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THE USE OF SODIUM SILICATE AND SULPHUR AS A DUST PALLIATIVE

by

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CORPS OF ENGINEERS

Vicksburg, Mississippi

under

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by

Southwest Research Institute

San Antonio, Texas

ARMY-MRC VICKSBURG, MISS.

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FOREWORD

This report covers the work performed under Contract No. DA-22-071-eng-482, dated 28 April 1966, between the U. S. Army Engineer Waterways Experiment Station and Southwest Research Institute (SwRI Project No. 02-1898). The research is sponsored by the U. S. Army Materiel Command under DA Project 1-v-0-21701-A-046, "Trafficability and Mobility Research, " Task 05, "Mobility Engineering Support (Dust Control, Southeast Asia)."

The purpose of this research project was to find, or otherwise develop, new or improved materials or methods applicable specifically to the problem of dust control in connection with military operations on roads and airfields in the theater of operations. The research was directed toward the general objective of improving military mobility through the utilization of suitable soil treatment materials or methods and was guided by requirements for an end item or product pertinent to the dust control problem, the laboratory tests and field tests to be performed by WES personnel. These are set forth as follows:

Appendix A - Qualitative Materiel Requirement for Dust Control Materiel; Appendix B - Laboratory and Field Procedures and Tests for Screening of Dust Control Materials Conducted at Waterways Experiment Station; Appendix C - Experimental and Laboratory Results on Sodium Silicate Based Formulations; Appendix D - Experimental and Laboratory Results on Sulphur Based Formulations.

The contract was monitored by Mr. G. R. Kozan, Chief, Stabilization Section, Expedient Surfaces Branch, under the general supervision of Mr. W. J. Turnbull, Chief, Soils Division, Waterways Experiment Station. Contracting Officers were COL J. R. Oswalt, Jr., CE, and COL L. A. Brown.

The contractual effort was divided into two fields of interest. The first was developed of sodium silicate formulations, and the second was development of sulphur base compositions. The sodium silicate phase of this program was the major effort although a small portion of the funds was expended in evaluation of the sulphur-base compositions.

The Southwest Research Institute team consisted of E. Jack Baker, Jr., John M. Dale, William A. Mallow, and Allen C. Ludwig. Mr. Baker served as project manager with the contributions of Messrs. Dale and Ludwig to this program being primarily in the area of sulphur-base materials. Mr. Mallow's work was concentrated on developing a sodium silicate base composition.

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SUMMARY

This report covers the work performed in evaluating sodium silicate and sulphur based formulations for their use as dust palliatives. The results of the experimental work are herein presented.

The conclusions drawn for each of these formulations are as follows:

- (1) Sodium silicate based formulations can be used as an efficient, inexpensive dust palliative when the silicate is sufficiently insolubilized to withstand normal weathering conditions, and a waterproof latex barrier is used to cover the base sodium silicate coating.
- (2) The sulphur based coatings have some very attractive features such as low cost and availability of materials, but the sulphur based coatings were not pursued to an end result because of the complications involved in applying the hot molten sulphur coatings.

THE USE OF SODIUM SILICATE AND SULPHUR AS A DUST PALLIATIVE

PART I: INTRODUCTION

Purpose

1. The purpose of this project was to study the feasibility of using sodium silicate and sulphur base materials as dust palliatives.

Scope

2. This report covers the work performed by Southwest Research Institute and includes the results of the laboratory and field tests on sodium silicate and sulphur based materials conducted during the course of the project. The information contained in this report reflects on the experimental work performed at SwRI and not the tests conducted at Waterways Experiment Station.

Background

3. Dust control has been a long-time topic under broad programs of soil stabilization undertaken by the Army and other agencies (1).^{*} The greater dependence on mobility and, in particular, the current demands for military airlift have magnified the significance of dust as a major factor in engine deterioration. The control of dust around aircraft and road vehicle operations is also important for reasons of operation, concealment, and convenience.

4. As defined for industry representatives at the 24 January 1966 Dust Control Meeting at WES, the top priority objective is dust-proofing around major (but perhaps remote) bases on airstrip shoulder and overrun areas not intended for regular traffic. Secondary objective would include dustproofing of areas subject to random ground traffic.

^{*}Numbers in parentheses refer to the References at the end of this report.

and the long-range objective is a versatile, multipurpose dust palliative technique. The WES problem statement given at the meeting adequately described the various characteristics and limitations which were to apply. Further clarification was set forth in the "Qualitative Material Requirements for Dust Control Materiel" which has been included herein as Appendix A.

PART II: THE USE OF SODIUM SILICATE AS A DUST PALLIATIVE

General Information

5. Let us briefly review what sodium silicate is and what the present commercial uses for this versatile material are. Sodium silicates are a group of chemicals having a wide range of characteristics. They are used every day by most of us in one or more ways in such commodities as soaps, paper, textiles, corrugated containers, gasoline, building board, and a host of others. Sodium silicate is a generic term given to a family of chemicals composed of sodium oxide (Na_2O), silica (SiO_2), and usually, but not always, water (H_2O).

6. The proportion of Na_2O to SiO_2 in sodium silicate is expressed on a ratio basis. For silicate less alkaline than the metasilicate (1 molecule of NaO to 1 molecule of SiO_2), the ratio is expressed on a weight basis with the Na_2O held at unity. For instance, the ratio of a liquid sodium silicate containing twice as much SiO_2 as Na_2O would be expressed as $\text{Na}_2\text{O}:2:00$ SiO_2 weight ratio or occasionally, simply "2.00 weight ratio."

7. The commercial grades of liquid sodium silicate are usually made as concentrated as can be conveniently handled. For example, a silicate having a 3.22 weight ratio can be easily used with a solids concentration of about 39.3 percent equivalent to approximately 42.5° Baumé. This concentration was chosen for this program because of availability, relatively low degree of alkalinity, and its adhesive properties. This grade of sodium silicate corresponds to Diamond Chemicals Grade 42. The following tabulation gives the typical values for the various properties of the grade 42 sodium silicate (2).

Specific gravity at 20°C	1.415 (42.5° Baumé)
Viscosity at 20°C	385 centipoise
Weight ratio	$\text{Na}_2\text{O}:3.22\text{SiO}_2$
Weight per gallon	11.78 pounds
Solids content	39.3%
Cost	\$0.0135/lb

<u>Available in Containers</u>	<u>Net Weight, lb</u>
Steel drum (55 gal)	640
Tank truck	30,000 to 40,000
Tank car	90,000 to 115,000

Uses

Adhesive operations
Asbestos products
Fibre drums
Laminated aluminum foil
Paper tube winding
Refractory cements
Sealing shipping containers
Thermal insulation board

8. It has been found that for handling liquid sodium silicate, such as grade 42, rotary or centrifugal type pumps are satisfactory. Flooded suction is required for centrifugal pumps, but such pumps normally require less maintenance since the packing gland is not subjected to full discharge pressure. All iron construction is satisfactory for silicate pumps, and standard black iron pipe meets the usual piping requirements. For most silicate installation, rubber diaphragm, plug, or gate valves are satisfactory. Globe valves are generally to be avoided.

9. Sodium silicates are nonflammable, nonexplosive, and non-toxic. However, as alkaline materials, they present the usual hazards to the eyes and skin. While the liquid $\text{Na}_2\text{O}:3.22\text{SiO}_2$ used in this program is very siliceous, it should be handled with care.

10. Some major factors indicate sodium silicate base materials could be an excellent dust palliative. Some of these are: availability, low cost, ease of application, nonflammable, nonexplosive, and non-toxic. Its major defect in this application is that sodium silicate is water soluble.

Laboratory Evaluations

11. We began to work in the laboratory to find additives that would tend to insolubilize sodium silicate. Naturally, the first test that any formulation had to pass was the water erosion resistance test.

12. The formulations were evaluated for water erosion resistance by putting samples on 1/4-in. thick cardboard panels. The panels were 6-in. wide and 12-in. long. Exactly 1.05 gm/in.² (3 lb/yd²) of each formulation was placed on a panel and allowed to dry. Most of the erosion tests were conducted after a 4-hour cure period at room

temperature, but a few samples were evaluated after an accelerated cure in a warm oven. Once the sample was cured, the panel was placed at an angle of approximately 60° from the horizontal under a slowly running hydrant. The rate of water flow across the face of the sample was equivalent to approximately 1 quart of water per minute. Over 200 formulations were compounded and evaluated in the laboratory. The formulations, cure conditions, and results of the water erosion test are tabulated in Appendix B.

Field Evaluations

13. The formulations that survived the water erosion test and appeared to be easy to apply to the soil were field tested at Southwest Research Institute. The test site consisted of three general soil types: sand, silt and clay. The sand was fine grained, poorly graded, and had a maximum dry density of 102 lb/ft³. No Atterburg limits could be obtained for this granular material. The silt was a brown inorganic top soil with an average liquid limit of 54% and a plastic limit average of 27%, giving a plasticity index of 27%. The clay used in this program had a liquid limit average of 72% and a plastic limit of 28%, giving a plasticity index of 44%. Grain size distribution of each soil is shown in Figure 1.

14. Each test formulation was compounded, and exactly 6 lb was put into a 2-gal pressure spray pot. Water was added when the viscosity of the coating was too high to obtain a uniform spray pattern with 30- to 40-psi pot pressure. The water of dilution was not considered part of the 3 lb/yd² of coating material. The 6 lb of material was applied to a 2-yd² area of one of the soil types. It was attempted to spray the formulations on the areas in a constant thickness. Pre-wetting of the soil with water was not normally done for the coatings. This dry soil condition did not affect the coating since none of the test soils could be considered of a fine, powder-like dust type, where pre-wetting is very necessary.

15. Approximately 4 hours after each coating has been applied, a simulated rainfall was produced on the sites using an oscillatory water sprinkler. The rate of rainfall was equivalent to 6 in./hour. After 1 hour of simulated rainfall, the water sprinkler was turned off, and the dust coating was allowed to dry. Only samples which survived at least ten wet and dry cycles of this nature were considered satisfactory for additional evaluations.

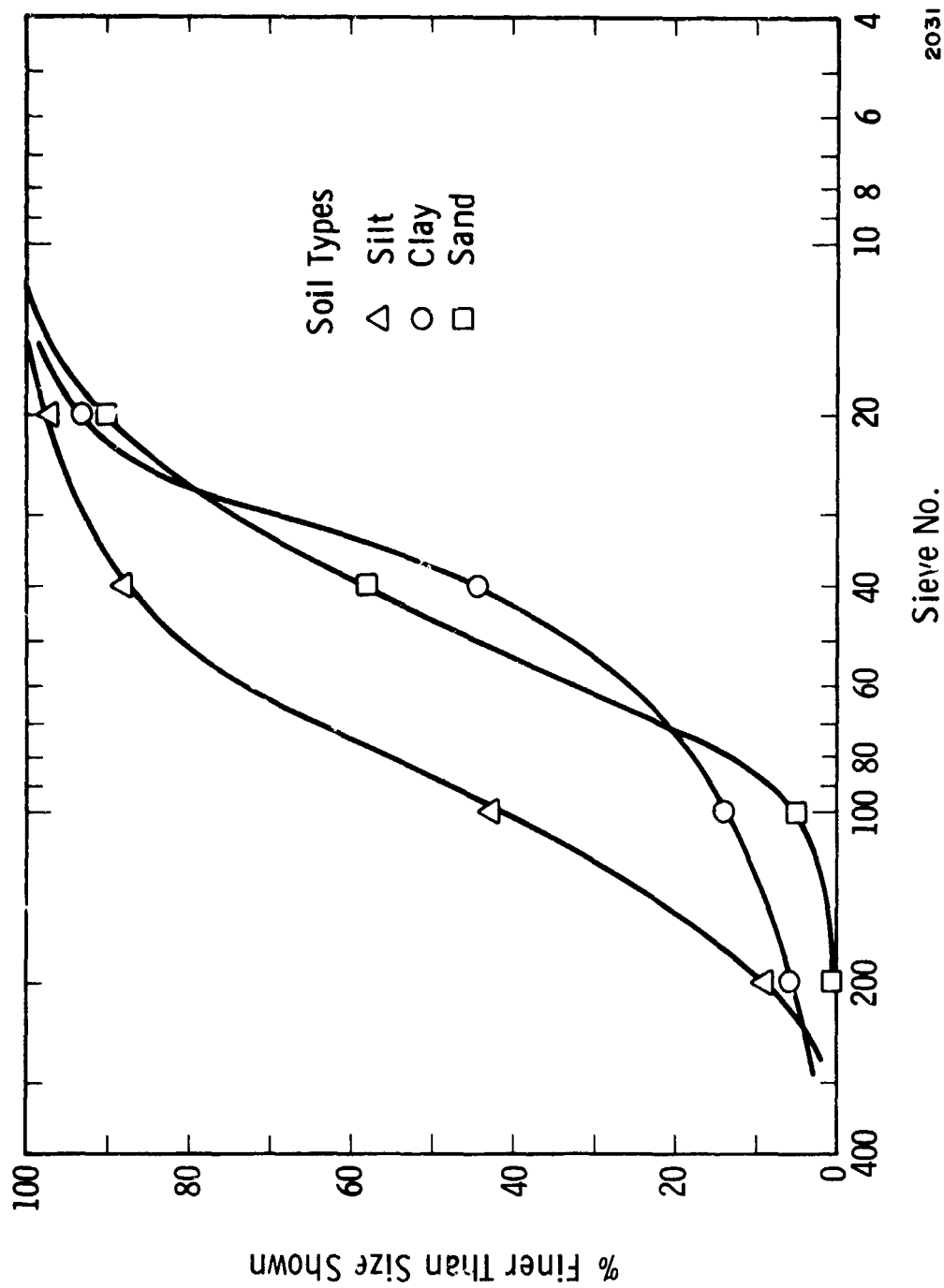


Figure 1. Grain Size Distribution

16. The typical failure of the coating was not primarily due to failure of the coating but instead was due to large expansion and contraction of the soil. The worse soil, as far as expansion and contraction, was the native topsoil which contains large percentage of bentonite clay. The mode of failure was cracking along a number of lines until the coating was in many small pieces. The rate of failure was not as rapid on the clay site, but the type of failure was the same. Since the expansion and contraction of the sand during wet-dry cycles was small, most of the coatings remained intact on this site.

17. The following seventeen coats were applied to the field site at Southwest Research Institute:

Coating No. 1

84% sodium silicate grade 42
8% acrylic latex (AC-34)*
8% aluminum naphthanate

The coating was applied with a two-component sprayer with the sodium silicate sprayed through one nozzle and the aluminum naphthanate/acrylic latex (AC-34) through the other. The effluent mixture was not homogeneous. A second area was sprayed with a single-component sprayer in which all of the materials were premixed. The resulting film was uniform and continuous. The film deteriorated on the native topsoil and clay sites after 2 weeks of exposure. The coating was still in evidence on the sand site though it was marginal.

Coating No. 2

77% sodium silicate grade 42
3% zinc naphthanate
3% zinc oxide
13% acrylic latex (AC-34)
4% polybutene

The coating was applied with a single-component spray system, and a well-defined film resulted. The coating survived 2 weeks' exposure on the sand and clay sites but deteriorated rapidly after the second day on the native topsoil.

*Trade name, Rohm & Haas Chemical Company.

Coating No. 3

76% sodium silicate grade 42
15% SBR latex (Dow 300)*
7% Cyclopol S102-5†
2% cobalt naphthanate

This coating was applied with a single-component spray system. The coating survived 2 weeks on sand, 1 week on clay, 3 days on native topsoil.

Coating No. 4

80% sodium silicate grade 42
8% SBR latex (Dow 300)
8% Cyclopol S102-5
2% zinc oxide
2% cobalt naphthanate

Each of the test sites was pretreated with 1 gal/yd² of 2-percent calcium chloride-water solution immediately before the coating was applied with a single-component spray system. The resulting film cracked and peeled almost immediately upon drying.

When the calcium chloride solution was allowed to dry thoroughly before application of the sodium silicate base coating, the coating survived for approximately 2 weeks before it began to deteriorate on any of the sites.

Coating No. 5

74% sodium silicate grade 42
15% SBR latex (Dow 300)
7% Cyclopol S102-5
2% cobalt naphthanate
2% zinc oxide

This coating was sprayed on each site immediately following application of 1 gal/yd² of 2-percent calcium chloride solution. The coating began to break up, crack, and peel 2 weeks after application.

*Trade name, Dow Chemical Company.

†Trade name, Koppers Company, Inc.

Coating No. 6

- 74% sodium silicate grade 42
- 15% SBR latex (Dow 300)
- 7% Cyclopol S102-5
- 2% cobalt naphthanate
- 2% zinc oxide

Again a 2-percent calcium chloride pretreatment was allowed to dry before applying the coating. This coating withstood wet and dry cycle procedures for approximately 2 weeks before it began to deteriorate.

Coating No. 7

- 74% sodium silicate grade 33
- 15% SBR latex (Dow 300)
- 7% Cyclopol S102-5
- 2% cobalt naphthanate
- 2% zinc oxide

Coating No. 7 was applied with a one-component spray system. There was no pretreatment of the soil. We detected no significant difference in performance of this coating as compared to any of the coatings in which grade 42 was used.

Coating No. 8

- 68% sodium silicate grade 33
- 19% poly (vinylacetate) latex
- 5% aluminum naphthanate
- 5% polybutene 24
- 3% zinc oxide

This coating was applied with a single-component spray system with the sodium silicate being blended last to the premixed additives. The coating survived 10 days on clay and sand without change, but on native topsoil it deteriorated within 1 week.

Coating No. 9

- 68% sodium silicate grade 42
- 19% poly (vinylacetate) latex
- 5% aluminum naphthanate
- 5% polybutene 24
- 3% zinc oxide

Coating No. 9 was the same formulation as Coating No. 8 except that grade 42 sodium silicate was substituted for grade 33 sodium silicate. The field results were almost identical; the coating remained virtually unchanged on the clay and soil for about 10 days, but it began to break up on the native topsoil within 1 week.

Coating No. 10

50% sodium silicate grade 42
50% poly (vinylacetate) latex

This coating was applied as a single-component, premixed solution. The coating deteriorated on all the sites treated within 2 weeks.

Coating No. 11

60% sodium silicate grade 42
30% SBR latex (Dow 300)
10% aluminum naphthanate

In preparing the formulation, it was necessary to take great pains to thoroughly dispense the metal soap (aluminum naphthanate) in the latex before adding it to the sodium silicate. This procedure prevented rapid gelation in the sodium silicate. The sand and clay sites survived approximately 3 weeks' exposure while the native topsoil deteriorated within 1 week.

Coating No. 12

54% sodium silicate grade 42
40% SBR latex (Dow 300)
3% lead octoate
3% 90 weight oil

The oil, lead octoate, and latex were mixed thoroughly before they were added to the sodium silicate. The formulation was then sprayed with a single-component spray gun on the three soil sites. The coating of the sand and clay sites withstood weathering for 10 weeks, but the coating on the native topsoil deteriorated within 2 weeks.

Coating No. 13

74% sodium silicate grade 42
15% No. 700-157 dust suppression latex*

*Trade name, B. F. Goodrich Company.

7% Cyclopol S102-5
4% aluminum naphthanate

The Cyclopol and aluminum naphthanate were blended and then added to the latex. These three components were thoroughly mixed and then added to the sodium silicate and agitated until a homogeneous solution was obtained. Coatings on the sand and clay sites were seriously damaged after 2 weeks, and the coating on the native topsoil was thoroughly degraded.

Coating No. 14

Part 1 - 83% sodium silicate grade 42
17% SBR latex (Dow 300)

Part 2 - 89% SBR latex (Dow 300)
11% lead octoate

Part 1 was applied to each of the three sites with a density of 2 lb/yd². This application was then followed by a second coat consisting of Part 2 with a concentration of 1 lb/yd². This coating stood up quite well on all three of the test sites for the first 3 months and experienced approximately twenty-five wet and dry cycles before the coating on the native topsoil began to deteriorate. The coating on the clay and sand still exhibited good dust suppression characteristics.

Coating No. 15

Part 1 - 83% sodium silicate grade 42
17% acrylic latex (AC-34)

Part 2 - 89% SBR latex (Dow 300)
11% lead octoate

This coating was sprayed in the same manner as Coating No. 14, and the results were almost identical.

Coating No. 16

Part 1 - 82% sodium silicate grade 42
9% methyl acrylate
9% water
0.1% sodium caseinate (10% solution)

Part 2 - 48% SBR latex (Dow 300)

5% lead octoate
47% water

The sodium casienate was used as a surfactant. The amount used was so small that the amount was expressed as a fraction of a percent of the total of the other constituents. The sodium casienate was added to the sodium silicate, and the methyl acrylate was added to the sodium silicate solution. The mixture was vigorously agitated until a smooth emulsion was obtained. Water was used to dilute Part 1 so that the viscosity was reduced enough to make it easy to spray. The water of dilution was not counted as part of the weight per unit area of applied coating. After coating the three test sites, Part 2 was mixed and sprayed directly over Part 1. No deterioration on any of the sites was observed during the first month. A 4,000-lb automobile was driven over the coating on the sand site, which failed only at the extreme edges of the coating.

Coating No. 17

100% Dow 300

This coating was applied at a 3-lb/yd² density on each of the three sites. Good water repellancy and elongation characteristics were observed on the sand and clay sites for over 6 weeks while the coating failed after only 2 weeks on the topsoil site.

Two-Pass Application Systems

18. It was decided that the dust palliative would have to prevent water penetration as well as survive water erosion in order to stop the large expansion and contraction of the soil. The waterproof coating would also assure better load bearings characteristics of the base soil. This was accomplished in the following manner: A 2-lb/yd² coating which was mostly sodium silicate was applied to the soil. Then, a 1-lb/yd² coating of latex and a metal soap was added. The latex was used to waterproof the coating, and the metal soap was used to insolubilize the sodium silicate. This two-pass coating system was evaluated at the SwRI field site with Coatings Nos. 14, 15, and 16. All the coatings worked very well and Coatings Nos. 14 and 16 were evaluated at the WES laboratory. Coating No. 16 was selected for additional field testing at WES.

19. Coating No. 16 was modified to reduce the viscosity and make it easier to spray. The revised formulation consisted of the following items and quantities:

Part 1	sodium silicate	77%
	methyl acrylate	8%
	water	15%
Part 2	Dow 300 latex	62%
	lead naphthanate	7%
	water	31%

Part 1 was applied at the rate of 2 lb/yd² and Part 2 applied at the rate of 1 lb/yd² (not counting the water of dilution). The cost of this formulation is about \$0.26/yd² with the latex making up about half of the cost. The sodium casienate was not required in the modified formulation. The lead naphthanate was substituted for lead octoate cited in field tests at SwRI because of the cost and availability of the lead naphthanate. It should be noted that all of the metal soaps cited above or in Appendix B have a tendency to insolubilize the sodium silicate. The higher the molar content of metal soap, the better the insolubilization. Some of the metal soaps used were the naphthanate and octoates of aluminum, calcium, cobalt, copper, iron, lead, and zinc.

WES Laboratory Test of Sodium Silicate Base Coating

20. Six sodium silicate base coatings were evaluated at Waterways Experiment Station. These tests were conducted at two different times. The first tests were on the following coatings:

<u>SwRI Designation</u>	<u>WES Designation</u>
Coating No. 5	SS 1182
Coating No. 8	SS 1183
Coating No. 11	SS 1181
Coating No. 12	SS 1180

None of the coatings stood up under the second air impingement test.

21. The second set of tests conducted at WES laboratory were on the following coatings:

<u>SwRI Designation</u>	<u>WES Designation</u>
Coating No. 14	SS 1203
Coating No. 16	SS 1202

Both of these coatings survived the second air impingement on all of the soil types except sand. Coating No. 16 was selected for further field testing at WES because the film formed appeared to be more flexible.

PART III: THE USE OF SULPHUR AS A DUST PALLIATIVE

General Information

22. The object of this phase of the study was to evaluate the feasibility of using sulphur or a modified sulphur formulation as a dust palliative for low traffic areas around helicopter pads and along airstrips. Pure solid elemental sulphur has a Shore B-2 hardness of 90 and an impact strength of 0.5 in. -lb. As a soil coating with a film density not to exceed 3 lb/yd², it was envisioned that a softer, more flexible composition would be desirable. During the course of previous work, various additives were found that alter the physical and mechanical properties of elemental sulphur, without significantly altering the economic advantage of sulphur. Sulphur of 99.5 percent purity is currently available for 2.0 cents/lb, f.o.b., Texas Gulf Coast, and with the addition of modifiers, formulation costs on the order of 3 to 5 cents/lb are not uncommon.

23. The most practical means of applying sulphur as a uniform film of this thickness (3 lb/yd² is equivalent to a 0.032-in. film thickness of sulphur) is by spraying the molten formulation onto the substrate to be coated. In the laboratory, this was accomplished by spraying by hand using a small heated pressure vessel with flexible discharge line.

24. In previous work for WES (3), the most promising formulation found when using sulphur as a soil stabilizing agent consisted of a composition containing 85-percent sulphur and 15-percent styrene monomer by weight. It was envisioned that the addition of various other modifiers to this sulphur styrene mixture might well be the best solution for the subject application. Upon initiation of this study, 50 lb of the 85-percent sulphur - 15-percent styrene mixture were supplied to WES for evaluations. The lack of a heated spray assembly at WES necessitated preparing the coating by hand which resulted in an 8-lb/yd² film density. At this density, the formulation proved to be highly resistant to the air blast and water erosion tests.

Laboratory Experiments

25. Initial effort was devoted to improving the wetting characteristics of the sulphur composition towards the soil. Among the

various additives screened were the halogenated aromatic compounds, such as the Aroclors and Halowax; silicones; detergents, such as sodium xylene sulfonate; and various terpene compounds, including turpentine and dipentene.

26. For screening purposes, each of these materials were added in quantities ranging from 2 to 5 percent by weight in elemental sulphur as well as in styrene-sulphur mixtures. The mixtures were poured on topsoil and sand, and the wetting and penetration characteristics were observed. The temperature at which these mixtures were poured was also a variable studied. The performance of the various formulations is shown in Appendix B.

27. Of the additives screened, dipentene was singled out as the most promising additive. When mixed with either elemental sulphur or the sulphur-styrene mixture, the dipentene at the higher concentrations allowed for the mixture to completely penetrate the various soils.

28. The next step in the development of a soil coating was to optimize the sulphur-styrene dipentene formulation. The styrene content was varied from 10 to 25 percent while the dipentene content was varied from 5 to 20 percent. It was found that a balance had to be made by controlling flexibility with the styrene and penetration with the dipentene. The various formulations and their performances are also recorded in Appendix B. Optimization of the formulations was conducted in the laboratory with 1-lb samples which were sprayed over various soils. For these applications, a small heated pressure pot was fitted with a spray nozzle and the soil specimens were passed under the nozzle at such a rate that a 20-mil film thickness was applied to the soil. It was found that if the dipentene was kept at a 5-percent level and the styrene content was increased, the flexibility increased to the point where the product became a very tacky mass requiring over an hour to cure. If the styrene content was held constant as the dipentene was increased, the penetration of the mixture increased to the point where the adhesion to the soil overcame the cohesion of the film and the result was a mass of wetted soil particles very loosely bonded together. The more attractive formulations fell within these two boundary conditions. At the conclusion of this phase, it appeared that the optimum formulation consisted of 75-percent sulphur, 20-percent styrene, and 5-percent dipentene by weight, applied at 155°C.

29. To investigate the burning characteristics of this particular formulation, a propane torch was played on the 20-mil coating until

the formulation ignited. The torch was then pulled away, and it was found that the fire would extinguish immediately. This was repeated until the formulation was completely consumed. Two other formulations were also prepared: one consisting of 75-percent sulphur, 20-percent styrene, and 5-percent tricresyl phosphate (TCP) by weight; and the second 70-percent sulphur, 25-percent styrene, and 5-percent TCP by weight. The TCP was substituted for the dipentene because of the known fire-retarding characteristics of the TCP-styrene combination in sulphur. When subjected to the same test as previously described, these two formulations reacted in an identical manner to the sulphur-styrene-dipentene. The use of TCP has the disadvantage of higher cost and a poor solubility in the sulphur formulations.

30. After the laboratory testing had been completed, soil coatings were applied on test areas 3 ft X 6 ft in size and evaluated under wet and dry conditions. The formulation, consisting of 75-percent sulphur, 20-percent styrene, and 5-percent dipentene by weight, was sprayed over sand and dry topsoil. To become better acquainted with the handling and spraying characteristics of this formulation, a spray unit capable of handling these quantities was assembled from components already available in our laboratory. The formulation was charged to the assembled unit and discharged under pressure through a flexible heated line to a spray nozzle and applied over several different soil types. Film densities of 3 lb/yd² were applied, which on cooling converted to a flexible, plastic coating. Its performance on sand was much better than on the topsoil. On the topsoil, this particular formulation remained tacky, and it became obvious that less styrene should produce a better film.

31. The final formulation which resulted consists of 80-percent sulphur, 15-percent styrene, and 5-percent dipentene by weight. The addition of the dipentene also allows for a more flexible film than that attained with the formulation of 85-percent sulphur and 15-percent styrene. Preliminary tests conducted in the laboratory for air blast and water resistance appeared very encouraging.

32. The use of a modified sulphur formulation as a dust palliative for light or nontraffic areas around aircraft landing sites is certainly an application worthy of further consideration. Although the developed formulation was not subjected to the rigid service tests at WES, preliminary laboratory tests at SwRI indicated that a sulphur-styrene-dipentene formulation might well show promise. One important advantage of the modified sulphur formulation is its extremely

low cost. A cost breakdown for the most promising formulation uncovered during the short course of this work is as follows:

<u>Component</u>	<u>Unit Cost (¢/lb)</u>	<u>Part by Weight (%)</u>	<u>Cost Contribution (¢/lb)</u>
Sulphur	2.0	80	1.60
Styrene	9.0	15	1.35
Dipentene	10.0	5	.50
Total Cost			<u>3.45</u>

At a film density of 3 lb/yd², this amounts to a cost of 10.4 cents / yd².

33. At this time, it was decided to discontinue the effort on the sulphur phase and concentrate on the sodium silicate phase of the project. The reasons for this decision were that:

- (1) The specialized equipment required to apply the hot molten sulphur coatings.
- (2) The extreme rate sensitivity of the plasticized sulphur material.
- (3) The objectionable odor of the sulphur based coatings.
- (4) The fact that the coatings would not allow the native grass and vegetation to grow back without removal of the coatings.

At the present time, there are a number of research programs dealing with sulphur technology which may overcome some of the objections stated above. When these programs are completed, or when the objections are overcome, it will possibly be worthwhile to take an additional look at sulphur as a dust palliative.

PART IV: CONCLUSIONS

34. During the course of this program, we have evaluated over 200 formulations of sodium silicate based materials and approximately 30 formulations of sulphur based materials for possible use as dust palliatives. We were able to obtain a satisfactory dust control coating using a sodium silicate base material. The sodium silicate base materials produced on this program have a number of distinct advantages in addition to their extremely low cost. They are easily applied, nontoxic, nonflammable, readily available, and the residual coating does not affect the native vegetation.

35. We feel that additional effort is warranted for further development of this type of coating and the equipment required to apply this material to large areas.

REFERENCES

1. "Guide Manual for Selection and Use of Dust Palliative and Soil Waterproofers in the Theater of Operations," by G. R. Kozan and R. A. Pimental, U. S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, Project No. 1-V-0-21701-A-046.
2. "Sodium Silicate Handbook," Diamond Alkali Company, 1967.
3. "Feasibility Study on the Rapid Stabilization of Soils by the Use of Sulphur," U. S. Army Engineers Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, Contract No. DA-22-079-eng-413, Army Materiel Command, Project No. 1-T-0-21701-A-046, SwRI Project No. 02-1569.

APPENDIX A

QUALITATIVE MATERIEL REQUIREMENT
FOR DUST CONTROL MATERIEL

Section I - Statement of Requirement

1. Statement of Requirement.

a. Dust Control Materiel.

b. Dust control materiel is required to provide the Army with an effective, efficient means of suppressing dust at airfields, helipads, operational bases, intermediate and cantonment areas as well as supply bases and roads where the presence of dust is detrimental to military operations. The materiel for adequate dust control will consist of dust control material(s) and equipment. Concurrent development of optimum techniques for application of dust control material(s) is considered to be an inherent requirement. This materiel will provide a dustproof land surface which will greatly increase capabilities for air and surface operations, reduce health and safety hazards, and enhance security by eliminating land surface areas, and it must be capable of achieving an operationally acceptable state under hot-dry or warm-wet and intermediate climatic conditions, as defined in Change 1, AR 705-15. Dust control materiel may be used independently or in conjunction with the use of landing mats and membranes. Application shall be by Army engineer troops, indigenous personnel under engineer supervision, and by other personnel responsible for area maintenance. (TF 66-70) (CDOG paragraph 639b(3)).

Section II - Operational, Organizational and Logistical Concepts

2. Operational Concepts.

a. Dust control materiel will be used in all areas where soil is easily eroded by aircraft propwash, helicopter downwash, vehicle movement, and where the generation of dust is detrimental to military operations, principally in tropical, desert, mountain and savanna areas.

b. The materiel will be used intermittently, on an "as required" basis, during peacetime and wartime, in the theater of operation, CONUS, and other areas where dust has an adverse effect on the operating efficiency of aircraft and ground vehicles and creates health, safety, and morale problems for personnel.

c. The materiel will suppress and control the formation of dust, thereby reducing aircraft and vehicle maintenance, operating hazards, health, safety, and morale problems, and aid in concealing military operations from the enemy.

d. Dust control materiel will be used by engineer troops, or other designated area maintenance personnel such as grounds maintenance crews at airfields, cantonments, supply depots, and similar facilities.

e. Planned deployment. Dust control materiel will be used worldwide in those areas where dust seriously impairs military operations.

f. Turnaround time. Desired turnaround time of dust control equipment is 20 minutes, assuming no repairs are required. Turnaround time is the time to service and check out the equipment for recommitment; it excludes reloading of equipment with dust control material(s) if this is required.

g. Reaction time. Not to exceed 50 minutes. This is defined as the time for operator to load the equipment with dust control material, to adjust equipment, and to start application of material.

h. Mission reliability. The dust control equipment must have a 97-percent probability of completing 12 hours of operation without failure.

i. Availability. The combat-ready rate will be not less than 90 percent.

j. Operational and maintenance environmental conditions. This materiel will be required to operate in intermediate, hot-dry, and warm-wet, and desirably cold climatic conditions. Winterization kits are acceptable for the equipment if required.

k. Planned utilization rate. This will vary depending upon area to be dust-proofed. Heaviest utilization rate is envisioned as two 10-hour work shifts per day.

3. Organizational and Logistical Concepts.

a. The dust control application equipment will require a two-man crew to operate and control the rate of application of the

material(s). Approximately one to four additional personnel may be required to load the application equipment with dust control material(s).

b. Materiel should be organic to Engineer Light Equipment Companies, possibly to a TOE 5-500 Team and Engineer Construction Battalions, and carried as a Class IV in depots for issue as required by other organizations.

c. A tentative basis of issue of four sets of equipment to each Engineer Light Equipment Company is recommended. The basis of issue to other organizations from Class IV Supply will depend upon specific area requirements. A final basis of issue will be established following development of specific equipments.

d. Other logistical considerations, to include CONUS channels of supply, and resupply factors, will be determined by US Army Materiel Command (USAMC).

Section III - Justification, Feasibility and Priority

4. Reason for the Requirement. New materiel is urgently required to control dust in areas of military operations. Now, more than ever before, the expanded use of airborne and airmobile operations has greatly increased both the use and the number of austere, unimproved airfields and landing zone surfaces, as well as roads, cantonment areas, and bases of supply. Due to the presence of dust in these areas, logistical problems have been increased tremendously by the drastic reduction in "usage expectancy" of machinery and equipment. For instance, rotor blades of helicopters have to be replaced in about 200 to 300 hours rather than an estimated 1100 hours, and helicopter engines have to be replaced in about one-third to one-half the normal usage period. Hence, the suppression of dust, inherent at operational bases, intermediate and cantonment areas and service roads, is of primary concern if normal "usage expectancy" of aircraft, vehicles, and equipment is to be achieved. The presence of dust also considerably reduces operational capabilities by impairing visibility of aircraft pilots, and vehicle and equipment operators, to such an extent that it constitutes a serious safety hazard and impairs health and morale. In addition, the presence of dust clouds at

operational sites not only provides a visual signature of the area of operation that is easily recognizable from afar, but it also reduces the number of sorties that can be flown within a given period and increases turnaround time of aircraft delayed in landing because of dust. Existing conventional dust control material(s) and equipment for its application are neither suitable nor effective on all soil conditions encountered. Their limitations were demonstrated during Exercise DESERT STRIKE and GOLDFIRE I, and in experiments at Waterways Experiment Station (WES) at Vicksburg, Mississippi. Failure to develop the proposed dust control materiel will prejudice the success of airmobile, airborne and supporting ground operations within the theater of operations, particularly in underdeveloped areas where airfields are either nonexistent or require major improvement. Finally, and particularly intolerable, is the tremendous demand for maintenance and repair parts support required merely to sustain normal operations. The development of new dust control materiel will aid substantially in increasing the "usage expectancy" of machinery and equipment and in greatly reducing the logistical support problem presently existing wherever the presence of dust is having deleterious effects on military operations.

a. There is no dust control materiel presently in the military system capable of meeting this requirement.

b. This requirement for dust control materiel is supported by the following CDOG general objectives:

- (1) 210b(2)
- (2) 610b(3)
- (3) 610b(6)
- (4) 610b(11)
- (5) 612b(5)
- (6) 1810b(6)

This requirement will be further supported by a proposed Qualitative Materiel Development Objective (QMDO) for a Rapid Soil Stabilization System presently in preparation by U. S. Army Combat Developments Command Engineer Agency (USACDCEA).

c. References which support this requirement are:

- (1) Letter, FOR DS SSS, HQ, DA ACSFOR, 25 January 1966, subject: Qualitative Materiel Requirement (QMR) Dust Control Materiel, with 1st Indorsement, CDCMR-O, HQ, USACDC, 4 February 1966, and 2d Indorsement, CSSG-M, HQ, USACDC Combat Service Support Group (USACDCCSSG), 8 February 1966.
- (2) Minutes of Conferences on Dust Control, January 1966, USAE Waterways Experiment Station, 4 February 1966.
- (3) Minutes of Meeting Dust Control Conference, 14 January 1966, Office, Chief of Research and Development, Department of the Army.
- (4) Miscellaneous Paper No. 4-756, Guide Manual for Selection and Use of Dust Palliatives and Soil Waterproofers in the Theater of Operations, November 1965, USAEWES.
- (5) TM 5-366, Planning and Design of Rapid Airfield Construction in the Theater of Operations, November 1965.
- (6) Army Airmobile Evaluation, HQ, USACDC, 15 February 1965.
- (7) Report of Joint Exercise GOLDFIRE I, 6 November 1964.
- (8) Final Report of Joint Exercise SWIFT STRIKE III, 20 November 1963.
- (9) Technical Report No. 3-350, Report 2, Dust Proofing of Soils, July 1963, USAESWES.

5. Technical Feasibility. The development of dust control materiel that can meet the requirement is considered feasible. This judgment is based on the results obtained to date by the following:

- a. An in-house laboratory testing program conducted by WES to evaluate the effectiveness of soil treatment materials on various types of soil and to evaluate dust control materials submitted by industry.

b. Contract studies to investigate soil treatment by such materials as bitumens, petroleum products, salts, cements, and certain epoxy formulations, styrene polyesters, selected organic resins, fluorosilicates, and proprietary items.

c. Field tests (in cooperation with the US Air Force) for the evaluation of the more promising dust control materials.

d. Conference at WES with industry representatives to discuss the dust control problem, January 1966.

e. Conference at Office, Chief of Engineers (OCE) with consultants to discuss the dust control problem, January 1966.

6. Priority. This materiel requirement is assigned Priority I in Functional Group 6, Protection and Environment, of the current CDOG Priority List.

Section IV - Characteristics

7. Performance Characteristics.

a. Dust control material(s) shall:

(1) (Essential). Be effective and operationally usable within 4 hours after application of the surface of all types of soil, and without extensive prior grading, scarifying, or preconditioning of the ground surface.

(2) (Essential). Withstand, without failure or peeling, helicopter rotor downwash (10-psf disc loading) and C-130 aircraft propwash (100-mph air velocity).

(3) (Essential). Be effective, with only minor maintenance, for the following minimum time:

(a) Six months in nontraffic areas.

(b) Three months in areas subjected to infrequent traffic of ground vehicles or aircraft, such as shoulders and overruns.

(c) One month in areas trafficked by ground vehicles or aircraft.

b. Dust control equipment shall:

(1) (Essential). Be capable of traversing and operating on soils having a Vehicle Cone Index of 50.

(2) (Essential). Be capable of dustproofing cross-country at speeds up to 10 mps and in convoy on roads at speeds up to 35 mph.

(3) (Essential). Be capable of dustproofing a medium lift forward area airfield, as defined in TM5-366, in 12 hours using one set of equipment. This will include dustproofing all traffic and overrun areas and an area 60 ft wide around the inside and outside perimeters of the entire installation, a total area of 1,123,000 ft² (25.8 acres).

(4) (Essential). Function satisfactorily under the climatic conditions as specified in paragraphs 7a, 7b, 7c, and desirably 7d, change 1, AR 705-15 with the use of aids in kit form where required. It must be capable of safe storage and transit under the conditions specified in paragraphs 7.1a and 7.1d, change 1, AR 705-15.

(5) (Essential). Use standard US Army fuels and lubricants. All hydraulic devices shall use a single standard-type hydraulic fluid.

(6) (Essential). Be powered by a military standard engine.

(7) (Essential). Have a mean time to first failure of 400 hours of operation for any event which prevents the equipment from performing its mission with only scheduled organizational maintenance. Subsequent mean-operating-time between failure shall be at least 380 hours up to 2400 hours (essential) and at least 320 hours throughout the remainder of service life (desirable).

(8) (Essential). Be capable of operating for an average of 2400 hours of operation without replacement of major power train components.

8. Physical Characteristics:

a. Dust Control Material(s) shall:

(1) (Essential). Be noncorrosive and non-injurious to metals, alloys, rubber, and plastics; be compatible for use in conjunction with prefabrication landing mats and membrane surfacings; and be suitable for trafficking by aircraft, ground vehicles, and application equipment without adverse effects to these.

(2) (Essential). Be nontoxic, noninjurious, and noncontaminating to human beings, animals, water supplies, and agricultural areas after being applied.

(3) (Essential). Be nonflammable and non-explosive within specified conditions of handling, storage, and application, and be fire retardant after being applied to soil surfaces.

(4) (Essential). Be capable of being stored in a controlled environment (an enclosed area with humidity and temperature control) for a minimum of 3 years; 5 years desirable. Be capable of being stored in other than controlled environmental storage conditions for a minimum of 1-1/2 years; 3 years desirable.

(5) (Essential). Have weight and volume characteristics of the material not exceeding 3 lb/yd² or 0.45 gal/yd² of ground surface treated on trafficked areas. If material requires dilution with water for application, volume shall not exceed 2 gal/yd² of ground surface treated.

(6) (Essential). Be available or manufacturable in quantities to treat at least 5 million yd² at a cost not to exceed \$0.50/yd² including material(s) and application equipment.

(7) (Essential). Be capable of being used, stored, and transported under the following conditions (AR 705-15).

(a) Use: (Essential). Intermediate, hot-dry and warm-wet climatic conditions, excluding precipitation, wind greater than 20 knots, and ambient air temperature below 40°F.

Desirably be capable of use under cold dry conditions with ambient air temperatures of 0°F.

(b) Storage: (Essential). Intermediate and high-temperature storage conditions.

(c) Transit: (Essential). Air transit conditions.

b. Dust control equipment shall:

(1) (Essential). Be designed for transportability without major disassembly by all surface modes in accordance with the provisions of AR 705-8; transportable in C-130 and C-141 US Air Force aircraft; and, as external load by CH-47 and CH-54 (Flying Crane) helicopters in accordance with provisions of AR 705-35. Maximum weight, empty of material(s), 12,000 lb.

(2) (Essential). Utilize, to the maximum extent possible, power plants and components now standard in or under development for the military supply system.

(3) (Essential). Have reliability after storage as follows:

(a) After depot storage in a controlled environment will meet the following availability criteria:

Up to 2 years - Operationally ready within 12 hours.

2 to 5 years - Operationally ready in 48 hours.

(b) After field or other environmental storage conditions will meet the following availability criteria:

Up to 2 years - Operationally ready in 12 hours.

2 to 5 years - Operationally ready in 72 hours.

(4) (Essential). Be designed so all components shall minimize corrosion of all essential elements to resist deterioration in service and storage conditions.

(5) (Essential). Offer suitable means for lifting and tie-down for rail, air, highway, and marine transport shall be provided as required by MIL STD 209B and AR 705-35. Be designed to withstand those shocks and vibration environments set forth in TB 55-100 (desirable).

(6) (Essential). Be capable of overseas transport in service ready condition.

(7) (Essential). Possess provisions for maximum safety to personnel and equipment during operation, storage, transport, and maintenance.

(8) (Essential). Be provided with lighting to permit operation and use of equipment at night.

(9) (Essential). Include portable fire extinguishers that will be provided for crew use. Agents used in fire extinguishers shall be nontoxic.

c. Dust control materiel, to be developed for this QMR, will eliminate the manpower and effort now being expended in inefficient and expedient methods of dust control, such as use of water sprinklers and crankcase oil. It will cost less than one-half the cost of covering ground areas with T17 membrane.

d. Equipment will be used intermittently, as required to control dust, on a two shift (20 hour) per day basis. It shall be designed for service life of 10 years based on an average of 2400 hours use per year.

e. Components shall be radio interference suppressed in accordance with US Army practice MIL-S-132378.

9. Maintenance Characteristics. Equipment shall:

a. (Desirable). Be designed to utilize multipurpose automatic test equipment.

b. (Essential). Incorporate in the design the utilization of modules to accomplish "repair by replacement" at all levels of maintenance.

c. (Essential). Be designed to permit ease of accessibility (ground level preferable) to often-checked items such as batteries, filters, and lubrication check points.

c. (Essential). Incorporate "go-no-go" simple test equipment and easily accessible test points into the design.

e. (Essential). Include warning devices that will alert the crew to potential equipment failure. These devices should have the capability of identifying incipient malfunctioning modules or assemblies.

f. (Essential). Provide permanent lubricant to the maximum extent possible through the use of sealed, self-lubricating, or dry-type bearings, particularly in places requiring lubrication which are not readily accessible.

g. (Essential). Utilize throw-away items whenever feasible to preclude maintenance effort on expendable items.

h. (Essential). Be designed to require minimum number of man-hours and skills to accomplish maintenance as indicated below:

(1) Organizational maintenance.

(a) Operator (crew). Limited to cleaning, minor lubrication and adjustments. Only such maintenance as can be accomplished with OEM tool and equipment kit will be performed. Crew maintenance should not average more than 1.0 man-hours per 50 hours of operation.

(b) Unit. Limited to scheduled and unscheduled maintenance. Service performed shall not average more than 2.0 man-hours per 50 hours of operation. Minimum time between scheduled maintenance actions shall be 200 hours of operations.

(2) Direct Support Maintenance. Tasks performed will include technical inspection and repair by adjustment, replacement of components. Tasks will average not more than 0.5 man-hour

per 50 hours of operation. Direct support units will provide direct exchange service for minor assemblies and components. Minimum hours of operation between scheduled direct support maintenance actions shall be 12 hours.

(3) General Support Maintenance. The general support maintenance unit will reinforce the direct support maintenance units and will accomplish major end item repair and repair of minor components and assemblies for return to stock. Extent of repairs will be determined by economic repair limits and stock status of replacement items. No general support maintenance will be scheduled.

i. (Essential). The mean downtime for scheduled maintenance actions (diagnosis and repair time only) shall not exceed 2 hours.

10. Human Engineering Characteristics. (Essential). Human Engineering factors shall be included in the selection of dust control material(s) and the design of application equipment.

11. Priority of Characteristics.

- a. Mission performance.
- b. Durability and reliability.
- c. Logistic support requirements.
- d. Air transportability.
- e. Maintainability.

Section V - Personnel and Training Considerations

12. Quantitative and Qualitative Personnel Considerations.

a. Dust control equipment will require a driver to control speed and direction of travel and an operator to control the rate of distribution of dust control material(s). Additional personnel, one to four, may be required to load dust control material(s) onto the application equipment. These personnel can be obtained from the unit being supported.

b. The dust control equipment shall be designed for ease of operation and be capable of being operated by construction machine operator, MOS 62E20, and maintained by engineer equipment mechanic, MOS 62B20, and engineer equipment repairman, MOS 62B30.

13. Training Considerations. No special training other than normal MOS and on-the-job training will be required. No equipment will be required solely for training purposes.

Section VI - Associated Considerations

14. Train Devices. None required. Items of materiel in the system will be utilized in training.

15. Related Materiel. No related materiel will be required.

16. Concealment and Deception. Normal camouflage considerations apply to the development of this materiel.

17. Probable interest by the British, Canadian, and Australian Armies is not known.

18. There are no existing items, and no items under development by other services or allied armies which can fulfill this requirement.

19. Communication Security. None.

20. Estimated dollar loss due to obsolescence of current inventory items: Negligible. Existing supplies of asphaltic and/or petroleum products can be utilized to satisfy the original requirements for which they were developed rather than as interim solutions to the dust control problem. Present inventory of water and asphalt distributors also can be utilized for conventional construction purposes.

21. Additional Comments. If, during the development phase, it appears to the developing agency that the characteristics listed herein require the incorporation of certain impracticable features and/or unnecessarily expensive and complicated components or devices, costly manufacturing methods or process, critical materials

or restrictive specifications which will prove excessively expensive or serve as a detriment to the military value of the unit, such matters will be brought to the immediate attention of the Chief of Research and Development, Department of the Army, and Headquarters, US Army Combat Developments Command for consideration before incorporation into a final design.

22. This materiel requirement is identified by USACDC Action Control Number (to be assigned) and supports the following:

- | | | |
|----|---|--|
| a. | Army Concept Program | Army 75 |
| b. | Study "Engineer 75;"
USACDC Action Control
Number | P6493 |
| c. | Army Tasks | 1: High Intensity Con-
flict
2: Mid Intensity Con-
flict
3: Low Intensity Con-
flict, Type I
4: Low Intensity Con-
flict, Type II
7: Complementing of
Allied Land Power |
| d. | Phase | Materiel |
| e. | Function | Service Support |

APPENDIX B

LABORATORY AND FIELD PROCEDURES AND TESTS FOR
SCREENING OF DUST CONTROL MATERIALS
CONDUCTED AT WATERWAYS
EXPERIMENT STATION

A. LABORATORY TESTS

1. Soil types. The following three soils will be used in the laboratory evaluation tests of dust control materials:

- a. Fine sand (SP).
- b. Silt (CL).
- c. Heavy clay (CH).

2. Test specimens. From the above test soils, soil specimens will be prepared at various initial conditions as follows and used to evaluate the effectiveness of a proposed dust palliative:

- a. Sand in a loose, dry state.
- b. Silt in a loose, dry state.
- c. Silt, compacted and dried back.
- d. Heavy clay in a loose, dry state.
- e. Heavy clay, compacted and dried back.

3. Processing of soils for molding. The fine sand will be dried to a water content of 1 percent or less. To prepare the silt and heavy clay for the loose, dry specimens, each soil will be processed to pass the No. 40 sieve, the material passing to be dried to water contents of 3 percent or less and 9 percent or less, respectively. At these conditions, the soils will be finely pulverized dust. To prepare the silt and heavy clay for the compacted specimens, each soil will be processed through a No. 4 sieve, the material passing to be brought to a water content of 18 and 28 percent, respectively. The latter two soils will be allowed to equilibrate at least 24 hours prior to molding.

4. Molding procedures. Molds, 6 in. square by 3 in. deep, will be used to contain the soil specimens. The soil for specimens that are to be prepared in a loose, dry state will be placed in a mold without any compaction effort. The remaining silt and heavy clay specimens will be prepared by statically compacting a preweighed quantity of the processed soil to achieve a dry density of 90 lb/ft³, then surface-dried for 1 hour under a heat lamp or similar means at a surface temperature of 120°F.

5. Prewetting of loose dust surfaces. For many surface-applied materials, the surface of the loose, dry soil specimens may require prewetting prior to treatment to break existing surface tensions. A simple test will be conducted consisting of placing the loose, dry soils in paper cups and applying a quantity of the dust control material. If it is apparent that the material is not absorbed by the soil surface, prewetting with water will be necessary. Prewetting of the prepared soil specimens will be accomplished by fog spraying with water.

6. Treatment level. Whenever the rate of treatment is not specified by the supplier, an application rate of 3 lb/yd² will be used to test a proposed dust palliative. Should failure occur under the subsequent air-impingement test at the rate specified by the supplier, the level of treatment will be doubled once, not to exceed 3 lb/yd², and the test repeated. Application will be accomplished with a specially devised laboratory spray device.

7. Cure. All treated specimens will be cured at ambient laboratory conditions for 4 hours.

8. Impingement test. At the end of the 4-hour cure period, the treated specimens will be subjected, successively, to air blasts generating stagnation pressures of 7, 30, and 55 psf. Each air blast will be sustained for a duration of 1 minute and directed to impinge the treated surface at an angle of 20°.

9. Rainfall erosion test. All treated specimens surviving the air-impingement test will be subjected to a simulated rainfall erosion test for a period of 1 hour. All specimens surviving this test will be resubjected to the air-impingement test immediately following the rainfall erosion test.

10. Drying cycle. Specimens surviving all preceding tests will be cured at ambient laboratory conditions for an additional 16-20 hours, then placed under a heating device for 1 hour at a surface temperature of 120°F. The specimens will then be resubjected to the air-impingement test.

11. Data obtained. Data obtained from the laboratory tests will include:

- a. Water content and dry density of the prepared soil specimen.

- b. Depth of penetration versus time during the curing period.
- c. Ability to withstand air impingement at the three levels of wind velocity.
- d. Ability to withstand the water-erosion test.
- e. Ability to withstand air impingement at the three levels of wind velocity following the water-erosion test.
- f. Supplementary observations pertinent to the ease of working with and applying the material, the condition of the surface after curing and testing, flexibility of the surface, and other comments which may be significant to the overall evaluation of the material.

12. Second-phase testing. All specimens surviving the aforementioned tests will be considered for further testing and evaluation under the helicopter downwash facility and/or field tests under traffic.

B. TRAFFIC TESTS OF DUST CONTROL MATERIALS

Purpose

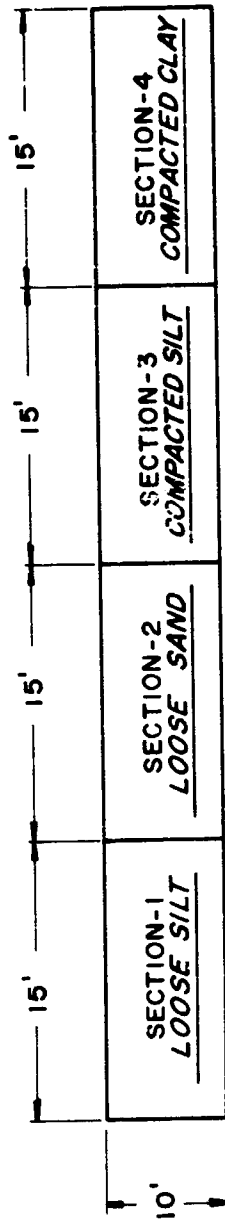
1. Traffic tests will be performed at WES on certain dust-proofing materials to determine their performance under random traffic. The tests will be run in conjunction with downwash blast tests conducted by the Surface Blast Effects Section. The tests will be conducted under shelter by the Field Test Section, Flexible Pavement Branch. Only those soil-treatment materials which, according to results obtained from laboratory screening tests, have shown a potential of being used as a dust palliative in the theater of operations will be examined in the traffic tests.

Tests

2. Test plot. A test plot, consisting of four consecutive 10 × 15-ft sections, will be prepared on a firm dry subgrade for treatment and random traffic tests under shelter (Hangar 4). A layout and typical cross section of the test plot are shown in Figure B1.

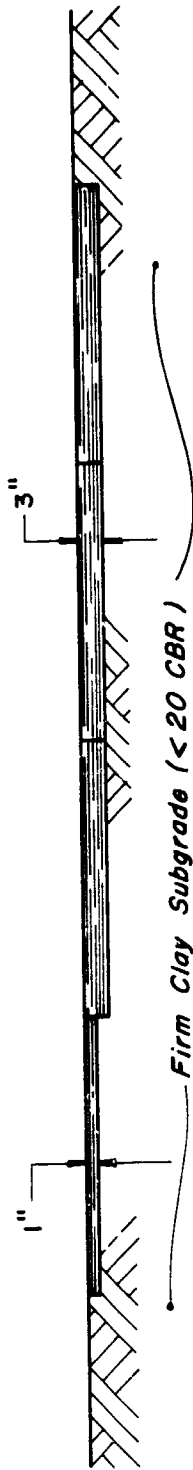
3. Test soils. The following soils and soil conditions will be used to prepare the surface layers of the test sections:

- a. A medium sand (SP-SM) having a water content of less than 1 percent.
- b. A silt (CL) of low plasticity (Plasticity Index equal 2 to 6) processed to pass the No. 4 sieve and having a water content of less than 5 percent.
- c. A silt (CL) of low plasticity (Plasticity Index equal 2 to 6) initially air dried and processed to pass the No. 4 sieve and subsequently equilibrated at a water content of 12 percent.
- d. A clay (CH) of high plasticity (Plasticity Index equal 34 to 38) initially air dried and processed to pass the No. 4 sieve and subsequently equilibrated at a water content of 18 percent.



PLAN VIEW

Not To Scale



TYPICAL X - SECTION

Not To Scale

2039

Figure B1. Traffic Test Plot

4. Preparation of surface layers. The silt having a water content of less than 5 percent will be loosely placed 1 in. thick in Section 1. The sand having a water content of less than 1 percent will be loosely placed 3 in. thick in Section 2. The silt, having a water content of 12 percent will be placed in Section 3; and the heavy clay, having a water content of 18 percent will be placed in Section 4; both are to be 3 in. thick. A compaction effort to achieve a dry density of 90 lb/ft³ will be applied to the latter two sections.

5. Treatment level. The rate of application for the soil-treatment material will be that recommended by the supplier or as determined to be effective in the laboratory screening tests. In no case, however, shall the rate of treatment exceed the 3 lb/yd² maximum established by present requirement criteria.

6. Cure. Treated sections will be cured at the prevailing atmospheric conditions for 4 hours prior to initiating random traffic tests. If the treated sections are not sufficiently cured to permit trafficking after this 4-hour period, trafficking will be withheld until such time that complete curing is obtained or that 24 hours have elapsed from the time of application.

7. Trafficking vehicles. The following vehicles with on-highway loads and tire pressures as specified will be used for traffic tests:

		<u>Axle Loading</u>		<u>Rear Tire</u>
		<u>Front</u>	<u>Rear</u>	<u>Pressure</u>
		<u>(lb)</u>	<u>(lb)</u>	<u>(psi)</u>
a.	1/4-ton utility truck 4 by 4, M151 (Jeep)	1475	2000	25
b.	3/4-ton cargo truck 4 by 4, M37B1	3251	4350	40
c.	2-1/2-ton cargo truck 6 by 6, M35A1	6525	8000	70

8. Failure criteria. Failure will be defined as that point when rutting and/or cracking reduce significantly the usefulness of the treated surface layer.

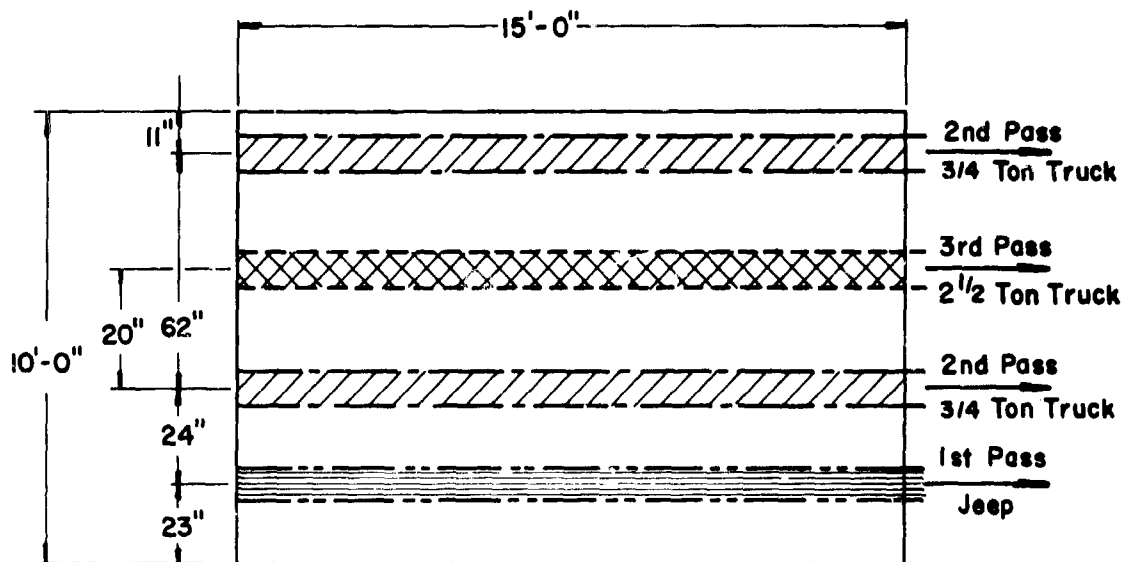
9. Trafficking pattern. The pattern of traffic over the treated sections to achieve random traffic will be conducted in the following manner:

- a. A single pass in the longitudinal direction of the test plot will be made with each of the vehicles in the order and pattern as shown in Incl. 2. One wheel of the jeep and of the 2-1/2-ton truck will be outside the test area.
- b. Trafficking also shall be conducted in the transverse direction of each section. Single passes will be made following the order and pattern as shown on Incl. 2, except that all wheels will traffic over the test area.
- c. If failure does not occur upon completion of the aforementioned vehicle trafficking, channelized traffic with the 3/4-ton cargo truck shall be continued in the longitudinal direction until failure occurs, or until 10 coverages.

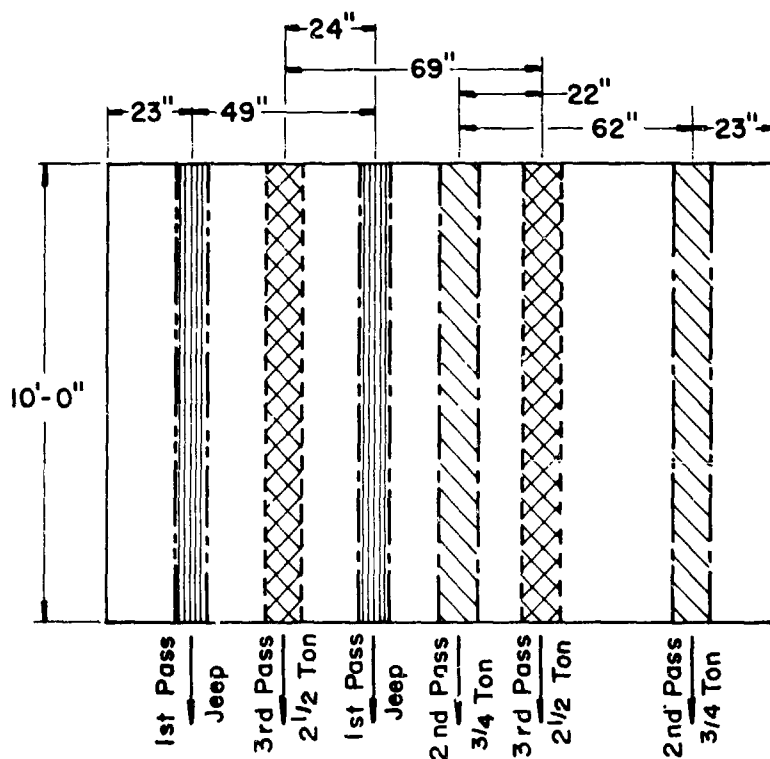
10. Data to be recorded.

- a. CBR strength of subgrade.
- b. Compaction effort necessary to achieve specified dry densities.
- c. Constructed densities and water contents of test soils.
- d. Rate of application of soil treatment.
- e. Length of cure time.
- f. Depth of penetration achieved by soil-treatment material.
- g. Any observations that will aid in evaluating the proposed dust palliative.
- h. Traffic wheel configuration and loading, tire size, and pressure.
- i. Number of coverages applied following random traffic test.
- j. Description of failure.
- k. Deformations imposed by trafficking vehicles.

Photographs and slides will be taken throughout the tests to properly assess each soil-treatment material.



Longitudinal Traffic Pattern



Transverse Traffic Pattern

2040

C. DUST STUDY

1. Dust alleviator tests - Surface effects blast facility testing procedure. Downwash blast tests will be conducted in the Surface Effects Blast Facility on various dust alleviators, mulches, and ground covers that show promise during a series of laboratory-type tests. These tests will utilize the fan-stand test equipment in which the Chinook and Huey helicopters' downwash characteristics will be simulated by models.

2. Fan-stand test equipment. The fan stand is located on Hudson Road about 400 ft east of the Surface Effects Blast Facility. It consists of a 50 X 50-ft concrete pad upon which three vertical columns 20 ft tall were placed. Three variable-speed electric motors have been fitted with two three-bladed propellers and one two-bladed propeller.

The propellers have been calibrated as disc load versus rpm for various Z/D (Z = vertical height; D = propeller diameter) ratios. Disc loading is computed as the pressure (force) on 1 ft² of rotor (propeller) area.

3. Dust-alleviator test section. The dust alleviators will be placed on three soil types as follows:

- a. Fine sand (Reid Bedford).
- b. Lean clay (loess).
- c. Heavy clay (buckshot).

Each soil type will be placed in the test section in two conditions: dry and damp. The test section will be prepared in a portable container 10 X 12-ft, 4-in. deep. The dry material will be placed with minimum compaction effort and screened as smoothly as practical. The moist soil will be placed in the test section at about optimum moisture content and hand tamped to provide a firm (not tight) test section surface. The surface will then be leveled to the container sides. A textured surface, such as foot-imprints and tire imprints, will be "embossed" over approximately one-half of the test section surface before applying the dust alleviator. The moist surface will be allowed to air-dry prior to application of the dust alleviator, unless it is recommended by the supplier that the surface be moist or wet before application. The dust alleviator will be applied to the prepared soil specimens as instructed

by the supplier; however, cure time will not exceed 4 hours. Should initial tests indicate that a heavier rate of application than that recommended by the supplier may be more satisfactory, the rate of application increase will not exceed 50 percent of recommended or a weight of 3 lb/yd².

The completed test section will be placed in the test area in such a manner that its surface will be on the same elevation as the surrounding area. The test area will be level for a least four propeller diameters from the center of model simulation. The propellers will then be lowered over the test section to a Z/D equivalent to the helicopter being considered as it rests on the ground.

4. Downwash tests. The test sections will be subjected to simulated takeoff disc loading for a period of 1 minute or until failure occurs, whichever is first. At this time, the propellers will be stopped and inspection and photographs of the test section will be made. Should the test section withstand this initial test, the disc load will be increased in 25 percent increments until the initial disc loading is doubled; each increment being held for 1 minute or until failure.

During the downwash tests, the dust intensity will be determined by using a WES fabricated dust meter which will give comparative results among the dust clouds. Also, 16-mm motion pictures will record test results for later visual study.

5. Fire-resistance tests. After completion of the downwash blast tests, the material will be tested for fire resistance by pouring about 1/2 pint of JP-4 fuel over a suitable area of the test section and igniting. Observations will be made during the burning of the fuel to determine the dust alleviating material's resistance to heat and its self-extinguishing ability. Should the material not be self-extinguishing, the test section will be extinguished with fire extinguishers on hand so that the remaining test section can be utilized for visual study.

6. Recorded data. Data to be recorded during the dust-alleviation test section preparations and testing shall include the following: soil type, condition, placing density, surface condition (dry, damp, or wet; smooth, or textured), application rate of dust alleviator, application observations, cure time, surface condition of dust alleviator after curing, Z/D ratio, disc loading, exposure time, dust-cloud intensity, surface downwash velocity, failure description (if any), fire resistance, and any observations that will aid in evaluating the dust alleviator. Photographs and slides will also be taken throughout the study to assist in preparing a written report and oral presentation.

APPENDIX C

EXPERIMENTAL AND LABORATORY RESULTS
ON SODIUM SILICATE BASED FORMULATIONS

The following table is an accumulation of the various formulations of sodium silicate based materials evaluated in the laboratories at Southwest Research Institute during the course of this program. The run numbers assigned to each of the formulations that appear in the table were not assigned chronologically. The various chemical and trade name designations of materials are abbreviated using a simplified code system. The complete list of code names is given in alphabetical order at the end of the table. The percentage of each chemical cited in the table is a percentage by weight. As indicated in the table, the cure time is in hours. In most cases, the cure temperature was ambient laboratory temperature and is designated by RT (room temperature). In the event that a cure temperature was different than ambient laboratory conditions, the temperature is indicated. The results of the water erosion test are given by one-word descriptors. In general, the table below describes the type of result observed.

Classification

Excellent	Negligible effect after water erosion test for 1 hour.
Good	Small amount of material removed after water erosion test (10-percent or less reduction in film thickness).
Fair	Small amount of material removed following water erosion test (25-percent reduction of film thickness).
Poor	Significant erosion following water test (greater than 25-percent reduction in film thickness).
Very Poor	Specimen completely eroded with segments of the surface completely removed.

The comments, in general, refer to the method of mixing and ease of application of the specimen.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS*

Run No.	Formulation†		Cure Time, hours	Cure Temp, °F	Results of Laboratory Erosion Test	General Comments
	Code‡	Percent				
1	AN D300 SS42	10 13 77	4	RT	Excellent	Too viscous for application. Slowly separates on standing.
2	AN PB24 OA D300 SS42	3 3 1 11 82	4	RT	Excellent	Sodium Silicate added last to premixed additives; slowly separates on standing.
3	Cyclopol D300 CoN SS42	8 15 3 74	4	Sunlight 95°	Excellent	Sodium Silicate added last to premixed additives; slowly separates on standing.
4	D300	100	14	RT	Excellent	
5	SS42 D300	50 50	14	RT	Excellent	
6	D300 AN SS42	30 10 60	14	RT	Excellent	Sodium Silicate added last to premixed additives; slowly separates on standing.
7	D300 AN SS42	40 10 50	14	RT	Excellent	Thick mix. Sodium Silicate added last to premixed additives; slowly separates on standing.
8	D300 AN SS42	30 20 50	14	RT	Excellent	Very lumpy & thick. Sodium Silicate added last to premixed additives; slowly separates on standing.
9	AN CoN LO AC34 SS42	5 2 8 8 77	2	RT	Good	Sodium Silicate added last to premixed additives.
10	ZnO Zonyl SS42 PB32 ZN D300	3 0.2 75 4 3 15	4	Sunlight 95°	Good to excellent	First 3 & last 3 components blended separately then combined. Slowly separates on standing.
11	ZO PB32 ZN MO Zonyl SS42	4 7 4 1 0.4 84	4	Sunlight 95°	Good to excellent	Sodium Silicate added last to premixed additives; slowly separates on standing.
12	AN D300 PB24 OA SS42	3 13 3 1 80	14	RT	Good	Sodium Silicate added last to premixed additives; slowly separates on standing.
13	ZN ZO PB24 D300 SS42	3 3 5 13 76	4	RT	Good	Slight flaking. Sodium Silicate added last to premixed additives; slowly separates on standing.

*Each component is thoroughly blended with the previous one before further additives are introduced; blended in order listed throughout tables.

†When numerals 1 and 2 appear, they refer to Coats 1 and 2, respectively.

‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation†		Cure Time, hours	Cure Temp, °F	Results of Laboratory Erosion Test	General Comments
	Code‡	Percent				
14	AN	4	14	Air	Good	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PB24	4				
	OA	1				
	D300	18				
	SS42	73				
15	Cyclopol	4	4	Sunlight 95°	Good	Sodium Silicate added last to premixed additives; slowly separates on standing.
	CoN	2				
	D300	15				
	ZO	4				
	SS42	75				
16	ZO	3	4	Sunlight 95°	Good +	Sodium Silicate added last to premixed additives; slowly separates on standing.
	OA	2				
	D300	11				
	PB24	3				
	SS42	81				
17	SS42	60	14	RT	Good	
	D300	40				
18	AN	8	4	RT	Fair	Poor mixture.
	AC34	8				
	SS42	84				
19	AN	8	1.5	RT	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AC34	8				
	SS42	84				
20	AN	4	14	RT	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PB24	4				
	OA	1				
	D300	18				
	SS42	73				
21	Cyclopol	4	4	Sunlight 95°	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	CoN	2				
	D300	16				
	SS42	78				
22	AN	4	1	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	CoN	2				
	LO	15				
	AC34	7				
	SS42	72				
23	AN	3	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AC34	12				
	SS42	85				
24	AN	3.5	1	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AC34	7.0				
	SS42	50				
25	DVB	9	1	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	CoN	2				
	AA	1				
	SS42	88				

*Each component is thoroughly blended with the previous one before further additives are introduced, blended in order listed throughout tables.

†When numerals 1 and 2 appear, they refer to Coats 1 and 2, respectively.

‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation†		Cure Time, hours	Cure Temp, °F	Results of Laboratory Erosion Test	General Comments
	Code‡	Percent				
26	DVB	8	1	180	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	CoN	2				
	AA	1				
	SA	1				
	AC34	4				
	SS42	84				
27	DVB	16	1	180	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	CoN	3				
	SS42	81				
28	DVB	8	1	180	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AN	3				
	CoN	2				
	AC34	4				
	SS42	83				
29	AN	3	1	180	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	CoN	2				
	DVB	9				
	SS42	86				
30	DVB	9	1	180	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	CoN	2				
	AC34	4				
	SS42	85				
31	AN	5	1	RT	Poor	Too thick. Sodium Silicate added to premixed additives; slowly separates on standing.
	AA	2				
	AC34	12				
	SS42	81				
32	AA	2	1	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	CoN	2				
	AC34	14				
	SS42	82				
33	TEA	5	1	180	Good	Sodium Silicate added last to premixed additives; slowly separates on standing.
	OA	3				
	AC34	15				
	SS42	77				
34	ZN	3	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	ZO	3				
	PB24	4				
	D300	13				
	SS42	77				
35	ZO	8	1.5	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AC34	8				
	SS42	84				
36	ZO	3	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PB24	4				
	D300	11				
	OA	2				
	SS42	80				
37	ZO	4	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	D300	9				
	SS42	87				

*Each component is thoroughly blended with the previous one before further additives are introduced; blended in order listed throughout tables.

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‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation†		Cure Time, hours	Cure Temp, °F	Results of Laboratory Erosion Test	General Comments
	Code‡	Percent				
38	AN	4	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	D300	15				
	PB24	4				
	OA	1				
	SS42	76				
39	D300	8	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PB24	4				
	AN	4				
	SS42	84				
40	ZN	3	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	D300	13				
	OA	2				
	SS42	82				
41	ZN	3	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PB24	4				
	D300	13				
	ZO	3				
	SS42	77				
42	AC34	15	4	Amb. sunlight 95°	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	ZO	8				
	SS42	77				
43	OA	2	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PB24	4				
	ZO	4				
	D300	15				
	SS42	75				
44	ZN	3	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PB24	4				
	ZO	3				
	AC34	13				
	SS42	77				
45	AO	4	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	ZoN	4				
	PB24	4				
	D300	15				
	SS42	73				
46	ZN	6	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PB32	6				
	D300	10				
	SS42	78				
47	AN	4	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	ZN	4				
	D300	15				
	PB32	4				
	SS42	73				
48	AO	4	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	ZN	4				
	D300	15				
	PB32	4				
	SS42	73				

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†When numerals 1 and 2 appear, they refer to Coats 1 and 2, respectively.

‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation†		Cure Time, hours	Cure Temp, °F	Results of Laboratory Erosion Test	General Comments
	Code‡	Percent				
49	ZN	4	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	D300	8				
	PB32	4				
	SS42	84				
50	ZN	4	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	D300	15				
	PB24	4				
	AO	4				
	SS42	73				
51	AN	4	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PB	8				
	AC34	8				
	SS42	80				
52	PS	5	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	Benzene	7				
	PB24	2				
	AN	4				
	SS42	82				
53	PS	4	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	Benzene	8				
	AN	4				
	SS42	84				
54	PB24	8	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AN	8				
	SS42	84				
55	D300	8	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AN	6				
	PB24	4				
	SS42	82				
56	AN	4	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AC31	8				
	S-2	4				
	S-1	84				
57	AN	4	4	RT	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	CoN	2				
	AC34	9				
	SS42	85				
58	AN	5	4	180	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	S-2	9				
	SS42	84				
59	AD	5	4	RT	Very poor	Sodium Silicate added last to premix.
	AN	5				
	SS42	90				
60	SS42	100	14	RT	Very poor	Sodium Silicate added last to premix.
61	OA	7	4	180	Excellent	Sodium Silicate added last to premix.
	AC34	14				
	H ₂ O	7				
	SS42	72				

*Each component is thoroughly blended with the previous one before further additives are introduced. Blended in order listed throughout tables.

†When numerals 1 and 2 appear, they refer to Coats 1 and 2, respectively.

‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation†		Cure Time, hours	Cure Temp., °F	Results of Laboratory Erosion Test	General Comments
	Code‡	Percent				
62	S-2 D300 SS42	6 16 78	1	180	Good	Sodium Silicate added last to premix.
63	AN CoN LO D300 SS42	4 2 8 8 78	4	160	Excellent	Sodium Silicate added last to premix.
64	ZO OA D300 PB24 SS42	3 2 11 3 81	0.5	160	Excellent	Sodium Silicate added last to premix.
65	AN D300 PB24 OA SS42	3 13 3 1 80	1	160	Excellent	Sodium Silicate added last to premix.
66	AN PB24 OA D300 SS42	4 4 1 18 73	1	160	Excellent	Sodium Silicate added last to premix.
67	AN PB24 OA D300 SS42	4 5 1 18 72	14	160	Excellent	Sodium Silicate added last to premixed additives; slowly separates on standing.
68	Cyclopul D300 CoN SS42	8 15 2 75	0.5	160	Excellent	Sodium Silicate added last to premixed additives; slowly separates on standing.
69	Cyclopul D300 CoN SS42	7 15 2 76	2	160	Excellent	Sodium Silicate added last to premixed additives; slowly separates on standing.
70	Cyclopul CoN D300 ZO SS42	4 2 15 4 75	2	160	Excellent	Sodium Silicate added last to premixed additives; slowly separates on standing.
71	AN PB24 OA D300 SS42	4 4 1 18 73	14	Oven	Excellent	Sodium Silicate added last to premixed additives; slowly separates on standing.
72	ZN PB24 D300 SS42	6 6 10 78	1	160	Excellent	Sodium Silicate added last to premixed additives; slowly separates on standing.

*Each component is thoroughly blended with the previous one before further additives are introduced, blended in order listed throughout tables.

†When numerals 1 and 2 appear, they refer to Coats 1 and 2, respectively.

‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation†		Cure Time, hours	Cure Temp. °F	Results of Laboratory Erosion Test	General Comments
	Code‡	Percent				
73	AN	7	1	180	Good	Sodium Silicate added last to premixed additives; slowly separates on standing.
	CoN	1				
	LO	4				
	Picco	4				
	SS42	84				
74	ZN	6	14	160	Good to excellent	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PB32	6				
	D300	10				
	SS	78				
75	ZN	3	1	160	Good	Sodium Silicate added last to premixed additives; slowly separates on standing.
	D300	13				
	JA	2				
	SS42	82				
76	ZO	3	1	160	Good	First 3 premixed & combined with premixed last 3 components. Slowly separates on standing.
	SS42	77				
	Zonyl	0.2				
	PB32	4				
	ZN	3				
	D300	13				
77	OA	2	3	160	Good	Sodium Silicate added last to premix.
	PB24	4				
	D300	11				
	ZO	3				
	SS42	80				
78	Cyclopol	4	1.5	160	Good	Sodium Silicate added last to premix.
	CoN	2				
	D300	16				
	SS42	78				
79	Cyclopol	19	0.5	160	Good	Sodium Silicate added last to premix.
	ZO	4				
	SS42	77				
80	D762W	15	1	140	Fair	Sodium Silicate added last to premix.
	AN	9				
	SS42	76				
81	FeN	3	1	180	Fair	Sodium Silicate added last to premix.
	D762W	16				
	SS42	81				
82	AN	6	1	180	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AC34	16				
	SS42	78				
83	AN	4	0.5	180	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	CoN	2				
	AC34	15				
	LO	7				
	SS42	72				
84	AN	8	0.75	180	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AC34	15				
	SS42	77				

*Each component is thoroughly blended with the previous one before further additives are introduced, blended in order listed throughout tables.

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‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation†		Cure Time, hours	Cure Temp. °F	Results of Laboratory Erosion Test	General Comments
	Code‡	Percent				
85	ZN	3	1	180	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PB24	4				
	ZO	3				
	AC34	13				
	SS42	77				
86	ZN	3	1	180	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	ZO	3				
	PB24	4				
	D300	13				
	SS42	77				
87	AN	4	1	160	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PB-24	4				
	OA	1				
	D300	15				
	SS42	76				
88	AN	3	4	160	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PB24	3				
	OA	1				
	D300	10				
	SS42	83				
89	PB24	4	10	160	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AN	4				
	D300	8				
	SS42	84				
90	AN	2	14	160	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	S-2	5				
	AC34	15				
	SS42	78				
91	ZO	3	14	160	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	ZN	3				
	PB24	4				
	AC34	13				
	SS42	77				
92	LO	15	1	160	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AN	4				
	CoN	2				
	AC34	7				
	SS42	72				
93	MO	1	4	160	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
	ZO	3				
	ZN	3				
	PB24	7				
	Zonyl	0.1				
94	SS42	86	1	140	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	CuN					
	D300	11				
95	SS42	75	1	140	Poor	Acid posttreatment. Sodium Silicate added last to premixed additives; slowly separates on standing.
	CoN	6				
	D300	9				
96	SS42	75	1	140	Poor	Acid posttreatment. Sodium Silicate added last to premixed additives; slowly separate on standing.
	CuN	6				
	AC34	19				

*Each component is thoroughly blended with the previous one before further additives are introduced. blend in order listed throughout tables.

†When numerals 1 and 2 appear, they refer to Coats 1 and 2, respectively.

‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation†		Cure Time, hours	Cure Temp. °F	Results of Laboratory Erosion Test	General Comments
	Code‡	Percent				
97	S-1 D300 SS42	6 16 78	1	160	Fair to poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
98	PPG4000 D300 ZN SS42	8 16 4 72	0.75	160	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
99	PPG4000 SS42	17 83	1	160	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
100	ZO SS42	9 91	1.5	180	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
101	PB24 D300 AN SS42	8 8 4 80	1	130	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
102	ZO AC34 SS42	4 9 87	1.5	180	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
103	D300 S-1	17 83	16	180	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
104	S132	100	4	130	Very poor	
105	AC34 OA H ₂ O SS42	14 7 7 72	1	180	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
106	MDA AN AC34 SS42	2 3 16 79	1.5	160	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
107	TEA OA AC34 SS42	5 3 15 77	1	160	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
108	Cyclopol SS42	20 80	0.25	160	Very poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
109	SS42 SC AN PB24 Cyclopol	80 5 5 5 5	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.

*Each component is thoroughly blended with the previous one before further additives are introduced. Blended in order listed throughout tables.

†When numerals 1 and 2 appear, they refer to Cate 1 and 2, respectively.

‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation† Code‡	Percent	Cure Time, hours	Cure Temp. °F	Results of Laboratory Erosion Test	General Comments
110	SS42 SC AN PB24 Toluene Cyclopel	79 6 4 3 3 3	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
111	SS42 SC AN PB24	72 7 14 7	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
112	Gen Flo-60	100	4	RT	Fair	
113	Gen Flo-60 SS42	20 80	4	RT	Poor	
114	Gen Flo-67	100	4	RT	Fair	
115	Gen Flo-67 SS42	20 80	4	RT	Poor	
116	Gen Flo-355	100	4	RT	Good	
117	Gen Flo-355 SS42	20 80	4	RT	Poor	
118	BFG PB24 AN Dup C SS42	14 7 4 0.2 75	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
119	BFG Cyclopel AN Dup C SS42	14 7 4 0.2 75	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
120	BFG PB24 AN Dup C SS42	14 7 7 0.2 75	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
121	BFG	100	4	RT	Good	
122	BFG SS42	20 80	4	RT	Poor	
123	AC34	100	4	RT	Good	
124	D100	100	4	RT	Good	
125	KAE	100	4	RT	Good	
126	KAE SS42	20 80	4	RT	Poor	
127	KAE AN SS42	14 6 78	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.

*Each component is thoroughly blended with the previous one before further additives are introduced. Blended in order listed throughout tables.
†When numerals 1 and 2 appear, they refer to Code 1 and 2, respectively.
‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS¹ (Cont'd)

Run No.	Formulation ¹		Cure Time, hours	Cure Temp, °F	Results of Laboratory Erosion Test	General Comments
	Code ²	Percent				
128	BFG AN Cyclopel SS42	15 3 8 74	4	130	Good	Sodium Silicate added last to premixed additives; slowly separates on standing.
129	PE24 AN ZO KAE SS42 H ₂ O	5 5 2 10 70 8	4	RT	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
130	AN KAE D300 ZO SS42 H ₂ O	10 5 5 5 70 5	4	RT	Fair	Sodium Silicate added last to premixed additives; slowly separates on standing.
131	AN PE24 D300 KAE SS42 H ₂ O	10 5 5 5 70 5	4	75	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
132	SS42 AO705	90 10	10	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
133	BFG KAE D300 ZO SS42	12 6 6 6 70	4	RT	Fair	
134	BFG KAE D300 ZO SS42	12 6 6 6 70	4	RT	Film curled & separated from surface	CaCl ₂ pretreated card- board used. Sodium Silicate added last to premixed addi- tives; slowly separates on standing.
135	BFG KAE D300 ZO SS42	12 6 6 6 70	4	RT	Poor (Separation from card board)	CaCl ₂ posttreatment on film. Sodium Silicate added last to premixed additives; slowly separates on standing.
136	BFG KAE D300 ZO SS42	12 6 6 6 70	4	RT	Separation from panel did not dissolve	Sprayed on 1/4 in. silt, posttreated with CaCl ₂ solution. Sodium Silicate added last to premixed addi- tives; slowly separates on standing.
137	BFG KAE D300 Zr M ₂ O ₃ SS42	12 6 6 6 5 65	4	RT	Fair	
138	AO(C133) D300 SS42	8 16 76	14	RT	Fair (Flaking off)	Sodium Silicate added last to premixed additives; slowly separates on standing.

¹Each component is thoroughly blended with the previous one before further additives are introduced, blended in order listed through-out tables.

²When numerals 1 and 2 appear, they refer to Code 1 and 2, respectively.

³Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation†		Cure Time, hours	Cure Temp, °F	Results of Laboratory Erosion Test	General Comments
	Code‡	Percent				
139	AO705	8	14	RT	Flaking	Sodium Silicate added last to premixed additives; slowly separates on standing.
	D300	16	4	130	Good	
	SS42	76				
140	AO(C333)	8	14	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	KAE	16	4	130	Good	
	SS42	76				
141	AO705	8	14	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	KAE	16				
	SS42	76				
142	AO(C333)	10	14	RT	Poor	
	SS42	90	4	130	Good	
143	MgCO ₃	8	4	RT	Good	First coat cured 1 hour then second coat applied.
	AO705	4				
	D300	25				
	SS42	63				
	2 { D300	100				
144	MgCO ₃	8	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AO705	4				
	D300	25				
	SS42	63				
145	AN	6	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	AO705	7				
	D300	14				
	SS42	73				
146	AO705	8	14	RT	Fair	First coat cured 1 hour then second coat applied.
	1 { MgCO ₃	8				
	SS42	84				
	2 { D300	90				
	AN	10				
147	AO705	8	14	RT	Fair	First coat cured 1 hour then second coat applied.
	1 { MgCO ₃	8				
	SS42	84				
	2 { D300	100				
148	AO705	8	14	RT	Fair	First coat cured 1 hour then second coat applied.
	1 { MgCO ₃	8				
	SS42	84				
	2 { KAE	100				
149	MgCO ₃	8	14	RT	Fair	First coat cured 1 hour then second coat applied.
	1 { AO705	8				
	SS42	84				
	2 { BFG	100				
150	AO705	4	4	RT	Poor	Sodium Silicate added last to premixed additives; slowly separates on standing.
	PC	14				
	SS42	78				
	H ₂ O	4				
151	1 { SS42	100	4	RT	Cracked & flaked	First coat cured 1 hour then second coat applied
	2 { CuN	17				
	Gen Flo-67	83				

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†When numerals 1 and 2 appear, they refer to Coats 1 and 2, respectively.

‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation†		Cure Time, hours	Cure Temp, °F	Results of Laboratory Erosion Test	General Comments
	Code‡	Percent				
152	1 { SS42	83	4	RT	Good	First coat cured 1 hour then second coat applied.
	2 { D300	17				
	1 { CuN	10				
	2 { D300	90				
153	1 { SS42	75	4	RT	Good	First coat cured 1 hour then second coat applied.
	2 { AC34	25				
	1 { AN	17				
	2 { D300	83				
154	1 { SS42	83	4	RT	Fair	First coat cured 1 hour then second coat applied.
	2 { AO(C333)	17				
	1 { AN	17				
	2 { Gen Flo-67	83				
155	SS42	93	4	RT	Poor	Gelation in 5 min. Hard set in 10 min.
	VA	7				
156	SS42	93	4	RT	Poor	Gelation in 5 minutes.
	VA	7				
157	1 { SS42	93	1	RT	Poor	Gelation in 5 minutes.
	2 { VA	7				
	1 { D300	100				
	2 { PbO	10				
158	1 { SS42	93		RT	Good	Gelation in 5 minutes.
	2 { VA	7				
	1 { D300	96				
	2 { PbO	10				
159	MMM	10	4	RT	Poor	No reaction in 4 hr.
	SS42	90				
160	EM	10	4	RT	Poor	No gelation in 4 hr.
	SS42	90				
161	EA	10	4	RT	Poor	Gelation in 2-3 hr. Hardened in 6 hr.
	SS42	90				
162	MMM	7	4	RT	Poor	Cured to a hard film in 10 min on C.B.
	FMM	2				
	SS42	91				
163	BA	7	--	--	--	No gelation in 8 hours; sepa- rates on standing.
	SS42	93				
164	BH	7	--	--	--	No gelation in 8 hours; sepa- rates on standing.
	SS42	93				
165	HEM	7	--	--	--	Instant gelation. Hardened in 4 hr.
	SS42	93				
166	LA	10	--	--	--	No gelation in 8 hours; sepa- rates on standing.
	SS42	90				
167	MBA	4	--	--	--	No gelation in 8 hours; sepa- rates on standing.
	SS42	96				
168	VA	2	--	--	--	Gelation in 30 min. Hardened in 1 hr.
	MA	6				
	SS42	92				

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‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation† Code‡ Percent	Cure Time, hours	Cure Temp, °F	Results of Laboratory Erosion Test	General Comments
169	VA 2 MA 6 (H ₂ O 10) SS42 92	--	--	--	Gelation in 30 min. Hardened in 1 hr (see note below).
170	MS 4 VA 5 SS42 91	4	RT	--	Gelation in 5 minutes.
171	Urea 7 VA 5 SS42 75 H ₂ O 13	4	RT	--	Gelation in 5 minutes.
172	DVB 8 VA 4 SS42 88	4	RT	--	Gelation in 5 minutes.
173	St 4 VA 5 SS42 91	4	RT	--	Gelation in 5 minutes.
174	1 { VA 5 H ₂ O 19 SS42 76 2 { D300 90 AN 10	4	RT	Good	Gelation in 5 min. First coat at 2 lb/yd ² (excluding H ₂ O) cured 1/2 hr. Second coat at 1 lb/yd ² .
175	VA 2 MA 5 SS42 93	--	--	--	Gelation in 8 min. Hard set in 1 hr.
176	VA 2 MA 5 SS42 85 H ₂ O 8	--	--	--	Gelation in 13 min. Hard set in 4 hr (semisolid in 1 hr).
177	VA 7 SS42 85 H ₂ O 8	--	--	--	Gelation in 5 min. Semi- solid in 10 min. Hard set in 1 hr.
178	Urea 7 H ₂ O 7 VA 3 SS42 69 D300 14	4	RT	Fair	Gelation in 5 min. Slight syneresis.
179	FA 20 H ₂ O 20 SS42 60	4	RT	Poor	Gelation in 5 min. Semi- solid in 1 hr. Syneresis.
180	FA 20 H ₂ O 19 SS42 61	4	RT	Poor	Gelation in 5 min. Weak solid in 1 hr. Syneresis.
181	VA 2 SS42 98	4	RT	Poor	Elastic gelation in 5 min.

NOTE: Film coats from Sodium Silicate, Acrylic or vinyl gels are brittle and relatively insoluble if cured 4 hours. They tend to crack and peel off but do not readily soften or dissolve.

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‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation†		Cure Time, hours	Cure Temp, °F	Results of Laboratory Erosion Test	General Comments
	Code‡	Percent				
182	ZNCO ₃	11	14	RT	Good	
	SS42	89	4	RT	Poor	
183	1 { VA	5	4	RT	Poor	(1) Unstable, incompatible mix. (2) Noncontinuous.
	SS42	86				
	D300	9				
	Zonyl	0.12				
	2 { D300	90				
	NA	10				
184	Sa	11	4	--	Poor	
	SS42	89				
185	CaCl ₂	11	4	--	Poor	
	SS42	89				
186	SiO ₂	63	4	--	Poor	
	SS42	28				
	H ₂ O	9				
187	DZ	15	4	--	Poor	
	SS42	85				
188	DNN	15	4	RT	Poor	
	SS42	85				
189	DAWP	15	4	RT	Poor	
	SS42	85				
190	DNCN	15	4	RT	Poor	
	SS42	85				
191	DNRF	15	4	RT	Poor	
	SS42	85				
192	DP	12	4	--	Poor	
	SS42	88				
193	DM	12	4	--	Poor	
	SS42	88				
194	TPP	14	4	--	Poor	Gelation in 3 min.
	SS42	86				
195	TEP	7	4	--	Poor	Gelation in 3 min.
	SS42	93				
196	ELVAX	17	4	RT	Poor	Stratified.
	SS42	83				
197	TEB	9	4	RT	Good	
	VA	9			(Separation	
	SS42	82			from C. B.	
					surface)	
198	CoS	11	4	RT	Fair	
	SS42	80				
	H ₂ O	9				
199	MgS	10	4	RT	Fair	
	SS42	77				
	H ₂ O	13				

*Each component is thoroughly blended with the previous one before further additives are introduced; blended in order listed throughout tables.

†When numerals 1 and 2 appear, they refer to Coats 1 and 2, respectively.

‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATIONS* (Cont'd)

Run No.	Formulation†		Cure Time, hours	Cure Temp, °F	Results of Laboratory Erosion Test	General Comments
	Code‡	Percent				
200	Ka	10	4	RT	Fair	
	SS42	77				
	H ₂ O	13				
201	TBB	10	4	RT	Fair	Gelation in 1 min.
	SS42	90				

CODE DESCRIPTION

Code Name	Chemical Name or Trade Name
A300	Atmos 300
AA	Aluminum Acetate
AC34	Acrylic Latex Dow AC-34
AcAc	Acetic Acid
AD	Armour Duomeen
AN	Aluminum Naphthenate (Aluminum 1.7%)
AO	Aluminum Oxide
AO705	Aluminum Oxide Hydral 705 - ALCOA
AO(C333)	Aluminum Oxide C333 - ALCOA
BA	Butyl Acrylate
BFG	BFG Latex 800-157
BM	Butyl Methacrylate
CaCl	Calcium Chloride
CaS	Calcium Silicate
CoN	Cobalt Naphthenate (Cobalt 6%)
CuN	Copper Naphthenate (Copper 8%)
Cyclopol	Cyclopol S102-5, Koppers
D300	Dow SBR Latex-300
D762W	Dow Latex 762-W
DAWP	Dupont Aridex WP
DM	Diethyl Malonate
DNGN	Dupont Nalan GN
DNN	Dupont Nalan N
DNR F	Dupont Nalan RF
DP	Diethyl Phthalate
DVB	Divinylbenzene Monomer
Dup C	Dupontol C
DZ	Dupont Zelan
EA	Ethyl Acrylate Monomer
EDA	Ethylene Diamine
ELVAX	ELVAX in Toluene
EM	Ethyl Methacrylate Monomer
FA	Formamide
FeN	Iron Naphthenate
FeO	Iron Octoate (Iron 6%)
Gen Flo-60	General Tire Co. SBR Latex
Gen Flo-67	General Tire Co. SBR Latex
Gen Flo-355	General Tire Co. SBR Latex
HEM	Hydroxyethylmethacrylate
Ka	Kaolin
KAE	Koppers Asphalt Emulsion
LA	Laurylacrylate
LO	Linseed Oil
MA	Methylacrylate
MBA	NN-Methylenebisacrylamide
MgCO ₃	Magnesium Carbonate - Fisher
MgS	Magnesium Silicate
MMM	Methyl Methacrylate Monomer, stabilized
MO	Mineral Oil
MS	Methyl Styrene
NA	Naphthenic Acid
OA	Oleic Acid

*Each component is thoroughly blended with the previous one before further additives are introduced; blended in order listed throughout tables.

†When numerals 1 and 2 appear, they refer to Coats 1 and 2, respectively.

‡Code description given at the end of this table.

EXPERIMENTAL AND LABORATORY RESULTS ON SODIUM SILICATE BASED FORMULATION3* (Cont'd)

CODE DESCRIPTION (Cont'd)

<u>Code Name</u>	<u>Chemical Name or Trade Name</u>
PB24	Polybutene 24, Oronite
PB32	Polybutene 32, Oronite
PbA	Lead Acetate
PbN	Lead Naphthenate (Lead 24%)
PC	Portland Cement
Picco	Piccolyte S115
PMM	Polymethyl Methacrylate
PPG4000	Polypropylene Glycol 4000
PS	Styrene Polymer
PVA	Polyvinyl Acetate Latex, Jones Blair
S-1	Siroc No. 1
S-2	Siroc No. 2
S132	Siroc No. 132
SA	Sodium Aluminate
Sa	Sauereisen
SC	Sodium Caseinate Solution 10%
SS42	Sodium Silicate 42
St	Styrene
1 DB	Tributylborate
TEA	Triethanolamine
TEB	Tri-2 Ethylhexylborate
TEP	Triethyl Phosphate
TPP	Triphenyl Phosphite
VA	Vinylacetate
ZN	Zinc Naphthenate (Zinc 8%)
ZO	Zinc Oxide
Zonyl	Zonyl A Surfactant DuPont

APPENDIX D

EXPERIMENTAL AND LABORATORY RESULTS
ON SULPHUR BASED FORMULATIONS

The following table presents the results of the experimental work performed on sulphur based formulations. The percentages cited are based on a weight ratio. The use of the terms "good," "fair," and "poor" are relative in nature and arbitrarily determined by visual observation. The comparison was based on the relative performance of each formulation with respect to the others, with "good" being the most preferred result.

EXPERIMENTAL AND LABORATORY RESULTS ON SULPHUR BASED FORMULATIONS

Formulation		Pour Temp. °C	Penetration	Flexibility	Miscibility
Component	Percent				
Sulphur	85	145	Poor	Good	Good
Styrene	15				
Sulphur	85	155	Poor	Good	Good
Styrene	15				
Sulphur	70	155	Fair	Good	Good
Styrene	30				
Sulphur	50	155	Fair	Fair	Good
Styrene	50				
Sulphur	95	155	Poor	Poor	Good
Aroclor 1221	5				
Sulphur	95	155	Poor	Poor	Good
Aroclor 1254	5				
Sulphur	98	155	Poor	Poor	Poor
Sodium Xylene Sulfonate	2				
Sulphur	98	155	Poor	Poor	Poor
Dimethyl Polysiloxane	2				
Sulphur	95	155	Poor	Poor	Good
Halowax 1000	5				
Sulphur	70	155	Good	Fair	Good
Dipentene	30				
Sulphur	80	155	Poor	Fair	Good
Styrene	15				
Aroclor 1221	5				
Sulphur	80	155	Poor	Fair	Good
Styrene	15				
Aroclor 1254	5				
Sulphur	83	155	Poor	Fair	Poor
Styrene	15				
Sodium Xylene Sulfonate	2				
Sulphur	83	155	Poor	Fair	Poor
Styrene	15				
Dimethyl Polysiloxane	2				
Sulphur	80	155	Poor	Fair	Good
Styrene	15				
Halowax 1000	5				
Sulphur	70	155	Poor	Fair	Good
Styrene	5				
Dipentene	5				
Sulphur	50	155	Fair	Fair	Good
Styrene	10				
Dipentene	10				
Sulphur	70	165	Fair	Fair	Good
Styrene	5				
Dipentene	5				

EXPERIMENTAL AND LABORATORY RESULTS ON SULPHUR BASED FORMULATIONS (Cont'd)

<u>Formulation</u>		<u>Pour Temp.</u> <u>°C</u>	<u>Penetration</u>	<u>Flexibility</u>	<u>Miscibility</u>
<u>Component</u>	<u>Percent</u>				
Sulphur	80	165	Good	Good	Good
Styrene	10				
Dipentene	10				
Sulphur	80	155	Poor	Poor	Fair
Styrene	10				
Turpentine	10				
Sulphur	75	165	Poor	Fair	Fair
Styrene	10				
Turpentine	15				
Sulphur	75	165	Good	Fair	Good
Styrene	10				
Dipentene	15				
Sulphur	75	165	Fair	Good	Good
Styrene	15				
Dipentene	10				
Sulphur	70	165	Good	Fair	Good
Styrene	10				
Dipentene	20				
Sulphur	60	165	Good	Good	Good
Styrene	20				
Dipentene	20				
Sulphur	70	155	Good	Good	Good
Styrene	15				
Dipentene	15				
Sulphur	80	155	Fair	Good	Good
Styrene	15				
Dipentene	5				
Sulphur	75	155	Good	Good	Good
Styrene	20				
Dipentene	5				
Sulphur	75	155	Fair	Good	Fair
Styrene	20				
TCP	5				
Sulphur	70	155	Fair	Good	Fair
Styrene	25				
TCP	5				

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13. ABSTRACT		
This report covers the work performed in evaluating sodium silicate and sulphur based formulations for their use as dust palliatives. The results of the experimental work are herein presented. The conclusions drawn for each of these formulations are as follows: (1) Sodium silicate based formulations can be used as an efficient, inexpensive dust palliative when the silicate is sufficiently insolubilized to withstand normal weathering conditions, and a waterproof latex barrier is used to cover the base sodium silicate coating. (2) The sulphur based coatings have some very attractive features such as low cost and availability of materials, but the sulphur based coatings were not pursued to an end result because of the complications involved in applying the hot molten sulphur coatings.		

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