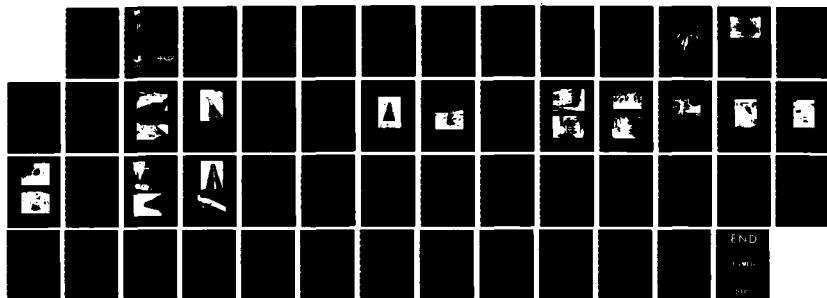


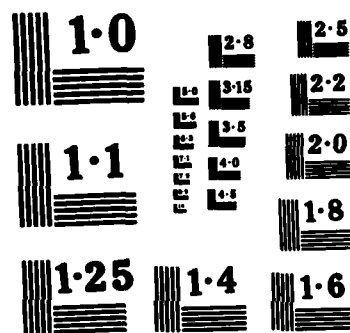
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A Durable Airfield Marking System

THOMAS NOVINSON, Ph. D.

JUNE 1985

FINAL REPORT

JUNE 23, 1980 - SEPTEMBER 30, 1984

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This report describes a 4-year work unit on the selection, development, and testing of a novel airfield marking system on ceramic-coated aluminized steel (CAS) tiles. The CAS tiles were developed to replace painted center marking lines that are obliterated by rubber streaks from jet tires from landing aircraft. The tiles are recessed or set into the pavement by grinding out 50- by 30-foot sections (1/8 inch deep) and bonding the tiles with epoxy/polyamide adhesive (2,000- to 5,000-psi tensile strength). The tiles can be easily cleaned by spraying with aqueous detergent and wiping off the rubber residue. The tiles are flexible, weather-resistant, chemically resistant, and highly reflective in day or evening, without retroreflective glass spheres. At \$2.00 to \$5.00/ft², the CAS tiles are much more expensive than Federal Specification TT-P-1952 latex paint (about \$0.10/ft²), but the high initial cost can be offset in 1 year by lower maintenance costs. Although these CAS tiles are still being tested for Air Force use, the life cycle might be 5 to 10 years before replacement.					
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PREFACE

This report was prepared by the Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California, under Job Order Number 2054-4P28, for the Engineering and Services Laboratory, Headquarters, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida.

This report covers work performed between June 1980 through September 1984. Mr. Charles E. Bailey was the AFESC/RDCF Project Officer.

The author wishes to thank Mr. Hector D'Aiutulo of the Federal Aviation Administration (FAA) in Atlantic City, N.J., for assistance with the tests; the airfield at NAEC Lakehurst, on simulated jet landings, photographic services, and other work; Mr. Val Hernandez and Mr. John Crahan of NCEL for assistance in testing the concrete plane and grinding machines, and Mr. Ray Bergman for the economic analysis; and Mr. Al Dotson at NAS Miramar, Mr. Craig Valentine at Elmendorf AFB, Mr. Roger Au at NAS Barbers Point, and Captain Pat Paddock at Homestead AFB for their assistance and cooperation for the installation of CAS plates at their respective airfields.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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TABLE OF CONTENTS

Section	Title	Page
I	INTRODUCTION	1
	BACKGROUND	1
	SCOPE	1
II	CRITERIA	4
	GENERAL REQUIREMENTS FOR A DURABLE AIRFIELD MARKING SYSTEM	4
III	APPROACH	5
	LABORATORY TESTS	5
	FIELD TESTS WITH SIMULATED AIRCRAFT	5
	ACTUAL TESTS ON AIRFIELDS	5
IV	TEST RESULTS ON AIRFIELDS	10
	CALIFORNIA (NAS MIRAMAR)	10
	HAWAII (NAS BARBERS POINT)	10
	FLORIDA (HOMESTEAD AFB)	10
	ALASKA (ELMENDORF AFB)	11
V	MATERIALS AND INSTALLATION SPECIFICATIONS	13
	INTRODUCTION	13
	MATERIALS SPECIFICATIONS	20
	Adhesive	20
	Ceramic-Aluminized Steel (CAS) Plates	20
VI	INSTALLATION METHODS	26
	EQUIPMENT	26
	CURED CONCRETE (HARDENED)	26
	FRESH CONCRETE (OVERLAYS)	27
	INSPECTION	28
	MAINTENANCE/CLEANING	28
	EMERGENCY REMOVAL	29

TABLE OF CONTENTS (CONCLUDED)

Section	Title	Page
VII	COST ANALYSIS	30
	COST ANALYSIS FOR INSTALLING CAS TILES	30
	1. Installation	30
	2. Maintenance	31
	3. Labor (Cleaning) and Installation Costs for CAS Tiles for 1 Year (52 Weeks)	31
	COST ANALYSIS FOR PAINTING THE AIRFIELD	32
	1. Calculation of Labor Costs	32
	2. Calculation of Material Costs	33
	COMPARISON OF CAS TILES VERSUS PAINTING (SUMMARY)	33
	SUMMARY	33
VIII	FINDINGS AND CONCLUSIONS	35
IX	RECOMMENDATIONS	36
	REFERENCES	37
	APPENDIXES	
A	TESTING OF FOUR MAJOR CLASSES OF MARKING MATERIALS	39
B	SUPPLIERS OF MATERIALS AND SERVICES	44

LIST OF FIGURES

Figure	Title	Page
1	Typical Rubber Skid Marks on an Airfield Runway	2
2	Paint and Rubber Buildup Begins to Flake at a Certain Thickness. The Loose Material can be Drawn into the Jet Engine Air Intakes, Causing Much Engine Damage	3
3	Simulated Jet Aircraft (Sled) Powered by Four Jet Engines. The Sled can Travel at Speeds up to 200 Knots on a 2-Mile Track	7
4	View of the 2-Mile-Long Test Track at NAEC Lakehurst (New Jersey)	7
5	View of the Tapes, CAS Tiles, Fluorocarbon Tiles, and Paints with Rubber Skid Marks from the Simulated Jet Aircraft at NAEC Lakehurst (New Jersey)	8
6	The CAS Tile Marking Line at NAS Miramar (San Diego, California) is Easily Cleaned Despite the Extremely Heavy Rubber Buildup from Aircraft Tires	11
7	In Alaska (Elmendorf AFB), the Adhesives, CAS Tiles, and Pavement were all Kept Warm (70°F) under a Polyethylene Bag Connected to a Hot-Air Blower (Hose is Shown). The Air Temperature was about 30°F During this Installation	12
8	EDCO® Grinder for Small Jobs	14
9	Closeup View of the Steel Cutting Blades	14
10	Target® Grinder (Diamond-Tipped Blades) Recommended for Large Jobs	15
11	Closeup View of the 3-Foot-Wide Diamond Cutting Blades	15
12	After the Concrete is Ground Down or Planed, the Debris and Water (to Cool the Diamond Cutters) must be Vacuumed off	16
13	The White Epoxide Resin is Mixed with the Black Curing Agent to Form the Epoxy Adhesive	17
14	The Gray Adhesive (White Resin Mixed with Black Curing Agent) is Coated as a Thin Layer on the Black (Metal) of the Ceramic-on-Aluminized-Steel (CAS) Tile	18
15	The Pavement is also Coated with Adhesive	19
16	The CAS Tile is Laid in Place	19
17	The CAS Tiles are Bonded in a Strip (about 1/4 inch Distance is Allowed Between Plates for Flexibility) to Replace the Painted Center Marking Line	21
18	Excess Adhesive is Removed by Wiping with a Clean Rag Dampened (not Soaking) with Methyl Ethyl Ketone Before the Epoxy has Hardened	21
19	Jet Aircraft Leave Rubber Tire Skid Marks on the CAS Tiles	22
20	The Rubber can be Rubbed off Easily	22

LIST OF TABLES

Table	Title	Page
1	Summary of Rubber Adhesion Tests at NAEC Lakehurst	6
2	Summary of Rubber Adhesion Tests at NAS Miramar	9
3	Cost Comparisons of Various Marking Materials	9
A-1	Summary of the Marking Materials Tested in the Laboratory	41
A-2	Representative Formulation for White Ceramic Coating (for Steel)	43
A-3	Characteristics of Concrete Cutters Tested	43

SECTION I

INTRODUCTION

The Air Force Engineering and Services Center (AFESC) asked the Naval Civil Engineering Laboratory (NCEL) for assistance in developing a new, more durable, rubber-resistant marking material because of NCEL's prior experience in airfield marking paints (Reference 1). This was done by laboratory and field testing of various striping materials over a 4-year period. Details and highlights from the first NCEL report on this work unit (Reference 2) are included in Appendix A of this report.

BACKGROUND

A major problem in the maintenance of Air Force and Navy airfield runways is that the center marking lines are obliterated with jet aircraft tire streaks soon after the lines are painted. The rubber streaks may cover as much as 3,000 to 4,000 feet of the field from the primary approach (Figure 1) to the midfield. If the fields are not clearly marked, pilots often complain about the lack of visibility of the airfield and the potential safety hazards in landing without proper guidelines. Visibility of the field is important in the daytime, but it is even more critical at night since the center marking lines must contain glass beads that mark the landing zone by reflecting the landing lights of the aircraft.

Current maintenance options include: (1) cleaning (waterblasting and mechanical abrasion) and repainting or (2) painting over the rubber streaks without removing the rubber. Neither option is entirely satisfactory.

The cleaning and restriping procedure may cost as much as \$25,000 and require shutdown of the airfield for up to 5 working days. Painting over the rubber streaks is convenient but introduces a new problem. Alternating layers of rubber and paint build up until the composite material becomes brittle and begins to flake or peel from the pavement (Figure 2). The rubber-paint debris then poses a hazard to landing jet aircraft because it could be drawn into the air intakes of the jet engines. Repair and maintenance of these expensive modern jet engines (\$2 million or more) may be as high as \$200,000 each.

SCOPE

This report describes the 4-year research, development, testing, and evaluation (RDT&E) of porcelain-enamelled (ceramic-coated) aluminum-coated steel (CAS) plates as a durable new airfield marking material. The plates,

size 3 by 3 feet (1/16 inch thick), are recessed in the pavement and permanently bonded in place with high-shear-strength epoxy adhesives. The plates can be installed in 48- or 51-foot sections to replace the 50- by 3-foot center marking lines currently painted on airfield runways.



Figure 1. Typical Rubber Skid Marks
on an Airfield Runway.

Although the CAS plates pick up rubber from jet aircraft tires (as do the pavement and painted lines), they can easily be cleaned with an aqueous detergent and light buffing with a cloth. Painted lines are permanently obliterated by rubber.

The initial costs of materials and labor for installation are much higher than painting the airfield once a year. However, if the airfield is repainted much more frequently, the CAS plate system will be cost-effective in 1 year or less because of reduced maintenance costs. With proper care, as discussed later in this report, the marking system may last 5 to 10 years.

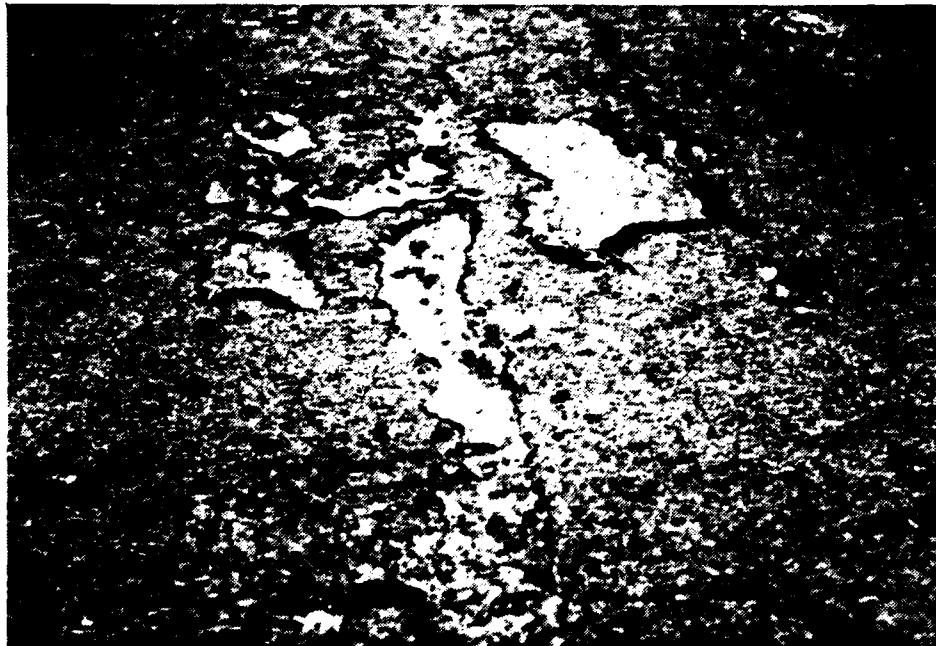


Figure 2. Paint and Rubber Buildup Begins to Flake at a Certain Thickness. The Loose Material can be Drawn into the Jet Engine Air Intakes, Causing Much Engine Damage.

This report establishes criteria for airfield marking materials and summarizes laboratory tests used in screening some 30 different materials (paints, traffic marking tapes, and composites) as well as describing preliminary tests of the CAS plates at the experimental test track (Naval Air Engineering Center) in New Jersey. Installations on active runways in California, Alaska, Hawaii, and Florida are also described. Finally, the report provides details for materials and equipment specifications and a cost analysis for CAS plate installation compared to painting the airfield at the Naval Air Station (NAS), Miramar, San Diego, California.

SECTION II

CRITERIA

GENERAL REQUIREMENTS FOR A DURABLE AIRFIELD MARKING SYSTEM

The following criteria were selected as materials requirement for the durable airfield marking system:

1. Rubber resistance. The material should pick up little or no rubber from the jet tires.
2. Cleanability. If the material does pick up rubber, it must be possible to clean the surface easily, preferably with aqueous detergent or environmentally acceptable solvents, to restore original visibility.
3. Ease of installation. The method of installing the material (spraying, adhesive bonding, etc.) must be relatively inexpensive and not require special technical skills.
4. Cost-effectiveness. The cost of materials and labor for installation must be competitive with painting, or if initial costs are high, the maintenance costs over a 2- to 3-year period must be competitive with painting over the same time period.
5. Durability and weatherability. The materials must be at least as durable as current Federal specification paints in exposure to hot weather, cold weather, high humidity, rain, snow, sunlight, and other weathering factors without changes in color (darkening, in the case of white marking lines) or materials (resistance to cracking, peeling, crazing, separation from the pavements, embrittlement, etc.). Resistance to jet fuel spills, solvents, grease, and oil is desirable, but not mandatory, if the material is considered for marking pavements other than the centerline approach (e.g., parking, refueling, and taxi zones).
6. Day and night visibility. The materials must be readily visible for marking lines up to 1,000 feet long in good weather (clear, sunshine, no precipitation) in the daytime and at least 500 feet at night. Retroreflectivity comparable to paints with glass beads is desirable, although not mandatory, if the lines are bright enough to be seen for 500 feet at night.
7. Life expectancy. The materials should be useful for a minimum period of 3 to 4 years.

SECTION III

APPROACH

The testing was conducted in three phases: laboratory (T_1), track-simulated jet landings (T_2), and actual jet landings (T_3) at four locations in the United States (see Appendix A).

LABORATORY TESTS

Laboratory tests were conducted at NCEL on the following materials:

- paints
- traffic marking tape, adhesive-backed
- fluorocarbon (Teflon[®] and Fluorogold[®]) metal composites (Reference 3)
- ceramic-coated metal and enamelized stoneware (Reference 4)

Selection of the most effective adhesives was conducted in another work unit (Reference 5).

FIELD TESTS WITH SIMULATED AIRCRAFT

Materials meeting most of the criteria of Section II (ease of installation, cost-effectiveness, and life expectancy were considered in later stages of testing) were then applied in 12- by 6-inch (or similar) lateral stripes on the concrete pavement of the test track at the Naval Air Engineering Center (NAEC), Lakehurst, New Jersey. A simulated jet vehicle was then propelled down the track at 200 knots. The vehicle was stopped with an electronic braking system, causing the same type of rubber skid marks on the pavement and marking materials as an actual jet aircraft. A 10,000-pound load, containing an auxiliary test tire, was dropped onto the track to further simulate actual jet landings. The materials were then examined, and attempts were made to remove the rubber with a scrub brush and detergent solution. Test results are summarized in Table 1. The simulated jet vehicle (sled) is shown in Figure 3, the test track is shown in Figure 4, and the materials being tested on the pavement near the end of the track are shown in Figure 5.

ACTUAL TESTS ON AIRFIELDS

The top candidates, i.e., the most easily cleaned materials, were installed in both the main runway and the simulated carrier deck at the Naval Air Station (NAS) Miramar, San Diego, California. The ceramic-coated steel plates were easily cleaned, as were the Teflon[®] fluorocarbon steel composites, but other materials, such as Fluorogold[®] fluorocarbon, were permanently obliterated. Test results at NAS Miramar are summarized in Table 2.

TABLE 1. SUMMARY OF RUBBER ADHESION TESTS AT NAEC LAKEHURST

Type of Materials	Surface Covered With Rubber (%)	Surface Cleanable With Detergent (%)
Paints	100	0
Alkyd (TT-P-85)	100	0
Chlorinated rubber	100	0
Polyester (peroxide-catalyzed)	100	0
Urethane	100	0
Epoxy polyamide	100	0
Acrylic latex (TT-P-1952)	100	0
Thermoplastic Tapes		
Type 1	100	0
Fluorocarbon Composites		
Teflon [®] polymer	0	Not needed
Fluorogold [®] polymer	50 to 60	10 to 20
Ceramic-Coated Materials		
Ceramic-pocelain stoneware	100	100
Ceramic-coated aluminum	100	100

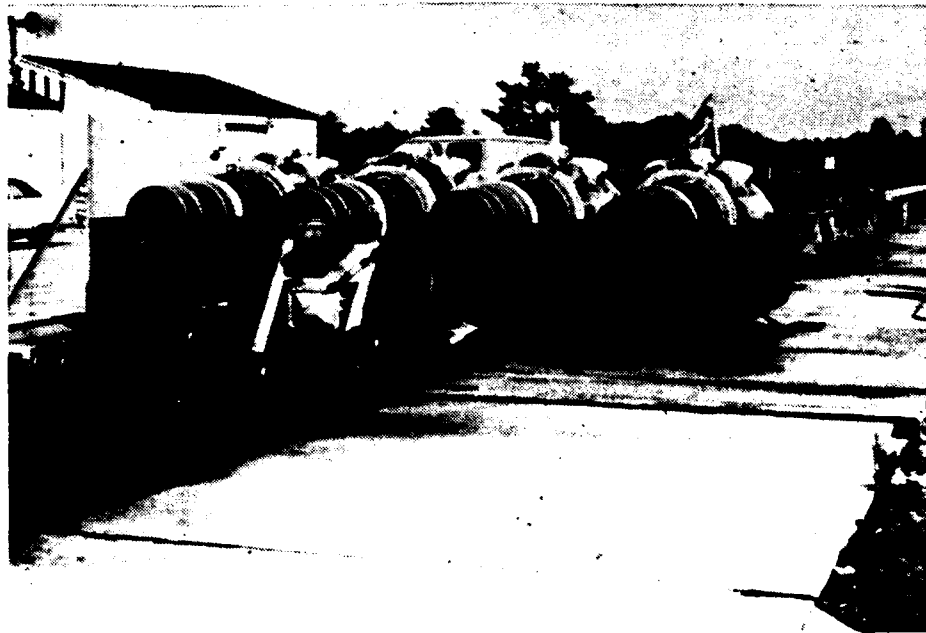


Figure 3. Simulated Jet Aircraft (Sled) Powered by Four Jet Engines. The Sled can Travel at Speeds up to 200 Knots on a 2-Mile Track.



Figure 4. View of the 2-Mile-Long Test Track at NAEC Lakehurst (New Jersey).



Figure 5. View of the Tapes, CAS Tiles, Fluorocarbon Tiles, and Paints with Rubber Skid Marks from the Simulated Jet Aircraft at NAEC Lakehurst (New Jersey).

Forty-five to 60 linear feet (actually 135 to 180 ft², since each plate is 3 by 3 feet) of marking lines were then installed at NAS Miramar (San Diego), NAS Barbers Point (Hawaii), Elmendorf Air Force Base (AFB) (Alaska), and Homestead AFB (Florida) for full-scale tests. Table 3 summarizes cost data comparisons for traffic marking tapes, CAS tiles, fluorocarbon composites (Teflon[®]), and acrylic latex paint TT-P-1952.

TABLE 2. SUMMARY OF RUBBER ADHESION TESTS AT NAS MIRAMAR

Type of Material	Surface Covered With Rubber (%)	Surface Cleanable With Detergent (%)
Paints		
Epoxy-polyamide	100	0
Acrylic latex (TT-P-1952)	100	0
Thermoplastic		
Type 1	100	0
Fluorocarbon Composites		
Teflon [®] polymer	0	Not needed
Fluorogold [®] polymer	50 to 60	10 to 20
Ceramic-Coated Materials		
Ceramic-coated aluminum	100	100

TABLE 3. COST COMPARISONS OF VARIOUS MARKING MATERIALS

Material	Cost per ft ² (for 1,000 ft ²) (\$)
Traffic marking tape (adhesive-backed, 0.09 in. thick with retroreflective glass beads)	3.00 to 5.00
Ceramic-coated aluminized steel (CAS)	2.75 to 5.00
Teflon [®] polymer on steel (composite plate), 12-gauge	12.00
Teflon [™] polymer on aluminum, 12-gauge	50.00
Acrylic latex marking paint (Federal Specification TT-P-1952)	0.03

SECTION IV

TEST RESULTS ON AIRFIELDS

Composite plates were originally bonded with adhesives to the (clean) concrete or asphaltic concrete. However, when it was learned that plates were being loosened by the impact and shear forces of the simulated jet vehicle runs at NAEC Lakehurst, the plates were recessed in the pavement. Details of the concrete grinding and recessing operation are provided in Section VI (Installation Methods).

CALIFORNIA (NAS MIRAMAR)

The CAS plates were installed on both the main runway and the simulated carrier deck (which is made of concrete, not steel) in 1982. The plates are presently being washed once a week with detergent to remove rubber, and they still appear as white as when they were installed (Figure 6). No signs of chipping, discoloration, decreased gloss, or other changes have been observed. The Commanding Officer at NAS Miramar has expressed interest in installing the CAS plates for the entire length of the airfield because maintenance (and the problem of peeling paint and rubber) of the painted lines has become quite expensive. NAS Miramar has hot (105°F), dry (20-30 percent relative humidity) summers and cool (60°F) winters with relatively little rain.

HAWAII (NAS BARBERS POINT)

The CAS plates were installed in both asphaltic (AC) and Portland cement concrete (PCC) at NAS Barbers Point in July 1984. After 9 months, one plate separated and two others were found to be loose. The other plates were found to be well-bonded, but all plates were removed in February 1985. The situation was investigated and it appeared that plate loss occurred when Barbers Point switched from lighter A-4 jets (10,000 pounds) to heavier F-4 jets (40,000 pounds).

NAS Barbers Point has a hot (80 to 95°F), humid (>75 percent relative humidity) climate year round, and experiences heavy rainfall.

FLORIDA (HOMESTEAD AFB)

The CAS plates were installed in PCC in July 1984. A contractor planed the pavement with the recommended diamond-tipped concrete planer (see Section VI). Within 2 months, however, two of the 15 plates were sheared off by landing jets. All of the plates were removed for safety precautions.

Since similar installation had been conducted in California without loss of the CAS plates, the Florida installation was further investigated. The plates were installed during rainy weather; therefore, failure may have occurred because the aluminized steel surface was damp. Proper adhesion, even with high-strength epoxies, is not possible if the metal surface is covered with a thin film of water.



Figure 6. The CAS Tile Marking Line at NAS Miramar (San Diego, California) is Easily Cleaned Despite the Extremely Heavy Rubber Buildup from Aircraft Tires.

ALASKA (ELMENDORF AFB)

The CAS plates were installed on both AC and PCC pavements at Elmendorf AFB in October 1983. The daytime temperature was already in the 40 to 50°F range. Both the pavement and the canned adhesives were maintained at 70 to

75°F under a polyethylene bag heated with a hot-air blower (Figure 7). After the plates were bonded to the pavement, the temperature under the bag was raised to 250°F to rapidly cure the epoxy adhesive (the adhesive can be heat-cured, thus reducing the normal cure time of 72 hours at 70°F to 2 hours at 250°F). The plates were badly scratched by steelwire brushes used on snow and ice removal equipment during the winter. It was learned later that the company producing the snow brushes manufactures them in nylon as well as steel. Further winter testing was not conducted, but it seems likely that nylon brushes would effectively remove the snow without damaging the CAS plate ceramic surface.



Figure 7. In Alaska (Elmendorf AFB), the Adhesives, CAS Tiles, and Pavement were all Kept Warm (70°F) under a Polyethylene Bag Connected to a Hot-Air Blower (Hose is Shown). The Air Temperature was about 30°F During this Installation.

SECTION V

MATERIALS AND INSTALLATION SPECIFICATIONS

INTRODUCTION

This section describes the materials and method of installing ceramic-aluminized steel (CAS) marking tiles as a novel, durable airfield marking system. The CAS tiles replace the painted center marking line at the approach end of the airfield. Painted lines are quickly and irreversibly obliterated by rubber from the tires of jet aircraft. CAS tiles also pick up rubber, but they can easily be cleaned by spraying a mild aqueous detergent (sodium phosphate, sodium carbonate) on the surface and wiping off the rubber. Thus, the plates can be restored to a clean, bright, reflective surface at low maintenance cost and on short notice. Suppliers of materials and installation-related services are found in Appendix B.

Successful installation of this marking system requires that the plates be recessed in the pavement (so that the plates are flush with the runway surface) and bonded with high shear (>2,500 psi) epoxy adhesives. Recessing the plates virtually eliminates their dislodging by aircraft arresting hooks and other objects dragging across the airfield runway.

Directions are given for recessing the plates in (a) cured concrete by grinding the pavement and (b) fresh concrete by stamping or molding a slot or trough.

NCEL used a small EDCO[®] grinder to plane the pavements at Elmendorf AFB (Alaska) and NAS Barbers Point (Hawaii) because it was impractical to have a contractor travel to the remote sites for a small grinding job. The EDCO[®] machine is shown in use in Figure 8, and Figure 9 shows a closeup view of the steel cutting blades. Tungsten carbide blades are also available from EDCO.

The larger Target[®] grinder, which was used by the contractor at Homestead AFB (Florida), is recommended for all large jobs. This grinder (Figure 10) has diamond-coated steel cutters on a 3-foot-wide cutting drum (Figure 11), which is efficient enough to cut a 1/4-inch-deep trough (3 feet wide) in one pass.

Since the cutting blades are cooled by water spraying, the water must be suctioned with a vacuum unit, as shown in Figure 12.

The two-component epoxy adhesive is then mixed (Figure 13) and applied to the back surface (metal) of the plates (Figure 14) and the pavement (Figure 15). It is best to coat only two or three plates and 6 to 9 ft² of pavement so that the plates can be laid in place (Figure 16) while the adhesive is still tacky.



Figure 8. EDCO® Grinder for Small Jobs.

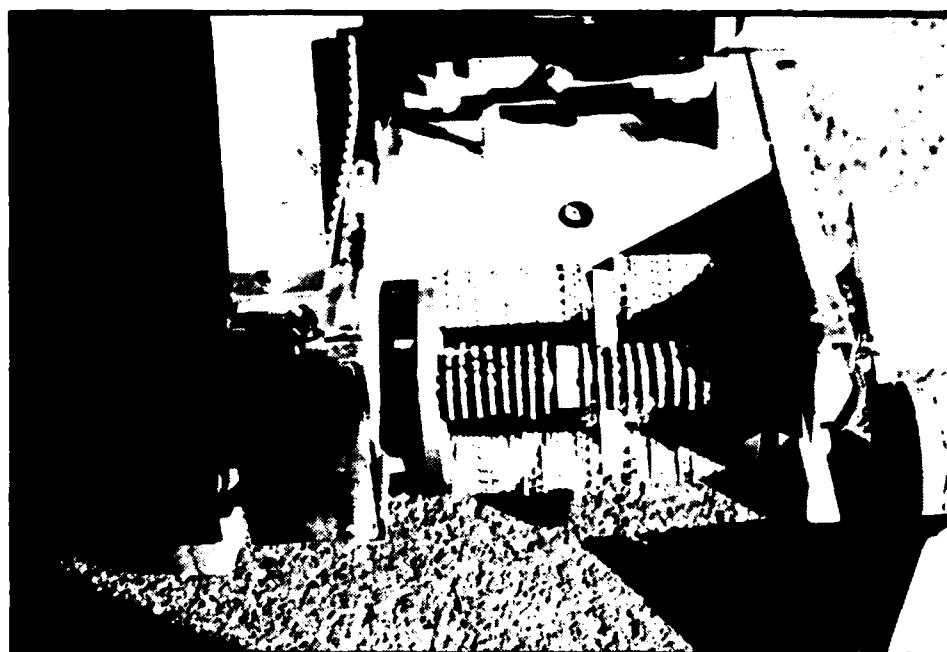


Figure 9. Closeup View of the Steel Cutting Blades.



Figure 10. Target® Grinder (Diamond-Tipped Blades)
Recommended for Large Jobs.



Figure 11. Closeup View of the 3-Foot-Wide
Diamond Cutting Blades.



Figure 12. After the Concrete is Ground Down or Planed, the Debris and Water (to Cool the Diamond Cutters) must be Vacuumed off.

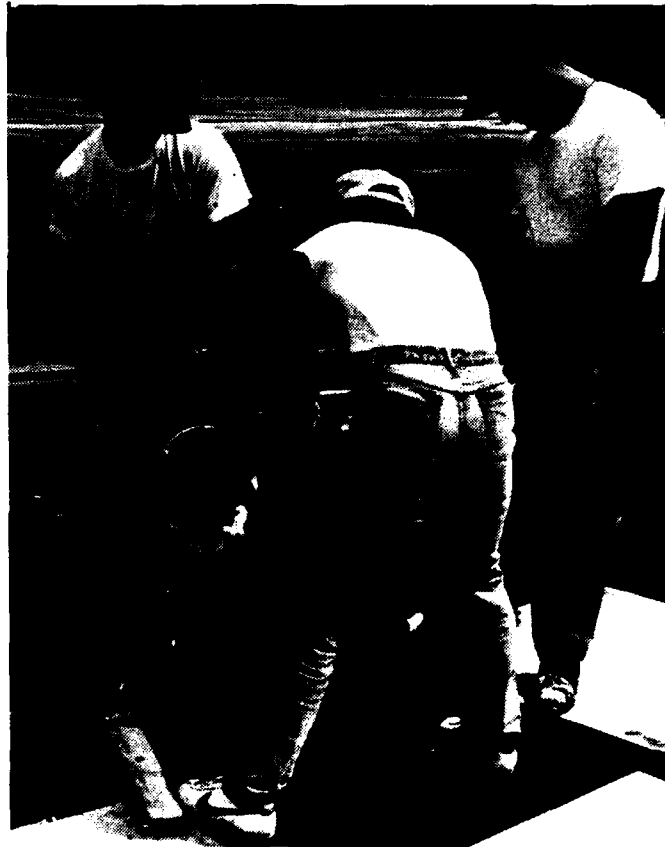


Figure 13. The White Epoxide Resin is Mixed with the Black Curing Agent to Form the Epoxy Adhesive.



Figure 14. The Gray Adhesive (White Resin Mixed with Black Curing Agent) is Coated as a Thin Layer on the Black (Metal) of the Ceramic-on-Aluminized-Steel (CAS) Tile.



Figure 15. The Pavement is also Coated with Adhesive.



Figure 16. The CAS Tile is Laid in Place.

After the CAS tiles are installed in a straight line (Figure 17), any excess epoxy should be wiped off with a clean rag dampened (not soaking) with methyl ethyl ketone before the epoxy has hardened (Figure 18).

When the installation is complete, rubber from the tires of landing jet aircraft will adhere to the CAS tiles (Figure 19), but these rubber deposits are easily removed (Figure 20). The rubber is best removed by spraying the CAS tiles with an aqueous detergent and then wiping off the deposits with cloths or a mechanical buffer.

MATERIALS SPECIFICATIONS

Adhesive

1. The adhesive must be a two-part epoxy based on the epichlorohydrin of bisphenol A resin (part A) and a polyamide curing agent (part B).
2. The adhesive must have a tensile strength of 2,000 psi minimum as defined by ASTM D897 for steel-to-concrete and aluminum-to-concrete.
3. The adhesive must have a shear strength of 2,500 psi minimum for steel-to-concrete or aluminum-to-concrete, as defined by ASTM D 1002.
4. The adhesive components (parts A and B) must have a shelf life of at least 6 months in a temperature range of 32 to 105°F.
5. The mixed adhesive must have a pot life of 10 minutes in a range of 70 to 90°F.

The following documents pertain to adhesives:

Tensile Tests

ASTM D 897 Tensile Properties of Adhesive Bonds

Shear Tests

ASTM D 1002 Shear Strength by Tensile Loading (Static)

ASTM D 3166 Fatigue Properties of Single Lap Shear Specimens by Tensile Loading (Dynamic)

Ceramic-Aluminized Steel (CAS) Plates

1. Plates shall be 36- by 36- by 1/16-inch hot-dipped aluminized steel with one side only coated with white porcelain enamel (ceramic).
2. The plates shall have "weep holes," 1/4 inch in diameter, 1/2 inch from each edge at all four corners, to allow the air bubbles to escape from the adhesive used in bonding the plates to a pavement.

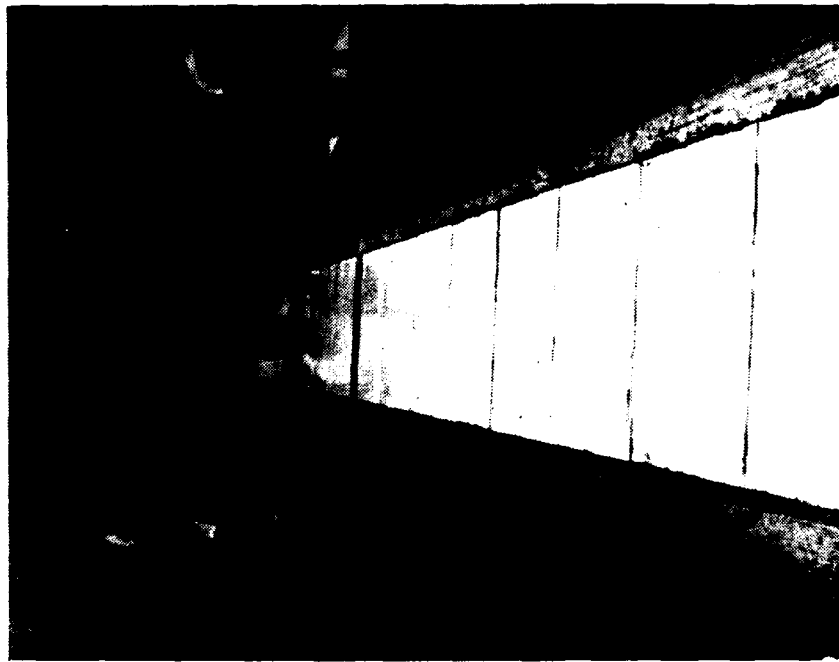


Figure 17. The CAS Tiles are Bonded in a Strip (about 1/4-inch Distance is Allowed Between Plates for Flexibility) to Replace the Painted Center Marking Line.



Figure 18. Excess Adhesive is Removed by Wiping with a Clean Rag Dampened (not Soaking) with Methyl Ethyl Ketone Before the Epoxy has Hardened.



Figure 19. Jet Aircraft Leave Rubber Tire Skid Marks on the CAS Tiles.



Figure 20. The Rubber can be Rubbed off Easily

3. The porcelain enamel shall be white and opaque.
4. The porcelain enamel shall be made from a frit suitable for aluminum surfaces and fired at 850°F. A frit is granular glass milled with water, clay, and pigments to produce the slip or wet coating mixture applied to the metal before firing.
5. The porcelain enamel shall pass the ASTM C 313 adherence test and the ASTM C 703 spalling test.
6. The enamel shall have a thickness of 0.0035 to 0.0045 inch (including the aluminum layer) as measured by either ASTM D 1186 or ASTM E 376.
7. The porcelain enamel shall have a gloss rating of 60 or higher as measured by ASTM method C346 or 45-degree specular gloss.
8. The porcelain enamel shall pass the ASTM C 282 acid-resistance test with no more than 15 mg/cm² material soluble in 6 percent citric acid.
9. The porcelain enamel shall pass the ASTM C 614 alkali-resistance test with no more than 15 mg/cm² being soluble in 10 percent trisodium phosphate.
10. The porcelain enamel shall be cleanable with 10 percent trisodium phosphate detergent as defined in ASTM C 756. Rubber must be easily removed from the porcelain enamel surface using this aqueous detergent without adverse changes in opacity, color, or gloss (using ASTM C 346 as a guide).
11. The porcelain enamel must release no more than 1 mg/m² lead (white) or cadmium (yellow) when cleaned with detergent, as defined by ASTM standard C 872.
12. The porcelain enamel must be completely insoluble in organic solvents, fats, waxes, oils, or greases.
13. The porcelain enamel must pass the torsion-resistance test or resistance to chipping described in ASTM for a 0.005-inch (5-mil) coating on 20-gauge steel.
14. The porcelain enamel must pass the ASTM C 448 abrasion-resistance test with a weight loss of less than 1 mg/cm².
15. The porcelain enamel must pass the ASTM C 385 thermal shock test in which the coated steel is quenched in ice water from a heated temperature of 400°F.
16. The porcelain enamel coating must be continuous, as described in ASTM C 743, with no voids, pits, or exposed metal areas on the coated side.

The following documents pertain to ceramic steel plates:

Adherence

- ASTM C 313 Adherence of Porcelain Enamel and Ceramic Coatings to Sheet Metal
- ASTM C 703 Spalling Resistance of Porcelain Enameled Aluminum (5 percent ammonium chloride)

Thickness

- ASTM D 1186 Dry Film Thickness of Nonmagnetic Coatings on a Magnetic Base
- ASTM E 376 Coating Thickness by Magnetic Field or Eddy Current Test Methods

Color and Gloss

- ASTM C 346 Gloss of Ceramic Materials, 45-Degree Specular (related methods)
- ASTM C 540 Image Gloss of Porcelain Enamel Surfaces
- ASTM C 347 Reflectance, Reflectivity, and Coefficient of Scatter of White Porcelain Enamels
- ASTM D 1535 Color by the Munsell System, Specifying

Chemical Resistance

- ASTM C 282 Acid Resistance of Porcelain Enamels (6 percent Citric Acid)
- ASTM C 614 Alkali Resistance of Porcelain Enamels (Trisodium Phosphate)
- ASTM C 756 Cleanability of Surface Finishes
- ASTM C 872 Lead and Cadmium Release From Porcelain Enamel Surfaces
- No Spec Resistance to Organic Solvents

Chipping Resistance

- ASTM C 409 Torsion Resistance of Laboratory Specimens of Enameled Steel

Abrasion Resistance

ASTM C 448 Abrasion Resistance of Porcelain Enamels

Thermal Shock

ASTM C 385 Thermal Shock Resistance of Porcelain-Enameled Utensils

Metal

ASTM C 774 Yield Strength of Enameling Steels After Straining and Firing

Coating

ASTM C 536 Continuity of Coatings in Glassed Steel Equipment by Electrical Testing

ASTM C 743 Continuity of Porcelain Enamel Coatings

SECTION VI

INSTALLATION METHODS

EQUIPMENT

The following equipment is needed for installing the CAS plates in older, cured concrete:

1. Grinding machine with 3-foot-wide steel drum and diamond-coated cutting teeth.
2. Water supply to cool the grinding blades.
3. Vacuum system to remove ground concrete, dust, other debris, or water from the pavement.
4. Hot-air blower to dry the pavement.
5. Electrical stirrer for mixing the adhesive components.
6. Tools for applying the adhesive (caulking blades, trowels, or other flat blades).
7. Boards (2 by 4) and weights (50-pound concrete girders or metal weights) to level and stabilize the plates while the adhesive is hardening.
8. Cloth rags for cleaning the plates.
9. Solvent (acetone or methyl ethyl ketone) for removing the uncured adhesive residue from the tiles' surface.

CURED CONCRETE (HARDENED)

1. Grind a trough or slot 1/8 inch deep and 3 feet wide (6 or 12 feet for stripe patterns), where required, for recessing the plates by making a single pass with a diamond-studded cutting drum 3 feet wide.
2. Sweep, vacuum, or otherwise remove all water, dust, wet dust, and concrete debris so that the surface of the pavement is clean and dry. Air-dry wet concrete under a stream of hot (>220°F) air. Allow the concrete to cool to ambient temperature before applying adhesive.
3. Ensure that the trough is reasonably flat with no corduroy ridges (which would affect the strength of the adhesive to concrete bond).
4. Mix equal parts of part A (resin) and part B (coreactant) of the epoxy to obtain a uniform gray color.

5. Coat one 3- by 3-foot section of the pavement trough with adhesive. Coat the metal side of one 3- by 3-foot ceramic-metal plate with adhesive, making certain that the entire metal surface is covered. The adhesive coating must have no streaks of white (resin) or black (coreactant) in the gray mixture. The adhesive layer must not contain bubbles. The metal surface must be clean, dry, uncorroded, and free of visible defects (bare spots) before applying the adhesive.

6. Place the ceramic-metal plate carefully over the pavement so that both adhesive surfaces are in contact with each other.

7. Level the plates with flat, wooden boards (2 by 4) weighted down with bricks, concrete blocks, sandbags, or other materials. Allow the adhesive to cure a minimum of 24 hours at 65 to 80°F (about 12 hours at 80 to 105°F). If the outside air temperature is below 65°F, cure the adhesive in an artificial, heated environment by covering the plates with a polyethylene bag connected to a hot-air blower.

8. Do not, under any circumstances, conduct the installation in (1) rainy weather, (2) during sand or dust storms, or (3) at low temperatures (below 65°F), other than as described with auxiliary heating. Do not jar the plates or move them in any way during the first 12 hours at 80°F or above, or 24 hours at 65°F or above (below 80°F).

FRESH CONCRETE (OVERLAYS)

1. Design the marking system for the runway, prepare drawings with dimensions, and forward to the contractor.

2. Cast in place the fresh concrete, using conventional construction techniques, and allow it to harden only to the point where a footprint can be made to a depth of 1/2 inch by a 150-pound man (10 to 45 minutes of curing time.)

3. Place molds or templates 3 feet wide by 9 feet long in the semi-hardened concrete and press into place to provide 9- by 3-foot by 1/2-inch depressions for the marking line. Do not "oil" the templates with oil, silicones, mold release agents, or any other lubricant, as this will coat the concrete and prevent good adhesion when the epoxy is used. The most useful molds or templates for this purpose can be made from plastic sheeting with low coefficients of friction (polyethylene, PVC, fluorocarbons, etc.) fastened to wood or steel planks.

4. Remove the templates when concrete is cured.

5. When the concrete has hardened to an acceptable level (e.g., aircraft would be allowed to land on the overlay), dry the pavement with a hot-air blower to remove any visible water. Allow the pavement to cool to ambient temperatures.

6. Mix the adhesive as described and apply to the pavement and plates as described above. Lay the plates in the slot and hold in place until the adhesive has hardened. Note the precautions against installing the plates during inclement or cold weather.

INSPECTION

1. Inspect the entire plate system for evenness and straightness (e.g., should be a straight line).
2. Inspect the individual plates for cleanliness. Plates should be free of adhesive residue, rubber marks from workshoes or boots, and dirt. The plates should be clean, white, and glossy.
3. Check the adhesive between joints or outside the plates to see that it is hard and fully cured. A pencil (eraser-end) pressed into the adhesive should not make a depression or pit.
4. Check the edge of the plates to be certain that all surfaces are bonded with no curling and that there is no separation (of adhesive or plate) from the pavement or other visible signs of poor adhesion.

MAINTENANCE/CLEANING

1. Clean the ceramic-steel plates of rubber by spraying an aqueous, environmentally safe detergent solution on the surface, allowing the solution to penetrate for 5 minutes, and buffing with cloth rags or a machine with cloth rollers.
2. Remove snow and ice from the plates using alcohol (methanol, ethanol, or isopropanol), urea, or mechanical snow removers (with nylon or other plastic brushes). Do not use steel wire brushes to remove snow or ice on the ceramic plates.
3. Use high-pressure waterblasting to remove rubber from the ceramic plates.
4. Do not use chemical mixtures containing chlorinated solvents (which may attack the adhesive), strong acids, or strong alkali (which may attack the ceramic) to clean the plates.
5. Do not use mechanical scrapers, polishers, metal buffers, or grinders to clean the plates. Use of air sweepers is permitted.

EMERGENCY REMOVAL

1. If any of the ceramic plates are dislodged or the ceramic surface is damaged, remove the plates by using a "peeling" action with a crowbar or similar tool. Although the shear strength of the epoxy adhesive is at least 2,500 psi, the peel strength is about 10 psi.

2. Drill a small hole into the pavement or the hardened epoxy near the edge of the plate. Insert a crowbar so that it touches the plate, and peel the plate toward the lateral side of the marking line. The plates should dislodge easily; if not, then drill holes along the edge at three points: one near the middle and one near each corner of the plate. Insert a crowbar at each hole and apply pressure at all three points to dislodge the plate.

3. If the bond between the plate and adhesive fails (e.g., the plate surface was wet, oily, greasy, or contained other debris when the adhesive was applied), the epoxy in the trough is probably still strong and should not be removed (removal will tear out part of the concrete). If the bond between the concrete and adhesive is weak (e.g., the concrete was wet, dusty, or otherwise contaminated before applying the adhesive), then chip out epoxy sections and refill the clean, dry trough with a mixture of epoxy and mineral filler, or acrylic adhesive and mineral filler, as specified in ASTM C 881 (Epoxy for Concrete Repair).

SECTION VII

COST ANALYSIS

A comparison was made between the costs of installing and cleaning 1,000 CAS tiles (9,000 ft²) and repainting the airfield on a weekly (52 weeks) and a quarterly (four times a year) basis. Although maintenance varies from 4, 6, 12, to 18 months at different airfields, the runway is actually repainted every week at NAS Miramar, where most of the NCEL field tests were conducted.

The costs are based on an estimate of 3,000 feet of marking lines 3 feet wide for the average Air Force (2,800 feet long) and Navy (2,880 feet long) airfields. The paints used on these airfields are either the organic-solvent-based alkyd, TT-P-85, or the water-based latex, TT-P-1952.

Labor costs were based on current Government wage grade salaries for civilian staff at NAS Miramar. Material costs vary, but they are calculated on the basis of 1,000 CAS tiles ordered from two different suppliers (East Coast and West Coast) and adhesives ordered in bulk (55-gallon drums) from the larger adhesives manufacturers. Costs of concrete grinding were estimated on the basis of the contractor work done at Homestead AFB, Florida. The costs of the paints were based on current GSA schedules. The cost of detergent was based on current price quotations (from the supplier) for 55-gallon drums.

COST ANALYSIS FOR INSTALLATING CAS TILES

1. Installation

<u>Item</u>	<u>Navy</u>	<u>Air Force</u>
Length of stripes, ft	120	100
Number of stripes	24	28
Total linear distance, ft	2,880	2,800
Total surface area, ft ²	8,640	8,400
Total number of 3- by 3-ft CAS tiles*	960	934

*Estimate 1,000 for best prices.

<u>Item</u>	Cost (\$) From--	
	<u>East Coast Supplier</u>	<u>West Coast Supplier</u>
3- by 3-ft plates (per plate for 1,000)	24.75	45.00
Adhesive (0.35 gal) per plate	13.48	13.48
Pavement grinding per yd ² (3 by 3 ft)	9.00	9.00
Installation labor per plate	8.38	8.38
Shipping (per plate) from vendor to airfield located 500 mi away	4.84	4.84
Total costs per plate	60.45	80.70
Total costs for installation of 1,000 tiles	60,450	80,700

2. Maintenance

<u>No. of Persons</u>	<u>Wage Grade</u>	<u>Salary (\$/hr)</u>	<u>Hours Per Week</u>	<u>Weeks Per Year</u>	<u>Total Hours</u>	<u>Total Costs (\$)</u>
1 (supervisor)	WL	12.33	2	52	104	1,282
2 (cleaners)	WG-7	10.81	3	52	312	<u>3,372</u>
Base labor cost (B)						4,654 (B)
Premium pay factor (holidays)*						4,840 (PP)
Overhead multiple (support)**						8,712 (T)
Total labor cost (T)						8,712
Detergent costs (\$5.70/gal for 55 gal)						313
52 drums (55 gal each)						16,276

*PP = 1.04 x B.

**T = 1.8 x PP.

3. Labor (Cleaning) and Installation Costs for CAS Tiles for 1 Year (52 Weeks)

Installation Costs

Materials	\$38,230	\$58,480
Installation labor	8,380	8,380
Transportation	4,840	4,840
Grinding	<u>9,000</u>	<u>9,000</u>
	\$60,450	\$80,700

Maintenance

Materials	\$16,276	\$16,276
Labor	<u>8,712</u>	<u>8,712</u>
	\$24,988	\$24,988
 Total Costs (for installing and cleaning plates)	 \$85,438	 \$105,688

COST ANALYSIS FOR PAINTING THE AIRFIELD

1. Calculation of Labor Costs

These costs are based only on a six-man crew (including a supervisor, two laborers to grind off rubber deposits, two painters, and one sweeper to remove debris) painting the field once a week for 52 weeks a year. Costs for water-blasting or other contractor cleaning may add another \$25,000 for an average 5-day pavement preparation.

<u>No. of Persons</u>	<u>Wage Grade</u>	<u>Salary (\$/hr)</u>	<u>Hours Per Week</u>	<u>Weeks Per Year</u>	<u>Total Hours</u>	<u>Total Costs (\$)</u>
1 (supervisor)	WL	12.33	4	52	208	2,565
2 (painters)	WG-9	12.03	32	52	3,328	40,036
2 (grinders)	WG-7	10.81	32	52	3,328	35,976
1 (sweeper)	WG-5	8.85	32	52	1,664	<u>14,726</u>
Base labor cost (B)						93,303 (B)
Premium pay factor (holidays)*						97,035 (PP)
Overhead multiple (support)**						174,663 (T)
Total labor cost (T)						174,663
(for painting 52 times per year)						

*PP = 1.04 x B.

**T = 1.80 x PP.

2. Calculation of Material Costs

<u>Item</u>	<u>Federal Specification--</u>	
	<u>TT-P-1952</u>	<u>TT-P-85</u>
Cost per gallon of paint, \$	6.00	12.00
Coverage, ft ² /gal	200	200
Surface area required, ft ²	8,400	8,400
No. of gallons required	42	42
Cost of paint per week, \$	252	504
Cost of paint per year (52 weeks), \$	13,104	26,208
Cost of supplies (30%), \$	3,931	7,862
Cost of paint, \$	17,035	34,070
Cost of labor (from part 1), \$	<u>174,663</u>	<u>174,663</u>
Total cost of painting the airfield (labor & materials) weekly for 1 yr, \$	191,698 to	208,733

COMPARISON OF CAS TILES VERSUS PAINTING (SUMMARY)

CAS Tiles

Installation and weekly cleaning costs (52 times per year)	\$85,438 to \$105,688
--	-----------------------

Painting

1. Repainting on a weekly basis (52 times per year)	\$191,698 to \$208,733
2. Repainting on a quarterly basis (four times per year) plus Waterblast cleaning	\$14,746 to \$16,056
	<u>\$25,000</u> <u>\$25,000</u>
	<u>\$39,746 to \$41,056</u>

SUMMARY

The costs of installing 1,000 of the 3- by 3-foot CAS tiles (9,000 ft² surface area) range from about \$60,000 to \$81,000, depending on the cost of the tiles (about \$25 to \$45 per tile). Procurement in large quantities (5,000 or 10,000 tiles) or competition among the four major suppliers may lower these costs. Maintenance on a weekly basis for 1 year (52 weeks) adds \$25,000. However, the total costs of \$85,000 to \$106,000 are considerably less than the \$192,000 to \$209,000 required for painting the airfield runway on a weekly basis (52 weeks) for 1 year.

The costs of waterblasting (to properly remove all the rubber deposits and create a clean surface) and painting four times a year average about \$40,000. However, freshly painted marking stripes are obliterated by tire marks within 1 week, so comparison with installation and weekly maintenance of the CAS tiles is not logical. The CAS tiles can be cleaned many times, with no perceptible damage to the enamel, thus providing excellent visibility throughout the year.

Another way to compare costs is to look beyond the initial expense of installing the CAS tiles (e.g., \$60,000 to \$81,000) and compare the costs of cleaning these tiles each year with repainting the field each year.

	Cost (\$K)		
	<u>1 yr</u>	<u>5 yr</u>	<u>10 yr</u>
CAS tile cleaning	25	125	250
Painting (52 times per year)	200*	1,000	2,000
Painting (4 times per year)	40	200	400

*Average cost.

These calculations demonstrate that it would cost 1.8 to 8 times as much to repaint the field than to clean the CAS tiles on a weekly basis for 5 years. Thus, it can be concluded that the CAS tiles would be cost-effective and offer the added convenience of marking line visibility throughout the year.

SECTION VIII

FINDINGS AND CONCLUSIONS

The results from the runway installations and aircraft landing tests in California (2 years) were very satisfactory. The plates were installed in dry weather, the adhesive was mixed properly and allowed to fully cure (72 hours at 70 to 80°F), and the plates were properly recessed.

Plate separation occurred in Florida because either the plate surface was wet when the epoxy adhesive was applied or water from rain reacted with the uncured epoxy resin.

Plate separation occurred in Hawaii either because of the impact of heavier jets (i.e., the adhesive may be limited to a maximum load or dynamic force) or the plates were not completely recessed (a diamond cutting machine was used only in Florida and California due to availability).

A similar situation existed in Alaska, where two plates might have loosened because they were not completely recessed. Possibly the adhesive aged and weakened because of the cold. The surfaces of the plates were scratched because steel snowplow brushes were used. This scratching might not occur with the nylon brushes available from the snowplow equipment vendor.

SECTION IX

RECOMMENDATIONS

The following recommendations are made on the basis of the limited testing and evaluation conducted at the four airfields:

1. Installations of the CAS plates on either AC or PCC pavements can be recommended in "sunbelt" locations as long as:

- a. The plates and pavement are dry and installation is conducted under favorable weather conditions (60°F or higher, no rain or snow).
- b. The recommended epoxy adhesives are used as directed (proper mixing and application).

2. Installation of the CAS plates at cold weather locations with heavy snowfall is inconclusive and cannot be recommended until further tests have been conducted.

3. The installations will not be successful if:

- a. The plates are not recessed properly (1/8 to 1/4 inch deep).
- b. The epoxy adhesive is improperly mixed or applied.
- c. The adhesive is not allowed to cure completely (70 to 90°F for 24 to 72 hours is recommended).
- d. The plate or pavement surfaces are wet, greasy, or dirty.

4. Additional engineering investigations are needed to improve the cost and methods of installation (e.g., machine mixing and application of adhesives, use of 3- by 9-foot CAS strips to lower labor costs).

If these recommendations are followed, the CAS marking system will prove to be an excellent, low-maintenance, durable (5 years or more) marking system to help solve the rubber obliteration problem in the touchdown zone of the airfield runway.

REFERENCES

1. R.W. Drisko. Technical Note N-1539: Airfield Marking Paints - A State-of-the-Art Report, Civil Engineering Laboratory, Port Hueneme, CA, Dec 1978.
2. T. Novinson. Technical Memorandum M-52-81-13: Development of Durable Airfield Marking Materials, Naval Civil Engineering Laboratory, Port Hueneme, CA, Nov 1981.
3. B.S. Lynn. Guide Marking for Jet Runway, U.S. Patent 3,096,694.1, Nov 1961.
4. F. Singer and S.S. Singer. Industrial Ceramics. Chemical Publishing Co., New York, 1963.
5. T. Novinson. Technical Memorandum M-52-81-14: Adhesives for Construction Repair and Maintenance at Shore Facilities, Naval Civil Engineering Laboratory, Port Hueneme, CA, Dec 1981.

APPENDIX A

TESTING OF FOUR MAJOR CLASSES OF MARKING MATERIALS

The first year's work was devoted to laboratory testings of 15 different products (Table A-1) selected from the four major classes of marking materials considered:

1. Paints
 - a. alkyds (TT-P-85)
 - b. chlorinated rubber
 - c. oleoresin-phenolic
 - d. polyester (peroxide-catalyzed)
 - e. urethane (aliphatic)
 - f. epoxy/polyamide
 - g. acrylic latex (TT-P-1952)
2. Thermoplastic tapes (unspecified plastic) with adhesive backing
3. Fluorocarbon-metal composites
 - a. on steel
 - b. on aluminum
4. Ceramic-coated materials
 - a. on stoneware
 - b. on aluminum
 - c. on steel
 - d. on aluminized steel

The results from the laboratory testing phase allowed us to eliminate some of the candidates from advanced field testing.

PAINTS

Two Federal specification marking paints are currently used on most airfield runways. TT-P-1952 is a water-based acrylic latex used on asphaltic concrete (AC) (because it does not bleed or dissolve asphalt) and on both AC and Portland cement concrete (PCC) in locations where a ban on environmentally polluting organic solvents exists. TT-P-85 is a medium-length alkyd in an organic solvent used principally on PCC (it bleeds on AC pavements) and outside of California and other such locations that have strict controls on solvent-based paints. Both types of paint are mixed with retroreflective glass beads to provide night visibility of the painted lines. Mild abrasion of the paint surface film (usually by aircraft tires) exposes the glass beads,

and they reflect the light from the landing lights on the aircraft so that the pilot can easily see the landing zone. However, when the painted lines have been obliterated by rubber streaks, the benefits of night visibility are lost.

TRAFFIC MARKING TAPES

Several new traffic marking tapes are now available. These tapes are thick (0.06 to 0.09 inch), thermoplastic material (unspecified polymer) with a rubber-cement-type adhesive on one side and a pigmented surface with retro-reflective glass beads on the other side. The tapes can be directly applied to a pavement surface and rolled into place under pressure (using a truck or steel roller), or the adhesive can be reinforced with a contact cement applied (as a liquid) to the adhesive backing and to the pavement. NCEL observed an installation of one of these tapes on a highway. Vendors have been marketing tapes at several Air Force and Navy bases, but these tapes have not been used on airfields because they are expensive (\$3 to \$5/ft²) and appear to be obliterated by rubber from the jet tires of landing aircraft. They could also be snagged by the jet tailhook or snowplow blade in snow belt areas.

FLUOROCARBON-METAL COMPOSITES

Fluorocarbon sheeting (e.g., Teflon[®] polytetrafluoroethylene or PTFE) has been proposed as an airfield marking material because of its extremely low coefficient of friction (0.04), but there is no evidence that the material was actually tested on airfields (Reference 3). In the current work, Teflon[®] polymer sheeting 0.006 inch thick was bonded to 20-gauge mild steel plates. The Teflon[®] sheeting was factory-prepared to NCEL's specifications, using existing technology. The Teflon[®] polymer sheeting was etched with a sodium metal dispersion in toluene-naphthalene solvent, then bonded to the steel with an epoxy/polyamide adhesive. A related material, Fluorogold[®] polymer sheeting (described by the manufacturer as glass-filled Teflon[®] sheeting), was also bonded to steel and aluminum plates. Fluorogold[®] has a somewhat higher coefficient of friction (0.12) than Teflon[®] polymer (0.04), but both were claimed by the manufacturers to be able to resist rubber adhesion better than other polymeric materials.

CERAMIC-COATED MATERIALS

Several different ceramic-coated materials were investigated because of the general chemical inertness and cleanability of ceramic surfaces. Ceramic-coated tiles and ceramic-coated steel and aluminum sheeting were procured in 12- by 12-inch sheets. The materials were bonded to the pavement with epoxy-polyamide adhesives, as described in Section VII of this report.

TABLE A-1. SUMMARY OF THE MARKING MATERIALS TESTED IN THE LABORATORY

Type of Material	Manufacturer	Trade Name	Surface Covered With Rubber (%)	Surface Cleaned of Rubber (%)	Comments
Paints					
Alkyd (TT-P-85)	Whittaker Corp., Los Angeles, Calif.	None	100	0	Used on airfields outside of California
Chlorinated rubber	Hercules Corp., Wilmington, Del.	Parlon TM	100	0	Used on highways in Northeast U.S.
Oleoresin-phenolic	DeSoto Corp., Chicago, Ill.	Syngard TM	100	0	Used on highways in Northeast U.S.
Polyester (peroxide-catalyzed)	SCH Glidden Corp., Cleveland, Ohio	Romark TM	100	0	Used on Ohio, Michigan highways
Urethane, aliphatic	DeSoto Corp., Chicago, Ill.	Desothane TM	100	0	Used on highways in Midwest
Epoxy-polyamide	H.B. Fuller Corp., Minneapolis, Minn.	None	100	0	Used on highways in Minnesota
Acrylic latex (TT-P-1952)	Whittaker Corp., Los Angeles, Calif.	None	100	0	Used on many airfields on both AC and PCC
Thermoplastic Tapes					
Type 1	3M Co., Minneapolis, Minn.	StaMark TM	100	0	New product introduced for highway marking
Type 2	Prismo Paint Corp., Atlanta, Ga.	None	100	0	New product introduced for highway marking
Fluorocarbon Composites					
Fluorocarbon polymer on steel	E.I. DuPont Corp., Wilmington, Del.	Teflon TM	0	Not necessary	Not previously tested for airfield runways or highways
Fluorocarbon polymer on aluminum	Fluorocarbon Corp., Anaheim, Calif.	Fluorogold TM	50	10 to 20	Not previously tested for airfield runways or highways
Ceramic-Coated Materials					
Ceramic porcelain stoneware	Coors Corp., Golden Colo.	None	50 to 60	100	Not previously tested for airfield runways or highways
Ceramic-coated aluminum	California Metal Enameling, Los Angeles, Calif.	None	50 to 60	100	Not previously tested for airfield runways or highways
Ceramic-coated steel (double-sided)	California Metal Enameling, Los Angeles, Calif.	None	50 to 60	100	Not previously tested for airfield runways or highways
Ceramic-coated aluminized steel (one-sided)	California Metal Enameling, Los Angeles, Calif.	None	50 to 60	100	Not previously tested for airfield runways or highways

The ceramic coatings, also applied by the factory, are slurried over the steel or aluminum plates as an aqueous dispersion. The finished coating is then baked on at 925°F (modern ceramics have low temperature fluxes and require less heat than older formulations). Although the present formulation is proprietary, a standard ceramic formulation is given in Table A-2 (Reference 4). Glass beads could not be used in the finish, but the ceramic coating could be applied to a textured metal surface to provide some night retroreflectivity. However, initial tests indicate that the plates are sufficiently visible to the pilots in night landings at NAS Miramar.

RECESSING THE PLATES: FLUSH-MOUNTING

Although the ceramic-metal and fluorocarbon-metal plates could be directly bonded to the pavement with adhesives, it was felt that the plates would adhere better if they were recessed or flush-mounted (because objects such as jet tailhooks and snowplow blades might catch the plates and dislodge them). To accomplish the flush-mounting, two methods were tried: (1) grinding or planing old concrete surfaces (AC or PCC), and (2) casting a slot or molded recess in a fresh concrete overlay.

Several different types of machines (Table A-3) were used to grind or plane the concrete:

1. The EDCO[®] concrete planer (Equipment Development Co., Md.)
2. The Tennant Model L concrete grinder (Tennant Co., Minneapolis, Minn.)
3. The Tennant Model G concrete grinder

The machines were evaluated for:

1. Amount of time needed to cut 3-foot-wide by 20-foot-long sections at 1/8-inch depth.
2. Ease of operation and control of the cutting blade.
3. Amount of noise produced.
4. Amount of dust produced.
5. Special requirements, such as water sprays (for cooling or dust control).
6. Suitability on both AC and PCC pavements.

The EDCO[®] machine is shown in Figure 8, with a closeup view of the steel cutting blades in Figure 9.

TABLE A-2. REPRESENTATIVE FORMULATION FOR WHITE
CERAMIC COATING (FOR STEEL) (REF 4)

Type of Material	Parts, by Weight
Pigments (White)	
Titanium dioxide	18.0
Barium dioxide	3.4
Lead dioxide	4.0
Lead carbonate	62.0
Flux Materials	
Sodium fluoride	4.0
Boric acid	7.6
Other Materials	
Sand or quartz	8.0

TABLE A-3. CHARACTERISTICS OF CONCRETE CUTTERS TESTED

Machine	Manufacturer	Cost (\$)	Comments
EDCO concrete planer	Equipment Development Co. (Maryland)	7,000	Takes 3 hr to cut 300 ft ² by 1/8 in. of PCC pavement (3- by 100-ft stripe). Cutting head is 9 in. wide.
Tennant Model G	Tennant Corp., (Minneapolis, Minn.)	10,000	Takes 4 hr to cut 300 ft ² x 1/8 in. of PCC pavement (3- by 100-ft stripe). Cutting drum is only 4 in. wide.
Tennant Model L	Tennant Corp., (Minneapolis, Minn.)	25,000	Takes 3 hr to cut 300 ft ² by 1/8 in. of PCC pavement (3- by 100-ft stripe). Cutting drum is 4 in. wide.

APPENDIX B

SUPPLIERS OF MATERIALS AND SERVICES

MATERIALS

Detergent (for cleaning CAS plates)

Biotek, Inc.
P.O. Box 20094
San Diego, CA 92120
(619) 286-1786

CAS Plates

California Metal Enameling Co.
6904 E. Slauson Ave. (P.O. Box 22073)
Los Angeles, CA 90022
(213) 726-1616

Colite Industries
P.O. Box 1000
Columbia, SC
(803) 796-1000
(800) 845-1800

H.H. Robertson Co.
Connersville, IN
(317) 825-1171
(213) 686-1510 (Los Angeles, CA)

Claridge Products, Inc.
Harrison, AR
(501) 743-2200
(415) 351-8183 (San Leandro, CA)

Adhesives

3M Co.
Adhesives, Coatings, & Sealers Division
3M Center, Building 223-6NE
St. Paul, MN 55101
(612) 733-1110

Dow Corning Corporation
Corporate Center
Midland, MI 48640
(517) 496-4000

Epoxylite Corporation
2971 Silver Drive
Columbus, OH 43224
(614) 261-0515

H.B. Fuller Co.
5220 Main St. N.E.
Minneapolis, MN 55421
(612) 560-4350

Hysol Division, Dexter Corporation
15051 E. Don Julian Road
City of Industry, CA 91749
(213) 968-6511

SERVICES

Pavement Contractors Using Diamond Cutting Equipment

Crete Planer Co.
3444 Garrison St.
San Diego, CA 92106
(619) 224-9449

Pavement Specialists Co.
P.O. Box 610327 (Dallas-Ft. Worth Airport)
Dallas, TX 75261
(214) 258-0660

J.F. Barton Co.
1814 W. Field Loop (P.O. Box 73525)
Houston, TX 77090
(713) 443-0613

Central Atlantic Co.
P.O. Box A
Aberdeen, MD 21001
(301) 575-6930

MU Corp.
P.O. Box 216
Lebanon, TN 37087
(615) 444-7027

Allstate Paving Co.
7200 Hemlock Lane North
Minneapolis, MN 55369
(612) 425-8616

The Pennhall Co.
16539 So. Broadway
Gardena, CA 90248

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