_2$, $106T_2$	4

In April 1968, an NCEL paint specialist examined the deteriorated roadway markings, the paint and glass spheres used in these markings and the application equipment used, and concluded that the following conditions contributed to premature failure of the markings:

1. Because of problems associated with procuring, packaging, and storing marking materials, the glass spheres had become contaminated with rust and dust. This resulted in poor adhesion of the spheres and discoloration of the markings.

2. Because of problems associated with procuring, packaging, and storing marking materials, the paint had greatly deteriorated before being used.

3. Because of the unavailability of suitable striping equipment, inadequate equipment was used that required appreciable thinning of the paint and resulted in reduction of film thickness and poor field performance.

Because problems existed with painted markings on both roadways and runways, a limited field testing program was initiated on both types of asphaltic pavement. Six of the paints that had previously performed well in test plots at CBC, Port Hueneme (see previous section of this report) were selected for testing. A seventh test paint was included at the request of PWC, Guam, because it was reported to have performed quite well in Hawaii. Analyses of the paints are given in Reference 7 and a brief description* of each is given below:

NCEL Formulation 108. This is an oleoresinous phenolic varnish paint of medium oil length. It generally has good flexibility, and similar formulations have performed well on asphaltic runways in Southern California.

NCEL Formulation 109. This is an oleoresinous phenolic varnish paint of long oil length. Consequently, it has a greater flexibility than Formulation 108. It too has performed well on a number of airfield runways in Southern California.

NCEL Formulation 110. This is similar to Formulation 108, except that some of the resin has been replaced by a plasticizer (tricresyl phosphate) to increase its flexibility.

NCEL Formulation 101. This is an alkyd formulation of medium oil length that generally has good flexibility. It has performed well in the plot tests at CBC, Port Hueneme, but other alkyd paints have frequently performed poorly on asphaltic runways in Southern California.

NCEL Formulation 115. This vinyl toluene-butadiene paint conforms to TT-P-115, type II, except that its pigmentation is identical to NCEL Formulations 101, 108, 109, and 110. The similarity of pigments

* The complete formulation and further descriptive information on all NCEL formulations can be found in Reference 6.

in these five formulations simplifies comparison of the performances of the binders. TT-P-115, type II, has generally performed better than TT-P-115, types I and III, on asphaltic runways in Southern California.

NCEL Formulation 114. This is a proprietary water-emulsion polyvinyl acetate marking paint.* It has tremendous flexibility and has shown no lifting of slurry seal in the CBC, Port Hueneme test plots after 4 years (see previous section). With all water-emulsion traffic paints, there is concern over the abrasion resistance as compared to that of formulations with organic solvents. Since it has no organic solvent, it does not have problems with softening asphaltic pavements or bleeding, and it meets the requirement of TT-P-85 that the thinner used shall comply with Rule 66.[22] Also, it drys fast and is not as sensitive to moisture as the other test paints. This is a real advantage in tropical areas such as Guam where there is normally a high humidity and frequent rainfall.

Proprietary Formulation A.* This is an alkyd paint and, thus, is somewhat similar to NCEL Formulation 101. It is reported to conform to TT-P-115, type I, and to have performed well in Hawaii.

Site at NAS, Agana. Seven 2 x 2-foot test plots (one of each test paint) was applied to a section of asphaltic overlay at one end of Runway 6 right 24 left of NAS, Agana in April 1968. It was convenient to add each test plot to the end of one of the existing centerline dashes so that it did not interfere with the runway striping pattern. The only paint spraying equipment available required several passes to obtain the desired wet-film thickness. Glass spheres conforming to TT-P-85 were manually sprinkled into the wet paint to impart retroreflectivity. Additional details on the application of the test paints are reported in Reference 9.

The test paints were rated periodically by PWC, Guam personnel and then examined and photographed by the NCEL project scientist 1 year after application. Because of the unsuitable method of paint application, there was poor retention of glass spheres, although the paint itself had been applied in a satisfactory manner. Test paint formulations were applied starting at one end of the runway in the following sequence: 108, 109, 110, 101, 115, 114. Starting from Formulation 108 and proceeding to Formulation 114, there were increasing amounts of rubber deposited by touchdown and traffic from aircraft (Figure 1) and consequently greater chance for chipping and erosion from aircraft tires. It can be seen from the 1-year rating data of Table 7 that those paints receiving less touchdown were generally rated higher than those receiving more, although Formulation 114 which received the most touchdown had the highest total rating. It was concluded that while touchdown was an important consideration, it was not a predominant factor in paint deterioration at NAS, Agana.

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* Proprietary identification is available to U.S. governmental agencies upon request.

Figure 1. Test area at NAS, Agana showing marks of aircraft touchdown.

In general, after 1 year all of the test paints were performing quite well and were in much better condition than the adjacent previously used paint, which had been in service 1-1/2 years (see Figure 3 of Reference 9). Rating totals in Table 7 were weighted so that reflectivity and retention of glass spheres (adversely affected by the improvised method of application) were less important than other properties. The three oleoresinous phenolic varnish paints (108, 109, and 110) generally performed better than the two alkyd paints, one of which (101) was in appreciably better condition than the other (A). The vinyl toluene-butadiene paint (115) had the lowest and the water-emulsion polyvinyl acetate paint (114) had the highest rating of all. Comments on the individual paints are given below:

Formulation 108, medium oil oleoresinous phenolic varnish. This paint (Figure 2) performed quite well, having good general appearance and the best reflectivity of all.

Formulation 109, long oil oleoresinous phenolic varnish. This paint (Figure 3) performed quite similarly to Formulation 108 but had slightly more cracking and less reflectivity.

Formulation 110, medium oil oleoresinous phenolic varnish with plasticizer. This paint (Figure 4) performed quite similarly to Formulation 109 but had slightly more cracking.

Formulation 101, medium oil alkyd. This paint (Figure 5) performed similarly to Formulation 110.

Formulation A, alkyd. This paint (Figure 6) lost virtually all of its glass spheres and was the dirtiest of all.

Formulation 115, vinyl toluene-butadiene. This paint (Figure 7) lost virtually all of its glass spheres and had the worst chipping and erosion of all.

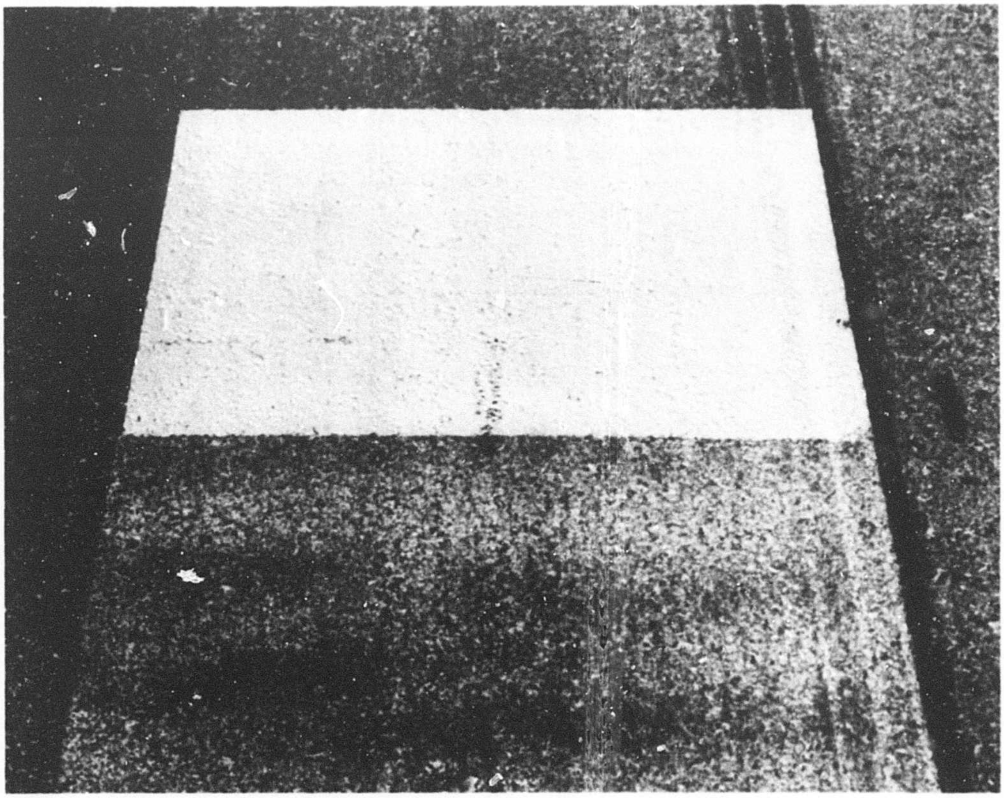

Figure 2. Test plot of Formulation 108 at NAS, Agana 1 year after application.

Table 7. Ratings of Paint Plots at NAS, Agana After 1 Year

Paint Formulation	Individual Rating for—						Weighted Total[g]
	Cracking[a]	Chipping[b]	Erosion[c]	Glass Sphere Retention[d]	Reflectivity[e]	General Appearance[f]	
108	8	8	8	4	7	8	75
109	7	8	8	4	4	8	70
110	6	8	8	4	4	8	68
101	6	8	8	4	4	8	68
A	6	8	8	0	0	3	50
115	6	6	6	0	0	5	46
114	10	10	8	7	4	5	77

[a] Cracking: 10 = none, 8 = very little, 6 = 1/3 that of old paint, 4 = 1/2 that of old paint, 2 = 2/3 that of old paint, 0 = that of old paint.

[b] Chipping: ASTM D913-51 rating (Reference 10).

[c] Erosion: ASTM D821-47 rating (Reference 11).

[d] Glass sphere retention: 10 = good, 7 = fair, 4 = poor, 0 = very poor.

[e] Reflectivity: 10 = good, 7 = fair, 4 = poor, 0 = very poor.

[f] General appearance: 10 = bright, 8 = very slightly dirty, 5 = slightly dirty, 3 = dirty, 0 = very dirty.

[g] Weighted total: 2 x cracking + 2 x chipping + 2 x erosion + glass sphere retention + reflectivity + 2 x general appearance; a high of 100 and a low of 0.

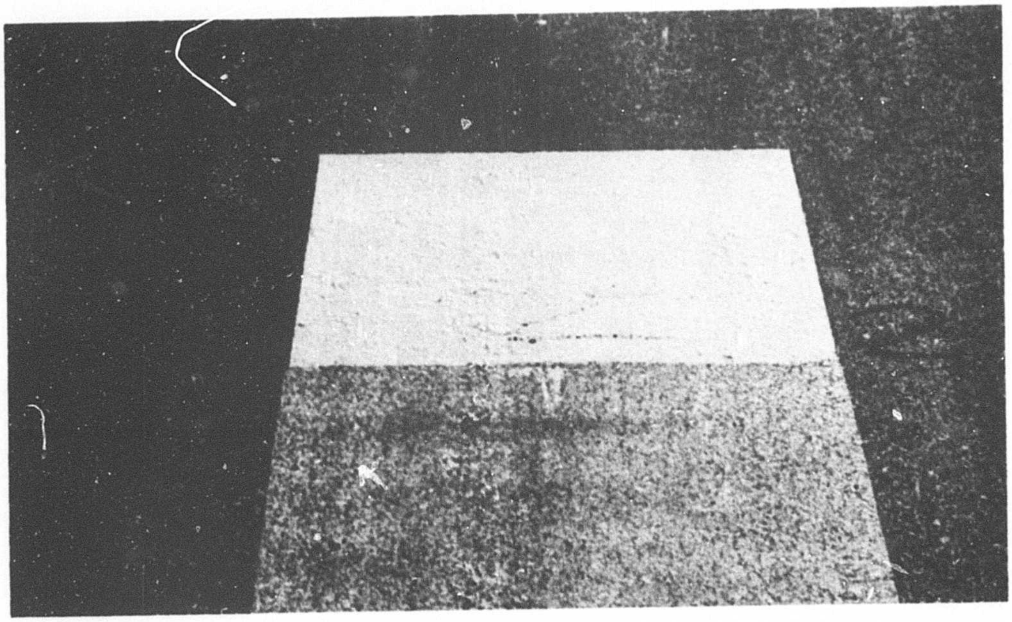

Figure 3. Test plot of Formulation 109 at NAS, Agana 1 year after application.

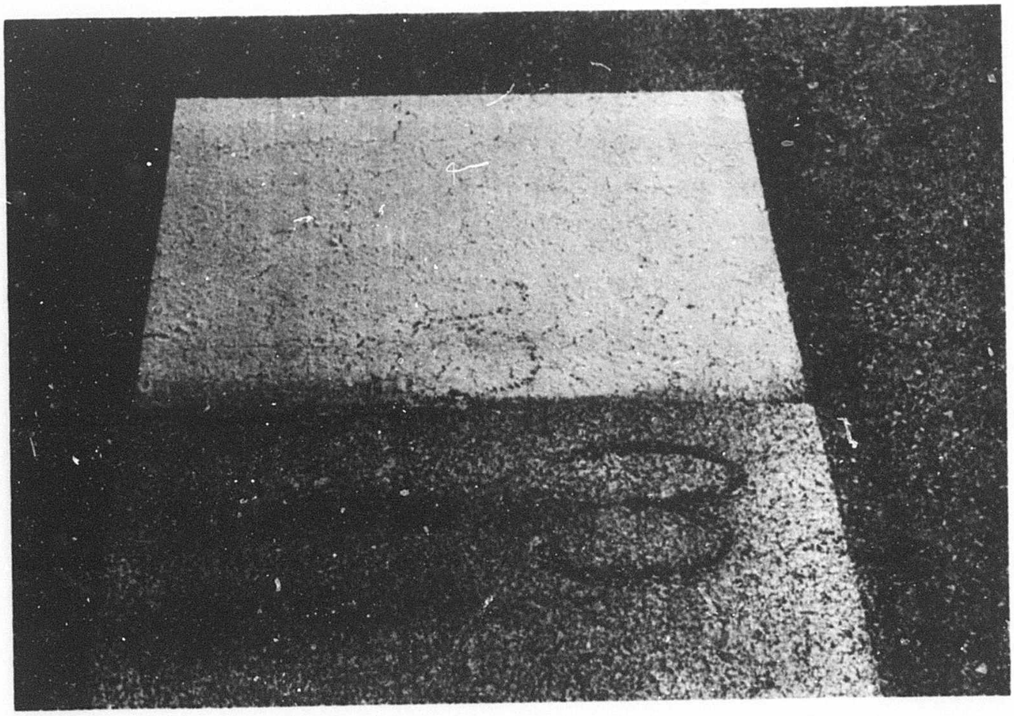

Figure 4. Test plot of Formulation 110 at NAS, Agana 1 year after application.

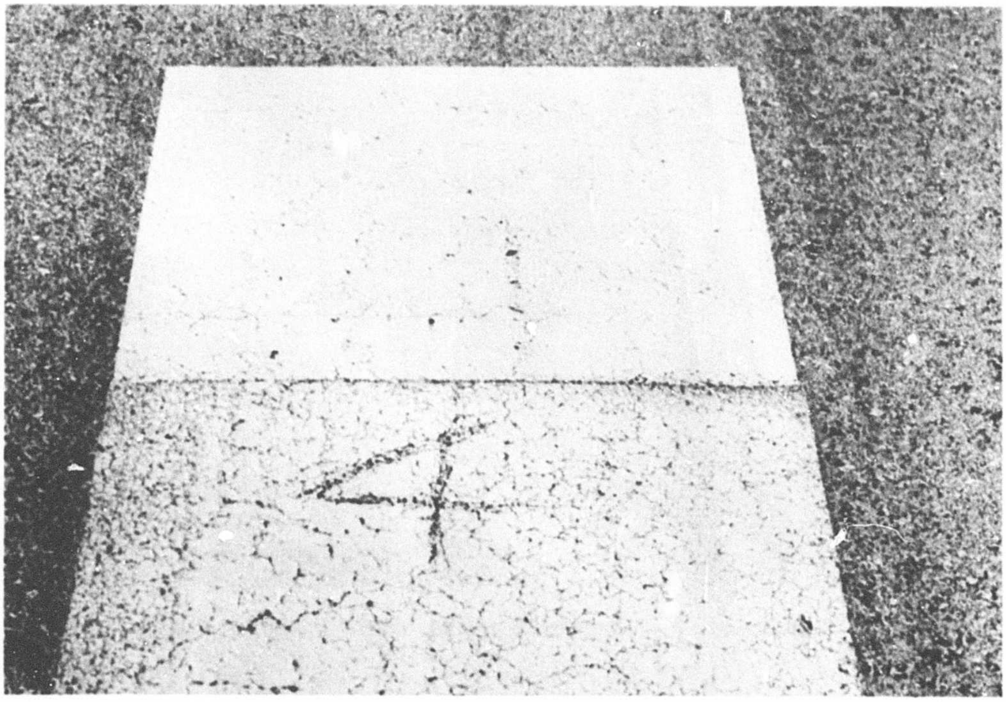

Figure 5. Test plot of Formulation 101 at NAS, Agana 1 year after application.

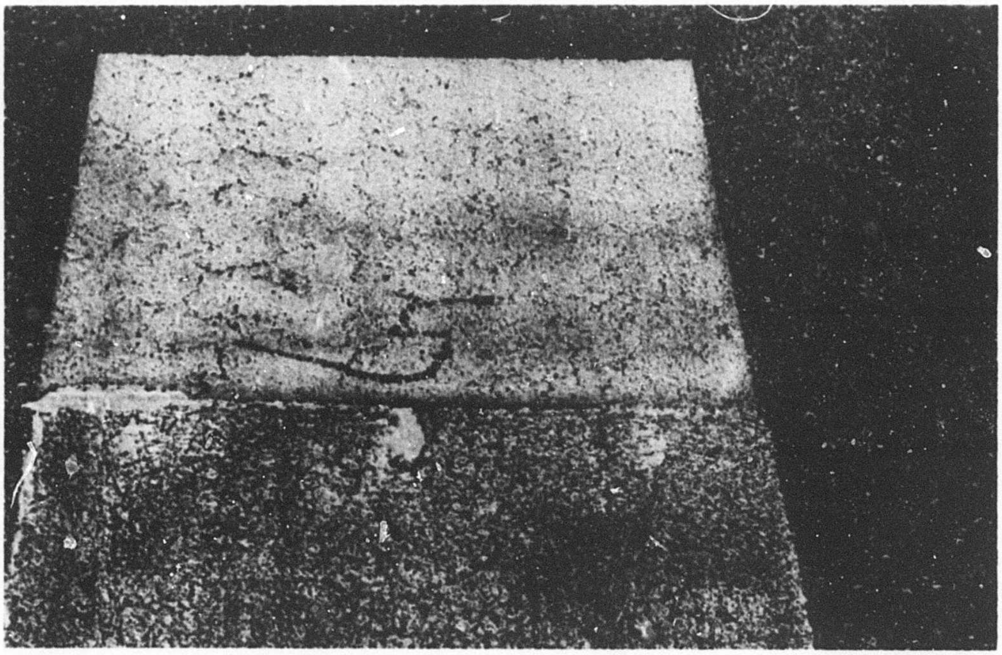

Figure 6. Test plot of Formulation A at NAS, Agana 1 year after application.

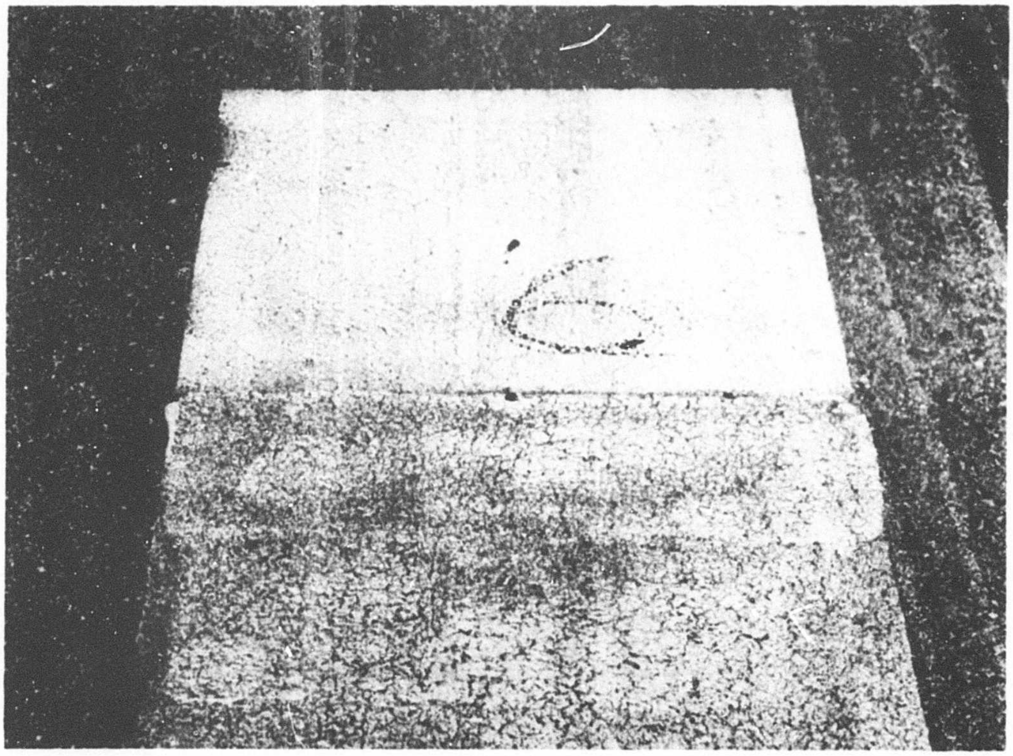

Figure 7. Test plot of Formulation 115 at NAS, Agana 1 year after application.

Formulation 114, water-emulsion polyvinyl acetate. This paint (Figure 8) had no cracking or chipping, and it had the best retention of glass spheres. Its erosion rating was as high as any of the others. Its reflectivity and general appearance ratings were probably affected more adversely by its greater touchdown of aircraft than those of the other paints.

Site at USNS, Guam. The site selected for roadway testing of marking paints at the U.S. Naval Station, Guam was on a downhill portion of Marine Drive (the main road) that had good drainage and no cause for stopping or turning. The test area was on one of the outer lanes of a four-lane portion of the asphaltic roadway with a speed limit of 35 mph, the maximum permitted at USNS, Guam. Three 4-inch-wide by 10-inch-long stripes of each of the seven test paints were applied across the lane perpendicular to the flow of traffic (Figure 9). Each of the stripes was applied at normal film thickness.* On a later day a second coat of normal film thickness was applied to one stripe of each set of three stripes. Two levels of paint thickness were used in order to determine whether chipping of the entire paint film or gradual abrasion or erosion of the surface was a more important factor in deterioration. The latter

* See Reference 9 for actual film thickness and more detailed application data.

would be expected to be proportional to paint film thickness while the former would not. The spray equipment used at NAS, Agana was also used at USNS, Guam. One of each single-thickness stripe and the second coat of each double-thickness stripe were sprinkled with glass spheres immediately after application of the paint by multiple passes.

The test stripes were rated periodically by PWC, Guam personnel and then examined and photographed by the NCEL project scientist 1 year after application. As at NAS, Agana, the unsuitable method of application had resulted in poor retention of glass spheres. There was some superficial dirt on the stripes that could be removed to a considerable degree by washing with water and a mild detergent. The seven sets were given a quick, overall ranking from best to worst, with appropriate comments, as indicated below:

Formulation 110, medium oil oleoresinous phenolic varnish with plasticizer. These stripes (Figure 10) were the cleanest and had little chipping or erosion.

Formulation 109, long oil oleoresinous phenolic varnish. These stripes (Figure 11) looked almost as good as those of Formulation 110.

Figure 8. Test plot of Formulation 114 at NAS, Agana 1 year after application.

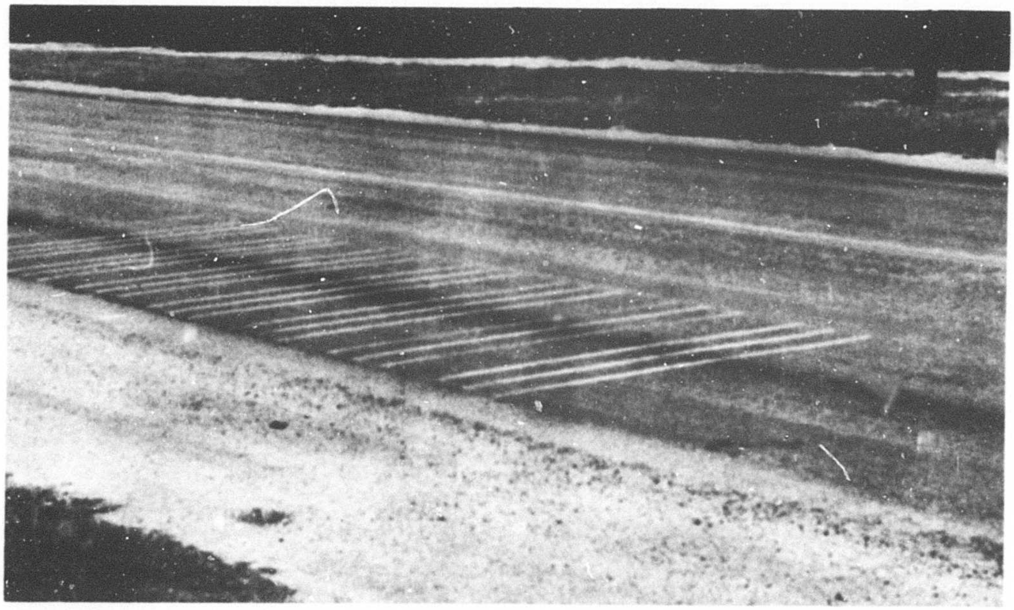

Figure 9. Roadway at USNS, Guam with the seven sets of painted stripes 1 year after application.

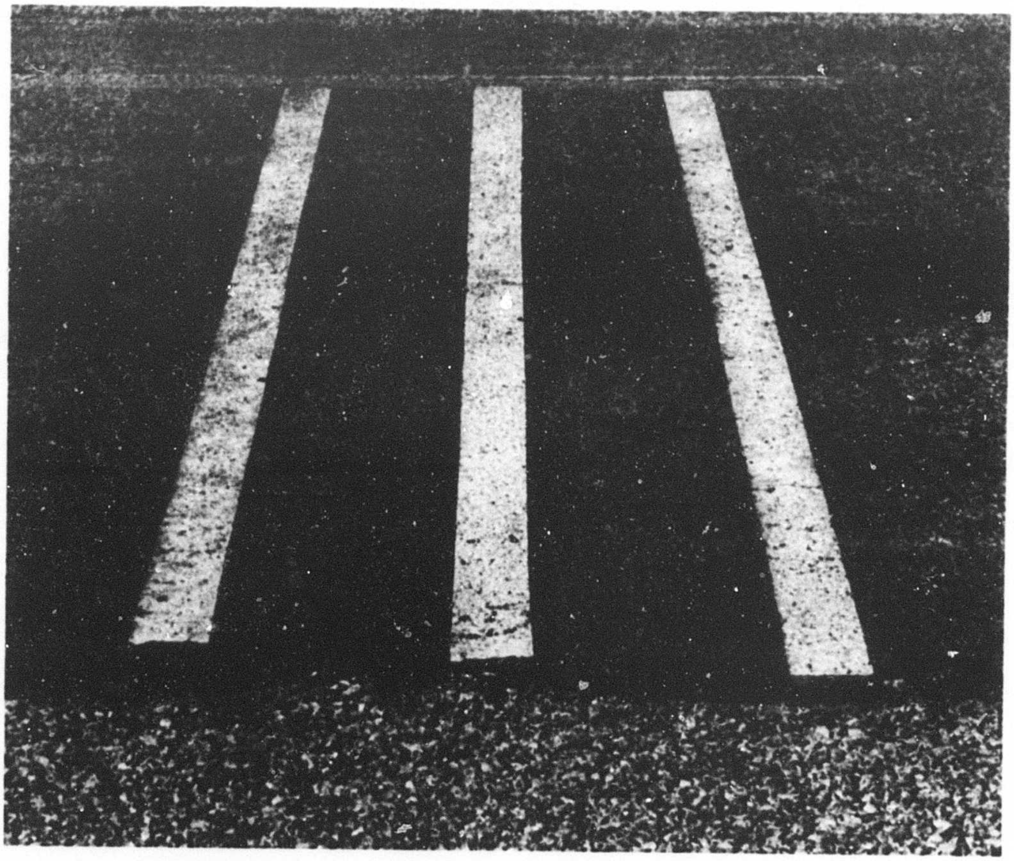

Figure 10. Set of stripes of Formulation 110 at USNS, Guam 1 year after application. Left to right: single-thickness, reflectorized; double-thickness, reflectorized; single-thickness, unreflectorized.

Figure 11. Set of stripes of Formulation 109 at USNS, Guam 1 year after application. Left to right: single-thickness, reflectorized; double-thickness, reflectorized; single-thickness, unreflectorized.

Formulation 108, medium oil oleoresinous phenolic varnish. These stripes (Figure 12) looked almost as good as those of Formulation 109.

Formulation 101, medium oil alkyd. These stripes (Figure 13) looked almost as good as those above but had slightly more cracking.

Formulation 114, water-emulsion polyvinyl acetate. These stripes (Figure 14) had the most erosion but the least chipping of all.

Formulation A, alkyd. These stripes (Figure 15) had the worst chipping of all.

Formulation 115, vinyl toluene-butadiene. These stripes (Figure 16) were very dirty and had extensive erosion.

After the initial above rating, individual properties were then rated on each of the stripes. These ratings are listed in Table 8. Overall, all seven paints performed quite well, much better than expected from the previous experiences with traffic paints at Guam. Many of the low ratings on reflectivity and appearance were due to the unsuitable method of application and to the heavy traffic encountered. Again the rating totals were weighted to lessen the factor of reflectivity. The weighted totals correlate quite well with the initial ranking. The three oleoresinous phenolic varnish formulations (108, 109, and 110) and one alkyd formulation (101) performed appreciably better than the others. The water-emulsion polyvinyl acetate formulation (114) did not place as high on the roadway stripes as on the runway plots because of its less resistance to traffic abrasion. The other alkyd formulation (A) performed relatively poorly again and the vinyl toluene-butadiene formulation (115) was rated lowest of all. Chipping contributed more than erosion to deterioration of most of the stripes, but the reverse was true for Formulation 114.

Table 8. Ratings of Paint Stripes at USNS, Guam After 1 Year

Paint Formulation	Test Stripe[a]	Individual Rating for—				Weighted Total[f]
		Chipping[b]	Erosion[c]	Reflectivity[d]	Appearance[e]	
108	T_1	6	8	–	3	51
	T_1 + B	6	8	4	3	55
	T_2 + B	6	8	4	3	55
109	T_1	6	8	–	3	51
	T_1 + B	6	8	4	3	55
	T_2 + B	6	8	4	3	55
110	T_1	6	8	–	3	51
	T_1 + B	6	8	4	5	61
	T_2 + B	6	8	4	3	55
101	T_1	6	8	–	3	51
	T_1 + B	6	8	4	3	55
	T_2 + B	6	8	4	3	55
A	T_1	4	8	–	3	45
	T_1 + B	4	8	0	3	45
	T_2 + B	4	8	0	3	45
115	T_1	6	6	–	3	45
	T_1 + B	6	6	0	0	36
	T_2 + B	6	6	0	0	36
114	T_1	8	4	–	3	45
	T_1 + B	8	6	0	3	51
	T_2 + B	8	6	0	3	51

[a] T_1 = single thickness, T_2 = double thickness, B = beads.

[b] Chipping: ASTM D913-51 rating (Reference 10).

[c] Erosion: ASTM D821-47 rating (Reference 11).

[d] Reflectivity: 10 = good, 7 = fair, 4 = poor, 0 = very poor.

[e] Appearance: 10 = bright, 8 = very slightly dirty, 5 = slightly dirty, 3 = dirty, 0 = very dirty.

[f] Weighted total: 3 x chipping + 3 x erosion + reflectivity + 3 x appearance; a high of 100 for beaded stripe and 90 for unbeaded stripe and a low of 0.

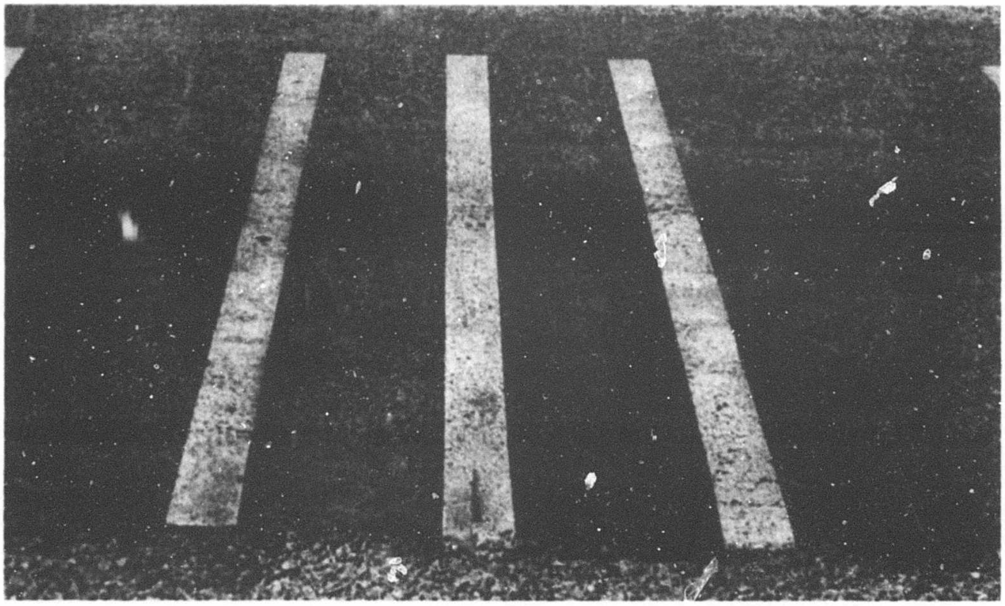

Figure 12. Set of stripes of Formulation 108 at USNS, Guam 1 year after application. Left to right: single-thickness, reflectorized; double-thickness, reflectorized; single-thickness, unreflectorized.

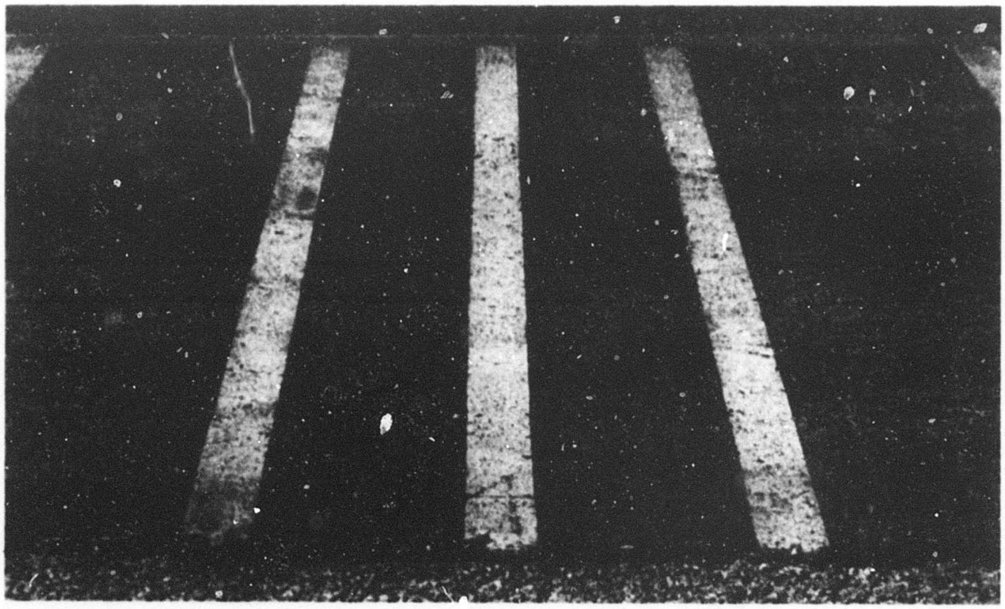

Figure 13. Set of stripes of Formulation 101 at USNS, Guam 1 year after application. Left to right: single-thickness, reflectorized; double-thickness, reflectorized; single-thickness, unreflectorized.

Figure 14. Set of stripes of Formulation 114 at USNS, Guam 1 year after application. Left to right: single-thickness, reflectorized; double-thickness, reflectorized; single-thickness, unreflectorized.

Figure 15. Set of stripes of Formulation A at USNS, Guam 1 year after application. Left to right: single-thickness, reflectorized; double-thickness, reflectorized; single-thickness, unreflectorized.

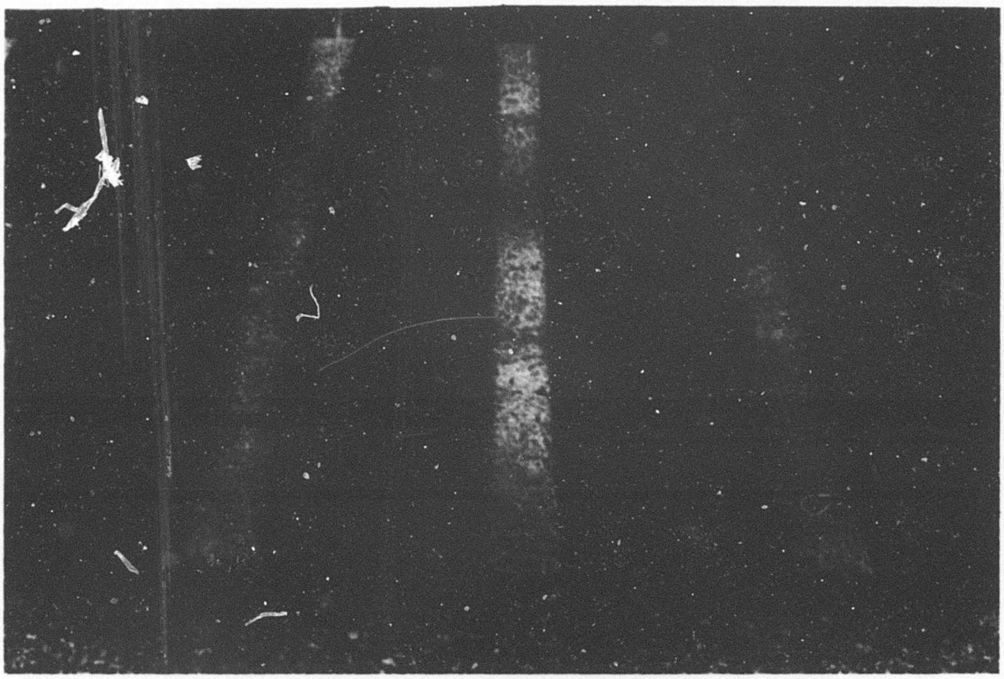

Figure 16. Set of stripes of Formulation 115 at USNS, Guam 1 year after application. Left to right: single-thickness, reflectorized; double-thickness, reflectorized; single-thickness, unreflectorized.

Runway Testing at NAS, Point Mugu

Runway 3-21 of NAS, Point Mugu was resurfaced in the summer of 1967. The overlay was placed and treated with a proprietary conditioner about 10 days prior to striping. Striping was performed by a contractor using NCEL Formulation 109. One of the centerline dashes in a touchdown area at one end of the runway was set aside for testing the other marking paints. This dash, 2 feet wide and 120 feet long, was divided into five sections, each 2 feet wide and 24 feet long. Starting from the end of the dash nearest the arresting cable and proceeding toward the ocean end of the runway, the sequence of test paints was Formulations 101, 108, 115, 110, 114. Thus, along with Formulation 109 used on the rest of the runway, all six NCEL paint formulations used in testing at Guam were also used at NAS, Point Mugu. The paint volumes, dry-film thicknesses, and other application data are reported in Reference 9.

The test sections deteriorated very slowly, but rapidly received black tire markings (Figure 17) from touchdown of aircraft. Ratings received after 8-1/2 and 26-1/2 months are listed in Table 9. The rating totals were weighted to minimize the factor of erosion, which was negligible throughout the test period. As at NAS, Agana, Formulation 114 had the highest and Formulation 115 the lowest rating totals. After 26-1/2 months the oleoresinous phenolic varnish paints (108 and 109) without plasticizer were rated slightly higher than the alkyd paint (101). The plasticized oleoresinous phenolic varnish paint (110) had deteriorated much more than these. The side line stripes (109) had less chipping than the centerline since it received no touchdown, but it had more cracking. Some resistance to cracking may have been imparted by the black rubber deposits on the centerline. Individual descriptions of the test paint sections are given below.

Table 9. Ratings of Paint Stripes at NAS, Point Mugu

Paint Formulation	Individual Rating for—					Weighted Total[f]
	Cracking[a]	Chipping[b]	Erosion[c]	Glass Sphere Retention[d]	Tire Tracking[e]	
8-1/2 Months After Application						
101	10	8	10	5	4	79
108	8	8	10	5	4	73
109C[g]	10	8	10	9	6	91
109S[g]	10	10	10	9	10	97
110	8	8	10	5	4	73
114	10	10	10	9	8	97
115	8	8	10	2-1/2	4	65-1/2
26-1/2 Months After Application						
101	4	6	10	1	2	43
108	4	4	10	5	2	49
109C[g]	6	6	10	2	2	52
109S[g]	4	10	10	2	10	58
110	4	2	10	2-1/2	2	35-1/2
114	8	10	10	9	4	91
115	4	4	10	0	2	32

[a] Cracking: 10 = virtually none, 8 = slight, 6 = moderate, 4 = extensive, 2 = very extensive, 0 = completely cracked.

[b] Chipping: ASTM D913-51 rating (Reference 10).

[c] Erosion: ASTM D821-47 rating (Reference 11).

[d] Glass sphere retention: % spheres retained divided by 10.

[e] Tire tracking: 10 = none, 8 = slight, 6 = moderate, 4 = extensive, 2 = very extensive, 0 = completely covered.

[f] Weighted total: 3 x cracking + 3 x chipping + erosion + 3 x glass sphere retention; a high of 100 and a low of 0.

[g] C = centerline, S = side line.

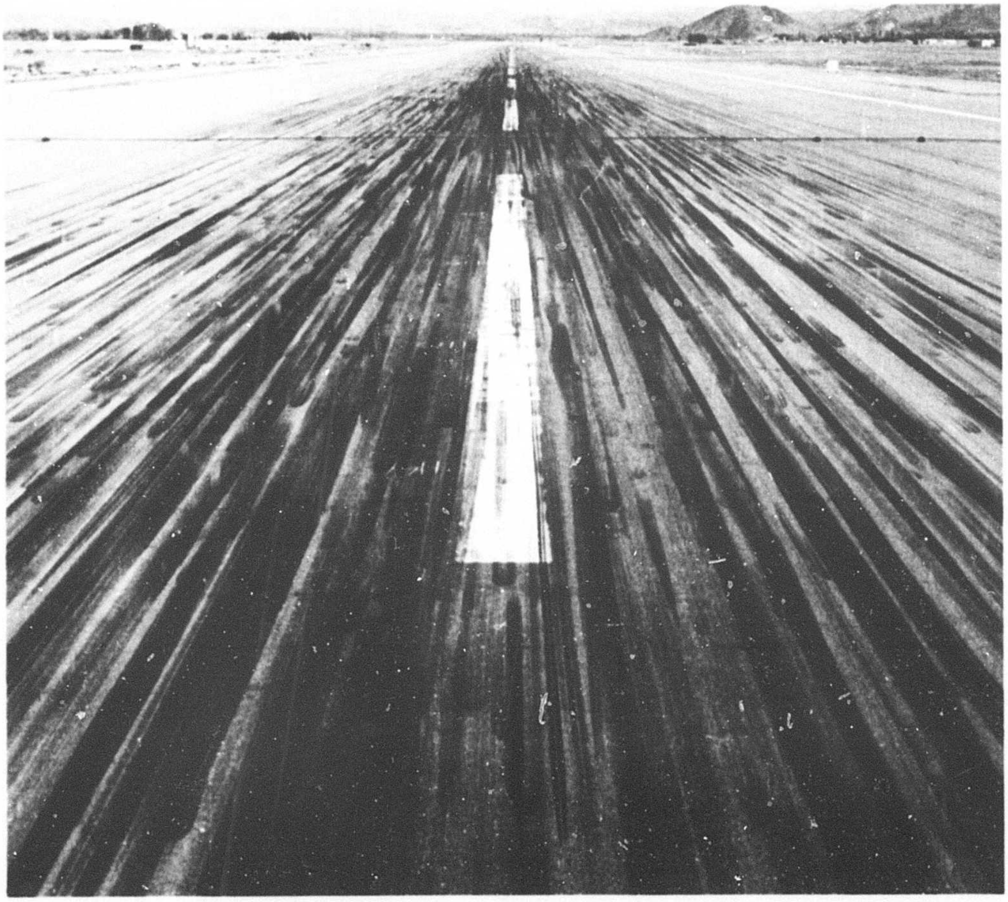

Figure 17. Sections of test paints at NAS, Point Mugu after 26-1/2 months.

Formulation 101, medium oil alkyd. This paint (Figure 18) had excessive loss of reflective spheres. It also had some localized damage from oil spillage.

Formulation 108, medium oil oleoresinous phenolic varnish. This paint (Figure 19) had relatively good retention of glass spheres and performed rather well despite appreciable chipping.

Formulation 109, long oil oleoresinous phenolic varnish. This paint performed rather well. The centerline (Figure 20) had greater chipping than the side line because of greater touchdown. The side line (Figure 21) had greater cracking than the centerline. Naturally there was no tire tracking on the side line.

Formulation 110, medium oil oleoresinous phenolic varnish with plasticizer. This paint (Figure 22) performed relatively poorly and had the most chipping of all.

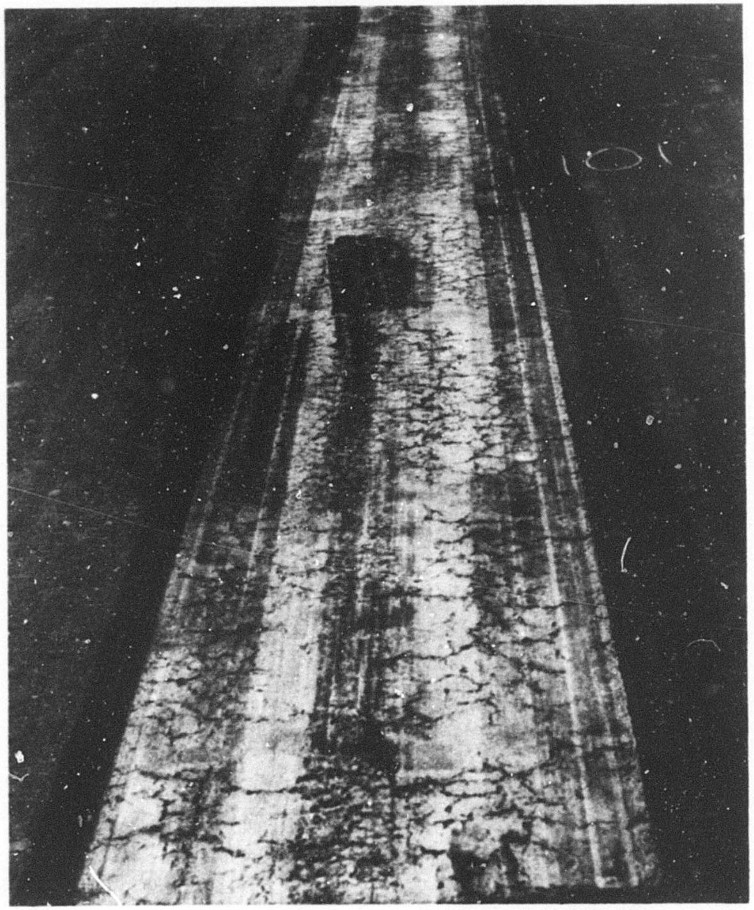

Figure 18. Formulation 101 at NAS, Point Mugu after 26-1/2 months.

Figure 19. Formulation 108 at NAS, Point Mugu after 26-1/2 months.

Figure 20. Formulation 109 on centerline at NAS, Point Mugu after 26-1/2 months.

Figure 21. Formulation 109 on side line at NAS, Point Mugu after 26-1/2 months.

Formulation 114, water-emulsion polyvinyl acetate. This paint (Figure 23) performed better and was noticeably whiter than the other test paints on the centerline throughout the 26-1/2 months of exposure.

Formulation 115, vinyl toluene-butadiene. This paint (Figure 24) performed poorest of all through 26-1/2 months of exposure with low cracking, chipping, and glass sphere retention ratings.

Miscellaneous Field Data

NCEL has been following the performance of marking paints on asphaltic runways at several military airfields, mostly in Southern California and Arizona. Because oleoresinous phenolic varnish formulations have given a more satisfactory general performance than have alkyd paints purchased under TT-P-85,[15] this type of paint was specified for use on several of these military airfields.

Oxnard Air Force Base. The runway at the Oxnard Air Force Base (now disestablished) consists of a section of portland cement concrete, a section with asphalt overlay, and a section of slurry-sealed asphaltic concrete. In the spring of 1965, the white markings along the runway were badly deteriorated, and the slurry seal underlying the recently applied alkyd paint was peeling off in sheets (Figure 25). Because of this serious problem, NCEL was contacted to examine the markings and recommend corrective action. In order to prevent recurrence of the deterioration associated with the alkyd paints, it was recommended that the old stripes be removed, the lost slurry seal be replaced, and the entire runway be striped with a medium oil length oleoresinous phenolic varnish paint conforming to TT-P-85. This action was completed in May 1965. In July 1966, the east 5,000 feet was fog-sealed to prevent further deterioration of the asphaltic surface, and the above specified paint was again applied to the markings.

The oleoresinous phenolic varnish paint performed in a most satisfactory manner. When examined in September 1967, the side line stripes were still in good condition and had retained good retroreflectivity, but the centerline required restriping due to deposition of rubber from touchdown of aircraft tires onto the paint. This was especially noticeable on the section of portland cement concrete; the black tire markings had reduced both visibility and retroreflectivity. The side line stripes on the overlay had reflection cracks (Figure 26) of the underlying portland cement concrete but showed none of the peeling associated with the previously used alkyd paint.

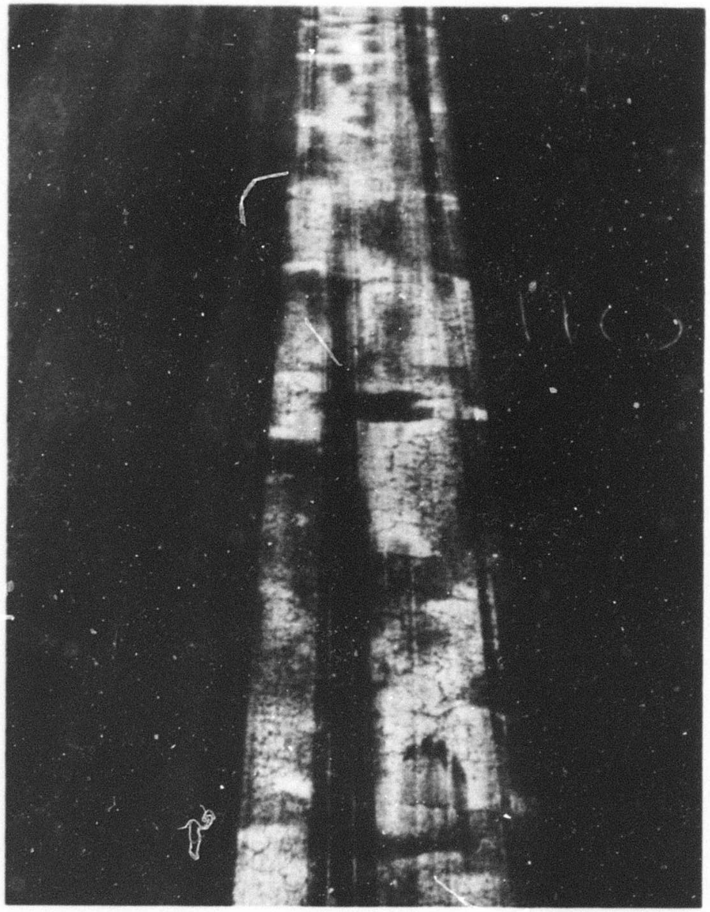

Figure 22. Formulation 110 at NAS, Point Mugu after 26-1/2 months.

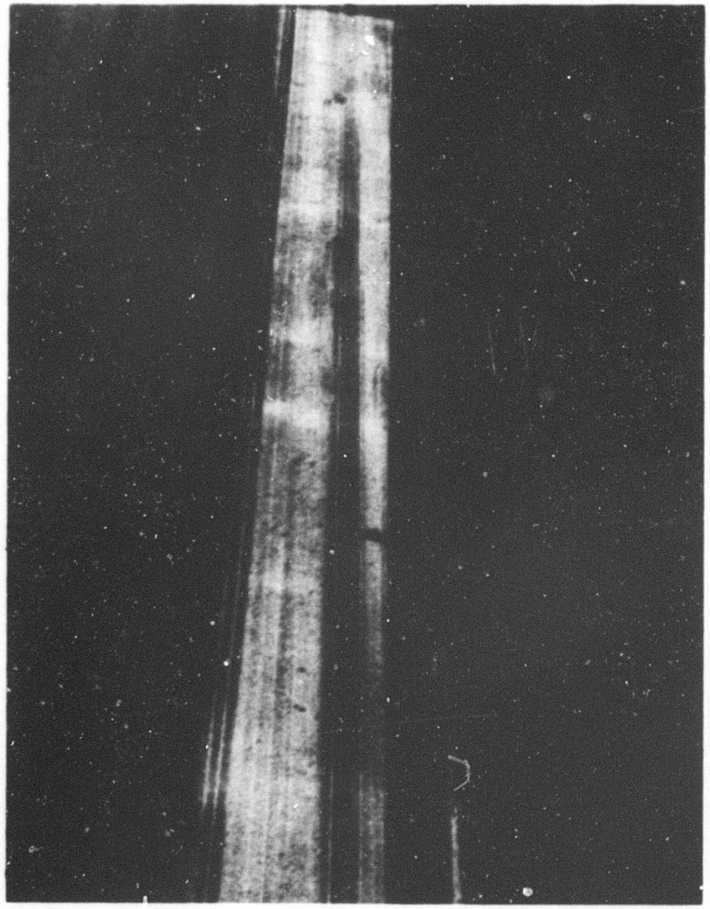

Figure 23. Formulation 114 at NAS, Point Mugu after 26-1/2 months.

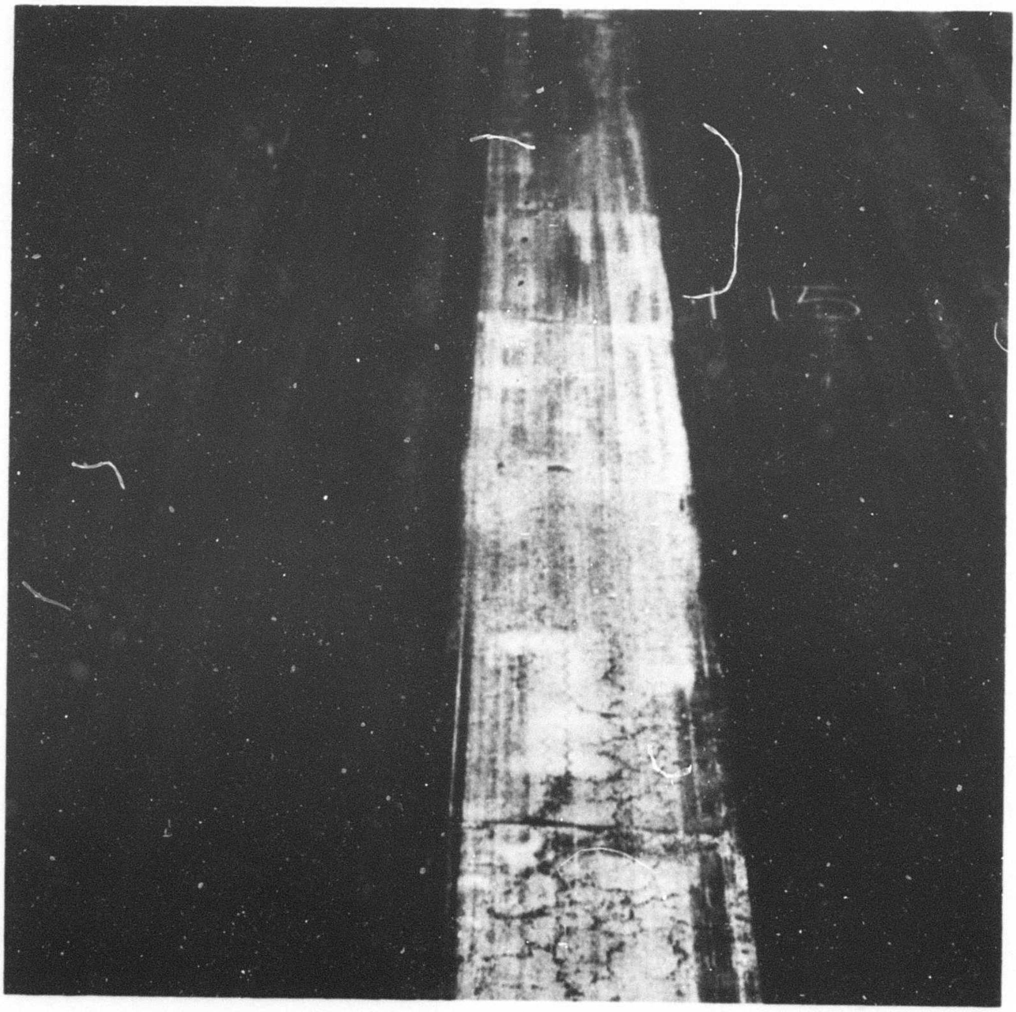

Figure 24. Formulation 115 at NAS, Point Mugu after 26-1/2 months.

The existing stripes on the runway were then overcoated with an alkyd paint conforming to TT-P-85, rather than an oleoresinous phenolic varnish paint, since restrictions limited the purchase to the federal supply system. Cracking and peeling of the paint and slurry seal on the asphaltic portion of the runway occurred as early as January 1968, and continued deterioration necessitated restriping in May 1968. Again, alkyd paint conforming to TT-P-85 was obtained for use from the federal supply system. Within 6 months after application, cracking and peeling of the paint had occurred to a significant extent. Plans were made for removal of the deteriorated paint and slurry seal, replacement of the lost slurry seal, and restriping of the entire runway with an oleoresinous phenolic varnish paint conforming to TT-P-85. These plans were postponed several times and finally abandoned when the base was scheduled for closing. When examined in December 1969, the centerline (Figure 27) was almost completely lost, and the side line stripes were in very bad condition. The condition on the asphaltic portion of the runway was much worse than that on the portland cement portion (Figure 28). When the broken pieces of the deteriorated stripings were held on edge, the alternate layers of white paint and asphalt seal (Figure 29) were readily visible. Although the original paint (oleoresinous phenolic varnish) had performed well, the two topcoats of alkyd paint had imposed sufficient additional strain on the marking that the bond between the underlying slurry seal and substrate was broken with the resultant peeling and loss of paint and slurry seal.

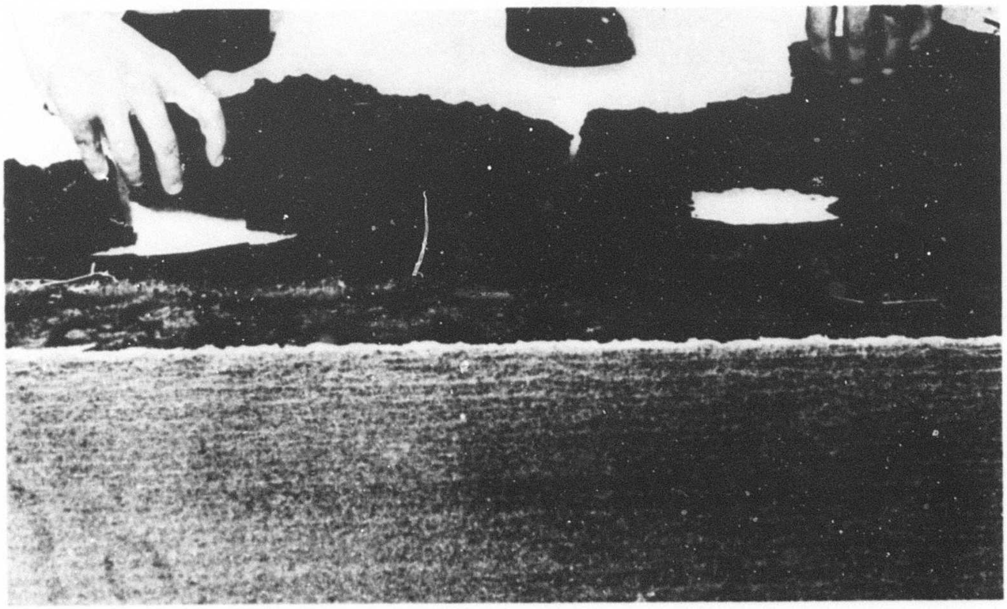

Figure 25. Peeled alkyd paint and slurry seal on side line striping of asphaltic runway at Oxnard Air Force Base, spring 1965.

NAS, Imperial Beach. NCEL was contacted in July 1966 by Southwest Division, NAVFAC, to investigate deterioration of the white marking paint and asphaltic substrate at NAS, Imperial Beach (then NAAS, Ream Field) and to recommend remedial action. The runway at NAS, Imperial Beach is used mostly by helicopters and does not have a heavy traffic of conventional aircraft. The very thin asphaltic pavement had previously been fog-sealed with cut-back asphalt, and sand had then been dropped into the wet asphalt. The runway was striped in October 1965 using a proprietary reflectorized alkyd paint reportedly conforming to TT-P-85[15] on the centerline and a proprietary unreflectorized alkyd paint reportedly conforming to TT-P-115, type I[17] on the side lines and for other markings. After a month, paint and sand seal began to crack (Figure 30) and come loose in large pieces from both the centerline and side lines. A representative of the Office of the Inspector of Naval Material inspected the runway to determine if the contractor should be required to restripe the runway because of poor paint application or inferior paint. The inspector accepted the paints as conforming to specification and attributed poor paint performance to the presence of moisture on the pavement at the time of application. Because Public Works personnel had the responsibility of determining the suitability of application conditions, the contractor was relieved of further responsibility.

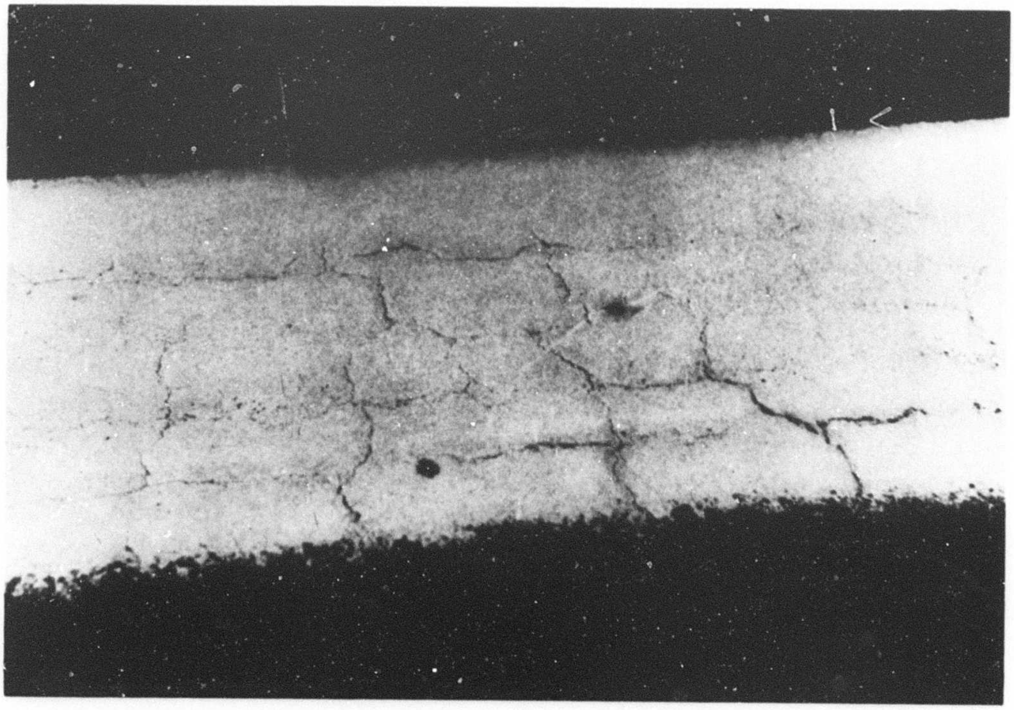

Figure 26. Oleoresinous phenolic varnish striping on side line of asphaltic runway at Oxnard Air Force Base, September 1967.

In August 1966 a paint specialist from NCEL examined the runway at NAS, Imperial Beach. The bonding of the paint to the immediate substrate was excellent, and the deterioration was attributed to (1) the poor bonding of the sand—asphalt seal to the substrate and (2) to the proprietary paints used which have a history of poor performance on slurry seal despite conformance to specification. The runway surface at NAS, Imperial Beach is very irregular with numerous bird baths present. The accumulation of rain water in these areas appeared to further accelerate the deterioration associated with the white markings. It was recommended that restriping be done with a long oil length oleoresinous phenolic varnish paint conforming to TT-P-85[15] and having a low boiling, high aromaticity solvent. Because of funding considerations, it was decided that only the loose paint and sand seal should be removed by chipping before replacement of the stripes.

Figure 27. Deteriorated centerline striping at Oxnard Air Force Base, December 1969.

In January 1967 the loose slurry seal was removed, and the runway was restriped with the recommended paint. The stripes showed little deterioration after 3 months, even where they passed through bird baths (Figure 31). After 5 months, however, there was appreciable loss of paint and slurry seal where the previous paint had not been removed before restriping (Figure 32). As was previously found at the Oxnard Air Force Base, the added strain of the topcoat had initiated cracking and peeling of paint and seal.

A new contract was let for removing the old markings, repairing and/or replacing the sand seal to extend 1 foot beyond the edges of the striping, and restriping of the runway with a long oil length oleoresinous phenolic varnish paint conforming to TT-P-85[15] and having a low boiling, high aromaticity solvent. The contract required that a sample of the marking paint be sent to NCEL for approval. The initial sample sent to NCEL was rejected when it was shown by infrared spectroscopy to be of the alkyd type, but a later sample of the specified type was subsequently approved. While the sand seal at NAS, Imperial

Beach was being repaired, a Navy representative removed a sample of the paint to be used from the contractor's truck for identification by NCEL. Infrared analysis indicated that the paint was of the alkyd type, as previously rejected. Consequently, Navy contract personnel insisted that the paint at the job site be replaced by that previously approved. The approved paint was consequently applied in an acceptable manner in the spring of 1968.

Figure 28. Deteriorated side line striping at Oxnard Air Force Base, December 1969. Note better condition of striping on portland cement concrete portion than on asphaltic portion.

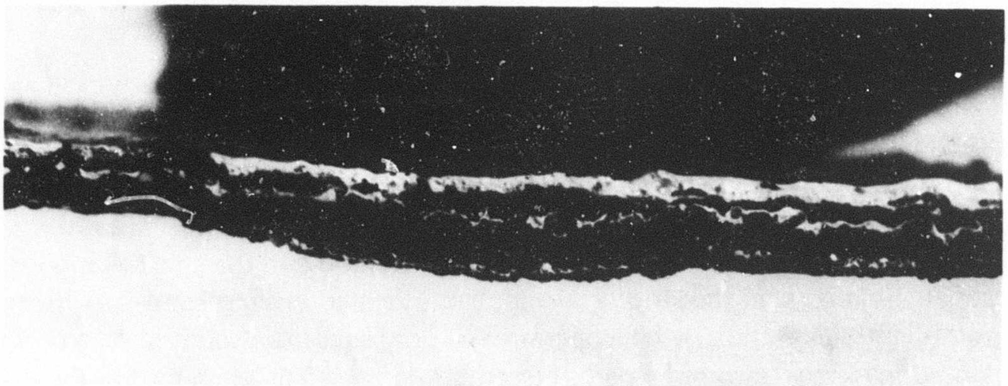

Figure 29. Edge view of peeled runway striping from Oxnard Air Force Base showing three alternate layers of paint and asphalt.

Figure 30. Airfield marking at NAS, Imperial Beach in August 1966, 10 months after striping.

The latest airfield markings have performed very well at NAS, Imperial Beach for 1-1/2 years on the centerline (Figure 33), on the side lines (Figure 34), and on the numerals identifying the runway at its extremities. There are very few cracks on the markings, no peeling of the sand seal, and excellent retention of reflectorized glass spheres. The absence of erosion and the small number of rubber tire marks on the striping are probably related in significant part to the use of light planes, mostly helicopters. The only significant deteriorations of painted markings occurred where the centerline passed through bird baths (Figure 35). The Public Works Office at NAS, Imperial Beach is quite pleased with the performance of this paint (similar to NCEL Formulation 109), especially when their past history of problems associated with airfield striping is considered.

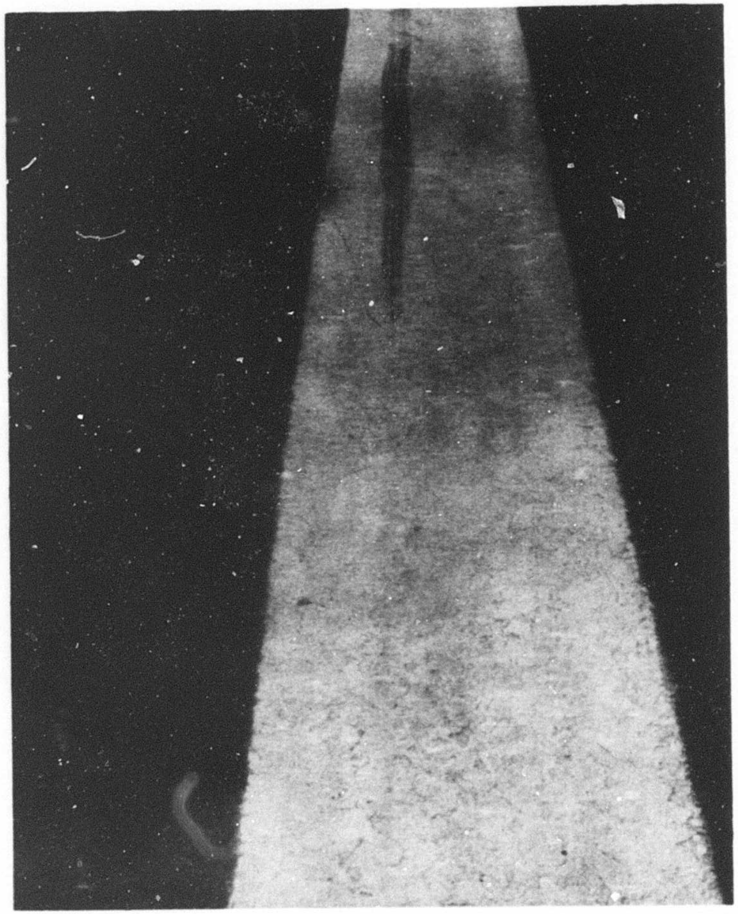

Figure 31. Restriped centerline passing through bird bath at NAS, Imperial Beach in April 1967, 3 months after restriping.

Figure 32. Restriped side line at NAS, Imperial Beach in June 1967, 5 months after restriping.

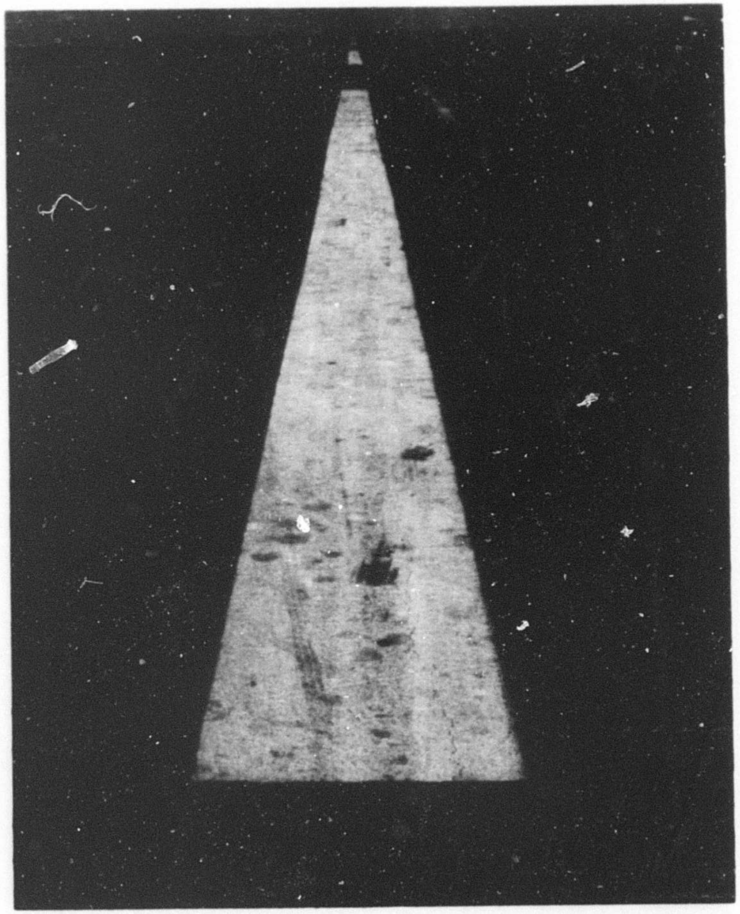

Figure 33. Side line at NAS, Imperial Beach in December 1969, 1-1/2 years after striping.

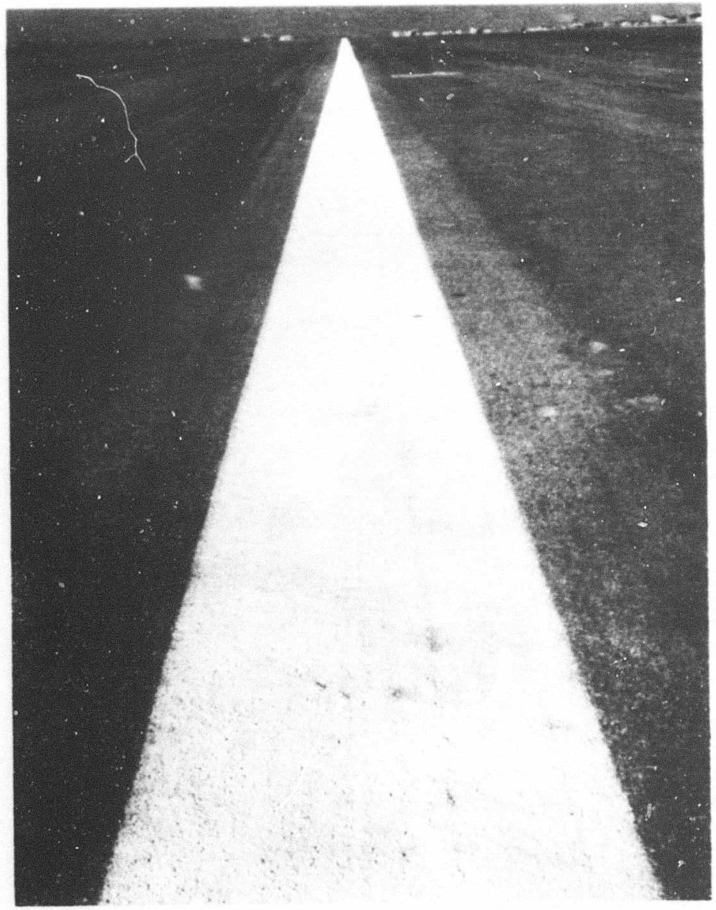

Figure 34. Side line at NAS, Imperial Beach in December 1969, 1-1/2 years after striping.

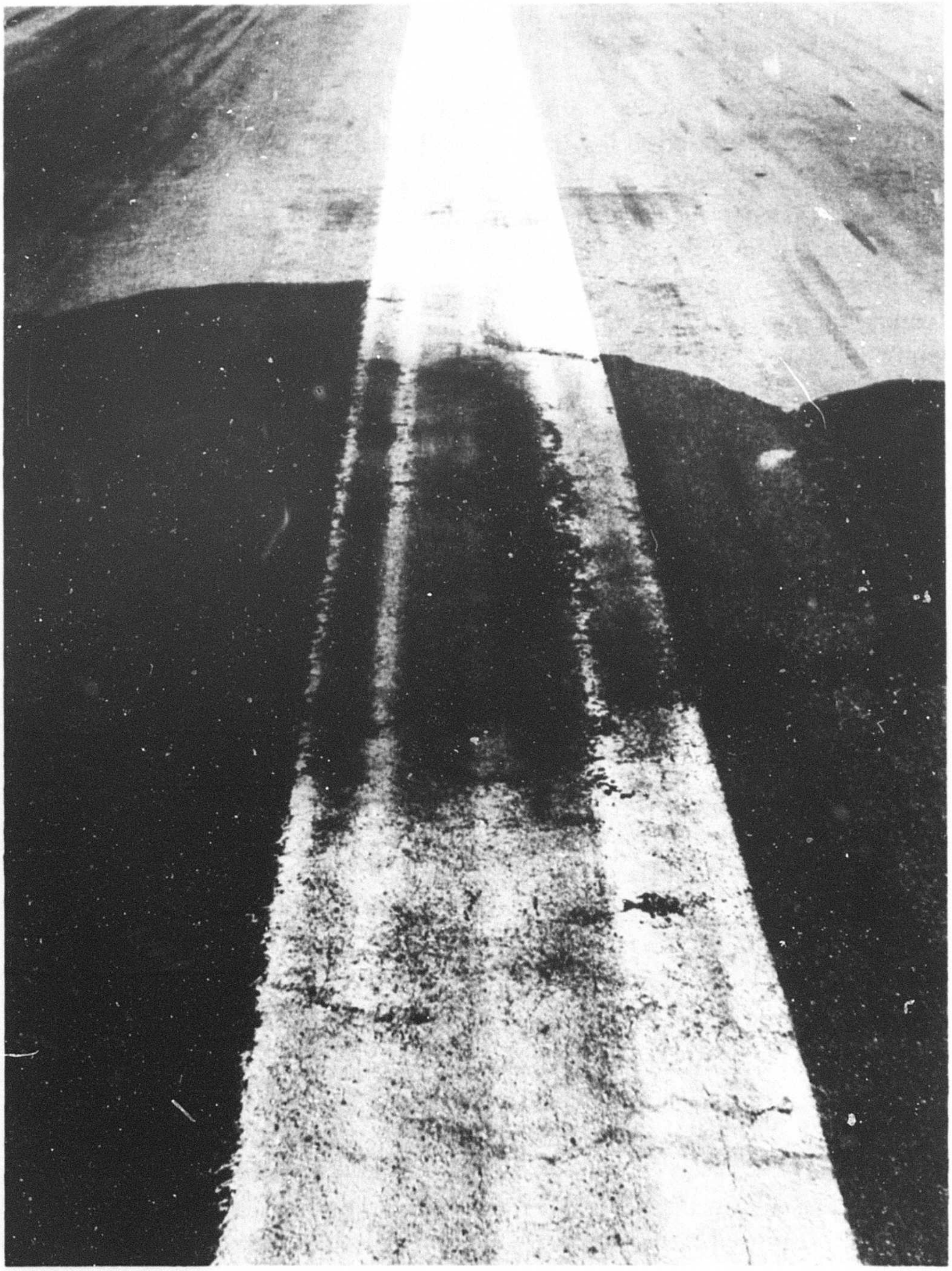

Figure 35. Paint deterioration on centerline at NAS, Imperial Beach where it passes through a bird bath.

MCAS, Yuma. MCAS, Yuma has three asphaltic runways that are used mostly for training marine pilots. Two of these have histories that merit special mention.

Runway 17-35 has a sand seal over a 1-1/2-inch asphaltic overlay. Both were constructed in the fall of 1967. Striping was accomplished by contractor in November 1967 at an estimated cost of $1,000. A white oleoresinous phenolic varnish paint conforming to TT-P-85[15] was specified on the runway. The identification numbers on the portland cement concrete pavements on the runway extremities were to be outlined in black with paint conforming to TT-P-110.[16] The contract specified that samples of the paint to be used were to be sent to NCEL for approval before application. The initial sample of white paint from the contractor's supplier was rejected because it was found to be an alkyd rather than an oleoresinous phenolic varnish paint, despite a notarized statement to the contrary. A subsequent sample from the supplier was approved for use when it was found by infrared spectroscopy to be of the required type. In February, the striping was examined by an ROICC inspector and found to be in satisfactory condition. However, deterioration proceeded rather rapidly after this and, when examined by a NCEL paint specialist in October 1968, the striping was found to be in very poor condition (Figure 36). There was extensive edge and interior cracking of the paint and underlying asphaltic substrate. The pavement had begun to peel back, exposing a depth of as much as 1/4 inch, but the chunks were usually still firmly held in place. The striping was in good condition on the portland cement concrete portion of the runway. At all locations the striping was well beaded with glass spheres for retroreflectivity. A portion of the deteriorated paint was removed and identified by infrared spectroscopy by both NCEL and a private laboratory as being of the alkyd type that was initially rejected. Because of this discrepancy, the contractor was required to remove the deteriorated striping, repair the damaged pavement, and replace the striping with the specified paint, all at his expense.

Runway 8-26 also has a sand seal over a 1-1/2-inch asphaltic overlay. Both were constructed in the summer of 1967. Again, the striping contract called for a white oleoresinous phenolic varnish paint conforming to TT-P-85.[15] The striping was accomplished at the risk of the contractor* before the samples were approved by NCEL. When the paint was subsequently shown by infrared spectroscopy at NCEL to be of the alkyd type rather than the oleoresinous phenolic varnish type, a credit of $395 was given by the contractor to MCAS, Yuma. The painted stripings on Runway 8-26 were in reasonably good condition when examined in October 1968 by an NCEL paint specialist. There was, however, a long crack in the striping, parallel to the direction of the striping (Figure 37).

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* Different from the one who striped Runway 17-35.

This appeared to be due to a seam in the underlying pavement, and there was no peeling associated with the cracking. The glass spheres that had been dropped into the wet paint to impart retroreflectivity were concentrated in the center one-third of the striping with very few, if any, occurring in the outer sections.

Asphaltic parking areas were constructed in 1969 at the gymnasium and chapel at MCAS, Yuma. For these areas, striping paint was applied by the contractor 38 and 87 days, respectively, after installation. The contractor reportedly used an alkyd paint conforming to TT-P-115, type I. Within 2 to 4 months after striping, there was extensive deterioration of the painted markings and the underlying asphalt (Figure 38). The contractor attributed the damage to an incompatibility of the asphalt pavement and the alkyd paint, referring to previous problems on Runway 17-35. An analysis of the paint used was made by NCEL in order to determine the cause of the extremely premature failure. The analysis, shown in Table 10, indicated that the damage was associated with the great deviation of the paint from the specification requirements—notably the great deficiency in percent nonvolatile vehicle and the great excess of thinner. This resulted in extremely poor paint flexibility. In light of the vehicle composition, the high viscosity must be attributed to heavy loading with absorbent filler pigments and/or excessive bodying of the resin.

Table 10. Analysis of Parking Lot Paint Used at MCAS, Yuma

Test	Requirement for TT-P-115, type I	Specimen
Weight per gallon (lb)	12.6 min	10.6[a]
Total solids (% by wt)	–	67.4
Pigment (% by wt)	61 to 63	59.1[a]
Nonvolatile vehicle (% by veh wt)	42 min	20.3[a]
Total thinner (% by veh wt)	58 max	79.7[a]
Consistency (Krebs units)	70 to 80	89[a]
Resin identification	alkyd	alkyd
Thinner identification	V, M, & P naphtha	V, M, & P naphtha
Boiling range of thinner:		
50% distilled (°F)	293 max	275
75% distilled (°F)	320 max	285
95% distilled (°F)	374 max	325
Flexibility	no cracking	cracked[a]

[a] Failed test.

Figure 36. Deteriorated side line striping on Runway 17-35, MCAS, Yuma, in October 1968.

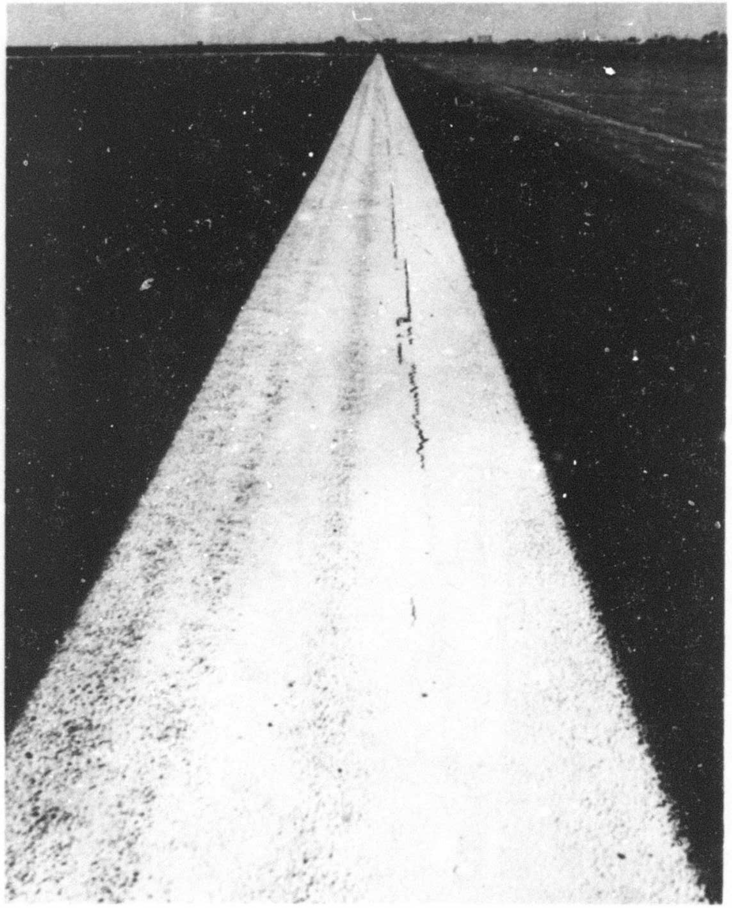

Figure 37. Striping on Runway 8-26, MCAS, Yuma, in October 1968. Note long crack parallel to direction of striping.

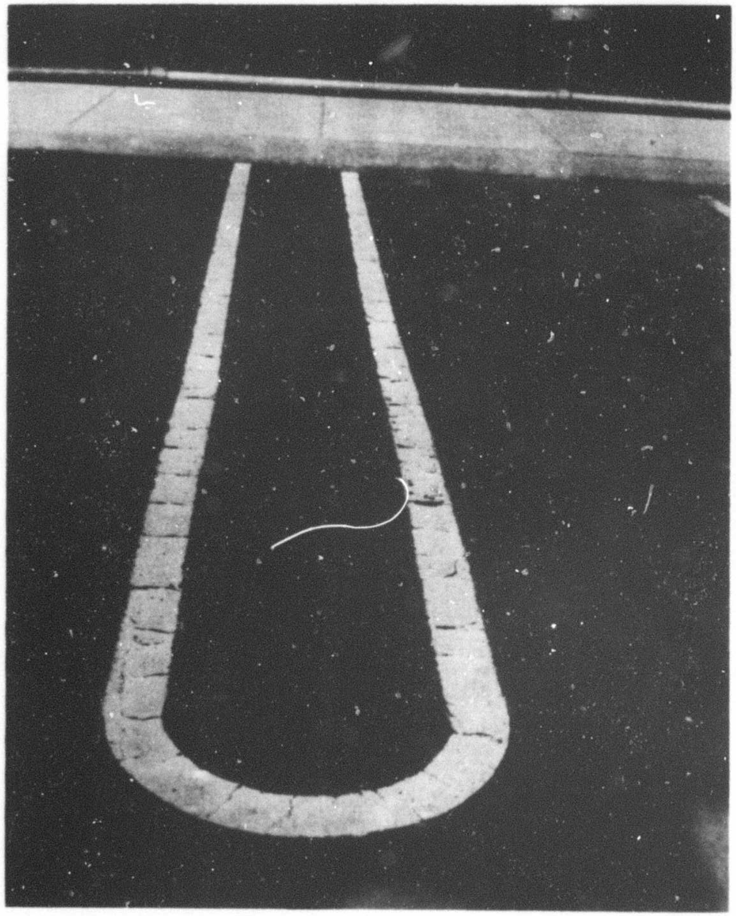

Figure 38. Deteriorated painted marking and underlying asphaltic substrate in parking lot at MCAS, Yuma.

Naval Facility, San Nicolas Island. The Naval Facility, San Nicolas Island* 10,000-foot asphaltic runway (12-30) was examined in November 1968 to determine the condition of the striping and to suggest remedial action. The side line markings had cracking, chipping, and peeling of paint and asphaltic substrate (Figure 39). The centerline was even worse; aircraft traffic had resulted in extensive chipping and tire tracking in addition to the type of deterioration found on the side line markings. The asphaltic runway itself was in poor condition with considerable amounts of exposed aggregate. Thus a resealing of the surface of the entire runway was recommended before its restriping. Despite its use by regularly scheduled aircraft, the remoteness of the installation from more active parts of the complex may in good part account for the run-down condition of the runway.

Figure 39. Deteriorated side line striping on asphaltic Runway 12-30 at San Nicolas Island.

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* Part of the Naval Missile Range, Point Mugu complex.

NAS, Key West. NAS, Key West has some coal tar slurry-sealed asphaltic helicopter pads. The asphaltic concrete has a thickness of 1-1/2 inches and the coal tar slurry seal a thickness of 1/8 to 3/16 inch. Coal tar rather than asphaltic slurry sealing was used in order to render the surface more resistant to degradation by spilled fuel. The slurry was applied 21 days after the asphaltic concrete, and a marking paint conforming to TT-P-85 and reflectorized glass spheres were applied 24 hours later. The white paint immediately discolored to a tan from bleed-through of coal tar. Consequently, the discolored paint was allowed to weather for 60 days, cleaned with a solution of "Bearcat Industrial Detergent," rinsed with freshwater, and dried overnight prior to application of a second coat of the TT-P-85 paint previously used. Although no bleeding was noted, shortly after application there was extensive cracking and peeling of both paint and underlying slurry seal.

Samples of both the wet paint and the peeled paint and slurry seal were forwarded to NCEL for analysis, determination of causes of observed failure, and recommended remedial action. Analysis showed the weathered paint to be of the alkyd type. Its dry-film thickness was excessive (as high as 30 mils) and the range of thickness varied widely. An analysis of the wet paint is given in Table 11. The bleeding of the initial paint was caused by the paint solvent carrying coal tar to the surface of the paint film. It should be noted that the 24-hour period between application of the slurry seal and application of the marking paint did not permit the more volatile components of the coal tar to be lost by curing. Also, marking paints are reported by their suppliers to be especially susceptible to bleeding when applied over a coal tar surface. The cracking and peeling that occurred after application of the second coat was no doubt accelerated by the excessive film thickness. Also, when the paint was checked for flexibility by bending over a conical mandrel, it barely passed the test.

A 1-gallon sample of Formulation 114 was sent to NAS, Key West for testing on the helicopter pads. It was applied to test areas in May 1969, and no bleeding or other deterioration was noted 10 months later. It is rather interesting that the large concentrations of marine birds that formerly inhabited the apron have not returned since application of the coal tar slurry seal.

OLF Spencer, Pensacola, Florida. Painted markings on the asphaltic runway at Outlying Landing Field Spencer, Pensacola, Florida, had excessive cracking and spalling of paint and underlying asphaltic concrete. Two samples of the deteriorated marking were sent to NCEL for analysis, determination of cause of failure, and recommended remedial action. Analysis showed the paint to be of the alkyd type and the dry-film thickness to be about 18 mils. No bleeding of asphalt through the paint was observed, nor were any reflectorized spheres or granules in evidence. It was concluded that the excessive dry-film thickness (more than twice the usual 7 to 8 mils) probably contributed significantly to the observed deterioration. It was recommended that the deteriorated striping be removed by sandblasting or scraping, that the scraped area be reslurry sealed, and that the striping paint be applied at the rate specified in TT-P-85.

Table 11. Analysis of Marking Paint Used at NAS, Key West

Test	Specimen	Requirement for TT-P-85
Weight per gallon (lb)	12.2	11.5 min
Total solids (% by wt)	76.0	67.0 to 77.5
Nonvolatile vehicle (% by veh wt)	40.7	38 to 44
Identification of nonvolatile vehicle	alkyd	none
Viscosity (Krebs units)	74	65 to 80
Flexibility	conformed	conform
Condition in container	good	good
Solvent distilling below 240°F (% by wt)	100	none[a]
Identification of solvent	saturated hydrocarbons	none[b]

[a] It is desirable that at least 80% distill below 240°F.

[b] It is desirable that hydrocarbon solvent of alkyd paints be saturated.

NAS, Albany, Georgia. The portland cement taxiway at NAS, Albany, Georgia, had heavy flaking of the painted markings. Samples of peeled paint from both ends of the runway were sent to NCEL for analysis, determination of the cause of failure, and suggested remedial action. Analysis showed that the paint was of the alkyd type and had a dry-film thickness of about 50 mils. There have been very few reported instances of premature marking paint failure on portland cement pavements; therefore, that at Albany was attributed to the extremely excessive thickness. It was recommended that the deteriorated paint be removed by scraping or sandblasting and be replaced at the specified thickness.

LABORATORY TESTING OF WATER-EMULSION PAINTS

Because of the outstanding performance of Formulation 114 in field tests and because of the interest expressed by Gulf Division, NAVFAC, in a proprietary water-emulsion traffic paint, some laboratory comparisons were made of these and two federal specification paints of similar generic types which were not intended for use as marking paints. Such water-emulsion paints have excellent flexibility, ease of application, and drying time, but there is a question of their durability under traffic. Thus in addition to the usual analyses, they were tested for washability, scrub resistance, and abrasion resistance. The test results are shown in Table 12. The composition of the proprietary product* was such that it did not meet the minimum weight per gallon and total solids requirements of TT-P-19. On the other hand, Formulation 114 greatly exceeded the minimum weight per gallon and total solids requirements of both TT-P-19 and TT-P-55. As suggested earlier, all four of the emulsion paints had extremely good elongation, much greater than that of the alkyd and oleoresinous phenolic varnish paints tested earlier.[9] The washability test data obtained from specular gloss measurements correlated very poorly with visual observations. The soiled paints remained dirty after scrubbing but had polished, glossy surfaces. The washability test data obtained from reflectance measurements correlated well with visual observations. It is interesting that the two federal specification paints gave better washability results, when measured by reflectance, than did the two marking paints. The results of the scrub resistance test were quite variable and consequently not believed to be reliable. The alkyd and oleoresinous paints previously tested[9] had much greater resistance to scrubbing. The abrasion resistance of these paints, however, was comparable to that of the four water-emulsion paints. Small patches of the water-emulsion paints showed no bleeding when applied to slurry-sealed asphalt. The appearance of these patches remained quite good for a period of 1 year in an area of limited traffic. Use of water-emulsion marking paints on runways appears to be well justified, but specification requirements and testing procedures must be established before they can be widely used.

DESIRABLE PROPERTY AND TEST REQUIREMENTS

The continued updating of paint specifications reflects both the increased knowledge in methods of improving formulations and test procedures and the changes in material requirements, such as conformance to new air pollution control standards. The test data presented in earlier sections of this report suggest criteria for obtaining marking paints of superior quality. Thus a consideration of desirable property and test requirements seems most appropriate.

* Proprietary identification is available to U.S. governmental agencies upon request.

Table 12. Laboratory Testing of Water-Emulsion Paints

Test	Test Paint					
	Acrylic Type			Polyvinyl Acetate Type		
	TT-P-19 Requirement	Proprietary Specimen	Federal Specification Specimen	TT-P-55, Type II Requirement	Formulation 114 Specimen	Federal Specification Specimen
Weight per gallon (lb)	11 min	10.7	11.8	11.0 min	11.8	11.1
Viscosity (Krebs units)	65 to 86	82	79	68 to 82	77	79
Total solids (% by wt)	56 min	50.3	57.7	50 min	59.3	50.5
Pigment (% by wt)	38 max	18.8	37.8	32 max	38.0	33.4
Elongation[a] (%)	–	12.04	11.17	–	12.84	11.60
Washability[b] (% difference)						
Specular gloss	–	-1	-1	–	-1.5	-1
Reflectance	–	-20.9	-15.6	–	-40.7	-11.7
Scrub resistance[c] (strokes to failure)	–	275	525	–	85	160
Abrasion resistance[d] (mils per 1,000 cycles)	–	1.70	2.19	–	1.60	1.59

[a] Flexibility (percent elongation): Method 6222 of Reference 23.

[b] Washability of paints: Method 6141 of Reference 23.

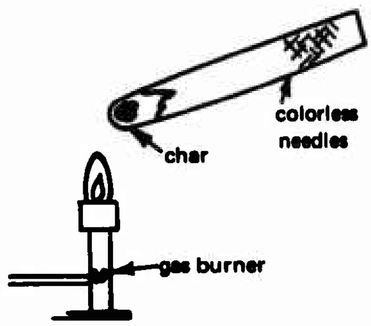
[c] Scrub resistance: Method 6142 of Reference 23.

[d] Abrasion resistance (Taber Abraser): Method 6192 of Reference 23 using 750g load.

Generic Type

While TT-P-85 does not have a requirement that a paint be of a specific generic type, there may be occasions when a paint of a particular generic type will be desired. Identification of wet paints as to generic type generally presents no difficulty if one has access to an infrared spectrometer. A compilation[24] of infrared spectra of paints, coatings, and polymers is available for reference. More often someone in the field without any available laboratory services would like to quickly verify the identity of a paint he has on hand. He might even wish to identify a weathered marking paint in order to determine cause of failure, compatibility of a topcoat, etc. NCEL has developed such a field test for identifying an alkyd paint. A simple test tube experiment in which colorless crystals either form or not upon heating is used to determine whether the weathered sample is of the alkyd type. This test can also be used on a wet paint, but first it is necessary to let some of the paint dry on a glass plate or other substrate from which it can be scraped after the solvent has completely evaporated.

A sample of the paint to be tested is placed in a Pyrex test tube. The test tube is held with a clamp, and the tube's bottom is heated until the paint chars and pyrolyzes (decomposes with heat). If the paint is an alkyd, colorless, needle-shaped crystals will form on the upper, cooler portion of the test tube. Infrared spectroscopy has shown that the crystals are liberated from the phthalic anhydride used in the resin portion of virtually all alkyd paints.



Small amounts of wood, metal, or concrete adhering to the weathered paint will not interfere with the test. If asphalt is adhering to the paint, it should be shaken with a portion of aromatic hydrocarbon (for example, toluene or xylene) or chlorinated hydrocarbon (for example, trichloroethylene) which will dissolve most of the asphalt and leave the paint unaffected. Care should be taken that the solvent vapors are not breathed or that the solvent is not in prolonged contact with the skin.

Chlorinated Rubber

Chlorinated rubber is frequently used in marking paints (for example, TT-P-115, type III). Its presence in such paints can readily be determined in the field by a simple Beilstein test[25] for organic compounds containing halogen (for example, chlorine, bromine, and iodine). The end of a piece of copper wire is bent into a loop and heated in a gas flame until the flame is no longer colored. The wire is then cooled and either is dipped into a sample of the paint or a piece of the weathered paint is placed on the loop. The loop is then heated in the edge of a gas flame. A green-colored flame gives a positive test.

The green color is produced by copper halide that forms through the decomposition of the organic binder. Although other materials may give a positive Beilstein test, they are not ordinarily found in paints. Since the test is very sensitive, a negative test (no green color) rules out the possibility of the paint containing any appreciable quantity of chlorinated rubber.

Flexibility

Flexibility (percent elongation) is among the most important properties of a marking paint, especially one to be used on an asphaltic pavement. If the paint film cannot accept the stresses arising from curing and differential expansion and contraction, cracking will occur. Paints containing drying oils or other vehicle components that form cross-linked bonds on prolonged curing or weathering tend to lose flexibility with aging. Chlorinated rubber, frequently used in marking paints to reduce drying time, generally reduces paint flexibility unless care is taken in the formulation to use chlorinated paraffin, chlorinated biphenyl, or some other type of plasticizer to ensure adequate flexibility. Federal Specifications TT-P-85[15] and TT-P-115[17] have somewhat similar testing procedures for determining adequate flexibility. A film of paint, 5 mils in wet-film thickness,* is applied to a tin panel, dried at a specified temperature, and then oven baked at an elevated temperature to achieve full curing of the paint. According to both specifications the test panel is then bent over a 1/2-inch-diameter mandrel (rod), and the paint is checked for cracking, flaking, or loss of adhesion. By using a conical mandrel, as described in Method 6222 of Federal Test Method Standard Number 141A[23] and in ASTM Standard D522-60,[26] instead of a cylincrical mandrel, as described in Method 6221, a quantitative measure of percent elongation can be obtained from a single operation. A comparison of these methods was made in Reference 7. Matsui and Drisko[7] also investigated a free-film method of determining paint elongation; they found it to be more precise than the methods using a mandrel and to have a wider range of values. Percent elongation values of paints determined by this method correlated very well with field performance. Tensile strength of the paint can also be determined by the free-film method.

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* It should be noted that the thickness of these specimens is less than half that applied in the field, and the cured product is somewhat different chemically from that obtained from slower, natural curing in the field.

Oil Length

Flexibility (percent elongation) of traffic paints is directly related to oil length which is defined[14] as "gallons of oil reacted with 100 pounds of resin." Therefore, drying time is inversely related to oil length. Thus short oil formulations dry more rapidly than long oil formulations and form a harder, less flexible film; long oil formulations, conversely, dry more slowly but have greater flexibility and better exterior durability. For alkyd formulations the oil length is best defined in terms of percent phthalic anhydride. Table 13 lists the criteria for short, medium, and long oil lengths. For a marking paint, long oil length is desirable in that it imparts good flexibility (percent elongation). On a highway, however, a short drying time requirement shortens the optimum oil length. An airfield runway is somewhat different in that striping generally requires shutting down the runway for most of a day, and a little extra drying time would only very slightly increase the time that the runway is out of service.

Table 13. Oil Lengths of Paints

Oil Length	Alkyd[a] (% phthalic anhydride)	Varnish[b] (gal oil/100 lb resin)
Short	40 to 50	below 15
Medium	30 to 40	15 to 30
Long	20 to 30	above 30

[a] Taken from Reference 27, page 280.
[b] Taken from Reference 19, page 6.

Oil length of alkyd paints is relatively easily determined by analyzing for phthalic anhydride by Methods 7021, 7022, or 7025 of Federal Test Method Standard 141A[23] or similar ASTM Methods D563-52,[28] D1306-56,[29] and D1307-56.[30] For oleoresinous phenolic varnish paints it is much more difficult to determine oil length, and presently there is no standard procedure. A number of physical measurements (for example, refractive index) were recorded for short, medium, and long oil oleoresinous phenolic varnish marking paints, but the differences were too small to be useful as a measure of oil length.

Most available oleoresinous phenolic varnish paints consist of some combination of the following nonvolatile vehicle ingredients: phenolic resin (modified or unmodified), ester gum, linseed oil, tung oil, and dehydrated castor oil. Of these, only ester gum and dehydrated castor oil have components that have naturally occurring asymmetric carbon atoms necessary for imparting optical activity. Ester gum is the glycerol ester of rosin (largely abietic acid), and dehydrated castor oil contains residual ricinoleic acid, the only naturally occurring optically active fatty acid found to any appreciable extent. The optical activities of these two materials and three marking paint resins were measured; the results are shown in Table 14.

Table 14. Optical Activity of Paint Components

Material Tested	$[\alpha]_D^{26^\circ}$ in Carbon Tetrachloride
Ester gum	+21.6
Dehydrated castor oil	+ 1.1
Short oil phenolic varnish	+ 9.5
Long oil phenolic varnish	+ 8.6
Medium oil alkyd resin	+ 0.0

It can be seen from this table that optical activity cannot be used effectively in determining oil length but can be used to determine ester gum content. It can also be used to distinguish between an alkyd and an oleoresinous phenolic varnish marking paint containing ester gum, but simpler tests for this have previously been described.

Both infrared and ultraviolet spectroscopy, successfully used by Bean and Chaiken[31] to direct adulteration of traffic paint vehicles, were investigated, but neither appeared to be useful in determining oil length.

Gas chromatography has been successfully used in the analysis of organic coatings.[32-35] A brief investigation was made into its use for determining oil length of resins. This was accomplished using an F and M model 80 pyrolysis unit in conjunction with an F and M research chromatograph model 810 with a hydrogen flame ionization detector. Pyrolysis was carried out at 1,000°C. Initial experiments indicated that pyrolysis of the unmodified resin resulted in retention of high boiling pyrolyzates on the column.

Subsequently the nonvolatile vehicles were saponified before pyrolysis. Saponification was accomplished by dissolving the vehicle in benzene and heating with a solution of sodium hydroxide in ethanol. When such a procedure was followed, pyrolyzates of short, medium, and long oil alkyd and oleoresinous phenolic varnish vehicles were rapidly distinguished by distinct chromatographic patterns on a General Electric SE30 (3.6%) column. Both unused vehicles and those from weathered paints could be identified, although differences between fresh and weathered products were noted. Incorporation of different pigments (for example, titanium dioxide, red lead, iron oxide, zinc yellow, etc.) into the resins had no noticeable effects on the chromatographic patterns. Additional laboratory work will have to be done to establish a program for controlling temperature and other variables before a standard test procedure for determining oil length can be utilized. As previously reported,[36] it is recommended that oleoresinous phenolic varnish airfield marking paints have an oil length between 30 and 35 and that alkyd airfield marking paints have a maximum phthalic anhydride content of 32%. At present, percent elongation is the best criterion for oil length.

Abrasion, Scrubbing, and Washability

Resistance to abrasion and scrubbing and washability of water-emulsion paints have been discussed previously. These are important considerations for other marking paints also. TT-P-85 has an abrasion resistance requirement using Method 6191 of Reference 23 (equivalent to ASTM Designation D968-51[37]) but TT-P-115 has no such requirement. This seems rather unusual, since traffic paints are much more subject to abrasion damage than are airfield marking paints. (It has been noted previously that touchdown of aircraft deposits rubber rather than removing paint.) The falling sand method of determining abrasion resistance for soft paints is generally better than the Taber Abraser Method (Method 6192 of Reference 23) because the paint tends to clog the abrasive wheels of the Taber abraser; the Taber abraser is generally better for tough paint films.

Solvent

Federal Specification TT-P-85 requires a certification by the supplier that the paint thinner used complies with Rule 66.[22] This restriction greatly limits the aromaticity of the paint solvent. While this is not so important with alkyd formulations, it does require the use of oxygen-containing solvents in oleoresinous phenolic varnish formulations. Suppliers of the latter products state that reformulation of the solvent has no effect on paint performance. As previously reported,[36] it is recommended that 50% of the solvent for marking paints boil below 240°F and 90% below 280°F.

SUMMARY OF GOOD STRIPING PRACTICES

Airfield marking paints are exposed to a number of widely differing environments and types of service. Test data to date indicate that different conditions affect the type of performance received. Thus a water-emulsion vinyl paint might perform well where it receives little traffic but erode rapidly under heavy traffic.

On new asphaltic pavements, there should be at least 21 days between laying of the pavement and application of the striping paint in order to prevent bleeding of uncured asphalt through the paint. The paint should be applied at the spreading rate specified in TT-P-85 or a corresponding wet-film thickness (about 15 mils). Appreciably less film thickness might result in early loss of visibility and reflectivity; appreciably greater films might result in early cracking and peeling of paint.

When restriping deteriorated markings, the remaining loose paint and substrate should be removed as completely as possible, preferably by sandblasting. If restriping is done quite frequently, such as the weekly striping of the simulated carrier deck at NAS, Miramar, a very flexible water-emulsion paint (for example, Formulation 114) could be used to advantage because multiple coats exert less stress on the substrate.

Because all organic solvents deteriorate asphalt to some extent, the paint solvents should be of a low boiling range (as were the test formulations) in order to minimize this effect. Alkyd paints should have a hydrocarbon solvent of relatively low aromaticity (such as with Formulations 101 to 106), because aromatic hydrocarbons are better solvents for asphalt than nonaromatic hydrocarbons. Oleoresinous phenolic varnish paints should have a hydrocarbon solvent of relatively high aromaticity (such as with Formulations 107 to 113) in order to minimize solvent entrapment by surface-skinning of the wet film.

If a complete analysis, according to TT-P-85, of the striping paints to be used on asphalt runways is not made, flexibility, weight per gallon, viscosity, total solids, and nonvolatile vehicle requirements should be tested. Since flexibility is such an important factor, paints that fail to pass this requirement should not be considered. By obtaining a minimum oil length for the striping paint, one can assure a satisfactory paint flexibility.

ALTERNATE SYSTEMS FOR MARKING PAVEMENTS

In addition to painting, there are several other systems for marking pavements. These include use of thermoplastic materials,[38-41] reflectorized tapes,[38,40,42] and raised reflectorized squares.[38]

Thermoplastic pavement striping material is usually applied by extrusion of a molten mass containing reflectorized glass spheres. Additional glass spheres are dropped into the hot plastic to impart immediate surface retroreflectivity. Thermoplastic markings are generally 1/8-inch thick with a width from 2-1/2 to 12 inches. Very clean pavement surfaces are required, as oil and other contaminants prevent good bonding. Unremoved, weathered traffic paint may also adversely affect adhesion. These factors in part account for sporadic and sometimes unexplained failures of thermoplastic markings on concrete surfaces. Thermoplastic striping is much more durable on bituminous pavements than on portland cement concrete pavements and generally is more durable on old than on new concrete pavements. Because placement of thermoplastic striping may cost 10 times that of conventional striping, economic advantages from its superior performance result only where the traffic density is very high. It cannot be used economically where appreciable use of snowplows occur, as such activity greatly affects adhesion of thermoplastic materials to pavements, especially those of portland cement concrete.

Green Lite striping of the 3M Company of Saint Paul, Minnesota, is a different type of thermoplastic material. It consists of a mixture of epoxy powder and reflective glass spheres that is dropped from a hopper through a propane flame which melts it so that it reaches the pavement in a molten condition. Green Lite striping has received relatively limited use to date, and its economic comparison with conventional striping or other marking materials has not been reported in the open literature.

Reflectorized tapes have been used only to a slight extent because of their generally poor performance (for example, their limited adhesion and their cracking at thicknesses approaching those of hot-extruded thermoplastic markings). Thus, they have been used mainly as temporary markings.

Raised squares are available in a variety of compositions, reflectorized on one or two sides and with clear, yellow, or red coloration. These are bonded to pavements with an epoxy adhesive and, as expected, require cleanliness of both pavement and marking for good adhesion. They provide excellent retroreflectivity at night and during inclement weather. They have the necessary height to keep them from being covered by a layer of water under wet conditions and thus are able to retain their high retroreflectivity.[43] Although these raised squares are quite expensive to purchase and install, their long life and outstanding retroreflectivity more than justify their use. Raised markings also provide an additional safety factor in that the rumbling of a car driving over them alerts the driver that he is changing lanes.

Perhaps more use of marking materials other than paint has been made on the Southern California freeway system than on any other roadway system. Thermoplastic striping materials were once used extensively on Southern California freeways, but their use is now largely restricted to crosswalks and legends.

They have been replaced on lane markings by systems using raised reflectorized squares. For additional reflectivity during daylight hours, the squares are used in conjunction with broken lines of conventional paint or unreflectorized 4-inch-diameter ceramic buttons. Plastic buttons were once used, but they were not as strong as those of ceramic, nor did they bond as well to pavements. Raised markings cannot be used on pavements serviced by snowplows or scrapers, because they are removed from the pavement along with the snow.

None of the above marking systems has been used on airfield runways. Tapes cannot withstand forces imposed by touchdown of aircraft. The use of thermoplastic marking materials would be harder to justify on runways than on roadways. Their advantage on roadways of greater thickness and consequently longer life is not so important on runways where deterioration of markings is more related to chipping and to discoloration by tire tracking than to gradual erosion by traffic. Raised reflectorized squares should provide excellent retroreflectivity to centerlines of runways if the angle of incidence of a plane's landing lights is similar to that of a car's headlights. As on roadways, their use would be limited to runways not using snowplows or scrapers. Physical damage to or loosening of squares by touchdown of aircraft might present a problem. Loosened squares could be sucked up into jet engines to cause extensive damage. Raised reflectorized squares would be used in conjunction with conventional striping to provide good visibility during the day. The relative merits of such a system and of centerline lighting could only be determined by an engineering investigation.

FINDINGS

Plot Testing at CBC, Port Hueneme

1. Relatively little deterioration of test stripes occurred during the second year of exposure, more occurred during the third year, and much more occurred during the fourth year.

2. The water-emulsion polyvinyl acetate paint (Formulation 114) stripes still received the maximum rating after 4 years. The final rating total for the vinyl toluene-butadiene paint (Formulation 115) stripes was appreciably below this but was still well above other final rating totals.

3. In all cases ratings of single-thickness stripes were as great as or greater than ratings of corresponding double-thickness stripes. This relatively better performance of single-thickness stripes increased with time up to 3 years.

4. Single-thickness stripes of alkyd and oleoresinous phenolic varnish paints had comparable ratings, but ratings of double-thickness alkyd stripes were much lower than ratings of double-thickness oleoresinous phenolic varnish paint stripes.

5. Incorporation of a plasticizer into the paint formulations had no apparent benefit.

Roadway and Airfield Testing at Guam

1. The test paints performed much better both on the runway at NAS, Agana and on the roadway at USNS, Guam than did the paints previously used at these locations.

2. At NAS, Agana the water-emulsion polyvinyl acetate (Formulation 114) rated highest, followed by the oleoresinous phenolic varnishes (Formulations 108, 109, and 110), the alkyds (Formulations 101 and A), and the vinyl toluene-butadiene (Formulation 115).

3. The three oleoresinous paints (Formulations 108, 109, and 110) and the one alkyd paint (Formulation 101) performed the best on the roadway at USNS, Guam. The water-emulsion polyvinyl acetate (Formulation 114) performed slightly poorer, and the other alkyd (Formulation A) and the vinyl toluene-butadiene (Formulation 115) much poorer than these.

4. Chipping and erosion ratings were both quite high on test paints at NAS, Agana. Except for the water-emulsion polyvinyl acetate formulation, all erosion ratings were as high as or higher than chipping ratings at USNS, Guam.

In-Service Testing on NAS, Point Mugu Runway

1. The rating totals after 26-1/2 months were much lower than the corresponding totals after 8-1/2 months.

2. Tire marking of the test sections was most consoicuous and contributed more than any other factor to reducing visibility.

3. Tire marking and general deterioration were much less on the side lines than on the centerline areas that received relatively heavy traffic.

4. As at NAS, Agana the water-emulsion polyvinyl acetate (Formulation 114) performed the best, and the vinyl toluene-butadiene (Formulation 115) performed the poorest of the six test paints.

Miscellaneous Field Data

1. Oleoresinous phenolic varnish paints performed much better than alkyd paints at Oxnard Air Force Base.

2. Deteriorated alkyd markings on the asphaltic runway at NAS, Imperial Beach were satisfactorily corrected by use of an oleoresinous phenolic varnish paint, but only after the old deteriorated markings were completely removed.

3. At MCAS, Yuma two asphaltic runways were striped with alkyd rather than the specified oleoresinous phenolic varnish paint. One set of stripes performed well, but the other deteriorated rapidly and was replaced with the specified paint by the contractor at his own expense.

4. At MCAS, Yuma deteriorated markings in two asphaltic parking areas were attributed to great deviations from the specification requirements.

5. At Naval Facility, San Nicolas Island, both the asphaltic runway and its striping were badly deteriorated.

6. At NAS, Key West an alkyd paint bled badly when applied to a coal tar slurry-sealed asphaltic pavement only 24 hours after slurrying. Later, topcoating with another coat of alkyd paint up to a maximum of 30 mils dry-film thickness resulted in cracking of the slurry seal. Test areas later coated with a water-emulsion polyvinyl acetate (Formulation 114) were in excellent condition after 10 months.

7. Deterioration of alkyd markings on an asphaltic concrete runway at OLF Spencer, Pensacola, Florida, and on a portland cement concrete runway at NAS, Albany, Georgia, was attributed to excessive paint thickness.

8. Laboratory testing of water-emulsion paints indicated specification requirements and testing procedures must be established before they can be widely used as traffic paints.

9. Simple test tube procedures were developed for identifying alkyd and chlorinated rubber resins in both fresh and weathered marking paints.

CONCLUSIONS

1. In test plots at CBC, Port Hueneme the outstanding performance of the water-emulsion polyvinyl acetate paint (Formulation 114) and to a lesser extent that of the vinyl toluene-butadiene paint (Formulation 115) was due in large part to their relatively high percent elongation.

2. The somewhat poorer relative performance of the water-emulsion polyvinyl acetate paint (Formulation 114) on the roadway at NAS, Agana as compared to that on runways at USNS, Guam and NAS, Point Mugu is related to its lesser resistance to erosion than that of the other test paints.

3. While touchdown of aircraft was an important factor in deterioration of test paints at NAS, Agana, it was not a predominant factor.

4. The poorer in-service performance of the vinyl toluene-butadiene formulation (115) as compared to its performance in plots at CBC, Port Hueneme is related to adverse effects of traffic.

5. Chipping contributes more than does erosion to deterioration of painted markings on asphaltic runways.

6. A special problem occurs with repainting existing stripes: Although removal of the old stripes may be quite costly, simply overcoating them frequently results in accelerated deterioration of both paint and substrate, especially slurry seal.

7. Alkyd and chlorinated rubber in marking paint vehicles can be identified in the field by simple tests.

RECOMMENDATIONS

1. Based upon field performance data obtained late in the program, greater use should be made of water-emulsion marking paints. Toward this end, necessary laboratory investigations should be conducted to establish specification requirements and testing procedures.

2. An investigation should be conducted into the use of pyrolysis in conjunction with gas chromatography to determine oil length of paint vehicles.

3. An investigation should be conducted into methods for removing rubber tire deposits from both runways and pavements.

4. An investigation should be conducted into methods for increasing the bonding of slurry seal to asphaltic pavements

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AIRFIELD MARKING PAINTS FOR ASPHALTIC PAVEMENTS

Technical Report R-705

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by

Richard W. Drisko

ABSTRACT

Specially formulated marking paints for striping airfields were field tested. The polyvinyl acetate paint at CBC, Port Hueneme was still in excellent condition 4 years after application. In all cases single-thickness ratings were as good as or better than corresponding double-thickness ratings, especially for the double-thickness alkyd ratings. The polyvinyl acetate paint performed best on the runway at Guam, but the three oleoresinous phenolic varnish paints and one of the two alkyd paints performed slightly better on the roadway. On a runway at NAS, Point Mugu the polyvinyl acetate paint performed the best of the six paints tested. Miscellaneous problems with airfield marking paints at other activities are discussed and solutions presented. Laboratory testing included analyzing water-emulsion paints for possible use as marking paints and developing simple test procedures for identifying alkyd and chlorinated resins in fresh and weathered marking paints.

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