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INVESTIGATION OF SINKING METHODS FOR REMOVAL OF OIL POLLUTION FROM WATER SURFACES. REPORT NO. 3. TESTS AND EVALUATION OF OIL SINKING MATERIALS

Billy J. Houston, et al

Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

April 1972

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INVESTIGATION OF SINKING METHODS FOR REMOVAL OF OIL POLLUTION FROM WATER SURFACES

TESTS AND EVALUATION OF OIL SINKING MATERIALS

by

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Vicksburg, Mississippi 39180

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The purpose of this program was to investigate materials that can be utilized in the cleanup of massive oil spills by sinking the oil. The program was divided into four phases as follows: Phase I, Survey of the State-of-the-Art; Phase II, Development of Standard Test Procedures; Phase III, Tests of Sinking Materials; Phase IV, Tests Analysis and Conclusions. This report completes the program as funded and covers the results of Phases III and IV; also this report recapitulates pertinent portions of Phases I and II, both of which have been previously reported. Twenty-three oil sinking materials, which had been located in Phase I, were screened and tested (Phase III) in accordance with applicable test methods developed in the Phase II study (Appendixes A, B, C, and D). On the basis of current information, these materials were evaluated (Phase IV) as dry-application sinking agents for oil. Factors such as cost, availability, effectiveness in sinking and retaining oil, and hazards to personnel and plant life were considered in making the evaluations. Eight materials were identified as dry application all-season sinking agents for one or more oils; nine materials were identified as dry-application provisional sinking agents for one or more oils. One material was identified as a dry-application all-season sinking agent for all of the oils tested; one material was a dry-application provisional sinking agent for all of the oils tested.

Details of illustrations in this document may be better studied on microfiche

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FOREWORD

This investigation was authorized by DD Form 448, dated 25 June 1970 and 15 October 1971, MIPR No. Z-70099-0-00583, from Commandant (FSP-1), U. S. Coast Guard.

The study was conducted at the U. S. Army Engineer Waterways Experiment Station (WES) under the direction of Messrs. B. Mather, J. M. Polatty, V. D. Edgerton, and L. Pepper. Messrs. B. J. Houston and R. W. Crisp served as project leaders for portions of the test program. This report was prepared by Messrs. B. J. Houston, E. C. Roshore, and V. D. Edgerton. Mr. Leo Tobias, Office, Chief of Engineers, served as liaison between the U. S. Coast Guard and the WES. Cdr William E. Lehr, Chief, Pollution Control Branch, Office of R&D, U. S. Coast Guard, was the project officer and was assisted by Mr. William C. McKay.

COL Ernest D. Peixotto, CE, was Director of the Waterways Experiment Station during the conduct of this study. Mr. F. R. Brown was Technical Director.

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CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
square inches	6.4516	square centimeters
square feet	0.092903	square meters
cubic feet	0.0283168	cubic meters
feet per second	0.3048	meters per second
knots (international)	0.5144444	meters per second
pounds	0.45359237	kilograms
tons (2000 pounds)	907.185	kilograms
pounds per square inch	0.00689476	megapascals
pounds per cubic foot	16.0185 0.0160185	kilograms per cubic meter grams per cubic centimeter
gallons (U. S. liquid)	3.785412	cubic decimeters
barrels	0.1589873	cubic meters
Fahrenheit degrees	5/9	Celsius or Kelvin degrees*
centipoises	0.001	newton-seconds per square meter
centistokes	0.01	square centimeters per second

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

SUMMARY

The purpose of this program was to investigate materials that can be utilized in the cleanup of massive oil spills by sinking the oil. The program was divided into four phases as follows:

Phase I: Survey of the State-of-the-Art

Phase II: Development of Standard Test Procedures

Phase III: Tests of Sinking Materials

Phase IV: Tests Analysis and Conclusions

This report completes the program as funded and covers the results of Phases III and IV; also this report recapitulates pertinent portions of Phases I and II, both of which have been previously reported.

Twenty-three oil sinking materials, which had been located in Phase I, were screened and tested (Phase III) in accordance with applicable test methods developed in the Phase II study (Appendixes A, B, C, and D). On the basis of current information, these materials were evaluated (Phase IV) as dry-application sinking agents for oil. Factors such as cost, availability, effectiveness in sinking and retaining oil, and hazards to personnel and plant life were considered in making the evaluations.

Eight materials were identified as dry-application all-season sinking agents for one or more oils, nine materials were identified as dry-application provisional sinking agents for one or more oils. One material was identified as a dry-application all-season sinking agent for all of the oils tested; one material was a dry-application provisional sinking agent for all of the oils tested.

GLOSSARY

SOM (Oil Sinking Material). Term used to identify materials submitted by manufacturers for evaluation as sinking agents.

Sinking agent. A material that, when applied to floating oil, sorbs (adsorbs and/or absorbs) oil, creating a high-density mass which sinks, with or without agitation, thus removing the oil from the surface.

Sorbent. A material that, when applied to floating oil, sorbs (adsorbs and/or absorbs) oil but does not effectively sink; oil and sorbent both remain on the surface.

Optimum oil retention potential. An index of the optimum capability of a SOM to retain a given oil submerged. The index is determined by the retained oil:SOM ratio by weight at 18 hr, under static laboratory conditions. This index may be determined both for sinking agents and sorbents as presented in Appendix A.

Ambient temperature. The temperature of the surrounding air.

Laboratory test conditions. A temperature of 73.4 ± 3.6 F (23 ± 2 C) and a relative humidity of 50 ± 5 percent.

Sinking efficiency. The ability of a SOM to act as a sinking agent for oil and sink an oil layer on water. Sinking efficiency is expressed by the oil:SOM ratio (by weight) required to sink at least 90 percent of the oil film thickness used. The test method is given as Appendix B.

Retention capability. Defined as the ability of the oil:sinking agent mass to retain its oil after sinking. The ratio of the weight of the oil retained to the weight of the sinking agent used is a measure of the retention capability.

Dynamic retention capability. The retention capability of a submerged oil:sinking agent mass determined under dynamic conditions, i.e., the submerged oil:sinking agent mass is subjected to variable currents and different bottom conditions. Dynamic retention capability is to be determined in accordance with the test methods presented as Appendixes C and D.

All-season sinking agents. Sinking agents which were tested for sinking efficiency at 40 F, 60 F, and 80 F and found to be effective.

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Provisional sinking agents. Sinking agents which were tested for sinking efficiency at 60 F only and found to be effective.

Nonsorbent. A material that does not adsorb or absorb oil.

INVESTIGATION OF SINKING METHODS FOR REMOVAL OF OIL POLLUTION FROM WATER SURFACES

Report 3

TESTS AND EVALUATION OF OIL SINKING MATERIALS

KEY

Oil Sinking Materials

Manufacturer	Identification No.	Trade Name
Phillips Scientific Corp. (a subsidiary of Phillips Petroleum Co.) Bartlesville, Okla. 74003	SOM-1	Latex coated barite
Pluess-Staufer (North American) Inc. 82 Beaver Street New York, N. Y. 10005	SOM-2	Omya Nautex H
Wyandotte Chemicals Corp. J. B. Ford Division Wyandotte, Mich. 48192	SOM-3	Zorb-All
United Sierra Division of Cyprus Mines Corp. Trenton, N. J. 08606	SOM-4	Mistron Vapor
United Sierra Division of Cyprus Mines Corp. Trenton, N. J. 08606	SOM-5	Mistron ZSC
United Sierra Division of Cyprus Mines Corp. Trenton, N. J. 08606	SOM-6	Glacier 200
Engelhard Minerals & Chemical Corp. Minerals & Chemical Division Menlo Park, Edison, N. J.	SOM-7	SCL-Speedi-Dry

Oil Sinking Materials (Continued)

Manufacturer	Identification No.	Trade Name
Union Carbide Corp. Mining and Metals Division R&D Department Niagara Falls, N. Y. 14302	SOM-8	Calidria Asbestos R-G444
Union Carbide Corp. Mining and Metals Division R&D Department Niagara Falls, N. Y. 14302	SOM-9	Calidria Asbestos S-G444
Union Carbide Corp. Mining and Metals Division R&D Department Niagara Falls, N. Y. 14302	SOM-10	Calidria Asbestos HPO (High Purity Open)
Waverly Minerals Products Co. 3018 Market Street Philadelphia, Pa. 19104	SOM-11	HI DRI
Waverly Minerals Products Co. 3018 Market Street Philadelphia, Pa. 19104	SOM-12	Megsite Fines
International Oil-Lok Control, Ltd. 1970 Spicer Road North Vancouver, B. C., Canada	SOM-13	Oil Lok
Dow Corning Corp. Midland, Mich. 48640	SOM-14	Silicone treated fly ash
Dow Corning Corp. Midland, Mich. 48640	SOM-15	Silicone treated fly ash
Dow Corning Corp. Midland, Mich. 48640	SOM-16	Silicone treated sand
Destroyl Ltd Goldlay, Burnt Mills Road Nevendon, Basildon Essex, United Kingdom	SOM-17	Cement byproduct
Aqua Pura Inc. 1000 Country Club Lane NW Albuquerque, N. Mex. 87114	SOM-18	Hydrated potassium aluminum silicate
The Burns & Russell Co. P. O. Box 6063 Baltimore, Md. 21231	SOM-19	Treated sand BR Globulator 101
The Burns & Russell Co. P. O. Box 6063 Baltimore, Md. 21231	SOM-20	Treated sand BR Encapsulator 201

Oil Sinking Materials (Continued)

Manufacturer	Identification No.	Trade Name
The Burns & Russell Co. P. O. Box 6063 Baltimore, Md. 21231	SOM-21	Treated sand BR Globulator 102
The Burns & Russell Co. P. O. Box 6063 Baltimore, Md. 21231	SOM-22	Treated sand BR Globulator 103
The Burns & Russell Co. P. O. Box 6063 Baltimore, Md. 21231	SOM-23	Treated sand BR Globulator 104

Oils

Identification No.	Description	Source
1	North Louisiana paraffinic-based crude (low-viscosity crude oil)	Humble Oil Co., Baton Rouge, La.
2	South Louisiana naphthenic-based crude (low-viscosity crude oil)	Humble Oil Co., Baton Rouge, La.
3	South Louisiana naphthenic-based crude (low-viscosity crude oil)	Federal Water Quality Control Administration, Edison, N. J.
4	Diesel oil (low viscosity)	Federal Water Quality Control Administration, Edison, N. J.
5	Residual fuel oil (Bunker C), a high-viscosity oil	Federal Water Quality Control Administration, Edison, N. J.
6	Bachaquera, Argentina type asphaltic high-viscosity crude oil from Tia Juana, Venezuela	Federal Water Quality Control Administration, Edison, N. J.
7	SAE 30-wt motor oil (lube oil)	American Oil Co., Vicksburg, Miss.

INVESTIGATION OF SINKING METHODS FOR REMOVAL OF OIL POLLUTION FROM WATER SURFACES

TESTS AND EVALUATION OF OIL SINKING MATERIALS

PART I: INTRODUCTION

Background

1. Oil pollution is a problem that has been present for most of the twentieth century, but the magnitude and frequency of oil spills have grown enormously during the past few years. During the period from 1956 to 1959, twenty-one major oil spills occurred near the United States, resulting in the spillage of approximately one million barrels* of oil into coastal waters.[1] Many research projects are being carried on by Government agencies and the petroleum industry to develop means of preventing oil spillage and to successfully deal with floating oil when it does occur.

2. When offshore spills occur, generally the first action is to attempt to contain the oil by use of booms and recover it by use of pumps, skimmers, or oil-attracting belts or cylinders. When this is not successful, floating materials are often spread on the oil to absorb it and are then collected for disposal. Control methods such as burning, dispersing with chemicals, and sinking are normally only to be used when the initial actions are unsuccessful and the oil is uncontained at sea and in danger of polluting the shoreline. The National Oil and Hazardous Materials Pollution Contingency Plan (June 1970)[2] specifies that sinking agents or dispersants are not to be used in marine waters less than 100 meters deep. Also, sinking agents should be used only when the current is not predominately shoreward and only when other control

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* A table of factors for converting British units of measurement to metric units is given on page vii.

methods are judged to be inadequate or unfeasible by the Federal Water Quality Administration. In spite of these restrictions, there are situations in which sinking methods are a valuable tool in controlling oil spills.

Purpose

3. The overall purpose of this investigation was to locate materials, establish test procedures, and evaluate materials that could be utilized in the cleanup of massive oil spills by sinking the oil. To accomplish this objective, the program was divided into four phases as follows:

- Phase I: Survey of the State-of-the-Art
- Phase II: Development of Standard Test Procedures
- Phase III: Tests of Oil Sinking Materials
- Phase IV: Tests Analysis and Conclusions

Scope

4. A literature survey (Phase I) was made and 23 potential oil sinking materials were located and samples procured. Laboratory test procedures were developed for evaluating oil sinking materials (Phase II). The procedures developed were for the determination of (a) optimum oil retention potential, (b) sinking efficiency, and (c) dynamic retention capability. The 23 materials located were tested (Phase III) using the test procedures developed in Phase II. Phase IV consisted of the evaluation of the 23 materials based on the results of all testing.

Previous Work

5. In Phase I,[3] many hundreds of articles and publications were reviewed to locate, and develop information on, oil sinking materials. Literature pertaining to oil sinking materials was not particularly abundant, and most of the work that has been done was done in Europe,

especially in England. It is believed, however, that practically all information of any value pertaining to dry-application oil sinking materials was located and processed during this literature survey.

6. Initially, eighteen materials offered by manufacturers were located for investigation These materials were assessed based on results of the literature search and on information supplied by the manufacturers and tentatively rated with regard to effectiveness in absorbing and sinking oil, effectiveness in retaining oil, availability and cost of the material, hazards to personnel and plant and animal life, and difficulty of application. This information was reported in Report 1[3] of this series, but portions thereof are also given in subsequent parts of this report. Since Report 1 was published, an additional six materials were located, and information on these materials is presented in this report.

7. It should be noted that the material identified as SOM-17 in Report 1 of this series, a silicone treated sand, was not tested in subsequent phases. The SOM-17 material tested in Phases II and III of the investigation is a cement byproduct and should not be confused with the SOM-17 assessed and referred to in Report 1.

8. In Phase II[4] of this investigation laboratory tests were developed to evaluate the effectiveness of oil sinking materials under varying conditions. In the development of the test methods, the effects of variation of the following parameters were taken into account:

a. Oil film thickness
b. Nature of oil film (fresh or weathered)
c. System temperature
d. Rate of application of sinking agent
e. Nature of surface condition (calm or agitated)
f. Type of bottom condition (sand, mud, gravel, etc.)
g. Current flow (fluid velocity)
h. Nature of water system (salt or fresh)
i. Effects of volatiles

Four methods of test were developed and the results were reported in Report 2[4] of this series. The test methods developed are given as

Appendixes A, B, C, and D herein and determine:

a. Optimum oil retention potential

b. Sinking efficiency

c. Dynamic retention capability

d. Volatile loss-time characteristics of oil retained on glass wool

The test methods developed are not applicable to residual fuel oil (Bunker C) due to its semisolid state under laboratory conditions. No significant difference was noted in results obtained due to water composition--fresh water or simulated sea water.

PART II: IDENTIFICATION OF MATERIALS

Oil Sinking Materials

9. In Phase I of this investigation, samples of 23 materials offered by manufacturers as sinking agents* for oil were procured. Information about each of these materials was obtained from the manufacturers and is presented as Appendix E. A general grouping of these materials would be as follows:

Type of Material	No. of Materials of This Type Procured
Barite	1
Chalk	1
Clay	5
Talc	3
Asbestos	3
Sand	7
Fly ash	2
Cement byproduct	1

Specific identification of the 23 materials is given in table 1.

Physical Characteristics

10. In order to determine the relative particle sizes of the oil sinking materials, sieve analyses were run. Sieve analyses of 11 of the coarser materials (SOM-3, -7, -11, -12, -13, -16, -19, -20, -21, -22, and -23) were conducted in accordance with applicable portions of ASTM Designation: C 136-67[5]. Partial sieve analyses were conducted on the remaining 12 materials, some of which were extremely fine powders (SOM-2, -4, and -5). The results of sieve analyses are given in table 2, in which the materials are arranged in order of fineness from left to right, with the coarsest material, SOM-11, on the left. One hundred percent of all materials passed the No. 4 (4.76-mm) sieve, while one hundred

* See Glossary for definition of terms used in this report.

percent of SOM-2, -4, and -5 passed the No. 400 (37-micron) sieve.

11. The particle specific gravity of each material was determined by use of a Beckman air comparison pycnometer, Model 930; loose volume density was determined by filling a calibrated container and weighing. The results of these tests are given in table 1. SOM-7 had the highest particle specific gravity (3.37) and SOM-8 the lowest (2.10). The highest loose volume density (108.1 lb/cu ft) was that of SOM-21; SOM-10 had the lowest (12.2 lb/cu ft).

Photomicrographs

12. Photomicrographs of each of the materials were made using magnifications of either 2, 10, or 100 depending on the fineness of the material. These photos are given in Appendix F.

Infrared analysis

13. Eight of the materials were selected for examination using infrared spectrophotometry (IR). First, an identification spectrum was obtained on the eight as-received materials. Six of these eight materials had been treated with organic substances. These six materials were placed in organic solvents to extract the coatings or treatments, and the extracted organic materials were identified using IR. The results of these identifications are given in table 1.

Oils

14. Seven unweathered oils were procured for use in this program. These oils can be generally classified as one of the following types: residual fuel oil, diesel oil, lube oil, and crude oil. The oils were assigned numbers and are identified below:

Oil No.	
1	North Louisiana paraffinic-based low-viscosity crude oil
2*	South Louisiana naphthenic-based low-viscosity crude oil
3*	South Louisiana naphthenic-based low-viscosity crude oil
4	Diesel oil (low viscosity)

(Continued)

* Oils 2 and 3 are essentially the same oil, so oil 3 was not used in subsequent oil sinking material testing.

Oil No.	
5**	Residual fuel oil (Bunker C), a high-viscosity oil
6	Venezuela (Bachaquera, Argentina type) asphaltic high-viscosity crude oil
7	Lube oil (SAE 30-wt motor oil), a medium-viscosity oil

** This oil was not used in the testing because of its semisolid state under laboratory conditions.

All of these oils were fresh or unweathered oils. Since significant exposure to outdoor weathering will change the physical properties of an oil, all procured oils were placed in airtight containers which were thoroughly agitated before samples of oil were removed for the various laboratory tests which were conducted. The oils which were utilized in each of the laboratory tests were therefore fresh or unweathered oils.

Physical characteristics

15. The specific gravity of the unweathered oils at 40, 73, and 100 F was determined by weighing in a calibrated container. Test results are given in table 3. A laboratory viscosimeter (Brookfield Model LVF 4529) was used to determine the viscosity-temperature relations for the seven oils; these data are presented in table 3 and plate 1. Laboratory tests were also conducted to determine the volatile loss-time relationships for the oils under various conditions; in these tests, uncovered samples (approximately 25 grams) of each oil were exposed in controlled environments for periods up to 7 days and the amount of oil which volatilized from a surface area of 25.97 sq in. was expressed as weight loss. The results obtained are summarized in table 4 and shown graphically in plate 2. Oils 1, 2, 3, and 4 are low-viscosity oils and are the most volatile of the oils tested while oils 5, 6, and 7 are heavier, more viscous oils of less volatility.

Infrared analysis

16. The seven unweathered oils were examined using infrared spectrophotometry (IR); spectra were obtained in the 2.5- to 16-micron region. The samples were prepared for IR testing by gently pressing the oil between sodium chloride crystals provided with a spacer and cell holder. The graphical results obtained are shown in Appendix G and the IR identification is summarized in table 3.

PART III: PRELIMINARY ASSESSMENT OF OIL SINKING MATERIALS

17. In the initial phases (Phases I and II)[3,4] of this investigation the oil sinking materials were assessed with regard to (a) availability and cost, (b) hazards to personnel and plant life, and (c) difficulty of application, and were tentatively classified. The results of these assessments and classifications are presented in the following paragraphs.

Availability and Cost

18. Untreated materials were generally more available than treated materials. Most manufacturers are not tooled for high production treatment of the materials but some could begin such production with a short lead time. Treated materials with a long shelf life could be produced and stockpiled at strategic locations for future use in an emergency.

19. The materials can be generally grouped into two broad categories with respect to current availability:

a. Those which are available in quantity with a short lead time

b. Those for which a treatment plant would be required for quantity production

The following tabulation groups the materials with respect to availability and also ranks them on a cost basis. Some manufacturers did not report cost, so an estimate of the cost of these materials is given in these cases.

Material No.	Cost Rank	General Description	Available?	Treatment Plant Required?	Cost Information
SOM-1	19.5	Barite	No	Yes	$140/ton, FOB plant
SOM-2	13	Chalk	Yes	No	$80/ton, FOB most major U. S. ports
SOM-3	9	Clay	Yes	No	$60/ton, FOB plant
SOM-4	17.5	Talc	Yes	No	$120/ton, FOB most major U. S. cities

(Continued)

Material No.	Cost Rank	General Description	Available?	Treatment Plant Required?	Cost Information
SOM-5	21	Talc	Yes	No	$160/ton, FOB most major U. S. cities
SOM-6	17.5	Talc	Yes	No	est.* $120/ton, FOB plant
SOM-7	6	Clay	Yes	No	$41/ton, FOB plant
SOM-8	23	Asbestos	Yes	No	$650/ton, FOB plant
SOM-9	22	Asbestos	Yes	No	$350/ton, FOB plant
SOM-10	19.5	Asbestos	Yes	No	$140/ton, FOB plant
SOM-11	2	Clay	Yes	No	$35/ton, FOB plant
SOM-12	1	Clay	Yes	No	est.* $20/ton, FOB plant
SOM-13	11	Sand	Yes	No	$75/ton, FOB plant
SOM-14	15	Fly ash	No	Yes	est.* $100/ton, FOB plant
SOM-15	15	Fly ash	No	Yes	est.* $100/ton, FOB plant
SOM-16	11	Sand	No	Yes	est.* $75/ton, FOB plant
SOM-17	15	Cement byproduct	Yes	No	est.* $100/ton, FOB plant
SOM-18	8	Clay	Yes	No	$58/ton, FOB plant
SOM-19	3.5	Sand	Yes	No	$36/ton, FOB plant
SOM-20	3.5	Sand	Yes	No	$36/ton, FOB plant
SOM-21	5	Sand	Yes	No	$40/ton, FOB plant
SOM-22	11	Sand	No	Yes	est.* $75/ton, FOB plant
SOM-23	7	Sand	Yes	No	$56/ton, FOB plant

* Estimated.

Hazards

Personnel health hazards

20. Masks should be used by personnel working with any of the materials, especially the finer materials. Any powdery material inhaled into the lungs over a long period of time will cause damage. The materials tested in this program can be grouped with regard to personnel hazards as follows:

Group 1: Least hazardous.

Barite (SOM-1)

Chalk (SOM-2)

Clays (SOM-3, -7, -11, -12, and -18)

Talcs (SOM-4, -5, and -6)

Group 2: Possible danger of silicosis from prolonged breathing.

Fly ash (SOM-14 and -15)

Sands (SOM-13, -16, -19, -20, -21, -22, and -23)

Cement byproduct (SOM-17)

Group 3: Danger of asbestosis (toxic materials).

Asbestos (SOM-8, -9, and -10)

21. In regard to Group 2, there is a possible danger of silicosis from prolonged breathing of materials in this group; however, contraction of silicosis would take prolonged exposure and, with masks, is not considered very likely for short-term exposure.

22. The danger of the development of a disabling lung disease called asbestosis is present when working with asbestos. The manufacturers of these (Group 3) materials recommend, for oil sinking, their application in an oil or water solution, which would reduce the problem.

Effect on flora and fauna

23. None of the sinking materials themselves are expected to adversely affect flora and fauna; however, the covering of animal and/or plant life by the oil:SOM conglomeration would undoubtedly have an adverse effect.

Difficulty of Application

24. The oil sinking materials were grouped as follows with regard to difficulty of application:

Group 1: Sprinkle or pressure apply dry, none or only slight agitation needed for sinking.

Barite (SOM-1)

Clays (SOM-11, -12, and -18)

Fly ash (SOM-14 and -15)

Group 1: <u>Sprinkle or pressure apply dry, none or only slight agitation needed for sinking. (Continued)</u>

Sands (SOM-13, -16, -19, -21, -22, and -23)

Cement byproduct (SOM-17)

Group 2: <u>Sprinkle or pressure apply dry, supplemental agitation needed for sinking.</u>

Chalk (SOM-2)

Clays (SOM-3 and -7)

Talc (SOM-4, if applied dry)

Group 3: <u>Spray apply in solution of either crude oil or water.</u>

Talcs (SOM-4, -5, and -6)--mix with water

Asbestos (SOM-8 and -9)--mix with oil

Asbestos (SOM-10)--mix with water

Sand (SOM-20)--mix with water

25. It should be noted that in the subsequent laboratory tests, all materials were tested as if they were all Group 2 materials. Those materials which are in Group 3 (SOM-5, -6, -8, -9, -10, and -20) could not be expected to perform in a very satisfactory manner as sinking agents since they were not applied as recommended by the manufacturers.

Preliminary Classification

26. Screening tests revealed that the 23 materials could be initially classified into two groups as follows:

a. Granular materials (sinking agents):

Barite	SOM-1
Clay	SOM-3, -7, -11, -12, -18
Treated sand	SOM-13, -16, -19, -20, -21, -22, -23
Fly ash	SOM-14, -15
Cement byproduct	SOM-17

b. Powdered materials (sorbents):

Chalk	SOM-2
Talc	SOM-4, -5, -6
Asbestos	SOM-8, -9, -10

The granular materials were generally considered to be sinking agents and the powdered materials were generally considered to be sorbents. The action of these materials in the screening tests indicated that this was a satisfactory preliminary classification.

PART IV: TESTS OF OIL SINKING MATERIALS

27. In Phase II[4] of this investigation, three test methods were developed for evaluation of the oil sinking materials; these test methods are given as Appendixes A, B, and C. Laboratory tests of the oil sinking materials were conducted using the test methods as discussed in the succeeding paragraphs. All oils used in the laboratory tests were unweathered oils to minimize the effects of volatile matter contained on the test results.

28. Short-term retention potential tests were conducted initially on all of the 23 materials obtained for use in this program. Materials were then selected to represent each of the five types of granular materials, which had been initially classified as sinking agents (see paragraph 26), for further testing and evaluation. Additional tests were also conducted on two of the fine powdered materials for comparison purposes. Table 5, which presents in tabular form the tests conducted, indicates the conditions of each test and which oils and oil sinking materials were involved. The chronological sequence of the testing is shown below:

- a. Short-term optimum oil retention potential tests.
- b. Short-term sinking efficiency tests at 40, 60, and 80 F using three oil thicknesses.
- c. Long-term retention potential tests.
- d. Short-term sinking efficiency tests at 60 F using one oil thickness (tests of materials which had not been previously tested under these conditions).
- e. Long-term sinking efficiency tests.
- f. Dynamic retention capability tests.

Optimum Oil Retention Potential

18-hr tests (short-term tests)

29. The 18-hr optimum oil retention potential of all 23 of the SOM's for six unweathered oils (oils 1, 2, 3, 4, 6, and 7) was determined using the Appendix A test method under laboratory test conditions.

Because of the nature of the test materials themselves, 16 materials initially classified as sinking agents (SOM-1, -3, -7, and -11 through -23) were tested using Method A of the test method and seven materials initially classified as sorbents (SOM-2, -4, -5, -6, -8, -9, and -10) were tested using Method B of the test method. Oil:SOM ratios (by weight)* obtained are given in table 6 and ranged as follows:

Oil 1	0.14 (for SOM-21) to 5.67 (for SOM-10)
Oil 2	0.15 (for SOM-21) to 5.95 (for SOM-8)
Oil 3	0.14 (for SOM-21) to 4.52 (for SOM-9)
Oil 4	0.14 (for SOM-21) to 4.93 (for SOM-8)
Oil 6	0.23 (for SOM-21) to 18.45 (for SOM-10)
Oil 7	0.10 (for SOM-23) to 8.44 (for SOM-10)

30. These test results indicated that, in general, the asbestos materials had the greatest potential for retaining the oils tested while the sands had the least potential.

Long-term tests

31. Additional optimum oil retention potential tests were conducted (as indicated by Pordes and Jongbloed[6]) for periods of one week or more using five unweathered oils (oils 1, 2, 4, 6, and 7) and 11 oil sinking materials (SOM-1, -3, -7, -11, -13, -14, -16, -17, -21, -22, and -23). The oil:SOM ratios (by weight) obtained are given in table 7 and ranged as follows:

Oil 1	0.13 (for SOM-21) to 1.73 (for SOM-1)
Oil 2	0.15 (for SOM-16) to 2.29 (for SOM-1)
Oil 4	0.15 (for SOM-23) to 2.05 (for SOM-1)
Oil 6	0.20 (for SOM-21) to 2.27 (for SOM-1)
Oil 7	0.07 (for SOM-23) to 1.11 (for SOM-1)

32. These test results indicated that, of the 11 materials tested, SOM-1 (barite) had the greatest potential for retaining the oils tested while the sands (SOM-13, -16, -21, -22, and -23) had the least potential.

* All oil:SOM ratios are by weight.

Also, no appreciable difference in oil:SOM ratio was noted between the short-term and long-term retention potential tests with oils 1, 2, and 4. However, as the absolute viscosity of the oil used exceeds 100 cp (oils 6 and 7), the difference between the oil:SOM ratios obtained in short-term and long-term tests became significant.

Sinking Efficiency

33. Laboratory tests were conducted to determine the sinking efficiency of all materials in accordance with the Appendix B test method, even though all materials had not been classified initially as sinking agents.

Short-term tests at three temperatures

34. Sinking efficiency tests on nine selected materials were conducted utilizing three thicknesses of five unweathered oils (oils 1, 2, 4, 6, and 7) at three temperatures (40 ± 2 F, 60 ± 2 F, 80 ± 2 F). This was a total of 405 individual tests, or nine tests of each of 45 different oil-SOM combinations. The individual oil:SOM ratios obtained in these tests are given in table 8. An inspection of the data in table 8 indicates that in general the sinking efficiency (oil:SOM ratio) was not proportional to temperature (which defines specific gravity and viscosity of the oil in use) or oil thickness. It appears that the effectiveness of an individual oil sinking material depended on a combination of many factors--SOM used, oil used, temperature, and oil thickness. The effect of any one parameter on the sinking efficiency depends on how the parameters interact for that particular case. In general, however, the nine SOM's tested are more effective on oil thicknesses of 0.10 or 0.15 in. (2.54 to 3.81 mm), and less effective on oil thicknesses of 0.01 and 0.05 in. (0.25 and 1.27 mm).

35. The tests of 28 of the 45 oil-SOM combinations yielded enough reliable data to warrant a statistical treatment for effect of oil thickness and temperature. The residual errors of the data from each of these 28 combinations were calculated and compared. The residual error

was found to be statistically the same for all and equal to 0.135 (in oil:SOM ratio) with 106 degrees of freedom. A statistical analysis of the data from each of the combinations using this residual error determined that oil thickness and/or temperature was significant at the 95 or 99% confidence level in only 14 combinations. Graphs are given (plates 3 and 4) for these 14 combinations for the parameter or parameters which are significant. The temperature or oil thickness is significant only at the 95% confidence level (significant) for the data given in plates 3a, 3g, and 4g. The data used in plates 3b through f, 4a through f, and 4h through k indicate that temperature or oil thickness is significant at the 99% confidence level (highly significant). A summary of this information is shown in table 9. The significance tests indicate that (a) the effectiveness of SOM-1 is, in most cases, influenced significantly by temperature, (b) the effectiveness of SOM-17 is, in most cases, influenced significantly by oil thickness, and (c) oil thickness is important in considering agents to be used for sinking oils 1 and 2 (light crude oils).

36. The test results indicate that one material tested (SOM-8) is not a sinking agent since it was not satisfactory for sinking any of the oils at these temperatures. Other information gleaned from these tests was (a) SOM-4 acted as a sinking agent for oil 4 (diesel oil) only, (b) only two of the SOM's tested, SOM-13 and -22, acted as sinking agents for oil 6 (Argentina crude), (c) SOM-1, -3, -14, and -17 were not effective for sinking oil 7 (lube oil) at 40 F in thicknesses of 0.10 and 0.15 in., (d) SOM-11 was not effective in sinking oil 7 (lube oil) in any of the three thicknesses used, and (e) SOM-13 was not effective in sinking oil 4 (diesel oil) at 40 F.

Short-term tests at 60 F

37. The sinking efficiency of all of the materials was determined at 60 ± 2 F using one thickness (0.05 in.) of five unweathered oils (oils 1, 2, 4, 6, and 7). The oil:SOM ratios obtained in these 115 tests are given in table 10. Some of these tests (45 of the 115 tests) had been previously conducted in the tests described in paragraph 35 and were therefore not repeated.

38. Some of the materials did not meet the minimum test requirements for sinking a given oil; some materials did not meet the test requirements for sinking any of the oils (SOM-5, -8, and -9) and therefore cannot be classed as sinking agents, but have to be classed as sorbents for the purposes of the materials evaluations. Some materials met the minimum requirements for the test but had excessive oil release within 15 minutes. This excessive oil release was noted and the materials which exhibited this release are not considered to be satisfactory as a sinking agent for the particular oil at this temperature.

39. The oil:SOM ratios obtained ranged as follows for materials which performed satisfactorily:

Oil 1	0.14 (for SOM-20) to 1.00 (for SOM-1)
Oil 2	0.29 (for SOM-13) to 0.98 (for SOM-17)
Oil 4	0.20 (for SOM-13) to 1.82 (for SOM-4)
Oil 6	0.29 (for SOM-23) to 1.00 (for SOM-15)
Oil 7	0.21 (for SOM-20) to 1.10 (for SOM-1)

40. The following materials did not perform satisfactorily with the oils shown below:

Oil 1	SOM-2, -4, -5, -8, -9, -10, -18, -21, -23
Oil 2	SOM-2, -4, -5, -8, -9, -10, -16, -18, -19, -20, -21, -23
Oil 4	SOM-2, -5, -7, -8, -9, -10, -18, -19, -20, -21, -23
Oil 6	SOM-1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -14, -17, -18, -20
Oil 7	SOM-2, -4, -5, -6, -7, -8, -9, -10, -11, -17, -18, -19, -21, -23

41. On the basis of the 60 F sinking efficiency tests, the following six materials, for the purposes of this evaluation, cannot be classified as sinking agents for any of these five oils: SOM-2, -5, -8, -9, -10, -18.

<u>Long-term tests at 60 F</u>

42. In order to develop more information about the sinking

efficiency of the test materials as suggested by Pordes at the 1971 conference on prevention an' control of oil spills,[6] an additional 19 tests were conducted at 60 ± 2 F using an oil thickness of 0.05 in. Ten SOM's and five oils were used in these tests, which were conducted by the Appendix B test method, and oil release was measured, using a glass funnel with a graduated stem, for periods up to 42 days. The results of these tests are shown in table 11. The test results indicate the relative effectiveness of the SOM's tested with the particular oil used. Four materials which had excessive oil release in the short-term sinking efficiency tests were tested in these long-term tests and each had considerable additional amounts of oil released during the longer period; this resulted in further diminution of the oil:SOM ratios as shown below:

Materials	Short-Term Test Oil:SOM Ratio	Long-Term Test Oil:SOM Ratio (at 42 days)
SOM-7 with oil 4	0.32+	0.16
SOM-7 with oil 6	1.02+	0.32
SOM-11 with oil 7	1.17+	0.36
SOM-17 with oil 7	1.18+	0.34

Note: + means excessive oil release within 15 min after test.

Dynamic Retention Capability

43. Dynamic retention capability tests were conducted in accordance with the test methods given as Appendixes C and D except that fresh water was used in all tests. These tests are discussed in the succeeding paragraphs, and test results are presented in table 12 and plate 5.

20-hr tests with oil 1

44. Laboratory tests were conducted, using the Appendix C test method, to determine the 20-hr dynamic retention capability of six SOM's with oil 1 (unweathered). The circular channel was filled with fresh water and adjusted, using necessary baffles, to give an average current velocity (from velocity profile) of 0.55 fps (0.32 knot) before the

oil:SOM mass was added to the moving channel. The necessary oil collections and calculations were made using the Appendix D test method to determine the volatile loss-time characteristics of oil 1 retained on glass wool. The initial and 20-hr oil:SOM ratios obtained in this series of tests are given in table 12 (see also figs. a through f of plate 5). The initial oil:SOM ratios used were governed by the amount of oil absorbed by each material and varied for each of the six materials. Twenty-hr oil:SOM ratios obtained varied from 0.14 for SOM-17 to 1.56 for SOM-1.

Additional tests

45. Four additional dynamic retention capability tests were conducted (using applicable provisions of Appendixes C and D test methods) with the following parameters:

Oil Sinking Material	Bottom Material	Oil No.*	Average Current Velocity fps (knots)
SOM-11	Gravel (1-in. max. size)	1	0.55 (0.32)
SOM-11	Mud (moist earth)	1	0.55 (0.32)
SOM-11	Fine sand	1	0.36 (0.21)
SOM-11	Fine sand	7	0.55 (0.32)

* Oils were unweathered.

These tests were conducted to demonstrate that the use of a different oil, another current velocity, or a different bottom material would influence the oil:SOM ratio obtained so the same oil sinking material (SOM-11) was used in all four of the tests and the data are given in table 12 and figs. g through j of plate 5.

46. The data reveal that under the conditions of the tests SOM-11 (a) is more effective with oil 1 (north Louisiana crude oil) than with oil 7 (lube oil), (b) is more effective at a current velocity of 0.36 fps than at a current velocity of 0.55 fps, (c) is more effective on a gravel bottom than on a fine sand or mud bottom, and (d) is more effective on a mud bottom than on a fine sand bottom.

PART V: COMPARISONS BASED ON TEST RESULTS

47. The oil sinking materials were ranked based on the results of the laboratory tests conducted. The materials were ranked in each of the tests in numerical order from best to worst. In some tests, however, only selected materials were used and consequently rankings are available for only those materials which were actually tested.

Tests of All 23 Materials

48. Only two of the laboratory tests conducted included all 23 of the oil sinking materials; these were: 18-hr optimum oil retention potential tests, and short-term sinking efficiency tests at 60 F using an oil thickness of 0.05 in. The materials are rated for these two tests both by type of oil and on an overall basis as shown.

Relative effectiveness in retaining oil

49. Table 13 gives the ratings as determined by the 18-hr optimum oil retention potential test and is an indication of the relative effectiveness of each material in retaining oil while submerged under the conditions of the test. The higher the oil:SOM ratio obtained in the test, the higher the rating.

Relative effectiveness in sinking oil

50. Table 14 rates all of the materials as determined by the short-term sinking efficiency test (conducted at 60 F using an oil thickness of 0.05 in.). Ratings are based on oil:SOM ratio and behavior of the materials during the test and indicate the relative effectiveness of a material in sinking oil under the conditions of the test.

Tests of Selected Materials Only

51. The relative ratings of the 11 selected materials tested in the long-term optimum oil retention potential tests (table 7) are given in table 15.

52. The relative ratings of the selected materials tested for

long-term sinking efficiency at 60 F (table 11) are shown below:

a. With oil 1 (at 60 F, oil thickness 0.05 in.) after 42 days:

SOM-11 >* SOM-13

b. With oil 2 (at 60 F, oil thickness 0.05 in.) after 7 days;

Material:	SOM-1 =	SOM-17 >	SOM-11 >	SOM-14 >	SOM-3 >	SOM-13 >	SOM-22
Rating:	1.5	1.5	3	4	5	6	7

c. With oil 4 (at 60 F, oil thickness 0.05 in.) after 42 days:

SOM-7 > SOM-13

d. With oil 6 (at 60 F, oil thickness of 0.05 in.) after 2 days;

Material:	SOM-15 >	SOM-22 >	SOM-13 =	SOM-16 >	SOM-7
Rating:	1	2	3.5	3.5	5

e. With oil 6 (at 60 F, oil thickness of 0.05 in.) after 42 days;

Material:	SOM-22 >	SOM-7 >	SOM-13
Rating:	1	2	3

f. With oil 7 (at 60 F, oil thickness of 0.05 in.) after 42 days;

Material:	SOM-11 >	SOM-17 >	SOM-13
Rating:	1	2	3

53. The relative ratings of the nine selected materials tested for sinking efficiency at three temperatures (table 8) are given in table 16.

54. The relative ratings for the six selected materials tested for dynamic retention capability (table 12) are given below:

Material		Rating with Low-Viscosity Crude Oil (Oil 1) (After 20 hr of Dynamic Test)
No.	Description	
SOM-1	Barite	1
SOM-11	Clay	2
SOM-3	Clay	3
SOM-7	Clay	4
SOM-13	Sand	5
SOM-17	Cement byproduct	6

* > = better than.

Classification of Materials

55. In the previous paragraphs the oil sinking materials were ranked with respect to each other on the basis of the laboratory tests. These comparative ratings are merely rankings and do not indicate whether or not a material is effective as a sinking agent for a given oil or oils. A further classification is needed to provide this information. Three categories were used to group materials with respect to performance with a given oil or oils.

- a. A material that sorbed (adsorbed and/or absorbed) oil and was effective in sinking the oil was classified as a "sinking agent."
- b. A material that sorbed oil but was not effective in sinking the oil was classified as a "sorbent."
- c. A material that did not adsorb or absorb oil was classified as a "nonsorbent."

Paraffinic-based low-viscosity crude oil (oil 1)

56. The 23 materials were classified as follows with respect to oil 1:

- a. Sinking agents: SOM-1, -3, -6, -7, -11, -12, -13, -14, -15, -16, -17, -19, -20, and -22
- b. Sorbents: SOM-2, -4, -5, -8, -9, -10, -18, -21, and -23
- c. Nonsorbents: None

Naphthenic-based low-viscosity crude oil (oils 2 and 3)

57. Classifications for oils 2 and 3 are shown below:

- a. Sinking agents: SOM-1, -3, -6, -7, -11, -12, -13, -14, -15, -17, and -22
- b. Sorbents: SOM-2, -4, -5, -8, -9, -10, -16, -18, -19, -20, -21, and -23
- c. Nonsorbents: None

Diesel oil (oil 4)

58. The 23 materials were classified with oil 4 as follows:

- a. Sinking agents: SOM-1, -3, -4, -6, -11, -12, -14, -15, -16, -17, and -22
- b. Sorbents: SOM-2, -5, -[illegible], -8, -10, -13, -18, -19, -20, -21, and -23
- c. Nonsorbents: SOM-9

High-viscosity crude oil (oil 6)

59. The 23 materials were classified as follows with respect to oil 6:

a. Sinking agents: SOM-13, -15, -16, -19, -21, -22, and -23

b. Sorbents: SOM-1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -14, -17, -18, and -20

c. Nonsorbents: None

Lube oil (oil 7)

60. Classifications for oil 7 are:

a. Sinking agents: SOM-12, -13, -15, -16, -20, and -22

b. Sorbents: SOM-1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -14, -17, -18, -19, -21, and -23

c. Nonsorbents: None

All six oils (oils 1, 2, 3, 4, 6, and 7)

61. Classifications of the 23 materials for oils 1, 2, 3, 4, 6, and 7 are given below:

a. Sinking agents: SOM-15 and -22

b. Sorbents: SOM-1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13, -14, -16, -17, -18, -19, -20, -21, and -23

SOM-9 was a sorbent for oils 1, 2, 3, 6, and 7

c. Nonsorbents: SOM-9 for oil 4 only

PART VI: FINAL ASSESSMENT OF SINKING AGENTS

62. In paragraphs 56-61, certain materials were designated as sinking agents for the various oils on the basis of the laboratory tests conducted. All materials were not tested in all tests and for this reason, before a final evaluation of materials was made, it was necessary to further group the materials so that they would be assessed properly.

63. For the purpose of a final evaluation of the materials, the sinking agents were divided into two types:

a. All-season type. Those sinking agents which were tested for sinking efficiency at three temperatures (40, 60, and 80 F) and found to be effective. This range of temperatures, 40 to 80 F, encompasses the total temperature range for which sinking agents are expected to be used and therefore this type has been designated "all-season."

b. Provisional type. Those sinking agents which were tested for sinking efficiency at one temperature (60 F) only and found to be effective. These agents have to be regarded as provisional or potential sinking agents since they need further evaluation.

64. In the laboratory tests, nine materials were evaluated for effectiveness as all-season sinking agents, while the other 14 materials were evaluated as provisional sinking agents. In addition, in order to designate which material is the best sinking agent for each of the two types for a particular oil or oils it was necessary to consider availability, cost, and hazards to personnel as well as all laboratory ratings. On these bases, final ratings of the sinking agents were made and these are given in subsequent paragraphs and summarized in table 17.

Sinking Agents for Oil 1

65. Fourteen materials were identified as sinking agents for oil 1 (paraffinic-based low-viscosity crude oil); these were classified as follows:

a. All-season sinking agents: SOM-1, -3, -11, -13, -14, -17, and -22

b. Provisional sinking agents: SOM-6, -7, -12, -15, -16, -19, and -20

All-season agents

66. Information about all-season sinking agents for oil 1 is given below:

Material No.	Comparative Rank in Laboratory Sinking Efficiency Tests	Available?	Treatment Plant Required?	Personnel Hazards	Cost/Ton	Final Overall Ranking
SOM-1	1	No	Yes	Least hazardous	$140	4
SOM-3	3.5	Yes	No	Least hazardous	60	2
SOM-11	2	Yes	No	Least hazardous	35	1
SOM-13	7	Yes	No	Possible danger	75	7
SOM-14	3.5	No	Yes	Possible danger	100 (est.)	5
SOM-17	5	Yes	No	Possible danger	100 (est.)	3
SOM-22	6	No	Yes	Possible danger	75	6

From the above, SOM-11, hydrated magnesium aluminum silicate, was the best all-season sinking agent for oil 1 since it is available in quantity at the least cost, is rated as "least hazardous," and performed well in the laboratory tests.

Provisional agents

67. Information about the provisional sinking agents for oil 1 is given below:

Material No.	Comparative Rank in Laboratory Sinking Efficiency Tests	Available?	Treatment Plant Required?	Personnel Hazards	Cost/Ton	Final Overall Ranking
SOM-6	2	Yes	No	Least hazardous	$120 (est.)	3
SOM-7	3	Yes	No	Least hazardous	41	2

(Continued)

Material No.	Comparative Rank in Laboratory Sinking Efficiency Tests	Available?	Treatment Plant Required?	Personnel Hazards	Cost/Ton	Final Overall Ranking
SOM-12	1	Yes	No	Least hazardous	$ 20 (est.)	1
SOM-15	4	No	Yes	Possible danger	100 (est.)	6
SOM-16	5	No	Yes	Possible danger	75 (est.)	7
SOM-19	6	Yes	No	Possible danger	36	4
SOM-20	7	Yes	No	Possible danger	36	5

SOM-12, a natural clay, was rated as the best provisional sinking agent for oil 1 and would be the choice for further evaluation since it is available in quantity at the least cost, is rated as "least hazardous," and performed well in the laboratory tests that were conducted.

Sinking Agents for Oils 2 and 3

68. Eleven materials were identified as sinking agents for oils 2 and 3 (naphthenic-based low-viscosity crude oils); these were:

a. All-season sinking agents: SOM-1, -3, -11, -13, -14, -17, and -22

b. Provisional sinking agents: SOM-6, -7, -12, and -15

All-season agents

69. Information about the seven all-season sinking agents in regard to availability, cost, and hazards is identical with the information given in the tabulation in paragraph 66. Other information is:

Material No.	Comparative Rank in Laboratory Sinking Efficiency Tests	Final Overall Ranking
SOM-1	2	4
SOM-3	4	2
SOM-11	1	1

(Continued)

Material No.	Comparative Rank in Laboratory Sinking Efficiency Tests	Final Overall Ranking
SOM-13	7	7
SOM-14	5	5
SOM-17	3	3
SOM-22	6	6

SOM-11, hydrated magnesium aluminum silicate, was the best all-season sinking agent for oils 2 and 3 when all factors are considered.

Provisional agents

70. The final overall ranking of the four provisional sinking agents for oils 2 and 3, considering laboratory tests, availability, cost, and hazards, is as follows:

Material No.	Comparative Rank in Laboratory Sinking Efficiency Tests	Final Overall Ranking
SOM-6	4	3.5
SOM-7	2.5	2
SOM-12	1	1
SOM-15	2.5	3.5

The natural clay, SOM-12, was rated as the best provisional sinking agent for oils 2 and 3.

Sinking Agents for Oil 4

71. Eleven materials were identified as sinking agents for diesel oil (oil 4). These were:

- a. All-season sinking agents: SOM-1, -3, -4, -11, -14, -17, and -22
- b. Provisional sinking agents: SOM-6, -12, -15, and -16

All-season agents

72. Information about the all-season sinking agents for oil 4 is tabulated below:

Material No.	Comparative Rank in Laboratory Sinking Efficiency Tests	Available?	Treatment Plant Required?	Personnel Hazards	Cost/Ton	Final Overall Ranking
SOM-1	2	No	Yes	Least hazardous	$140	5
SOM-3	5	Yes	No	Least hazardous	60	3
SOM-4	1	Yes	No	Least hazardous	120	2
SOM-11	4	Yes	No	Least hazardous	35	1
SOM-14	6	No	Yes	Possible danger	100 (est.)	6
SOM-17	3	Yes	No	Possible danger	100 (est.)	4
SOM-22	7	No	Yes	Possible danger	75	7

The best all-season sinking agent for oil 4 based on all factors was SOM-11, hydrated magnesium aluminum silicate.

Provisional agents

73. Rankings for the provisional sinking agents for oil 4 are:

Material No.	Comparative Rank in Laboratory Sinking Efficiency Tests	Final Overall Ranking
SOM-6	2	2
SOM-12	1	1
SOM-15	3	3
SOM-16	4	4

Comparisons of the availability, cost, and hazards of these four materials were given in paragraph 67. The natural clay, SOM-12, was rated as the best provisional sinking agent for oil 4 and would be the choice for further evaluation.

Sinking Agents for Oil 6

74. Only seven materials were identified as sinking agents for oil 6 (high-viscosity crude oil); these were:

a. All-season sinking agents: SOM-13 and -22

b. Provisional sinking agents: SOM-15, -16, -19, -21, and -23

All-season agents

75. Both all-season sinking agents for oil 6, SOM-13 and -22, were treated sands and both have a cost per ton of approximately $75. The laboratory performances of these two agents were essentially equal, but since SOM-13 is now available and SOM-22 is not, SOM-13 has to be rated as the better of the two materials for oil 6 when all factors are considered.

Provisional agents

76. Information about the provisional sinking agents for oil 6 is given below:

Material No.	Comparative Rank in Laboratory Sinking Efficiency Tests	Available?	Treatment Plant Required?	Personnel Hazards	Cost/Ton	Final Overall Ranking
SOM-15	1	No	Yes	Possible danger	$100 (est.)	3
SOM-16	2	No	Yes	Possible danger	75 (est.)	4
SOM-19	3	Yes	No	Possible danger	36	1
SOM-21	4	Yes	No	Possible danger	40	2
SOM-23	5	Yes	No	Possible danger	56	5

SOM-19, a sand treated with a proprietary chemical, was rated as the best of the provisional sinking agents for oil 6 principally because of its availability at low cost, and would be the choice for further evaluation.

Sinking Agents for Oil 7

77. Six materials were identified as sinking agents for lube oil (oil 7); these were:

a. All-season sinking agents: SOM-13, and -22

b. Provisional sinking agents: SOM-12, -15, -16, and -20

All-season agents

78. The two all-season sinking agents for lube oil (oil 7) were ranked as follows:

Material No.	Comparative Rank in Laboratory Sinking Efficiency Tests	Final Overall Ranking
SOM-13	1.5	1
SOM-22	1.5	2

SOM-13, a carbonized, chemically coated sand, was rated as the better all-season sinking agent for oil 7 since it is now available and all other considerations are essentially equal between the two materials.

Provisional agents

79. Information about the provisional sinking agents for lube oil (oil 7) is given below:

Material No.	Comparative Rank in Laboratory Sinking Efficiency Tests	Available?	Treatment Plant Required?	Personnel Hazards	Cost/Ton	Final Overall Ranking
SOM-12	1	Yes	No	Least hazardous	$ 20 (est.)	1
SOM-15	2	No	Yes	Possible danger	100 (est.)	3
SOM-16	3	No	Yes	Possible danger	75 (est.)	4
SOM-20	4	Yes	No	Possible danger	36	2

The natural clay, SOM-12, was rated as the best provisional sinking agent for oil 7 when all factors were considered.

Sinking Agents for All Oils Tested

80. Only two materials, SOM-15 and -22, were identified as

sinking agents for all six oils (oils 1, 2, 3, 4, 6, and 7). SOM-22 is an all-season sinking agent while SOM-15 is a provisional sinking agent. Neither of these materials is available in quantity at the present time.

Available All-Season Sinking Agents

81. At the present time, if the need arose for a dry-application all-season sinking agent to clean up a massive oil spill, the choice would be restricted to five sinking agents: SOM-3, -4, -11, -13, and -17. These are the only WES-tested all-season sinking agents which are now available. The final choice of which of these sinking agents to use would be governed by the kind of oil spilled and other factors not dealt with in this report.

a. If the oil was a low-viscosity crude oil (oils 1, 2, or 3), the choices available would be:

Material No.	Material Description	Final Overall Ranking as All-Season Sinking Agent
SOM-11	Hydrated magnesium aluminum silicate	1
SOM-3	A natural clay	2
SOM-17	Cement byproduct	3
SOM-13	Treated sand	7

b. If the oil was a diesel oil (oil 4), the choices available would be:

Material No.	Material Description	Final Overall Ranking as All-Season Sinking Agent
SOM-11	Hydrated magnesium aluminum silicate	1
SOM-4	Untreated talc	2
SOM-3	A natural clay	3
SOM-17	Cement byproduct	4

c. If the oil was a high-viscosity crude oil (oil 6) or a lube oil (oil 7) the choice would be SOM-13, a carbonized, chemically coated sand.

PART VII: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

82. Based on the results of the literature survey, information supplied by the manufacturers, and the laboratory tests conducted, the 23 materials offered by manufacturers have been assessed and rated herein as sinking agents for dry application. Eight materials have been identified as dry-application all-season sinking agents for one or more oils (see table 17). In addition, nine materials were identified as dry-application provisional sinking agents for one or more oils (see table 17). One material was identified as a dry-application all-season sinking agent for all of the oils tested, and one material was a dry-application provisional sinking agent for all oils.

83. From the laboratory tests of the oil sinking materials, the following additional conclusions can be drawn:

<u>a</u>. The test method (Appendix A) for determination of optimum oil retention potential provides a means for determining the amount of oil which an oil sinking material can adsorb or absorb under optimum conditions. This test does not indicate how effective a material is in sinking oil and therefore the test data obtained do not correlate with test data collected from the sinking efficiency test. Long-term optimum oil retention potential tests appear to be needed for tests with oils of absolute viscosity greater than 100 cp (oils 6 and 7), while the short-term (up to 24 hr) tests are apparently sufficient for the lighter oils (oils 1, 2, 3, and 4).

<u>b</u>. The sinking efficiency test (Appendix B) furnishes a means for evaluating the oil sinking efficiency of an oil sinking material and appears to be a most useful test. The effectiveness of a sinking agent depends on (1) the SOM used, (2) the oil used, (3) the temperature, and (4) the oil thickness. Sinking efficiency is apparently generally not proportional to temperature (which defines the viscosity and specific gravity of the materials) or oil thickness but possibly depends on the surface tension considerations of the particular system being used as well as the temperature and the oil thickness. The data suggest that the sinking efficiency test should be lengthened to include measurement of oil release up to at least 24 hr when using the less viscous oils (oils 1, 2, 3,

and 4) and for longer periods for the more viscous oils (oils 6 and 7).

c. The dynamic retention capability test (Appendix C) can be used to determine the effect of currents and bottom condition on the amount of oil retained by a given sinking agent. Funding and time limitations prevented a more comprehensive study of this test and the accumulation of more test data on the oil sinking materials themselves. The test results obtained in the 10 tests which were performed indicate that retention capability can be significantly affected by (1) sinking agent, (2) oil used, (3) current velocity, and (4) bottom material. The tests conducted suggest that a sinking agent may be more effective on a gravel bottom than on a mud or sand bottom when you have appreciable currents; also, less oil is released when the bottom material is mud than when the bottom material is sand. Also, in two of the dynamic retention capability tests (see plates 5c and 5e), a sand bottom material increased the effectiveness of the sinking agent even though a current of 0.55 fps was employed. The sand on the bottom evidently retained some of the oil, thus preventing its release to the surface. This did not occur in any of the other retention capability tests, as, in general, oil:SOM ratio decreased with increasing current velocity.

d. Three of the types of materials tested, i.e., talc, asbestos, and chalk, are generally not satisfactory as dry-application sinking agents. These materials are usually good sorbents for oil but will not, in most cases, sink the oil.

e. Treated sands and treated fly ash do not absorb and/or adsorb much oil but some do act as sinking agents when applied dry to floating oil.

f. Some naturally occurring clays can be utilized as dry-application sinking agents but they generally release considerable oil over a period of time.

g. Special materials such as cement byproduct and latex coated barite can, in some cases, be utilized as dry-application sinking agents for certain oils but are rather expensive.

h. The heavier, more viscous oils (oils 6 and 7) are generally more difficult to sink by dry application of sinking agent than are the lighter, less viscous oils (oils 1, 2, 3, and 4).

84. It is emphasized that the assessments given in this report are based on current knowledge of the materials tested and on the results of the tests conducted.

Recommendations

85. It would be extremely useful and desirable to evaluate a potential oil sinking material by means of a single test. Such a test would allow industry to screen the potential of their own materials.

86. It is believed, on the basis of the laboratory tests conducted, that the sinking efficiency test (Appendix B) would serve as this index or screening test and it is recommended that it be adopted as the screening test for oil sinking materials. The residual error of this test has been determined (see paragraph 35) and modifications could be made to improve this testing error if desired.

87. It is recommended that the Appendix B sinking efficiency test (amended to include 15-min period in which oil release is measured) be used to screen potential oil sinking materials by determining the sinking efficiency of the test material with oil 6 (high-viscosity crude oil) at 60 ± 2 F. Materials which can sink oil 6 under these conditions have the potential for being a dry-application all-season sinking agent for most oils. It is noted that only 7 of the 23 materials tested in this study would pass this initial screening test. Further tests could then be conducted on materials which pass the initial screening test to fully evaluate each material for all test oils.

88. The methods of test developed during this investigation and presented herein do not encompass all of the many parameters which should be examined. Such an elaborate undertaking would have required time and financial support many times the magnitude of those available to this study. Further investigation is therefore recommended in the following areas:

- a. Effects of variation in pressure on the behavior of submerged oil-sinking agent masses. This, it seems, would be imperative as the National Contingency Plan limits use of sinking agents to areas where depths are greater than or equal to 100 meters.
- b. Effects of variation in temperature, ocean floor topography, nature of fluid currents, and percentage of sorption capacity of sinking agent actually taxed during the sorption process upon retention characteristics of the submerged oil-sinking agent mass.

c. Effects of the many various types of agitation, above and beyond that examined in this study, upon sinking efficiency and retention.

d. The testing and sinking of highly viscous residual fuel oil (Bunker C).

e. Development of procedures to evaluate the retention characteristics of a submerged oil-sinking agent mass which is the product of realistic sinking agent application and sinking (material will not act at 100% efficiency) as opposed to the method of mixing and submerging (required to approach the 90% efficiency level specifically requested) used in the method of test presented in Appendix B of this report.

f. Refinement of the test methods developed in this investigation.

g. Modification of the sinking efficiency test to encompass long-time evaluation.

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Table 1

Identification of Oil Sinking Materials

No.	Material Description	Constituents as Determined by Infrared Spectrophotometry	Average* Particle Specific Gravity	Average* Loose Volume Density lb/cu ft
SOM-1	Latex coated barite	Barium sulfate plus polybutadiene and a salt of carboxylic acid	3.3[illegible]	86.0
-2	Chalk treated with stearic acid	Calcium carbonate with small amount of carboxylic acid	2.26	58.2
-3	Calcined clay	--	2.85	[illegible].6
-4	Untreated talc	Magnesium silicate	2.75	16.6
-5	Talc treated with zinc stearate	Magnesium silicate plus an alkyd phthalate resin	2.76	18.4
-6	Untreated talc	--	2.78	46.8
-7	Expansive clay (Fullers earth)	--	3.37	33.7
-8	Asbestos treated with stearates	Calcium-magnesium silicate plus a carboxylate salt plus carboxylic acid	2.10	13.3
-9	Treated asbestos	--	2.67	14.7
-10	Cationic asbestos	Calcium-magnesium silicate	2.62	12.2
-11	Hydrated magnesium aluminum silicate	--	3.06	31.8
-12	Natural clay (montmorillonite and palygorskite)	--	2.73	35.8
-13	Carbonized chemically coated sand	--	2.65	87.7
-14	Silicone treated fly ash	Fly ash plus methyl silicone	2.57	64.1
-15	Silicone treated fly ash	Fly ash plus silicone plus a carboxylic compound	2.54	69.9
-16	Silicone treated sand	--	2.66	106.7
-17	Cement byproduct	--	2.82	50.0
-18	Kaolinite clay	--	2.44	62.4
-19	Treated sand	--	2.67	100.7
-20	Treated sand	--	2.67	98.1
-21	Treated sand	--	2.66	108.1
-22	Treated sand	--	2.66	104.7
-23	Treated sand	--	2.66	92.0

* Values given are the average of three tests.

Table 2

Sieve Analyses Of Oil Sinking Materials

Sieve Designation Standard	Alternate	(1) SOM-11 (Clay)	(1) SOM-7 (Clay)	(1) SOM-3 (Clay)	(1) SOM-23 (Sand)	(2) SOM-18 (Clay)	(1) SOM-13 (Sand)	(2) SOM-15 (Fly Ash)	(1) SOM-21 (Sand)	(1) SOM-12 (Clay)	(2) SOM-14 (Fly Ash)	(1) SOM-22 (Sand)	(3) SOM-8 (Asbestos)	(1) SOM-20 (Sand)
		Cumulative Percent Passing Standard Sieves												
4.76 mm	No. 4	100	--	--	--	--	--	--	--	--	--	--	--	--
2.38 mm	8	90	100	100	100	100	100	--	--	--	--	--	--	--
1.19 mm	16	50	30	46	49	84	86	100	--	--	--	--	--	--
595 µ	30	16	3	16	3	64	19	92	100	100	100	100	100	100
297 µ	50	3	0	0.5	0	46	3	73	30	87	88	92	93	95
149 µ	100	1	--	--	--	32	1	55	6	50	63	15	--	18
74 µ	200	0.4	--	--	--	16	--	36	--	25	37	1	--	1
44 µ	325	--	--	--	--	--	--	18	--	--	14	--	--	--
37 µ	400	--	--	--	--	--	--	--	--	--	--	--	--	--

Sieve Designation Standard	Alternate	(1) SOM-19 (Sand)	(1) SOM-16 (Sand)	(3) SOM-10 (Asbestos)	(3) SOM-1 (Barite)	(3) SOM-9 (Asbestos)	(3) SOM-17 (Byproduct)	(3) SOM-6 (Talc)	(3) SOM-5 (Talc)	(3) SOM-4 (Talc)	(3) SOM-2 (Chalk)
		Cumulative Percent Passing Standard Sieves									
4.76 mm	No. 4	--	--	--	--	--	--	--	--	--	--
2.38 mm	8	--	--	--	--	--	--	--	--	--	--
1.19 mm	16	--	--	--	--	--	--	--	--	--	--
595 µ	30	100	100	.	--	--	--	--	--	--	--
297 µ	50	96	97	100	100	100	--	--	--	--	--
149 µ	100	18	34	94	95	96	100	100	--	--	--
74 µ	200	1	2	--	--	--	95	99	--	--	--
44 µ	325	--	--	--	--	--	--	--	--	--	--
37 µ	400	--	--	--	--	--	--	--	100	100	100

Note: (1) Analysis conducted in accordance with ASTM Designation: C 136-67.[5]
(2) Partial analysis only, using hand sieves.
(3) Partial analysis only, using fineness tester (Alpine).

Table 3

Identification of Oils

Oil No.	Description	Temperature °F	Specific Gravity at Temperature Shown	Absolute Viscosity, cp, at Temperature Shown	Kinematic Viscosity, cs, at Temperature Shown	Identification* by Infrared Spectrophotometry
1	Paraffinic-based low-viscosity crude oil	40	0.83	124**	149**	Primarily long chain aliphatic hydrocarbon with lesser aromatic constituents and little carboxylate.
		73	0.82	8.1	9.9	
		100	0.81	5.5	6.8	
2	Naphthenic-based low-viscosity crude oil	40	0.86	51.5**	59.9**	Mixture of long chain aliphatic and aromatic hydrocarbons, more aromatic than oil 1.
		73	0.85	13.4	15.8	
		100	0.84	7.9	9.4	
3	Napnthenic-based low-viscosity crude oil	40	0.85	20.9**	24.6**	Same as oil 2.
		73	0.85	8.8	10.4	
		100	0.84	6.6	7.9	
4	Diesel oil (low viscosity)	40	0.85	5.7**	6.7**	Mixture of aromatic, olefinic, and aliphatic hydrocarbons, very little or no long chain hydrocarbons.
		73	0.84	4.7	5.6	
		100	0.84	4.0	4.8	
5	Residual fuel oil (Bunker C)	40	†	†	†	Mixture of long chain aliphatic and aromatic hydrocarbons. More aliphatic than aromatic.
		73	†	714,000	775,000 (approx.)	
		100	0.91	23,000	25,275	
6	Asphaltic high-viscosity crude oil	40	†	22,800**	23,505**	Primarily aromatic hydrocarbons with some aliphatic constituents. Evidence of carbonyl and carboxylate constituents.
		73	0.97	3,530	3,639	
		100	0.96	750	781	
7	Lube oil (30-wt motor oil)	40	†	1,400**	1,573**	Mixture of long chain aliphatic and aromatic constituents.
		73	0.89	283	318	
		100	0.88	113	128	

* See Appendix G for infrared spectra.

** Viscosity values obtained at 40 F are not considered to be reliable due to unsteady state of temperature. The 40 F values are therefore not used in plate 1.

† This oil too viscous for determination of this value at this temperature with equipment being used.

Table 4

Volatile Loss-Time Relationships for Oils Under Various Conditions

Oil No.	1	2	3	5	6	8	15	22	24	40	48	72	96	110	120	144	168
	Loss in Weight, %, After Exposure for Time Shown, hr, Under Conditions Shown																
									73 ± 1 F, RH 50%								
1	9.2	13.6	15.3	17.0	18.7	20.0			22.7		25.4	27.1				30.6	
2	9.3	10.8	12.0	13.3	14.3	15.4			18.4		21.2	22.6				25.5	
3	11.4	13.1	14.9	16.3	17.6	18.7			22.9		25.1	26.5				30.2	
4	1.8	2.3	3.5	4.5	6.5	7.6			16.2		23.2	28.6				39.2	
5	0.0	0.0	0.0	0.1	0.1	0.1			0.1		0.3	0.4				0.6	
6	0.4	0.4	0.8	1.2	1.3	1.5			2.6		3.4	4.0				5.5	
									73 ± 1 F, RH 98%								
1	11.2	16.0	16.8	17.4	16.8	17.9			20.8		23.4	25.1				28.3	
2	8.3	10.3	11.5	12.7	13.9	14.9			17.9							18.4	
3	10.8	13.3	14.7	16.4	17.5	18.3			21.2		23.5	25.3				27.9	
4	1.2	2.5	3.4	4.3	5.7	6.8			13.2							33.5	
5	0.0	0.0	0.0	0.0	0.0	0.0			0.0		0.0	0.0				0.0	
6	0.3	0.3	0.3	0.5	0.8	1.0			2.0		3.0	3.6				4.8	
									100 F, RH 60%								
1									28.3		31.6		34				36.0
2									26.2		29.3		31				32.2
3									32.9		34.8		37				37.0
4									45.2		59.4		70				72.0
6									8.0		8.2		10				
7									1.8		1.8		1.8				2.0
									150 F, RH 60%								
1							48.3			54.8				60.7			
2							42.4			48.4				48.7			
4							96.2			100				100			
6							15.9			17.1				22.5			
7							0.0			0.0				1.6			
									210 F in Forced-air Oven								
1	51.5	54.4		64.8				81.5			81.5				81.5		
2	44.0	50.0		56.3				65.0			68.1				71.6		
4	100.0																
6	14.4	16.4		20.6				27.0			27.0				31.1		
7	2.0	3.8		2.7				5.0			5.0				6.7		

Table 5

Summary of Tests

	Oil Sinking Materials																						
	Sinking Agents*																Sorbents*						
	Barite	Clay					Treated Sand							Treated Fly Ash		Cement By-product	Chalk		Talc		Asbestos		
	SOM-1	SOM-3	SOM-7	SOM-11	SOM-12	SOM-18	SOM-13	SOM-16	SOM-19	SOM-20	SOM-21	SOM-22	SOM-23	SOM-14	SOM-15	SOM-17	SOM-2	SOM-4	SOM-5	SOM-6	SOM-8	SOM-9	SOM-10
Test No. (1), Short-Term Retention Potential																							
Oil No. 1	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X
6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Test No. (3), Long-Term Retention Potential																							
Oil No. 1	X	X	X	X			X	X			X	X	X	X		X							
2	X	X	X	X			X	X			X	X	X	X		X							
4	X	X	X	X			X	X			X	X	X	X		X							
6	X	X	X	X			X	X			X	X	X	X		X							
7	X	X	X	X			X	X			X	X	X	X		X							
Test Nos. (2) and (4), Short-Term Sinking Efficiency																							
Oil No. 1 Oil thickness = 0.01 in.	X	X		X			X					X		X		X		--			--		
= 0.05 in.	X	X	X	X	X	•	X	X	X	X	•	X	•	X	X	X	•	--	--	X	--	--	•
= 0.10 in.	X	X		X			X					X		X		X		--			--		
Oil No. 2 Oil thickness = 0.01 in.	X	X		X			X					X		X		X		--			--		
= 0.05 in.	X	X	X	X	X	•	X	X	•	•	•	X	•	X	X	X	•	--	--	X	--	--	•
= 0.10 in.	X	X		X			X					X		X		X		--			--		
Oil No. 4 Oil thickness = 0.05 in.	X	X	•	X	X	•	a	X	•	•	•	X	•	X	X	X	•	X	--	X	--	--	•
= 0.10 in.	X	X		X			a					X		X		X		X			--		
= 0.15 in.	X	X		X			a					X		X		X		X			--		
Oil No. 6 Oil thickness = 0.01 in.	--	--		--			X					X		--		--		--			--		
= 0.05 in.	--	--	•	--	--	•	X	X	X	•	X	X	X	--	X	--	--	--	--	--	--	--	--
= 0.10 in.	--	--		--			X					X		--		--		--			--		
Oil No. 7 Oil thickness = 0.05 in.	X	X	•	•	X	•	X	X	•	•	•	X	•	X	X	d	--	--	--	--	--	--	•
= 0.10 in.	a	a		•			X					X		a		b		--			--		
= 0.15 in.	a	a		•			X					X		a		b		--			--		
Test No. (5), Long-Term Sinking Efficiency																							
Oil thickness = 0.05 in. Oil No. 1				X			X																
2	X	X		X			X					X		X		X							
4			X				X																
6			X				X	X				X			X								
7				X			X									X							
Test No. (6), Dynamic Tests																							
Oil No. 1 Velocity = 0.55 fps Sand bottom	X	X	X	X			X									X							
Gravel bottom				X																			
Mud bottom				X																			
Oil No. 3 Velocity = 0.30 fps Sand bottom				•																			
Oil No. 7 Velocity = 0.55 fps Sand bottom				X																			

Chronological Sequence	Tests
(1)	Short-term retention potential test, 18 hr at 73 F. Results are given in table 6.
(2)	Short-term sinking efficiency tests at 40, 60 and 80 F for oil thicknesses of 0.01, 0.05, 0.10, and 0.15 in. Results are given in table 8.
(3)	Long-term retention potential test, up to 14 days at 73 F. Results are given in table 7.
(4)	Short-term sinking efficiency tests at 60 F for oil thickness of 0.05 in. Results are given in table 10.
(5)	Long-term sinking efficiency tests at 60 F for oil thickness of 0.05 in. Results are given in table 11.
(6)	Dynamic retention capability tests at 73 F. Results are given in table 12 and plate 5.

Symbol	Notes
X	Valid test was conducted (test requirements met).
O	Would not retain this oil.
--	Conducted test but SOM did not sink 90% of the oil initially.
•	Conducted test but SOM did not retain 90% of the oil for 15 minutes.
a	• at 40 F; X at 60 F and 80 F.
b	• at 40 F and 60 F; X at 80 F.
c	• at 40 F and 80 F; X at 60 F.
d	• at 60 F and 80 F; X at 40 F.
	Any entry in any column indicates that a test was conducted.

* Preliminary classification given these oil sinking materials based on initial laboratory screening tests.

Table 6

Short-Term Optimum Oil Retention Potential (Appendix A Test Method)

Material No.	Material Description	Oil:SOM Ratio (by Weight), After 18 hr at 73 F: Oil 1	Oil 2	Oil 3	Oil 4	Oil 6	Oil 7
SOM-1	Barite	1.84	2.16	2.11	1.88	2.78	1.14
-2	Chalk	0.41	0.49	0.43	0.46	8.11	0.58
-3	Clay	0.94	0.95	0.90	0.45	1.27	0.88
-4	Talc	1.22	1.41	1.40	3.31	9.38	3.00
-5	Talc	1.36	1.65	1.42	3.72	9.09	2.13
-6	Talc	0.40	0.45	0.41	0.66	3.66	0.82
-7	Clay	0.54	0.41	0.37	0.49	2.00	0.38
-8	Asbestos	4.23	5.95	4.29	4.93	14.66	7.50
-9	Asbestos	3.95	5.00	4.52	*	14.29	7.95
-10	Asbestos	5.67	5.75	3.44	1.89	18.45	8.44
-11	Clay	1.20	1.24	1.13	0.51	1.63	1.11
-12	Clay	1.23	0.98	0.86	0.42	1.93	1.11
SOM-13	Sand	0.21	0.21	0.22	0.22	0.29	0.14
-14	Fly ash	0.42	0.44	0.43	0.43	0.79	0.49
-15	Fly ash	0.35	0.33	0.39	0.39	0.64	0.42
-16	Sand	0.15	0.16	0.15	0.17	0.27	0.18
-17	Cement byproduct	0.78	0.69	0.54	0.80	4.81	0.91
-18	Clay	0.18	0.27	0.23	0.15	1.29	0.80
-19	Sand	0.16	0.17	0.17	0.17	0.26	0.18
-20	Sand	0.16	0.17	0.16	0.16	0.77	0.18
-21	Sand	0.14	0.15	0.14	0.14	0.23	0.15
-22	Sand	0.16	0.16	0.17	0.16	0.31	0.18
-23	Sand	0.20	0.19	0.21	0.17	0.29	0.10

* Did not retain oil.

Table 7

Long-Term* Optimum Oil Retention Potential (Appendix A Test Method)

Material No.	Description	Oil 1: 1 hr	2 hr	3 hr	1d	3d	7d	14d	Oil 2: 1 hr	2 hr	3 hr	1d	3d	7d	14d	Oil 4: 1 hr	2 hr	3 hr	1d	3d	7d	14d
SOM-1	Barite	1.77	1.77	1.73	1.73	1.73	1.73	1.73	2.36	2.36	2.29	2.29	2.29	2.29	--	2.12	2.08	2.08	--	2.05	2.05	2.05
-3	Clay	0.98	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.94	0.92	0.92	0.92	0.92	--	--	--	0.60	0.40	0.36	--
-7	Clay	--	--	--	0.58	0.55	0.46	--	0.66	0.59	0.50	0.37	0.35	0.35	0.35	0.53	0.52	0.52	0.52	0.52	0.52	0.52
-11	Clay	1.23	1.21	1.19	1.19	1.17	1.16	1.12	1.27	1.24	1.24	1.19	1.17	1.15	1.10	0.68	0.66	0.65	0.54	0.54	0.54	--
-13	Sand	0.20	0.20	0.20	0.19	0.19	0.19	0.19	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.22	0.21	0.21	0.21	0.21	0.20	0.19
-14	Fly ash	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.45	0.45	0.45	--	0.45	0.45	0.45
-16	Sand	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16	--	0.16	0.16	0.16
-17	Cement byproduct	0.91	0.84	0.78	0.75	0.73	0.73	0.73	0.83	0.72	0.65	0.65	0.65	0.65	--	0.99	0.97	0.95	--	90	0.90	0.90
-21	Sand	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.17	--	0.17	0.17	0.17
-22	Sand	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.16	0.16	0.16	--	0.16	0.16	0.16
-23	Sand	0.21	0.21	0.21	0.20	0.20	0.20	0.20	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.17	0.17	0.17	--	0.16	0.15	0.12

Material No.	Description	Oil 6: 1 hr	2 hr	3 hr	1d	3d	7d	14d	Oil 7: 1 hr	2 hr	3 hr	1d	3d	7d	14d
SOM-1	Barite	3.00	3.00	3.00	3.00	2.85	2.27	2.03	1.17	1.17	1.17	1.11	1.11	1.11	1.11
-3	Clay	1.64	1.55	1.52	1.39	1.39	1.39	1.39	0.86	0.79	0.79	0.71	0.58	0.58	0.58
-7	Clay	2.42	2.22	2.03	1.88	1.84	1.74	1.50	0.62	0.55	0.52	0.36	0.31	0.29	0.26
-11	Clay	1.97	1.94	1.94	1.74	1.74	1.74	1.74	1.25	1.17	1.17	1.12	1.07	1.02	1.02
-13	Sand	0.32	0.31	0.30	0.29	0.29	0.27	0.27	0.21	0.20	0.20	0.16	0.13	0.12	0.11
-14	Fly ash	1.00	1.00	1.00	0.87	0.84	0.81	0.61	0.53	0.52	0.51	0.49	0.47	0.47	0.47
-16	Sand	0.37	0.37	0.37	0.32	0.30	0.27	0.27	0.19	0.19	0.18	0.18	0.18	0.18	0.18
-17	Cement byproduct	6.00	6.00	6.00	5.42	3.09	1.73	1.73	1.24	1.22	1.17	1.03	0.83	0.70	0.75
-21	Sand	0.28	0.25	0.24	0.22	0.21	0.20	0.20	0.16	0.15	0.15	0.15	0.15	0.15	0.14
-22	Sand	0.35	0.33	0.32	0.28	0.27	0.26	0.26	0.19	0.19	0.19	0.18	0.18	0.18	0.18
-23	Sand	0.37	0.35	0.34	0.29	0.28	0.28	0.28	0.19	0.14	[illegible]	0.09	0.07	0.07	0.06

* This was determined for ages up to 14 days or longer for some materials (1d = 1 day, 14d = 14 day, etc.)

Table 8

Short-Term Sinking Efficiency at Three Temperatures

Material No.	Material Description	Oil Film Thickness in.	Oil 1 40 F	Oil 1 60 F	Oil 1 80 F	Oil 2 40 F	Oil 2 60 F	Oil 2 80 F	Oil 4 40 F	Oil 4 60 F	Oil 4 80 F	Oil 6 40 F	Oil 6 60 F	Oil 6 80 F	Oil 7 40 F	Oil 7 60 F	Oil 7 80 F
			Oil:SOM Ratio (by Weight)														
SOM-1	Barite	0.01	0.42	0.36	0.93	0.21	0.58	0.98	--	--	--	Material did not penetrate into oil			--	--	--
		0.05	0.97	1.00	1.10	0.72	0.88	1.14	0.52	1.10	1.11				0.55	1.10	1.24
		0.10	0.72	1.35	1.00	0.99	0.96	0.95	0.63	1.10	1.58				0.95*	0.89	1.38
		0.15	--	--	--	--	--	--	0.81	1.35	1.25				1.25*	1.10	1.52
SOM-3	Clay	0.01	0.40	0.37	0.55	0.18	0.55	0.69	--	--	--				--	--	--
		0.05	0.79	0.76	0.81	0.68	0.73	0.67	0.64	0.50	0.63				0.72	0.77	0.88
		0.10	0.49	0.50	0.60	0.76	0.71	0.69	0.60	0.59	0.57				0.74*	0.74	0.89*
		0.15	--	--	--	--	--	--	0.67	0.67	0.61				0.80*	0.69	0.72
SOM-4	Talc	0.01	**	**	**	0.42	**	**	--	--	--				--	--	--
		0.05	**	**	**	**	**	**	1.39	1.82	1.72				**	**	**
		0.10	**	**	**	**	**	**	1.68	1.86	1.81				**	**	**
		0.15	--	--	--	--	--	--	1.12	1.96	2.01				**	**	**
SOM-5	Asbestos	0.0	**	**	**	**	**	**	--	--	--				--	-	--
		0.05	**	**	**	**	**	**	**	**	**				**	**	**
		0.10	**	**	**	**	**	**	**	**	**				**	**	**
		0.15	--	--	--	--	--	--	**	**	**				**	**	**
SOM-11	Clay	0.01	0.48	0.69	0.48	0.21	0.76	0.65	--	--	--				--	--	--
		0.05	0.85	0.91	0.98	0.82	0.93	0.88	0.53	0.60	0.67				**	1.1[illegible]	0.90*
		0.10	0.76	0.91	0.97	1.13	0.93	0.98	0.73	0.81	0.70				**	1.00*	1.00*
		0.15	--	-	--	--	--	--	0.73	0.92	0.82				**	0.72*	0.52*
SOM-13	Sand	0.01	0.13	0.11	0.12	0.17	0.16	0.13	--	--	--	0.20	0.21	0.19	--	--	--
		0.05	0.19	0.23	0.15	0.33	0.29	0.19	0.31*	0.20	0.21	0.60	0.36	0.72	0.30	0.27	0.36
		0.10	0.23	0.23	0.22	0.34	0.28	0.24	0.18*	0.20	0.14	0.83	0.54	0.63	0.43	0.29	0.38
		0.15	--	--	--	--	--	--	0.25*	0.22	0.19	--	--	--	0.52	0.36	0.25
SOM-14	Fly ash	0.01	0.46	0.43	0.49	0.25	0.56	0.35	--	--	--	Material did not penetrate into oil			--	--	--
		0.05	0.80	0.61	0.55	0.84	0.53	0.39	0.48	0.74	0.61				0.91	0.97	0.8[illegible]
		0.10	0.96	0.71	0.56	0.72	0.63	0.63	0.52	0.55	0.67				1.45*	1.04	1.10
		0.15	--	--	--	--	--	--	0.50	0.63	0.59				2.57*	0.86	0.71
SOM-17	Cement byproduct	0.01	0.52	0.27	0.22	0.29	0.55	0.70	--	--	--	Material did not penetrate into oil			--	--	--
		0.05	0.41	0.63	0.67	0.73	0.96	0.68	0.57	0.71	0.82				0.92	1.18*	1.50*
		0.10	0.59	0.84	0.65	0.89	1.09	0.87	0.85	1.15	1.02				1.01*	1.37*	1.12
		0.15	--	--	--	--	--	--	0.64	1.26	1.10				1.60*	1.21*	1.02
SOM-22	Sand	0.01	0.20	0.17	0.20	0.13	0.22	0.24	--	--	--	0.19	0.25	0.20	--	--	--
		0.05	0.27	0.25	0.27	0.39	0.37	0.33	0.46	0.43	0.47	0.68	0.43	0.35	0.21	0.42	0.4[illegible]
		0.10	0.3[illegible]	0.28	0.27	0.34	0.38	0.32	0.41	0.37	0.37	0.92	0.32	0.19	0.38	0.30	0.28
		0.15	--	--	--	--	--	--	0.40	0.33	0.34	--	--	--	0.47	0.37	0.35

* Excessive oil release occurred within 15 minutes after test.

** Did not sink enough oil (90%) to meet minimum requirement for this test.

Table 9

Summary of Significance of Temperature and Oil Thickness in Short-Term Sinking Efficiency Test at Three Temperatures for Three Oil Thicknesses

Combination (1) Material	Oil No.	Effect Of Temperature	Effect Of Oil Thickness
SOM-1 (barite)	1	S (2)	HS (3)
	2	HS	HS
	4	HS	N (4)
	7	HS	N
SOM-3 (clay)	1	N	HS
	2	N	N
	4	N	N
SOM-4 (talc)	4	HS	N
SOM-11 (clay)	1	N	HS
	2	N	HS
		N	N
SOM-13 (sand)	1	N	N
	2	N	N
	4	N	N
	6	N	HS
	7	N	N
SOM-14 (fly ash)	1	N	S
	2	N	N
	4	N	N
	7	N	N
SOM-17 (cement byproduct)	1	N	HS
	2	N	HS
	4	HS	HS
SOM-22 (sand)	1	N	N
	2	N	N
	4	N	N
	6	HS	S
	7	N	N

Note: (1) Data from the 28 combinations listed were tested for significance.
(2) S = significant at 95% confidence level.
(3) HS = Highly significant--significant at 99% confidence level.
(4) N = Not significant.

Table 10

Short-Term Sinking Efficiency (Appendix B Test Method)

Material No.	Description	Oil:SOM Ratio (by Weight) at 60 F for an Oil Thickness of 0.05 in. Oil 1	Oil 2	Oil 4	Oil 6	Oil 7
SOM-1	Barite	1.00	0.88	1.10	DNSO**	1.10
-2	Chalk	0.84*	0.97*	0.75*	DNSO**	DNSO**
-3	Clay	0.76	0.73	0.50	DNSO**	0.77
-4	Talc	DNSO**	DNSO**	1.82	DNSO**	DNSO**
-5	Talc	DNSO**	DNSO**	DNSO**	DNSO**	DNSO**
-6	Talc	[illegible]	0.34	0.52	DNSO**	DNSO**
-7	Clay	0.52	0.39	0.32*	1.02*	0.53*
-8	Asbestos	DNSO**	DNSO**	DNSO**	DNSO**	DNSO**
-9	Asbestos	DNSO**	DNSO**	DNSO**	DNSO**	DNSO**
-10	Asbestos	1.51*	1.06*	1.52*	DNSO**	1.12*
-11	Clay	[illegible]	0.93	0.60	DNSO**	1.17*
-12	Clay	0.73	[illegible]	0.57	DNSO**	0.88
SOM-13	Sand	0.23	0.29	[illegible]	0.36	0.37
-14	Fly ash	0.61	0.53	[illegible]	DNSO**	0.87
-15	Fly ash	0.29	0.39	0.14	1.00†	0.53
-16	Sand	0.18	0.19*	0.29	[illegible]	0.22
-17	Cement byproduct	0.63	0.98	0.71	DNSO**	1.18*
-18	Clay	0.68*	0.41*	0.35*	0.35*	0.65*
-19	Sand	0.16	0.32*	0.42*	0.34	0.23*
-20	Sand	0.14	0.38*	0.44*	0.38*	0.21
-21	Sand	0.23*	0.40*	0.48*	0.33	0.27*
-22	Sand	0.25	0.37	0.43	0.43	0.42
-23	Sand	0.21*	0.16*	0.17*	0.29	0.33*

* Excessive oil release occurred within 15 min after test.
** Did not sink enough oil (DNSO) to meet minimum requirement for this test.
† These materials do not release excess oil in 15 min, but have considerable oil release during first day. (See Table 11.)

Table 11

Long-Term* Sinking Efficiency

Material No.	Material Description	Oil No.	Oil:SOM Ratio (by Weight) at 60 F for Oil Thickness of 0.05 in. After 18 Hr	After 1 Day	After 2 Days	After 3 Days	After 5 Days	After 7 Days	After 14 Days	After 42 Days
SOM-11	Clay	1	0.78	0.78	0.78	--	--	0.78	0.78	0.75
SOM-13	Sand	1	0.31	0.31	0.30	--	--	0.30	0.30	0.28
SOM-1	Barite	2	0.92	0.92	0.92	0.9[illegible]	--	0.92	--	--
SOM-3	Clay	2	0.65	0.65	0.63	0.62	--	0.62	--	--
SOM-11	Clay	2	0.81	0.81	0.80	0.80	--	0.78	--	--
SOM-13	Sand	2	0.33	0.33	0.33	0.32	--	0.32	--	--
SOM-14	Fly ash	2	0.71	0.69	0.68	0.66	--	0.66	--	--
SOM-17	Cement byproduct	2	0.92	0.92	0.92	0.92	--	0.92	--	--
SOM-22	Sand	2	0.28	0.28	0.28	0.27	--	0.26	--	--
SOM-7	Clay	4	0.16	0.16	0.16	--	--	0.16	0.16	0.16
SOM-13	Sand	4	0.10	0.09	0.08	--	--	0.08	0.06	0.06
SOM-7	Clay	6	0.43	0.42	0.36	--	--	0.35	0.32	0.32
SOM-13	Sand	6	0.49	0.43	0.41	--	--	0.38	0.30	0.30
SOM-15	Fly ash	6	--	0.71	0.69	--	0.63	--	--	--
SOM-16	Sand	6	--	0.43	0.41	--	0.37	--	--	--
SOM-22	Sand	6	0.59	0.4[illegible]	0.42	--	--	0.36	0.33	0.33
SOM-11	Clay	7	0.52	0.49	0.4[illegible]	--	--	0.40	0.39	0.36
SOM-13	Sand	7	0.27	0.27	0.27	--	--	0.27	0.27	0.27
SOM-17	Cement byproduct	7	0.61	0.54	0.50	--	--	0.48	0.43	0.3[illegible]

* For periods up to 42 days for some materials.

Table 12

Results of Dynamic Retention Capability Tests Including Comparison of Test Results:

Dynamic Versus Static Retention Capability

Material No.	Material Description	Oil No.	Average Fluid Velocity fps	Bottom Material	Optimum Oil Retention Potential Tests (Static) Oil:SOM Ratio (by Weight) At Start of Test	After 1 Hr	After 2 Hr	After 3 Hr	After 20 Hr	Dynamic Retention Capability Tests (Dynamic) Oil:SOM Ratio (by Weight) At Start of Test	After 1 Hr	After 2 Hr	After 3 Hr	After 20 Hr
Effect of Fluid Velocity and Sand Bottom on Retention Capability														
SOM-1	Barite	1	0.55	Fine sand	1.77	1.77	1.77	1.73	1.73	1.77	1.66	1.65	1.63	1.[illegible]
SOM-3	Clay	1	0.55	Fine sand	0.98	0.98	0.96	0.96	0.96	0.98	0.89	0.89	0.89	0.87
SOM-7	Clay	1	0.55	Fine sand	0.74	0.72	[illegible]	--	0.58	0.74	0.69	0.69	0.69	0.69
SOM-11	Clay	1	0.55	Fine sand	1.27	1.21	1.21	1.19	1.19	1.27	1.01	0.99	0.98	0.93
SOM-13	Sand	1	0.55	Fine sand	0.20	0.20	0.20	0.20	0.19	0.20	0.20	0.20	0.20	0.20
SOM-17	Cement byproduct	1	0.55	Fine sand	1.00	0.91	[illegible]	0.75	0.75	1.00	0.48	0.48	0.25	0.14
Effect of Bottom Condition on Retention Capability														
SOM-11	Clay	1	0.55	Fine sand	1.27	1.21	1.21	1.19	1.19	1.27	1.01	0.99	0.98	0.93
SOM-11	Clay	1	0.55	Gravel	1.27	1.21	1.20	1.19	1.19	1.27	1.09	1.09	1.07	1.02
SOM-11	Clay	1	0.55	Mud	1.27	1.21	1.21	1.19	1.19	1.27	0.99	0.99	0.98	0.97
Effect of Fluid Velocity on Retention Capability														
SOM-11	Clay	1	0.55	Fine sand	1.27	1.21	1.21	1.19	1.19	1.27	1.01	0.99	0.98	0.93
SOM-11	Clay	1	0.36	Fine sand	1.27	1.21	1.21	1.19	1.19	1.27	1.08	1.08	1.06	1.04
Effect of Oil on Retention Capability														
SOM-11	Clay	1	0.55	Fine sand	1.27	1.21	1.21	1.19	1.19	1.27	1.01	0.99	0.98	0.93
SOM-11	Clay	7	0.55	Fine sand	1.52	1.2[illegible]	1.17	1.17	1.12	1.52	1.01	0.9[illegible]	0.9[illegible]	0.76

Table 13

Relative Effectiveness of 23 Materials in Retaining Oil While Submerged--

18-hr Test for Optimum Oil Retention Potential

Material No.	Material Description	Numerical Rating*: With Paraffinic-Based Low-Viscosity Crude Oil (Oil 1)	With Naphthenic-Based Low-Viscosity Crude Oil (Oils 2 and 3)	With Diesel Oil (Oil 4)	With High-Viscosity Crude Oil (Oil 6)	With Lube Oil (Oil 7)	With All Six Oil Types (Oils 1, 2, 3, 4, 6, 7)
SOM-10	Asbestos	1	1	4	1	1	1
SOM-8	Asbestos	2	2	1	2	2	2
SOM-5	Talc	5	5	2	5	5	3
SOM-4	Talc	7	6	3	4	4	4
SOM-1	Barite	4	4	5	9	6	5
SOM-17	Cement byproduct	10	10	6	7	9	6
SOM-11	Clay	8	7	8	12	7.5	7
SOM-12	Clay	6	9	13	11	7.5	8
SOM-3	Clay	9	8	11	14	10	9
SOM-2	Chalk	13	11	10	6	13	10
SOM-6	Talc	14	13	7	8	11	11
SOM-7	Clay	11	14	9	10	16	12
SOM-14	Fly ash	12	12	12	15	14	13
SOM-15	Fly ash	15	15	14	16	15	14
SOM-18	Clay	18	16	21	13	12	15
SOM-13	Sand	16	17	15	18.5	22	16
SOM-23	Sand	17	18	17	18.5	23	17
SOM-22	Sand	20	20.5	19.5	17	18.5	18
SOM-19	Sand	20	19	17	22	18.5	19
SOM-20	Sand	20	20.5	19.5	20.5	18.5	20
SOM-16	Sand	22	22	17	20.5	18.5	21
SOM-21	Sand	23	23	22	23	21	22
SOM-9	Asbestos	3	3	23	3	3	23**

* Rating of 1 indicates the best material for that oil and 23 the worst material. Actual test data are given in table 6.

** Did not retain oil 4.

Table 14

Relative Effectiveness of 23 Materials in Sinking Oil; Short-Term Tests

at 60 F, Oil Thickness of 0.05 in.

Material No.	Material Description	Numerical Rating*: With Low-Viscosity Crude Oil (Oil 1)	With Low-Viscosity Crude Oil (Oil 2)	With Diesel Oil (Oil 4)	With High-Viscosity Crude Oil (Oil 6)	With Lube Oil (Oil 7)	With All Five Oil Types (Oils 1, 2, 4, 6, 7)
SOM-15	Fly ash	9	7.5	9	1	5	1
SOM-22	Sand	10	9	10	3	6	2
SOM-13	Sand	11	11	12	4	7	3
SOM-1	Barite	1	3	2	17**	1	4†
SOM-12	Clay	4	5	6	17**	2	5†
SOM-14	Fly ash	6	6	3	17**	3	6†
SOM-3	Clay	3	4	8	17**	4	7†
SOM-16	Sand	12	18**	11	2	8	8†
SOM-17	Cement byproduct	5	1	4	17**	10**	9†
SOM-11	Clay	2	2	5	17**	11**	10†
SOM-6	Talc	7	10	7	17**	20.5**	11†
SOM-7	Clay	8	7.5	19**	8**	14**	12†
SOM-20	Sand	14	16**	16**	9**	[illegible]	13†
SOM-19	Sand	13	17**	17**	5	17**	14†
SOM-21	Sand	18**	15**	15**	6	16**	15†
SOM-23	Sand	19**	19**	20**	7	15**	16†
SOM-4	Talc	21.5**	21.5**	1	17**	20.5**	17†
SOM-10	Asbestos	15*	12**	13**	17**	12**	18†
SOM-18	Clay	17**	14**	18**	10**	13**	19†
SOM-2	Chalk	16**	13**	14**	17**	20.5**	20†
SOM-5	Talc	21.5**	21.5**	21**	17**	20.5**	22†
SOM-8	Asbestos	21.5**	21.5**	21**	17**	20.5**	22†
SOM-9	Asbestos	21.5**	21.5**	21**	17**	20.5**	22†

* Rating of 1 indicates the best material for that oil; see table 10 for actual test data.

** Did not perform satisfactorily with this oil.

† Not satisfactory for sinking all oils at this temperature and oil thickness.

Table 15

Relative Long-Term Effectiveness of 11 Materials in Retaining Oil While Submerged--7-Day Tests for Optimum Oil Retention Potential

Material No.	Material Description	Numerical Ratings*: With Paraffinic-Based Low-Viscosity Crude Oil (Oil 1)	With Naphthenic-Based Low-Viscosity Crude Oil (Oil 2)	With Diesel Oil (Oil 4)	With High-Viscosity Crude Oil (Oil 6)	With Lube Oil (Oil 7)	With All Five Oil Types (Oils 1, 2, 4, 6, 7)
SOM-1	Barite	1	1	1	1	1	1
SOM-11	Clay	2	2	3	2.5	2	2
SOM-17	Cement byproduct	4	4	2	4	3	3
SOM-3	Clay	3	3	6	5	4	4
SOM-7	Clay	5	6	4	2.5	6	5
SOM-14	Fly ash	6	5	5	6	5	6
SOM-13	Sand	9	7	7	6.5	10	7
SOM-16	Sand	7	11	9.5	8.5	7.5	8
SOM-23	Sand	8	8	11	7	11	9
SOM-22	Sand	10	9.5	9.5	10	7.5	10
SOM-21	Sand	11	9.5	8	11	9	11

* Actual test data given in table 7. Rating of 1 indicates best material, rating of 11 indicates worst material in this group.

Table 16

Relative Effectiveness of Nine Materials in Sinking Oil; Short-Term Tests at Three Temperatures and Three Oil Thicknesses

Material No.	Material Description	Numerical Rating*: With Low-Viscosity Crude Oil (Oil 1)	With Low-Viscosity Crude Oil (Oil 2)	With Diesel Oil (Oil 4)	With High-Viscosity Crude Oil (Oil 6)	With Lube Oil (Oil 7)	With All Five Oil Types (Oils 1, 2, 4, 6, 7)
SOM-22	Sand	6	6	7	1	1.5	1
SOM-13	Sand	7	7	8**	2	1.5	2†
SOM-1	Barite	1	2	2	6**	3**	3†
SOM-11	Clay	2	1	4	6**	7**	4†
SOM-17	Cement byproduct	5	3	3	6**	6**	5†
SOM-3	Clay	3.5	4	5	6**	5**	6†
SOM-14	Fly ash	3.5	5	6	6**	4**	7†
SOM-4	Talc	8.5**	8.5**	1	6**	8.5**	8†
SOM-8	Asbestos	8.5**	8.5**	9**	6**	8.5**	9†

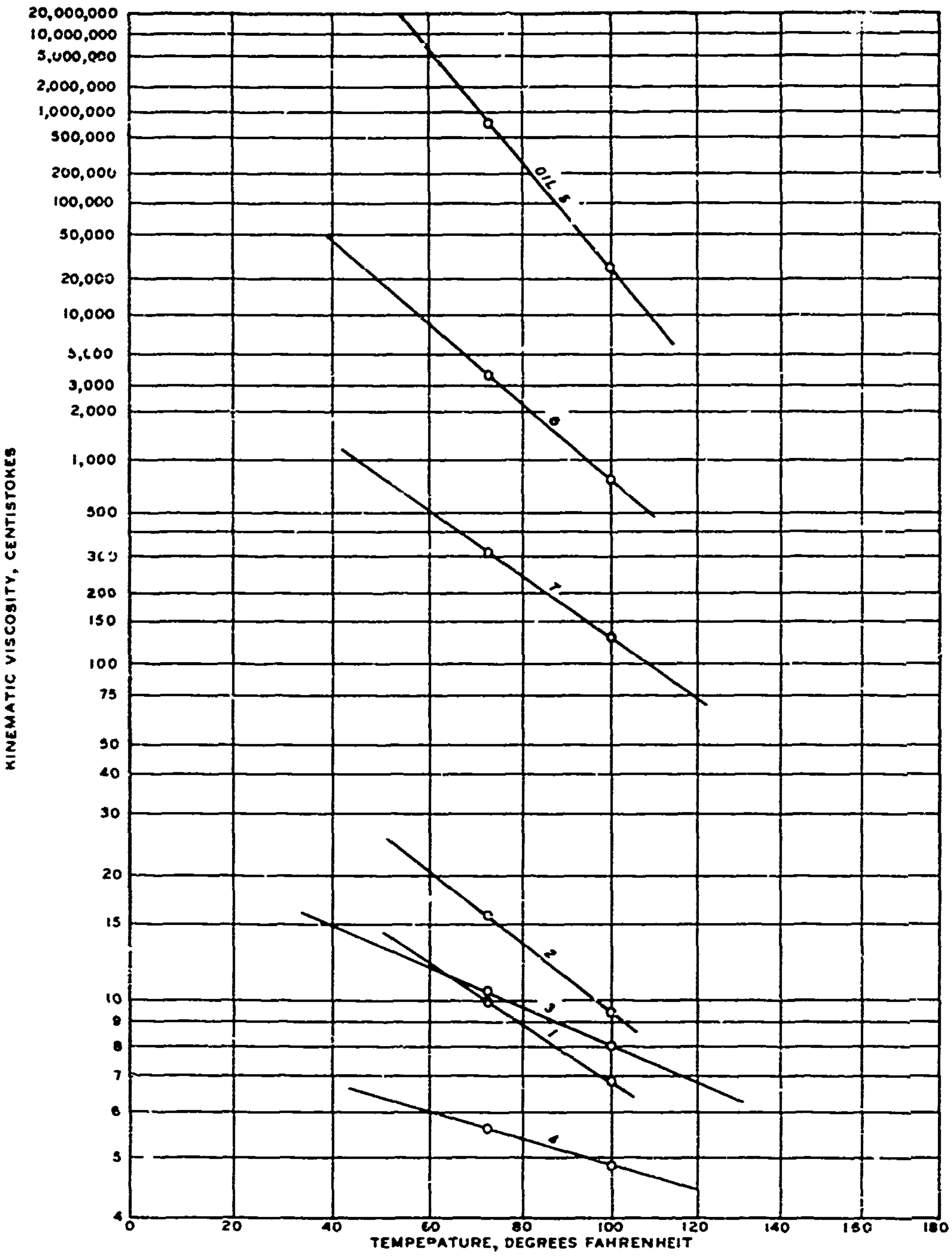
* Test data given in table 8; rating of 1 is best.
** Did not perform satisfactorily with this oil.
† Not satisfactory for sinking all oils at all three temperatures.

Table 17

Dry-Application Sinking Agents

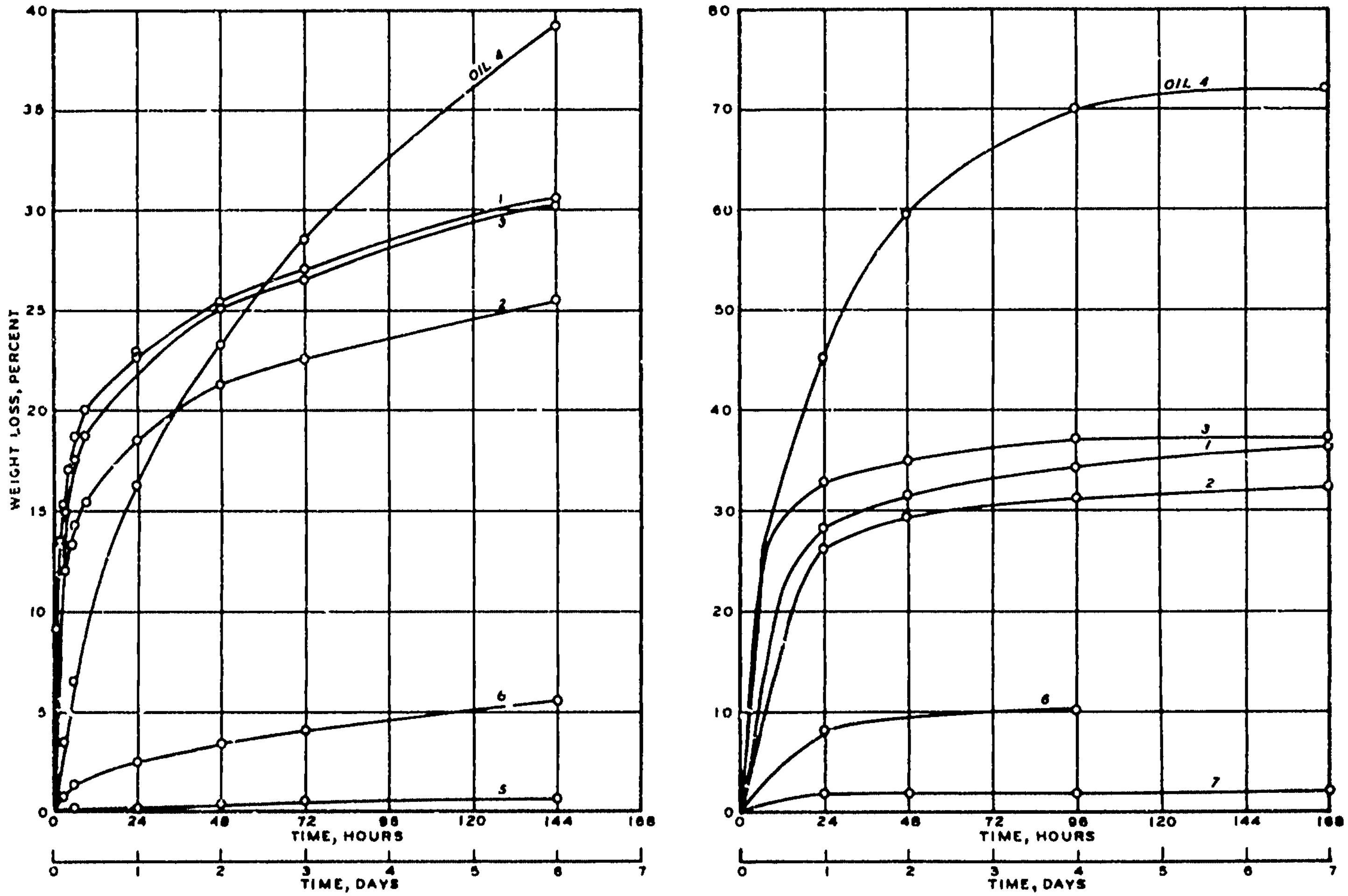
Material No.	Material Description	Paraffinic-Based Low-Viscosity Crude Oil (Oil 1)	Naphthenic-Based Low-Viscosity Crude Oil (Oils 2 and 3)	Diesel Oil (Oil 4)	High-Viscosity Crude Oil (Oil 6)	Lube Oil (Oil 7)	All Six Oil Types (Oils 1, 2, 3, 4, 6, 7)
		Overall Final Ranking* with Oil or Oils Shown					
		All-Season Sinking Agents					
SOM-1	Barite	4	4	5	--	--	--
SOM-3	Clay	2	2	3	--	--	--
SOM-4	Talc	--	--	2	--	--	--
SOM-11	Clay	1	1	1	--	--	--
SOM-13	Sand	7	7	--	1	1	--
SOM-14	Fly ash	5	5	6	--	--	--
SOM-17	Cement byproduct	3	3	4	--	--	--
SOM-22	Sand	6	6	7	2	2	1
		Provisional Sinking Agents					
SOM-6	Talc	3	3.5	2	--	--	--
SOM-7	Clay	2	2	--	--	--	--
SOM-12	Clay	1	1	1	--	1	--
SOM-15	Fly ash	6	3.5	3	3	3	1
SOM-16	Sand	7	--	4	4	4	--
SOM-19	Sand	4	--	--	1	--	--
SOM-20	Sand	5	--	--	--	2	--
SOM-21	Sand	--	--	--	2	--	--
SOM-23	Sand	--	--	--	5	--	--

* Rank of 1 is best.



NOTE: AN INCREASE IN TEMPERATURE CAUSES A DECREASE IN VISCOSITY.

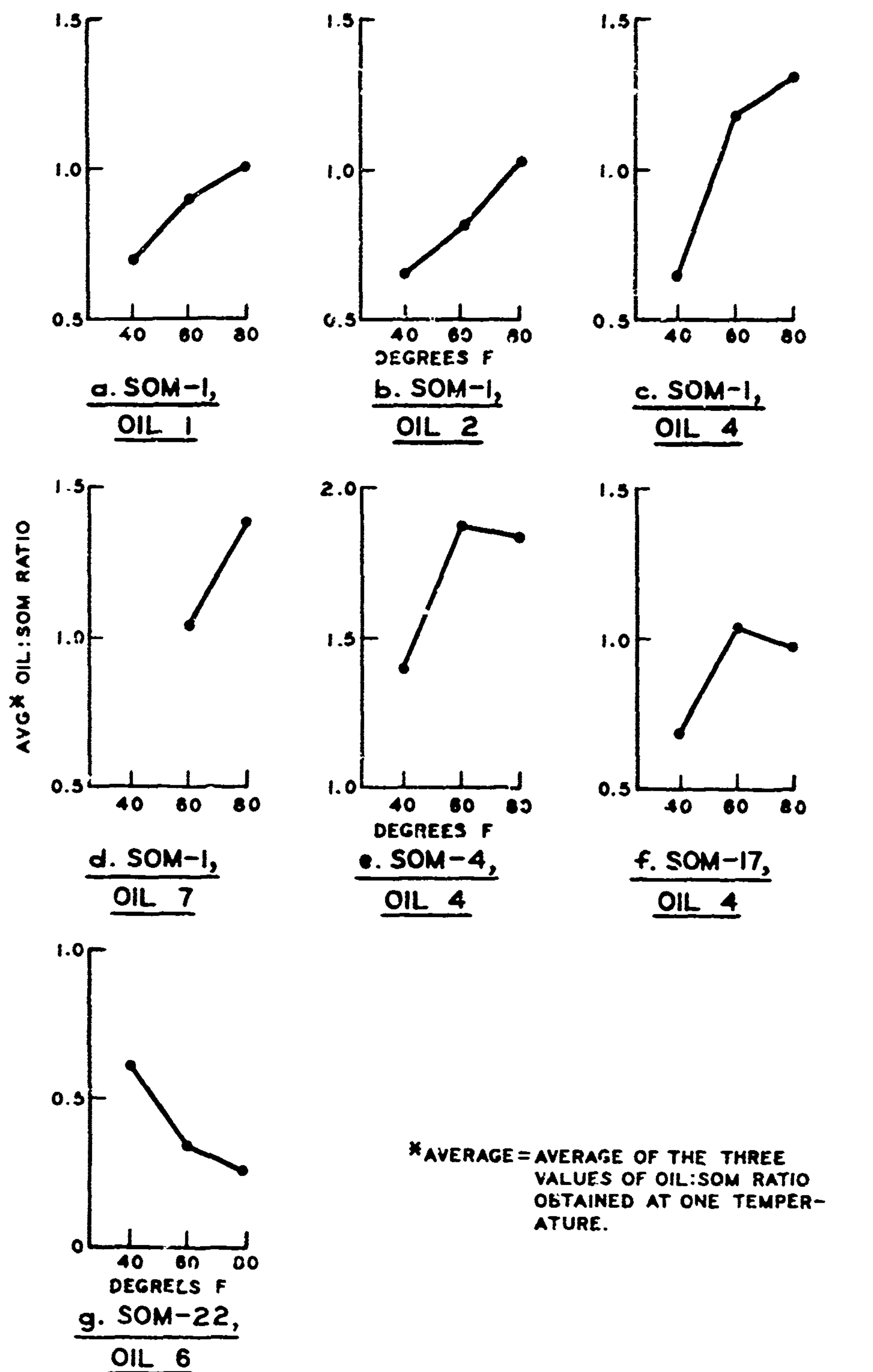
VISCOSITY-TEMPERATURE RELATIONS OF OILS



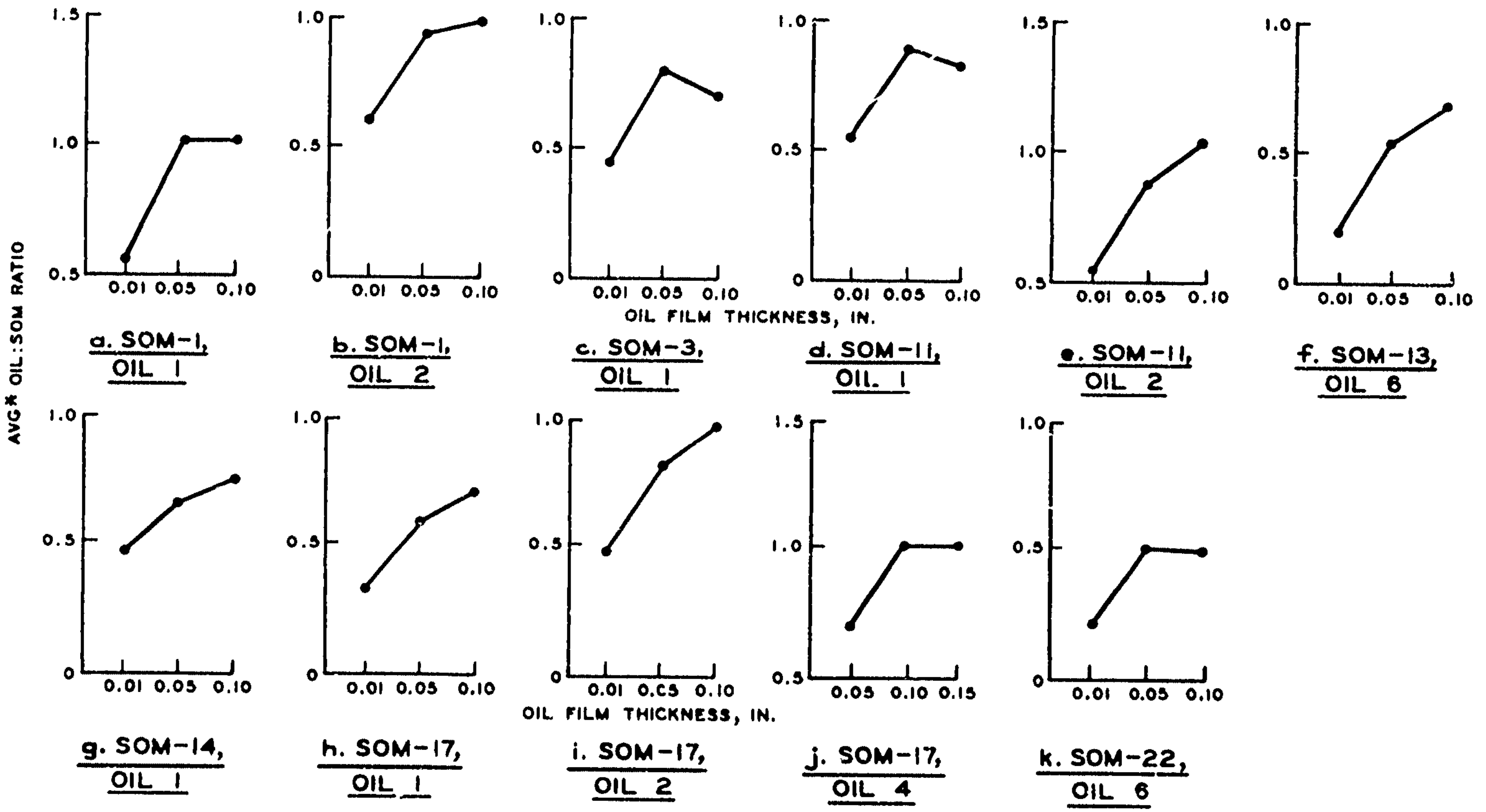
a. 73F AND 50 PERCENT RELATIVE HUMIDITY

b. 100F AND 60 PERCENT RELATIVE HUMIDITY

VOLATILITY OF OILS

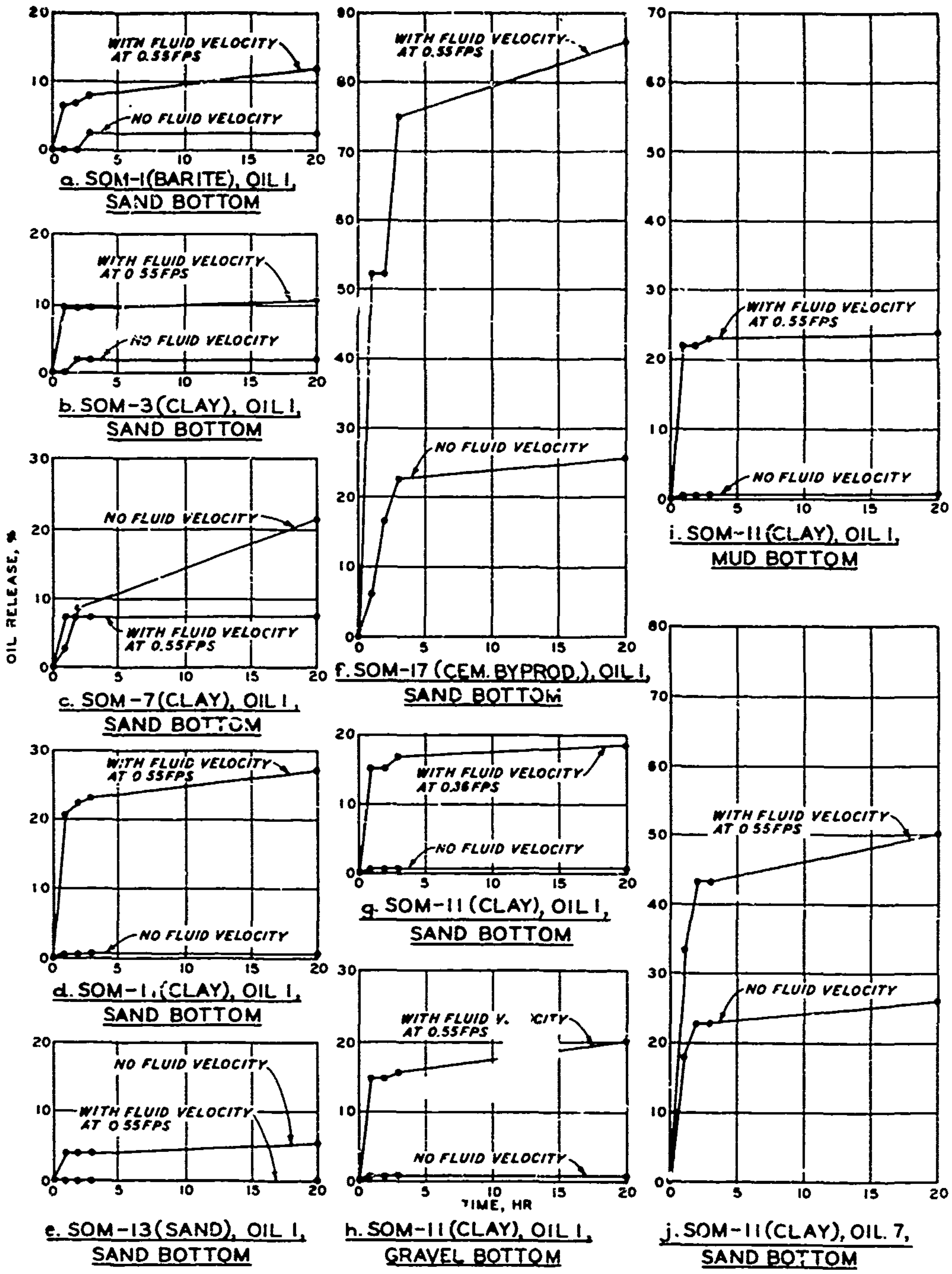


AVERAGE OIL:SOM RATIO VS TEMPERATURE



*AVERAGE = AVERAGE OF THE THREE VALUES OF OIL:SOM RATIO OBTAINED AT ONE OIL THICKNESS.

AVERAGE OIL:SOM RATIO VS OIL FILM THICKNESS



EFFECTS OF FLUID VELOCITY ON RETENTION CHARACTERISTICS

PERCENT OIL RELEASE AS A FUNCTION OF TIME

APPENDIX A: PROPOSED METHOD OF TEST FOR DETERMINATION OF OPTIMUM OIL RETENTION POTENTIAL OF SINKING AGENTS OR SORBENTS FOR OIL

APPENDIX A

PROPOSED METHOD OF TEST FOR DETERMINATION OF OPTIMUM OIL RETENTION POTENTIAL OF SINKING AGENTS OR SORBENTS FOR OIL

Scope

1. This proposed method of test covers procedures for determining the optimum oil retention potential of a sinking agent or sorbent, which is an index of the ability of a material to retain sorbed oil when submerged. A sinking agent for oil is defined as a material that, when applied to floating oil, sorbs (adsorbs and/or absorbs) oil and sinks with the oil, thus removing oil from the surface. A sorbent for oil is a material that, when applied to floating oil, sorbs (adsorbs and/or absorbs) oil but does not sink; oil and sorbent both remain on the surface. Optimum oil retention potential is the optimum capacity of an oil-sinking agent or oil-sorbent mixture to retain oil while submerged. It is expressed by the oil:SOM ratio (oil:sinking agent or oil:sorbent ratio) used.

Apparatus

2. The testing apparatus shall consist of the following:

- a. 250-ml Erlenmeyer flask with ground joint.
- b. 25-ml graduated cylinder with ground joint (units a and b to be used as indicated in fig. A1).
- c. 400-ml beaker.
- d. Variable-frequency vibrating table.
- e. Balance sensitive to 0.01 g.
- f. Burrell shaker.
- g. 10-ml hypodermic syringe and needle (gage of needle should be determined so as to allow for easy but controlled flow of the particular grade of oil to be used).
- h. Glass stirring rod.
- i. Small-diameter plastic or rubber hose.
- j. Funnel (small).
- k. Vacuum apparatus (see fig. A2).
- l. Rubber stopper for Erlenmeyer flask.

Materials

3. Materials used in this method are:

a. Test material (sinking agent or sorbent).

b. Oil (30 g).

c. ASTM substitute ocean water (ASTM designation: D-1141, Section 4) or distilled water.

d. Surfactant-Isomal 265 (Johnson-March Corp., Philadelphia, Pennsylvania).

e. Petroleum jelly.

Procedure

4. Method A (for sinking agents):

a. The inside of each flask and graduated cylinder (fig. A1) to be used should be coated with a solution of one part Isomal mixed with ten parts of water (by volume). After coating, the glassware should be oven dried at approximately 175 F for at least 2 hr. This treatment minimizes the tendency of the surfacing oil to adhere to the sides of the flask and cylinder and thus reduces the degree of inaccuracy of the test results. Allow glassware to cool to 73 F.

b. Weigh the flask to nearest 0.01 g (cylinder removed), add the SOM, and reweigh the flask. The final weight minus the initial weight will indicate the weight of SOM being used. The proportions of oil to SOM required to yield approximately 10 cc of free oil should be used. This volume of free oil is needed to allow for test variation within the range of volume of free oil released. Thirty grams of oil should be used in each test. A preliminary screening test to indicate the weight of a given SOM suitable for use with 30 g of a given oil can be made by placing 30 g of the oil in a 400-ml beaker, adding SOM to the oil from a preweighed container until the oil-SOM mass starts to thicken, lose gloss, or become viscous. At this point the mass should be stirred, water should be added, and the mass stirred an additional 30 sec. After the mixture stands for 10 to 15 min, the extent of surface oil will indicate whether too much or too little SOM has been used. The weight of SOM used can be determined by difference in the initial and final weighings of the container plus SOM. Additional screening tests with necessary adjustments should be conducted which will minimize work and time required to obtain the test results.

c. Add the 30 g of oil to the flask. This step may be simplified by use of the hypodermic syringe which will minimize the amount of oil brought into contact with the sides of the flask during this step of the operation. The balance may be used to indicate the point at which the required weight of oil has been added.

d. Use a rubber stopper to seal the flask and shake for 15 min with a Burrell shaker, adjusting the motion of the shaker as necessary to obtain good distribution of oil throughout the SOM. Several flasks may be shaken simultaneously, depending upon the capacity of the individual shaker. In any event, if test results are to be comparable, each test (or set of tests) must be performed under the same conditions. If necessary, the contents of each flask may be stirred to ensure that all portions of the SOM have been brought into contact with the oil. This will be particularly necessary when the more viscous oils are being evaluated. Care should be taken, however, to prevent any unnecessary contact between the oil-SOM mass and the uppermost sides of the flask.

e. Apply 30-in. mercury vacuum (fig. A2) until such time as there is no loss in vacuum over a 5-min period of time.

f. Allow flask to stand for a period of time such that the total time elapsed in steps e and f is 1 hr.

g. Vibrate the stoppered flask for 30 min, adjusting the frequency of the vibrating table as necessary. Several flasks can be vibrated simultaneously; however, the vibratory motion of the table will have to be adjusted in order to accommodate the additional weight. It is emphasized, however, that if test results are to be comparable all tests must be performed under the same conditions. This step is particularly important in that it results in release of the free oil which is entrapped between solid particles and is not actually sorbed (absorbed and/or adsorbed). This consolidation process improves the reproducibility of test results, particularly for the coarser materials.

h. Remove stopper and affix the graduated cylinder in the top of the flask. The quality of the seal can be improved by coating the ground glass surfaces with petroleum jelly.

i. Add enough ASTM substitute ocean water to the flask-cylinder system to bring the free oil surface level to the 0.0-ml mark. The water should be added in such a manner as to minimize disturbance of the oil-SOM mass and minimize emulsification of the free oil. This can be facilitated by using a flexible rubber or plastic tube and funnel as illustrated in fig. A3. This will minimize the free-fall distance and disturbance. Care must be exercised to prevent the lower end of the tube from coming into contact with the rising liquid surface, since some of the oil would become attached to the tube.

j. Determine, by use of the cylinder graduations, the volume of free oil released. This measurement should be made to the nearest 0.5 ml and should include any sorbent which is suspended in the free oil column. Since test method A is designed to evaluate sinking agents, it is felt that this procedure would adequately penalize any materials which do not act fully as sinking agents. These readings should be made 2 hr after the addition of the water and 18 hr after the addition of the water. In most instances, volumetric differences between the 2- and

18-hr readings will be negligible. However, for certain materials, particularly the expansive clays and some oils, the differences will be substantial. In these cases, both readings should be reported and the 18-hr reading should be used to compute the optimum oil retention potential.

k. Multiply the volumetric measurement of oil in cubic centimeters by the specific gravity of the oil used (determined at 73 F) to yield the weight in grams of free oil. Subtract this weight from the original weight of oil added to the flask to obtain, i. grams, the weight of oil effectively sorbed and retained.

l. Divide the weight of oil adsorbed and/or absorbed by the weight of test material used to obtain the optimum retention potential expressed as an oil:SOM ratio. Any interesting or unusual items, such as volume of floating sorbents, should be noted in the test results. This test should be repeated at least three times for each individual oil and test material used and the results averaged.

5. Method B (for powdered materials):

a. Conduct test as described in method A, paragraphs a through g. The amount of sorbent used (see paragraph b, method A) should, in the end, be such that no free oil and/or oil-sinker mass floats to the surface upon addition of water to the flask. Several tests will probably be necessary to determine the optimum weight of sorbent required. (It should be kept in mind that while many different amounts of the same sorbent may be sufficient to retain the particular amount of oil used, there is a minimum amount of sorbent which adequately retains the oil. It is toward the determination of this minimum weight of sorbent that this test is directed.)

b. Allow the entire system to stand for 18 hr. Should, at any time during this 18-hr period, any appreciable volume (more than a trace) of free oil and/or oil-SOM mass rise to the water surface, repeat the test using slightly less sorbent than was previously used. Continue testing in this manner until the weight of sorbent which will yield only a trace of free oil and/or oil-SOM mass on the water surface is determined and verified by at least two additional tests.

c. Divide the weight of oil used by the minimum weight of sorbent used (the minimum weight which will satisfactorily retain the oil in the bottom of the flask) to obtain the optimum potential expressed as an oil:SOM ratio.

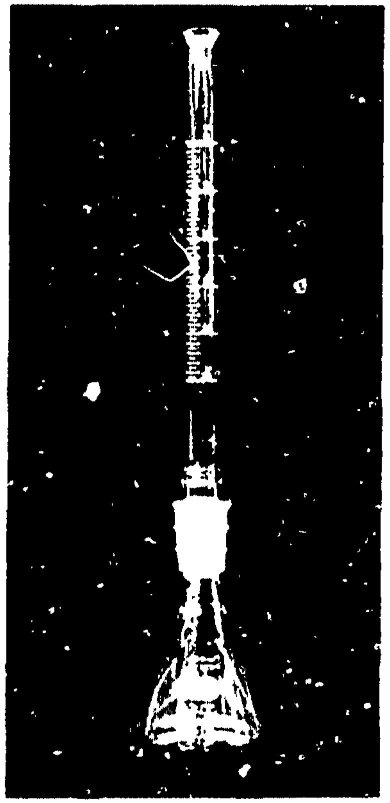


Fig. A1. 250-ml Erlenmeyer flask equipped with graduated cylinder

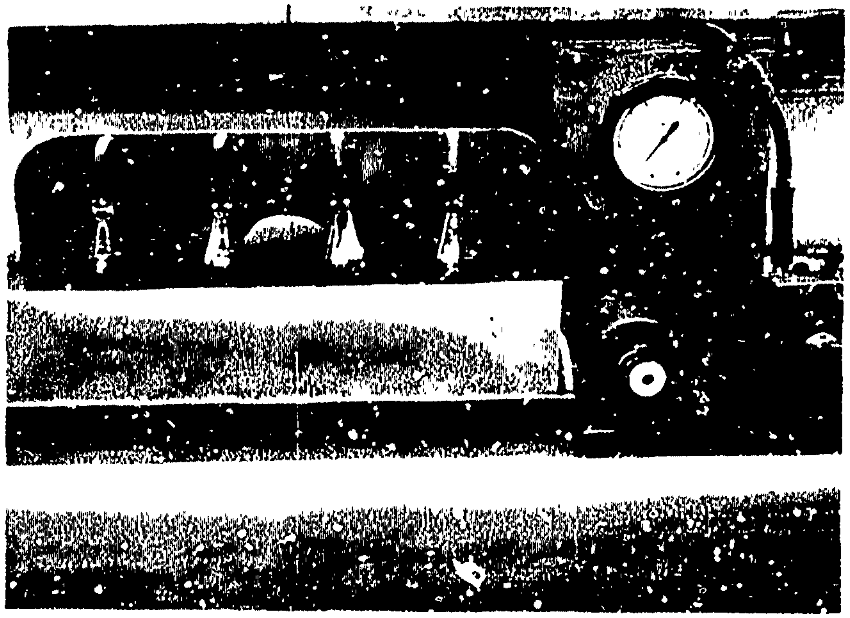


Fig. A2. Oil-SOM mixtures being subjected to entrapped air evacuation in vacuum apparatus

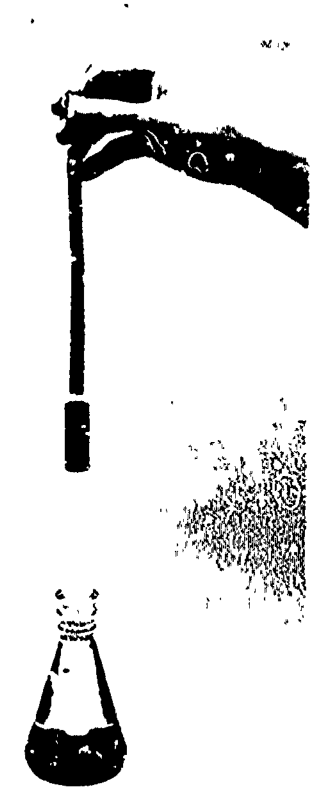


Fig. A3. Addition of water to 250-ml Erlenmeyer flask-graduated cylinder assembly

APPENDIX B: PROPOSED METHOD OF TEST FOR EVALUATION OF THE SINKING EFFICIENCY OF SINKING AGENTS FOR OIL (DRY APPLICATION)

APPENDIX B

PROPOSED METHOD OF TEST FOR EVALUATION OF THE SINKING EFFICIENCY OF SINKING AGENTS FOR OIL (DRY APPLICATION)

Scope

1. This proposed method of test covers a procedure for evaluating the sinking efficiency of sinking agents for oil. A sinking agent for oil is a material that, when applied to floating oil, sorbs (adsorbs and/or absorbs) oil and sinks with the oil, thus removing oil from the surface. Sinking efficiency is the ability of a material to act as a sinking agent for an oil film on water. Sinking efficiency is expressed by the oil:sinking agent ratio (by weight) required to sink at least 90% of the oil film which is at the surface of an oil-water mixture. A material which does not sink oil, such as a sorbent, has no sinking efficiency and does not meet the minimum requirement for this test.

2. Of the many different factors which contribute to the interaction of an individual sinking agent with a particular oil, the most important are: (a) system temperature, (b) initial oil film thickness, and (c) nature of oil film (fresh or weathered). All of these factors should be examined in order to adequately evaluate the performance of various sinking agents when used with various types of oils.

Apparatus

3. The testing apparatus shall consist of the following:

a. Stirring rod.

b. 4000-ml beaker (Griffin low form, Pyrex).

c. Balance sensitive to 0.01 g.

d. 10-cc hypodermic syringe and needle (gage of needle should be determined so as to allow for easy but controlled flow of the particular grade of oil to be used).

e. Device for controlling application of sinking agents (see fig. B1).

f. Variable-temperature water bath or variable-temperature room.

g. Timing device.

Materials

4. Materials used are:

   a. Test material (sinking agent or sorbent).

   b. Oil.

   c. ASTM substitute ocean water (ASTM designation: D-1141, Section 4).

   d. Oil-soluble dye (for use with nearly transparent oils).

Procedures

5. Test procedures are as follows:

   a. Bring components of the test apparatus and test materials to equilibrium at the designated test temperature. This will best be accomplished with a variable-temperature control room in which the entire testing operation can be performed. If desired, a water bath can be used in conjunction with a variable-temperature room to perform tests at air temperatures somewhat different from the fluid system temperature.

   b. Add 2000 ml of water to the 4000-ml beaker. At this level, the cross-sectional area of the water surface in the standard Griffin low form Pyrex beaker is 194.8 cm^2. Weigh the beaker and water to the nearest 0.01 g.

   c. Add oil to the water surface, the volume (weight) of which will be dictated by the particular oil film thickness desired, the type of oil used, and the system temperature at which the test is to be performed. The weight of oil required can be computed from the known surface area and the known density of the oil at the particular temperature of interest. If necessary, an oil-soluble dye can be used in conjunction with the oil to help eliminate problems of visually determining when the oil slick has been effectively sunk. Place the beaker in position for application of the sinking agent through the application device (see fig. B1).

   d. Sprinkle the sinking agent through the top of the sorbent application funnel. This apparatus is designed simply to ensure that (1) all tests are conducted using the same free-fall distance (30 in.) for each SOM, and (2) all SOM's applied actually fall on the fluid surface.

   The SOM should be applied uniformly and at a constant rate until barely enough material has been applied to effectively sink 90 to 100% of the oil. The time elapsed during the actual application-sorption-sinking operation should not exceed 10 min and should not be less than 5 min.

   In all instances, some if not all of the oil-sinking agent mass will float until significant agitation is applied. This can be accomplished by stirring the system vigorously after the sinking agent has been applied. The stirring should not be so violent as to emulsify any free oil.

This phase of the test procedure requires some experience and good judgment on the part of the test personnel in that, with most materials not sinking until after vigorous agitation is applied, a decision must be made as to when barely enough material has been applied to effectively sink 90 to 100% of the oil. In the majority of cases, it can be safely assumed that this point has been reached when the fluid surface is no longer glossy as it is when appreciable free oil is present. Fig. B2 illustrates these conditions.

e. Sinking efficiency of the sinking agent used is, in each case, computed by dividing the weight of oil sunk by the weight of the sinking agent required to sink the oil. The test should be conducted three times and the results of the three tests averaged. Any pertinent observations such as oil release (see note) with time should be noted with the test results.

Note: If long-term oil release measurements are desired, a glass funnel with a graduated stem may be placed over the sunken oil-sinking agent mass and the volume of oil release may be measured for as long as desired.

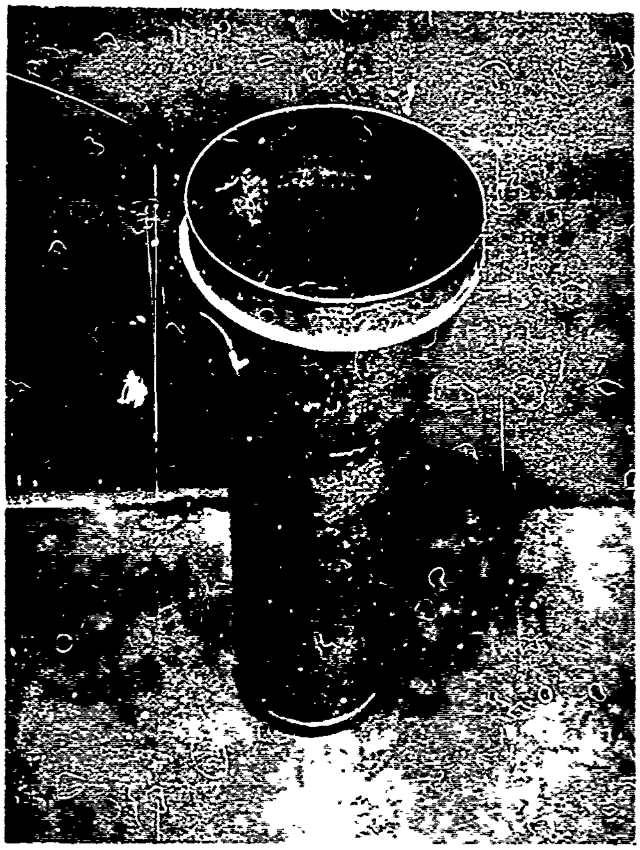
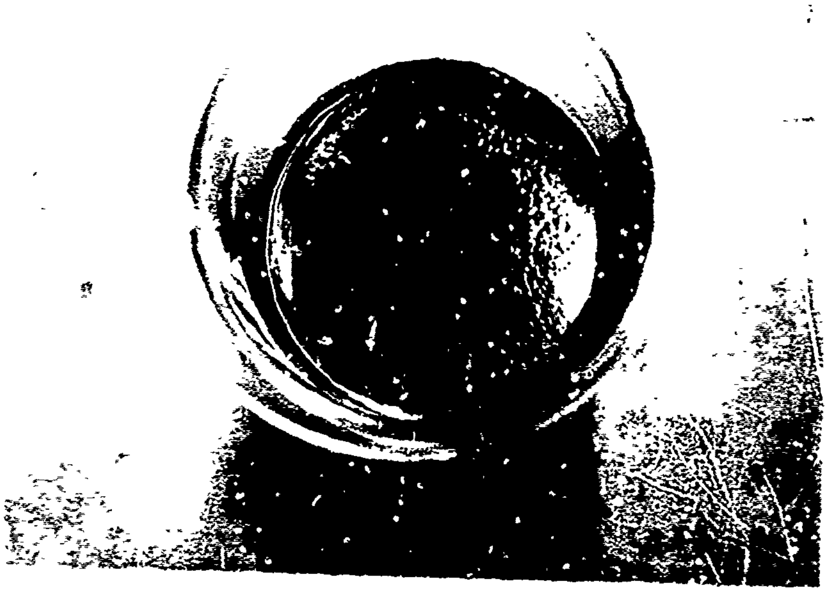


Fig. B1. Device to aid in controlling application of sinking agents



a. Amount of sinking agent insufficient for total sinking

b. Amount of sinking agent barely sufficient for total sinking

Fig. B2. Typical appearance of oil-slick surface after application of sinking agent

APPENDIX C: PROPOSED METHOD OF TEST FOR DETERMINATION OF DYNAMIC RETENTION CAPABILITY OF SINKING AGENTS FOR OILS

APPENDIX C

PROPOSED METHOD OF TEST FOR DETERMINATION OF DYNAMIC RETENTION CAPABILITY OF SINKING AGENTS FOR OILS

Scope

1. This proposed method of test covers a procedure for determining the dynamic retention capability of a sinking agent for oil. Retention capability is defined as the ability of the oil:sinking agent mass to retain its oil after sinking. This is expressed as the ratio of the weight of the oil retained to the weight of sinking agent used. Dynamic retention capability is the retention capability determined under dynamic conditions, i.e., the oil and sinking agent are placed on a moving water surface. A sinking agent for oil is defined as a material that, when applied to floating oil, sorbs (adsorbs and/or absorbs) oil and sinks with the oil.

2. Factors which will affect the retention capabilities of the various sinking agents and the effects of which should be examined are: (a) fluid velocity and (b) bottom conditions (sand, mud, rock, etc.).

Apparatus

3. The testing apparatus shall consist of the following:

- a. Circular flow channel for simulation of current flow (see fig. C1).
- b. Current meter (see fig. C2).
- c. Variable-frequency vibrating table.
- d. Balance sensitive to 0.01 g.
- e. 400-ml beaker.
- f. 10-cc hypodermic syringe and needle (gage of needle should be determined so as to allow for easy but controlled flow of the particular grade of oil to be used).
- g. Weighing pan (aluminum pie plate).

Materials

4. Materials to be used are:

- a. Sinking agent.
- b. Oil.
- c. ASTM substitute ocean water (ASTM designation: D-1141, Section 4).

d. Fine glass wool.

e. Bed material for bottom of channel (sand, mud, rock, etc).

Procedures

5. Test procedures are as follows:

a. Place the bed material desired (sand, mud, or rock) in the circular flow channel. This bed material should be clean enough to prevent contamination of the water as such will result in collection of impurities along with the released oil. This in turn will cause the calculated weight of oil released (based on volatile loss-time relationships) to be too great.

b. Add ASTM substitute ocean water to the flow channel and allow the system to reach standard laboratory temperature (i.e., 73 ± 2 F).

c. Begin actual fluid flow (mechanical rotation of the circular channel in this case) and allow the currents to reach equilibrium. This step will require different periods of time for different fluid velocities and different types of channels. The point at which stabilization of velocity is reached can be determined with a current meter similar to the one pictured in fig. C2. After stabilization has been achieved, the velocity profile of the channel cross section should also be determined.

d. Place known amounts of sinking agent and oil (at standard temperature) in the 400-ml beaker, using the hypodermic syringe for the addition of the oil. The total amount of sinking agent and oil is determined by the cross section of the particular flow channel used, and the ratio (by weight) of the two components is determined by the amount of oil that the particular sinking agent will adsorb and/or absorb. This ratio should have been previously obtained in the determination of the optimum retention potential of the sinking agent.

e. Place the beaker containing the sinking agent and oil on the vibrating table and vibrate for 45 min. The beaker should be covered appropriately during this operation.

f. Allow covered beaker to stand at standard laboratory temperature (73 ± 2 F) until all components are in temperature equilibrium. This standing time should not exceed 75 min.

g. Add the known weight of sinking agent-oil mass to the moving channel. Any residue left in the beaker should be weighed, this weight to be proportioned according to the original weights of sinking agent and oil mixed, and then subtracted from these original weights to yield the actual weights of materials subjected to test. (Example: Assume that 700 g of sinking agent was mixed with 300 g of oil and that 10 g of oil-sinking agent mass remained in the mixing container after the majority of the mass was added to the channel. Then by proportion of weights originally mixed, 7 g of sinking agent and 3 g of oil remained as residue in the container. Therefore, 693 g of sinking agent and 297 g of oil were added to the channel.)

h. Weights of oil released should be determined (according to step i) at points in time (with reference to initial immersion, i.e., addition of the oil-sinking agent mass to the channel) of t = 0, 1, 2, 3, 12, and 24 hr, and t = 3, 7, 14, and 21 days. Some of the later release measurements may be eliminated, obviously, if at some point it is observed that release is no longer occurring.

i. Determination of the weight of free unweathered oil floating on the surface at any time should be accomplished by removing this free oil, using the fine glass wool, driving off volatile fractions at a temperature and for a period of time determined by the type of oil being examined and by the volatile loss characteristics determined according to the "Proposed Procedure for Determination of Volatile Loss-Time Characteristics of Oil Retained on Glass Wool," and determining the weight of oil residue remaining after volatile evaporation.

j. This weight of oil residue should then be divided by a conversion factor previously determined according to the "Proposed Procedure for Determination of Volatile Loss-Time Characteristics of Oil Retained on Glass Wool," this computation yielding the weight of free unweathered oil released since the time of the previous collection of surface oil.

k. This weight of free unweathered oil collected should then be added to the weights of oil collected at the preceding times of removal. This total weight multiplied by 100 and then divided by the weight of oil placed in the channel as determined in step g of this test method will represent the weight of free unweathered oil released over the period of time, t , expressed as a percentage of the weight of free unweathered oil originally adsorbed and/or absorbed. Such time-release characteristics for a specific sinking agent, oil, and fluid velocity can be represented in graphical form as indicated in fig. C3.

l. The weight of oil retained is determined by subtracting the total weight of oil collected (see paragraph k above) from the weight of oil placed in the channel.

m. The dynamic retention capability is then computed by dividing the weight of oil retained by the weight of sinking agent used.

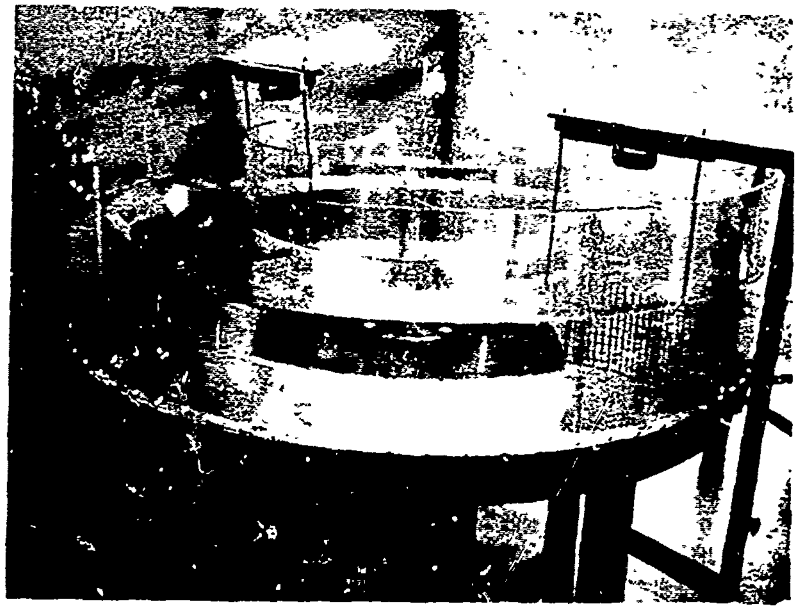


Fig. C1. Circular channel for simulating current flow

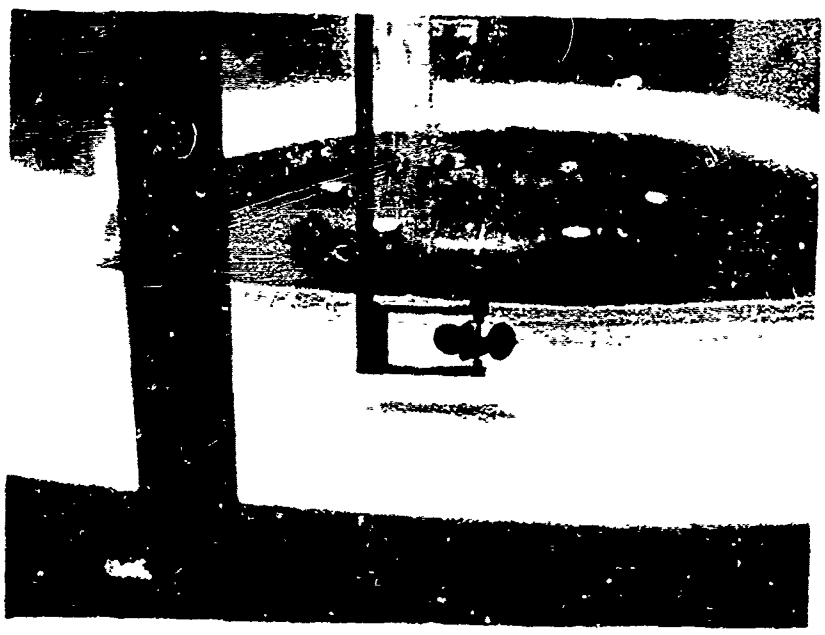


Fig. C2. Current meter

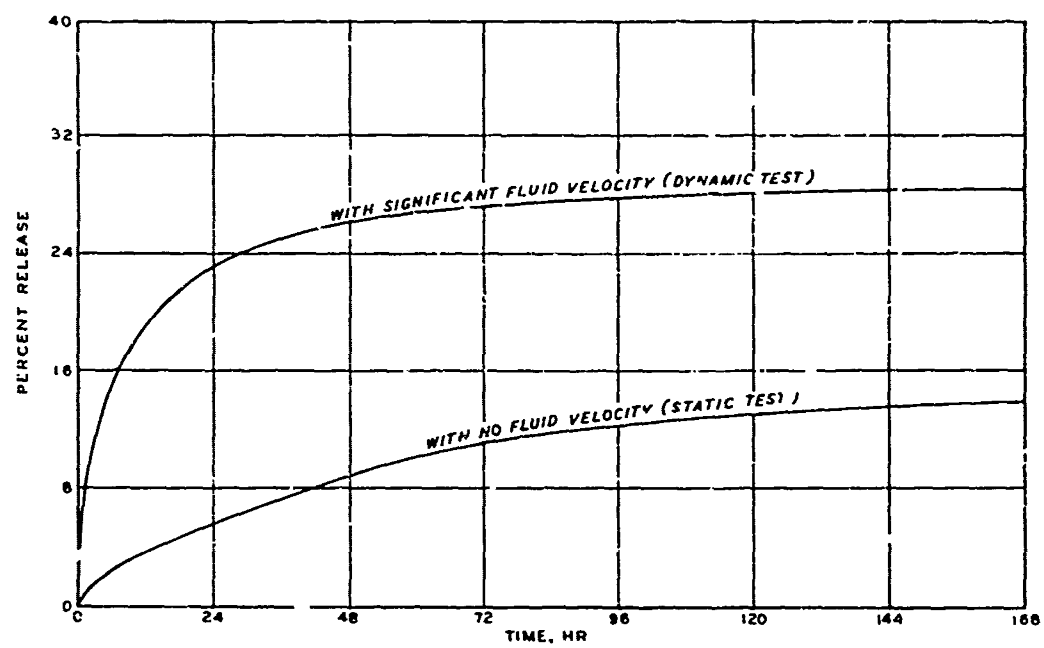


Fig. C3. Effects of fluid velocity on retention characteristics; percent release as a function of time

APPENDIX D: PROPOSED PROCEDURE FOR DETERMINATION OF VOLATILE LOSS-TIME CHARACTERISTICS OF OIL RETAINED ON GLASS WOOL

APPENDIX D

PROPOSED PROCEDURE FOR DETERMINATION OF VOLATILE LOSS-TIME CHARACTERISTICS OF OIL RETAINED ON GLASS WOOL

Scope

1. This test is intended to be used for calibration purposes, the resulting volatile loss-time relations to be used in the computation of the actual weights of unweathered free oil floating on a water surface.

2. The basic premise underlying this procedure is: if one determines, for a particular weight oil-water-glass wool combination and evaporation temperature, the volatile loss-time relation after total evaporation of the water component at low relative humidity, one can then use this relation to compute the weight of unweathered free oil removed from a system by evaporating the volatiles from this removed oil (at the same temperature and for the same evaporation period), determining the weight of the oil residue, and multiplying this weight by an appropriate factor based on the "calibration" test.

3. The accuracy of this operation is highly dependent upon using an evaporation period the length of which is great enough to ensure complete evaporation of the water component (usually less than 24 hr) and that the mathematical computations are based on the relatively flat portion of the residual oil volatile loss-time curve. It is also important that the evaporation temperature used, for a particular oil, be high enough so that equilibrium (no appreciable loss) is reached in a realistic period of time, and at the same time low enough so that enough residue is left to make reasonably accurate computations. In particular, diesel fuel must be treated at somewhat lower temperatures than those used for crude oils since total evaporation of diesel fuel will occur at the higher temperatures. Total evaporation would yield no useful data. Low humidity environment appreciably decreases the time required for water evaporation, and thus system equilibrium.

Apparatus

4. The apparatus used for this test are:

a. Oven.

b. Weighing pan (aluminum pie plate).

c. Fine glass wool.

d. Large pan for containing water and oil film.

e. Balance sensitive to 0.01 g.

f. Desiccator.

Materials

5. Materials used in the test are:

a. Oil.

b. ASTM substitute ocean water.*

c. Oil-soluble dye.

Procedures

6. Test procedures are as follows:

a. Allow all materials to stabilize at standard laboratory temperature (73 ± 2 F).

b. Add ASTM substitute ocean water* to large pan.

c. Determine tare weight of aluminum pie plate and glass wool to nearest 0.01 g.

d. Place 10 g of fresh oil on the water surface and allow significant dispersion to occur.

e. Remove the free oil from the water surface by dragging the fine glass wool over the surface as illustrated in fig. D1.

f. Place all glass wool (contaminated and uncontaminated) in the weighing pan, weigh the system to the nearest 0.01 g, and place this unit in an oven or room (less than 30% relative humidity desirable).

g. Continue evaporation of volatiles at 100 F until equilibrium is essentially reached. The unit should be weighed at 24, 48, and 72 hr so that any appreciable decrease in rate of evaporation will be obvious. Experience has indicated that evaporation periods of 24, 48, and 72 hr are normally adequate to obtain a calibration curve.

h. Allow the unit to cool to 73 F at 50% relative humidity.

i. Weigh the unit to the nearest 0.01 g.

j. Subtract the tare weight (step c) from the total weight (step i) to yield the weight of residual.

k. Divide this weight by 10 to obtain the number of grams of residual yielded per gram of unweathered free oil.

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* ASTM Designation: D1141, Section 4

7. This test should be conducted three times recording residual weights at 24, 48, and 72 hr. The values determined in step k should be averaged to yield the conversion factor for each time increment which, when divided into the weight of residual determined in any future test, will yield the weight of unweathered free oil collected in that test. The three time intervals should be plotted so that a conversion factor can be obtained for the convenient time used. Values less than 24 hr are meaningless, since the procedure is based on the complete evaporation of the water which will normally require 12 to 20 hr. It is also important to note that the conversion factor should be obtained on the same approximate amount of oil, as the oil-water relation will affect the rate of volatile evaporation from the oil during the first 24 hr.

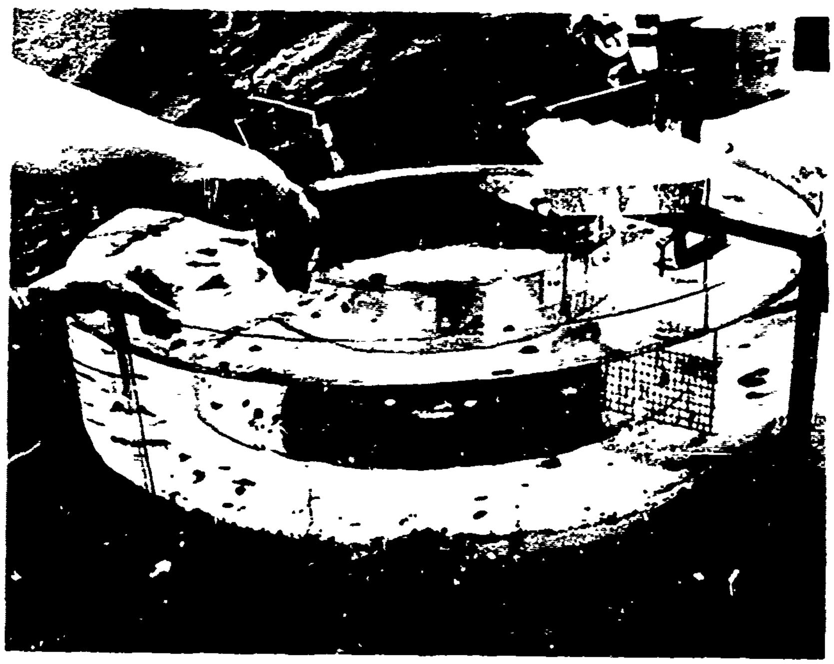


Fig. D1. Removal of released oil from fluid surface by using glass wool

APPENDIX E: INFORMATION ON OIL SINKING MATERIALS SUPPLIED BY THE MANUFACTURERS

MATERIAL IDENTIFICATION: SOM-1

CHEMICAL–PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Barite with 10 percent latex rubber.

SPECIFIC GRAVITY: 3.3 g/cc. Bulk density 80 pcf.
FLASH POINT: Very high.
ICC CLASS:
VISCOSITY: Solid powder.
MISCIBILITY: Compatible with oils; not easily wet by water.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Probably several years.

COST: 6 to 8 cents per pound; pilot plant for production would have to be constructed.

DOSAGE RATE: By manufacturer - 1:1.3 agent to oil.

APPLICATION METHOD: By manufacturer - apply by any method that will uniformly spread the material on the surface of the floating oil.

AVAILABILITY: Quantity unlimited if treatment plant constructed.

USE RECOMMENDATIONS AND LIMITATIONS: Anywhere oil can be sunk.

SPILL EXPERIENCE: Laboratory tests by manufacturer.

EFFECTIVENESS: Observations during tests by manufacturer indicated material to be capable of sinking 1.3 to 1.[illegible] lb of crude oil per pound of material. Material more effective on lower density, less viscous oils.

TOXICITY: Nontoxic.

MATERIAL IDENTIFICATION: SOM-2

CHEMICAL-PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Hydrophobic calcium carbonate, particle enclosed in a film of fatty acid (stearic acid about 1%).
SPECIFIC GRAVITY: 2.7.
FLASH POINT: Not applicable.
ICC CLASS: Standard.
VISCOSITY: Solid
MISCIBILITY: Hydrophobic (nonsolutle in water).
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Indefinite.

COST: $80.00 per ton, FOB major port cities (U. S.).

DOSAGE RATE: By manufacturer - 1:1.5 agent to oil by weight.

APPLICATION METHOD: By manufacturer - spread on surface of sea water or oil spill. Heavy sea agitation is desired. The agent that falls on the water will float until it contacts oil. Once it contacts oil it compounds and hydrostatically sinks, forming small stable patches on the sea bed. Reaction time - depends on ratio used and sea water movement or agitation.

AVAILABILITY: 5 tons inventory in New York City - normal four weeks production rates unlimited.

USE RECOMMENDATIONS AND LIMITATIONS: By manufacturer - re[illegible]nded for open sea and bay for use on fresh and weathere[illegible]es and distillate fuels. No special storage requirement [illegible]ecessary.

SPILL EXPERIENCE: By manufacturer - laboratory and field [illegible]perience as well as experience in the [illegible] CANYON incident - 4000 tons used.

EFFECTIVENESS: By manufacturer - 90%.

TOXICITY:
By manufacturer -
For operators - no recorded cases of respiratory problems 19[illegible]-1[illegible] (suggest use of filter mask).
For marine life - no limit, nontoxic material $CaCO_3$.

MATERIAL IDENTIFICATION: SOM-3

CHEMICAL–PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: 100% calcinated clay.

SPECIFIC GRAVITY: Density 35 pcf.
FLASH POINT: None
ICC CLASS: Calcinated clay.
VISCOSITY: Granular dry material.
MISCIBILITY: None
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Indefinite.

COST: $60.00 per ton in 40- to 50-lb bags.

DOSAGE RATE: By manufacturer - not specifically defined. Apply to oil surface, as necessary.

APPLICATION METHOD: By manufacturer - applied by blowing or sprinkling onto the surface of the oil. Spills on hard surfaces can be swept up after absorbing with the material. Recovery of spent agent is not feasible. It can be removed and hauled away to a dump area or sunk by applying a little water spray to the oil and agent floating in the water. Reaction time - will sink in a few minutes.

AVAILABILITY: Available in most U. S. cities.

USE RECOMMENDATIONS AND LIMITATIONS: By manufacturer - recommended to be used in areas where permissible for treatment of Bunker C, fresh crude, and distillate fuel oils. There is no limiting storage temperature range or other storage constraints. Recommended for small spills in loading areas and on docks and decks to keep oil out of the water.

SPILL EXPERIENCE: By manufacturer - material is used primarily for on deck or loading spills where either a quick pickup is required or sinking is desired.

EFFECTIVENESS: By manufacturer - percent effectiveness is not specified. For pickup, it absorbs about its own weight of oil (0.9 m³/g).

TOXICITY:
By manufacturer -
For operators - not reported.
For marine life - inert and nontoxic.

MATERIAL IDENTIFICATION: SOM-4

CHEMICAL–PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Talc, 10 micron (70% organophilic, 30% hydrophilic), no stabilizer.

SPECIFIC GRAVITY: 2.75.
FLASH POINT: Does not burn.
ICC CLASS: Not reported.
VISCOSITY: Not applicable.
MISCIBILITY: Insoluble in water.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Indefinite.

COST: 4 to 8 cents per pound in carload lots. FOB Seattle, Portland, San Francisco, Los Angeles, Chicago, Trenton, and Boston.

DOSAGE RATE: By manufacturer - estimated 2 to 3 parts agent for each part of oil.

APPLICATION METHOD: By manufacturer - Broadcast dry onto oil slick. Agitate. May also be mixed 1 lb/gal with water and sprayed onto oil slick. Dry application most effective. Oil disperses and sinks. Reaction time - immediate to several hours depending on agitation. For beach protection, spread 15 to 20 ft wide before tide comes in. For rock cleaning, mix with painter's naphtha, apply, and wash with high-pressure water stream.

AVAILABILITY: Inventory quantity 10 to 40 tons at Seattle, Portland, San Francisco, Los Angeles, Chicago, Trenton, and Boston. Production of 70 tons/day possible with 1 week lead time or, in emergency, 1 day lead time.

USE RECOMMENDATIONS AND LIMITATIONS: By manufacturer - recommended for open sea, bay, harbor, estuary, and shore for fresh crude and distillate fuels. Not effective on Bunker C or heavy fractions. Use for beach protection, beach cleaning, and rock cleaning. Some of the product can float to shore either oil-contaminated or clean and leave a deposit. Storage requirements - keep dry.

SPILL EXPERIENCE: By manufacturer - The San Juan Puerto Rico Dept. of Public Works used two 50-lb bags every low tide at Caribe Hilton Hotel Beach, Puerto Rico (OCEAN EAGLE Spill - March 1968). Spread 15 to 20 ft wide on 600 ft beach. Tide carried oil and talc out and kept beach open and free of oil (amount of oil at this beach was not large according to manufacturer). Santa Barbara - used by Crosby and Overton, Long Beach, Calif., on beaches to polish cleanup after most oil removed manually, and for cleaning rocks (1969).

EFFECTIVENESS: By manufacturer - no estimate or test data reported. By others - tests by University of Puerto Rico rated absorbency "Excellent. Able to remove thin films of oil. Good for cleaning sands also" and rated leaching "Leaches most of the oil if exposed to the sun."

TOXICITY:
By manufacturer -
For operators - nontoxic; no silicosis hazard.
For marine life - no toxicity; documented by laboratory tests by marine biologist at University of Puerto Rico.

By others - 100% mortality in 6 hr at 1000 ppm for moharra.

MATERIAL IDENTIFICATION: SOM-5

CHEMICAL-PHYSICAL PROPERTIES:

- **CHEMICAL COMPOSITION:** Talc, 10 micron, zinc stearate coated (100% organophilic; 100% hydrophobic). No stabilizer.
- **SPECIFIC GRAVITY:** 2.75 (treated material does not sink in water).
- **FLASH POINT:** Does not burn.
- **ICC CLASS:** Not reported.
- **VISCOSITY:** Not applicable.
- **MISCIBILITY:** Insoluble in water.
- **SOLVENT COMPATIBILITY:** Not applicable.
- **SHELF LIFE:** Indefinite.

COST: 6 to 10 cents per pound in carload lots. FOB Seattle, Portland, San Francisco, Los Angeles, Chicago, Trenton, and Boston.

DOSAGE RATE: By manufacturer - not determined. Estimates 2 to 3 parts agent for each part of oil.

APPLICATION METHOD: By manufacturer - broadcast dry onto oil slick. Only harvesting method used to date is manual retrieval on shore. Reaction time - not reported. Does not sink oil.

AVAILABILITY: Inventory quantity 1 to 20 tons at Seattle, Portland, San Francisco, Los Angeles, Chicago, Trenton, and Boston. Production of 35 tons/day possible.

USE RECOMMENDATIONS AND LIMITATIONS: By manufacturer - recommended for open sea, bay, harbor, and estuary on fresh crude and distillate fuels. Not effective on Bunker C or heavy fractions. Does not sink the oil.

SPILL EXPERIENCE: By manufacturer - used on a small floating slick at Caribe Hilton Hotel lagoon in Puerto Rico (OCEAN EAGLE Spill). Hand broadcast, agitated with boat, drove slick to shore, and picked up with squeegees, pushed up and shoveled sand away.

EFFECTIVENESS: By manufacturer - no estimate or test data.

TOXICITY:

By manufacturer -
For operators - nontoxic; no silicosis hazard.
For marine life - nontoxic.

MATERIAL IDENTIFICATION: SOM-6

CHEMICAL-PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: High purity talc.

SPECIFIC GRAVITY: 2.75.
FLASH POINT: Does not burn.
ICC CLASS: Not reported.
VISCOSITY: Not applicable.
MISCIBILITY: Insoluble in water.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Indefinite.

COST: Not reported. (Estimated $120 per ton.)

DOSAGE RATE: Manufacturer estimates 2 to 3 parts of agent for each part of oil.

APPLICATION METHOD: Mix 1 lb/gal with water or sea water and spray on oil slick.

AVAILABILITY: Available.

USE RECOMMENDATIONS AND LIMITATIONS: Not reported.

SPILL EXPERIENCE: Not reported.

EFFECTIVENESS: No estimate or test data.

TOXICITY:
By manufacturer -
For operators - nontoxic; no silicosis hazard.
For marine life - no toxicity.

MATERIAL IDENTIFICATION: SCM-7

CHEMICAL--PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Fullers earth (attapulgite).

SPECIFIC GRAVITY: 2.45.
FLASH POINT: Not applicable.
ICC CLASS: Clay, NOIBN.
VISCOSITY: Solid.
MISCIBILITY: Miscible with all liquids.
SOLVENT COMPATIBILITY. Not applicable.
SHELF LIFE: Unlimited.

COST: $41.00 per ton in carload or truckload lots, FOB Attapulgus, Ga. Locally available at dealers' warehouses at a higher cost.

DOSAGE RATE: By manufacturer - as required.

APPLICATION METHOD: By manufacturer - not specified. Reaction time - not reported.

AVAILABILITY: In regular production and available on short notice.

USE RECOMMENDATIONS AND LIMITATIONS: By manufacturer - no use limitations or recommendations were reported. By others - Keystone Shipping Co., Philadelphia, reports that it absorbs petroleum products and sinks, that it is difficult to apply to spills in winds exceeding 15 miles per hour, and that it is effective for small spills on ship's deck.

SPILL EXPERIENCE: By manufacturer - not reported. Used primarily as an all-purpose mineral absorbent. By others - Keystone Shipping Co., Philadelphia, reports using 25 to 100 lb for small spills.

EFFECTIVENESS: Not reported.

TOXICITY:
By manufacturer -
For operators - no limit.
For marine life - no limit.

MATERIAL IDENTIFICATION: SOM-8

CHEMICAL--PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Chrysotile asbestos - surface treated.

SPECIFIC GRAVITY: 2.4 (in solid form), package bulk density - 19.6 pcf.
FLASH POINT: None.
ICC CLASS: Not reported.
VISCOSITY: Not applicable.
MISCIBILITY: Not applicable.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Infinite.

COST: 32.5 cents per pound for minimum order of 1 ton. FOB King City, Calif. Packaged in 40-lb bags, 3-ply paper with polyethylene overwrap; size - 28 by 18 by 17 in.

DOSAGE RATE: By manufacturer - 6 to 15% of the weight of oil.

APPLICATION METHOD: By manufacturer - apply by scoop around slick to contain and absorb it or apply by blowers to surface of oil to absorb it. Agitate with bow wake or apply surfactant or alcohol to drive oil into the asbestos. Remove by strainers, sieving, skimming, or burning. Ignition and flame propagation do not require special chemicals or equipment. For sinking, use one part agent to 8 parts crude oil by weight, agitate vigorously. At 10% agent by weight of oil, agglomerate remains floating. Reaction time - instantaneous when contacting fresh oil surface, increases to several minutes through oil-water interface.

AVAILABILITY: Available nationwide at 12 warehouse locations. Plant and warehouse inventories are subject to adjustment commensurate with use requirements.

USE RECOMMENDATIONS AND LIMITATIONS: By manufacturer - recommended for open sea, bay, harbor, estuary, and shore for Bunker C, fresh and weathered crudes, and distillate fuels. No limits on temperature or sea state. Should be applied prior to dispersants and surfactants. Not effective on emulsified oils. Uncontacted material floats on water surface. Intense agitation will displace air film and permit it to sink. Apply offshore of beaches to intercept and agglomerate the oil.

SPILL EXPERIENCE: By manufacturer - no spill experience to date - laboratory tests and a limited test on the Buffalo River.

EFFECTIVENESS: By manufacturer - 100% - high removal effected with use of surfactant scavenging of agglomerated oil. Material is hydrophobic and oleophilic.

TOXICITY:

By manufacturer -

For operators - per Sax "Dangerous properties of Industrial Materials" 2nd Ed., acute local, irritant slight, inhalation moderate: acute systemic none; chronic local inhalation high; chronic systemic unknown. Inhalation per U. S. Department of Labor - 2 x 10^6 particles per cubic foot of air maximum permissible.

For marine life - basic mineral and surfactant are insoluble.

MATERIAL IDENTIFICATION: SOM-9

CHEMICAL–PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Asbestos - surface treated.

SPECIFIC GRAVITY: 2.45.
FLASH POINT: None.
ICC CLASS: Not reported.
VISCOSITY: Not applicable.
MISCIBILITY: None.
SOLVENT COMPATIBILITY. Not applicable.
SHELF LIFE: Infinite.

COST: Priced from 15 to 20 cents per pound depending on quantity, FOB King City, Calif.

DOSAGE RATE: By manufacturer - 10 to 15% of the weight of oil.

APPLICATION METHOD: For sinking, use one part agent to eight parts crude oil by weight, agitate vigorously. Reaction time - instantaneous when contacting fresh oil surface. Increases to several minutes with weathered or emulsified oil.

AVAILABILITY: 100-ton inventory quantity; 30 tons/day production rate possible upon 72-hr notice.

USE RECOMMENDATIONS AND LIMITATIONS: By manufacturer - recommended for open sea, bay, harbor, estuary, and shore for Bunker C, fresh and weathered crudes, and distillate fuels. No limits on temperature or sea state. Should be applied prior to dispersants and surfactants. Not effective on emulsified oil. Uncontacted material will float for a short time.

SPILL EXPERIENCE: By manufacturer - no spill experience to date; laboratory tests and limited field tests have been conducted.

EFFECTIVENESS: By manufacturer - 100%; high removal effected with use of surfactant scavenging of agglomerated oil.

TOXICITY: By manufacturer - insoluble; per Sax "Dangerous Properties of Industrial Materials," 2nd edition, acute local, irritant slight, inhalation moderate; acute systemic none; chronic local, inhalation high; chronic systemic unknown. Inhalation per U. S. Department of Labor - 2×10^6 particles per cubic foot of air maximum permissible.

MATERIAL IDENTIFICATION: SOM-10

CHEMICAL--PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Cationic asbestos.

SPECIFIC GRAVITY: 2.45.
FLASH POINT: None.
ICC CLASS: Not reported.
VISCOSITY: Not applicable.
MISCIBILITY: None.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Infinite.

COST: 7.0 cents per pound for orders of less than 1600 lb, FOB King City, California. Packaged in 40-lb bags. Pallet weight 1600 lb. Available at slightly reduced rates for orders greater than 1600 lb.

DOSAGE RATE: By manufacturer - 10 to 15% of the weight of oil.

APPLICATION METHOD: By manufacturer - add directly to the oil-contaminated waste water with enough agitation to assure adequate contact. The asbestos/oil agglomerates can then be removed by skimming, straining, or sedimentation.

AVAILABILITY: 1000-ton inventory at King City, California; 50 tons/day production rate possible upon 24-hr notice.

USE RECOMMENDATIONS AND LIMITATIONS: By manufacturer - recommended for open sea, bay, harbor, estuary, and shore for Bunker C, fresh or weathered crude, and distillate fuels. No limits on temperature or sea state. Should be applied prior to dispersant and surfactants. Agglomerated oil does not float.

SPILL EXPERIENCE: By manufacturer - no spill experience to date. Laboratory tests and limited field tests have been conducted.

EFFECTIVENESS: By manufacturer - 100% - instantaneous reaction when contacting fresh oil surface, increases to several minutes through oil-water interface.

TOXICITY: By manufacturer - for operators - per Sax "Dangerous Properties of Industrial Materials," 2d edition, acute local, irritant slight, inhalation moderate; acute systemic none; chronic local, inhalation high; chronic systemic unknown. Inhalation per U. S. Department of Labor - 2 x 10^{6} particles per cubic foot of air maximum permissible.

MATERIAL IDENTIFICATION: SOM-11

CHEMICAL-PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Hydrated magnesium aluminum silicate.

SPECIFIC GRAVITY: Bulk density - 27 to 33 pcf.
FLASH POINT: None.
ICC CLASS: Not reported.
VISCOSITY: Not applicable (dry granular product).
MISCIBILITY: Insoluble.
SOLVENT COMPATIBILITY: Inert and insoluble.
SHELF LIFE: No limit.

COST: $50 per ton in truckload lots, $33.25 to $37.25 per ton in carload lots (60,000 lb), FOB Meigs, Georgia.

DOSAGE RATE: By manufacturer - 1:1 to 1:3 agent to oil by weight.

APPLICATION METHOD: By manufacturer - apply by dusters. No agitation required. After absorption is complete, mixture of clay and oil on water will sink on slight agitation or addition of surfactant. For beach cleaning, sprinkle on beach to absorb deposited oil; remove and dispose of oil-soaked clay. Reaction time - not reported.

AVAILABILITY: Inventory - 500 tons at Meigs, Georgia. Production of 10 tons/hr possible at Meigs. Available in different mesh sizes.

USE RECOMMENDATIONS AND LIMITATIONS: By manufacturer - recommended for open sea, bay, harbor, estuary, and shore for use on Bunker C, fresh and weathered crudes, and distillate fuels, as a sorbent, sinking agent, and beach cleaner. Stable under all temperature conditions for storage.

SPILL EXPERIENCE: By manufacturer - laboratory tests have been performed. No spill experience reported.

EFFECTIVENESS: By manufacturer - one part of agent by weight will absorb 1 to 3 parts of oil.

TOXICITY:
By manufacturer -
For operators - completely nontoxic and nonhazardous.
For marine life - nontoxic.

MATERIAL IDENTIFICATION: SOM-12

CHEMICAL–PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Naturally occurring montmorillonite and palygorskite.

SPECIFIC GRAVITY: Bulk density - 27 to 40 pcf.
FLASH POINT: None.
ICC CLASS: Not reported.
VISCOSITY: Not applicable (dry granular product).
MISCIBILITY: Insoluble.
SOLVENT COMPATIBILITY: Good.
SHELF LIFE: No limit.

COST: Not reported. (Estimated $20 per ton.)

DOSAGE RATE: By manufacturer - 1:1 to 1:3 agent to oil by weight.

APPLICATION METHOD: By manufacturer - apply by dusters. No agitation required. After absorption is complete, mixture of clay and oil on water will sink on slight agitation or addition of surfactant. For beach cleaning, sprinkle on beach to absorb deposited oil; remove and dispose of oil-soaked clay. Reaction time - not reported.

AVAILABILITY: Inventory - 500 tons at Meigs, Georgia. Production of 10 tons/hr possible at Meigs. Available in different mesh sizes.

USE RECOMMENDATIONS AND LIMITATIONS: By manufacturer - recommended for open sea, bay, harbor, estuary, and shore for use on Bunker C, fresh and weathered crudes, and distillate fuels, as a sorbent, sinking agent, and beach cleaner. Stable under all temperature conditions for storage.

SPILL EXPERIENCE: By manufacturer - laboratory tests have been performed. No spill experience reported.

EFFECTIVENESS: By manufacturer - one part of agent by weight will absorb 1 to 3 parts of oil.

TOXICITY:
By manufacturer -
For operators - completely nontoxic and nonhazardous.
For marine life - nontoxic.

MATERIAL IDENTIFICATION: SOM-13

CHEMICAL--PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Carbonized, chemically coated sand.

SPECIFIC GRAVITY: 2.60; bulk density 1.468 g/cc.
FLASH POINT: None. Will not ignite.
ICC CLASS: Chemical NOI.
VISCOSITY: Dry solids.
MISCIBILITY: Hydrophobic.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Indefinite.

COST: By manufacturer - $3.75 per 100 lb, or $75 to $80 per ton.

DOSAGE RATE: By manufacturer - 2 to 3 parts of agent to 1 part of oil for all types of oil.

APPLICATION METHOD: By manufacturer - variable pressure apparatus; for example, for thin oil films a near zero velocity application such as dusting gives better results, whereas for thicker layers a higher velocity application from an air hose or sandblaster apparatus seems to be more suitable.

AVAILABILITY: Will be available by Jan 1, 1971.

USE RECOMMENDATIONS AND LIMITATIONS: By manufacturer - material will sink all types of oil in fresh or salt water. It is more efficient, however, in sinking the more viscous oils such as crude and bunker.

SPILL EXPERIENCE: No large spill experience to date.

EFFECTIVENESS: By manufacturer - 100% effective in sinking and holding oil when applied properly. Material which does not contact visible oil is wasted.

TOXICITY: Nontoxic.

MATERIAL IDENTIFICATION: SOM-14

CHEMICAL-PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Fly ash treated with chlorosilane residue, then neutralized.

SPECIFIC GRAVITY: Bulk density: 0.9 g/cc.
FLASH POINT: Not applicable.
ICC CLASS: None.
VISCOSITY: Not applicable.
MISCIBILITY: Not applicable.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Unlimited.

COST: Not reported. (Estimated $100 per ton.)

DOSAGE RATE: 1:0.5 to 1:0.9 agent to oil by weight.

APPLICATION METHOD: Any method that will apply the material dry.

AVAILABILITY: Unlimited with pilot plant for surface treatment.

USE RECOMMENDATIONS AND LIMITATIONS: No limitations.

SPILL EXPERIENCE: Not reported.

EFFECTIVENESS: Not reported.

TOXICITY: Unknown.

MATERIAL IDENTIFICATION: SOM-15

CHEMICAL--PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Fly ash treated with Dow Corning 120g Silane, then neutralized.

SPECIFIC GRAVITY: Bulk density: 0.83 g/cc.
FLASH POINT: Not applicable.
ICC CLASS: None.
VISCOSITY: Not applicable.
MISCIBILITY: Not applicable.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Unlimited.

COST: Not reported. (Estimated $100 per ton.)

DOSAGE RATE: Approximately 1:0.5 agent to oil by weight.

APPLICATION METHOD: Any method that will apply the material dry.

AVAILABILITY: Unlimited with pilot plant for surface treatment.

USE RECOMMENDATIONS AND LIMITATIONS: No limitation.

SPILL EXPERIENCE: None.

EFFECTIVENESS: Not reported.

TOXICITY: Unknown.

MATERIAL IDENTIFICATION: SOX-16

CHEMICAL PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Sand treated with Dow Corning 120g Silane, then neutralized.

SPECIFIC GRAVITY: Bulk density: 1.46 g/cc.
FLASH POINT: Not applicable.
ICC CLASS: None.
VISCOSITY: Not applicable.
MISCIBILITY: Not applicable.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Unlimited.

COST: Not reported. (Estimated $75 per ton.)

DOSAGE RATE: Approximately 1:0.5 agent to oil by weight.

APPLICATION METHOD: Any method that will apply the material dry.

AVAILABILITY: Unlimited with pilot plant for surface treatment.

USE RECOMMENDATIONS AND LIMITATIONS: No limitations.

SPILL EXPERIENCE: Not reported.

EFFECTIVENESS: Not reported.

TOXICITY: Unknown.

MATERIAL IDENTIFICATION: SOM-17

CHEMICAL-PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: Cement byproduct, major ingredients SiO_2 (13.41%) and CaO (51.3%).
SPECIFIC GRAVITY: Bulk density: 50 pcf
FLASH POINT: Not applicable.
ICC CLASS: None.
VISCOSITY: Not applicable.
MISCIBILITY: Not applicable.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: At least 1 yr in steel silo.

COST: Not reported. (Estimated $100 per ton.)

DOSAGE RATE: Not reported.

APPLICATION METHOD: Any method that will apply the material dry.

AVAILABILITY: Unlimited.

USE RECOMMENDATIONS AND LIMITATIONS: No limitations.

SPILL EXPERIENCE: Used in small moat contaminated with diesel fuel with good results. Twelve mallard ducks and a moorhen heavily coated with diesel fuel were cleaned using the dry material to remove oil from feathers. Results were excellent.

EFFECTIVENESS: Not reported.

TOXICITY: Nontoxic.

MATERIAL IDENTIFICATION: SOM-18

CHEMICAL–PHYSICAL PROPERTIES:

- **CHEMICAL COMPOSITION:** Major ingredient - kaolinite; remainder - amorphous silica (beta-crystobalite).
- **SPECIFIC GRAVITY:** Not reported.
- **FLASH POINT:** Not applicable.
- **ICC CLASS:** Crude clay.
- **VISCOSITY:** Not applicable.
- **MISCIBILITY:** Insoluble in water.
- **SOLVENT COMPATIBILITY:** Not applicable.
- **SHELF LIFE:** Unlimited.

COST: $58 per ton, 50-lb bags, FOB Socorro, New Mexico.

DOSAGE RATE: By manufacturer - 2.5:1 agent to oil by weight.

APPLICATION METHOD: By manufacturer - apply by any method that will uniformly spread the material on the surface of the floating oil. A method using air spray has been developed. Reaction time - immediate.

AVAILABILITY: Inventory quantity - 50,000 tons in New Mexico. Production rate of 75 tons/day - can be expanded to meet demand.

USE RECOMMENDATIONS AND LIMITATIONS: By manufacturer - recommended for open sea, bay, harbor, estuary, and shore on Bunker C, fresh and weathered crudes, and distillate fuels, under any conditions of temperature and sea state. Store to protect bags from rain.

SPILL EXPERIENCE: By manufacturer - successfully tested by Union Oil on Santa Barbara oil slick in May 1969.

EFFECTIVENESS: By manufacturer - observations during bioassay test for manufacturer indicate that at 2.5:1 and 4:1 dosages (agent to oil by weight), most oil settled. Some floating oil remained. At 6:1 and 8:1, nearly all oil settled; however, some oil returned to the surface.

TOXICITY:

By manufacturer -
For operators - no limit, nontoxic.
For marine life - nontoxic.

By others -
Cook Research Laboratories, Inc., work indicates:

a. Up to 4 g of SOM-18 per liter of water produced 100% survival of (Fundulus) fish using standard methods and FWPCA interim toxicity procedures.
b. Tests with SOM-18 and oils (#2 fuel oil, #6 fuel oil, West Texas crude, and Santa Barbara Channel crude) indicated at least 80% survival of Fundulus in 24-, 48-, and 96-hr standard methods and FWPCA interim toxicity procedures tests.

Tests performed by Pacific Engineering Laboratory for the manufacturer indicate LD50 using standard methods and FWPCA tests were inconclusive. It was stated that neither SOM-18 alone nor with oil indicated a high degree of toxicity.

MATERIAL IDENTIFICATION: SOM-19

CHEMICAL–PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: SiO_2 particles rendered oleophilic with proprietary treatment.

SPECIFIC GRAVITY: 2.65.
FLASH POINT: Does not burn and will extinguish fire.
ICC CLASS:
VISCOSITY:
MISCIBILITY: Insoluble in water.
SOLVENT COMPATIBILITY:
SHELF LIFE: Indefinite.

COST: FOB plant, approximately $0.0179 per lb in 100-lb bags palletized and loaded in railroad boxcars. FOB Baltimore, Md., approximately $0.0227 per lb in 50-ton lots.

DOSAGE RATE: Varies between 1:1 to 4.7:1 parts adsorbent to oil by volume depending upon rate of application, application method, type of oil, and temperatures.

APPLICATION METHOD: For most effective removal, slow continuous feeding of the oil slick through a system of tubes is recommended. Material may also be applied via a sieve or direct pour.

AVAILABILITY: 100,000-lb carloads available from receipt of order. Small quantities available immediately.

USE RECOMMENDATIONS AND LIMITATIONS: Recommended for removal of oil from the sea by sinking or for removal of oil from harbors, bays, and open sea in conjunction with the manufacturer's Sub-surface Recovery System.

SPILL EXPERIENCE: Laboratory models only.

EFFECTIVENESS: The material is 95 to 100% effective on light and medium-viscosity oils. Removal is immediate. On very heavy oils, removal takes more time and repeated application may be necessary.

TOXICITY: No known toxicity.

MATERIAL IDENTIFICATION: SOM-20

CHEMICAL-PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: SiO_2 particles with proprietary treatment including water.

SPECIFIC GRAVITY: 2.65.
FLASH POINT: Does not burn and will extinguish fire.
ICC CLASS:
VISCOSITY: Approximately 60 to 80 seconds in H_2O slurry tested on #4 Ford Cup at 72 F.
MISCIBILITY: Insoluble in water.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Indefinite.

COST: FOB plant, approximately $0.0179 per lb in 100-lb bags palletized and loaded in railroad boxcars. Railroad boxcars have 50-ton minimum freight charge. FOB Baltimore, Md., approximately $0.0227 per lb in 50-ton lots.

DOSAGE RATE: Varies between 1.4:1 to 4.5:1 parts slurry to oil by weight depending upon rate of application, application method, type of oil, and temperatures. Thick oils require less slurry.

APPLICATION METHOD: Add fresh or salt water in ratio of 1 part water to 4 parts SOM-20 and mix until pastelike consistency obtained. Spray slurry onto oil slick.

AVAILABILITY: Plant presently available for production.

USE RECOMMENDATIONS AND LIMITATIONS: This material is most ideally suited for use in conjunction with the manufacturer's Sub-surface Recovery System. The material enables oil to be transformed from a slick floating on the surface to balls of oil coated with an encapsulating blanket of white sand particles. The blanket of sand around each ball of oil not only contains the oil but increases the weight sufficiently to allow gravity to pull the oil into a subsurface containment bin or to the bottom of the ocean.

SPILL EXPERIENCE: Laboratory models only.

EFFECTIVENESS: The slurry system is more effective with heavy oils than light oils. It is also more effective on thick layers of oil than on extremely thin layers of oil.

TOXICITY: No known toxicity.

MATERIAL IDENTIFICATION: SOM-21

CHEMICAL--PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: SiO_2 particles rendered oleophilic by proprietary treatment.

SPECIFIC GRAVITY: 2.65.
FLASH POINT: Does not burn and will extinguish fire.
ICC CLASS:
VISCOSITY: Not applicable.
MISCIBILITY: Insoluble in water.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Not definite.

COST: FOB plant, approximately $0.02 per lb in 100-lb bags palletized and loaded in railroad boxcars. Railroad boxcars have 50-ton minimum freight charge.

DOSAGE RATE: Dosage varies between 1:1 to 5:1 parts adsorbent to oil by volume depending upon rate of application, application method, types of oil, and temperature.

APPLICATION METHOD: For most effective removal, slow continuous feeding of the oil slick through a system of tubes is recommended. Material may also be applied via a sieve or direct pour.

AVAILABILITY: 100,000-lb carloads available 2 weeks from receipt of order. Small quantities available immediately.

USE RECOMMENDATIONS AND LIMITATIONS: Recommended for removal of oil from the sea by sinking or for removal of oil from harbors, bays, and open sea in conjunction with the manufacturer's Sub-surface Recovery System.

SPILL EXPERIENCE: Laboratory models only.

EFFECTIVENESS: Material is 95 to 100% effective on light and medium-viscosity oils. Removal is is immediate. On very heavy oils, removal takes more time and repeated applications may be necessary.

TOXICITY: No known toxicity.

MATERIAL IDENTIFICATION: SOM-22

CHEMICAL--PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: SiO_2 particles rendered oleophilic by proprietary treatment.

SPECIFIC GRAVITY: 2.65.
FLASH POINT: Does not burn and will suffocate fire.
ICC CLASS:
VISCOSITY: Not applicable.
MISCIBILITY: Insoluble in water.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Indefinite.

COST: Undetermined. (Estimated $75 per ton.)

DOSAGE RATE: Dosage varies between 1:1 to 2:1 parts adsorbent to oil by volume depending upon rate of application, application method, type of oil, and temperature.

APPLICATION METHOD: For most effective removal, slow continuous feeding of the oil slick through a system of tubes is recommended. Material may also be applied via a sieve or direct pour.

AVAILABILITY: At the present time this material is available on an experimental basis only.

USE RECOMMENDATIONS AND LIMITATIONS: Recommended for removal of oil from the sea by sinking or for removal of oil from harbors, bays, and open sea in conjunction with the manufacturer's Sub-surface Recovery System.

SPILL EXPERIENCE: Laboratory models only.

EFFECTIVENESS: Material is 95 to 100% effective on light and medium-viscosity oils. Removal is immediate. On very heavy oils, removal takes more time and repeated applications may be necessary.

TOXICITY: No known toxicity.

MATERIAL IDENTIFICATION: SOM-23

CHEMICAL—PHYSICAL PROPERTIES:

CHEMICAL COMPOSITION: SiO_2 particles rendered oleophilic by proprietary treatment.

SPECIFIC GRAVITY: 2.60.
FLASH POINT: Does not burn and will extinguish fire.
ICC CLASS:
VISCOSITY: Not applicable.
MISCIBILITY: Insoluble in water.
SOLVENT COMPATIBILITY: Not applicable.
SHELF LIFE: Indefinite.

COST: FOB plant, approximately $0.0279 per lb in 100-lb bags palletized and loaded in railroad boxcars.

DOSAGE RATE: Dosage varies between 0.8:1 to 3:1 parts adsorbent to oil by volume depending upon rate of application, application method, type of oil, and temperature.

APPLICATION METHOD: For most effective removal, slow continuous feeding of the oil slick through a system of tubes is recommended. Material may also be applied via a sieve or direct pour.

AVAILABILITY: This material has never been produced commercially but large production plant exists.

USE RECOMMENDATIONS AND LIMITATIONS: Recommended for removal of oil from the sea by sinking or for removal of oil from harbors, bays, and open sea by the manufacturer's Sub-surface Recovery System

SPILL EXPERIENCE: Laboratory models only.

EFFECTIVENESS: Material is 95 to 100% effective on light and medium-viscosity oils. Removal is immediate. On very heavy oils, removal takes more time and repeated application may be necessary.

TOXICITY: No known toxicity.

APPENDIX F: PHOTOGRAPHS SHOWING PARTICLE
SHAPES OF OIL SINKING MATERIALS

F-1A

Photo F1. Top: SOM-23, treated sand; bottom left: SOM-20, treated sand; and bottom right: SOM-2, treated chalk. Magnified ×10 for comparison

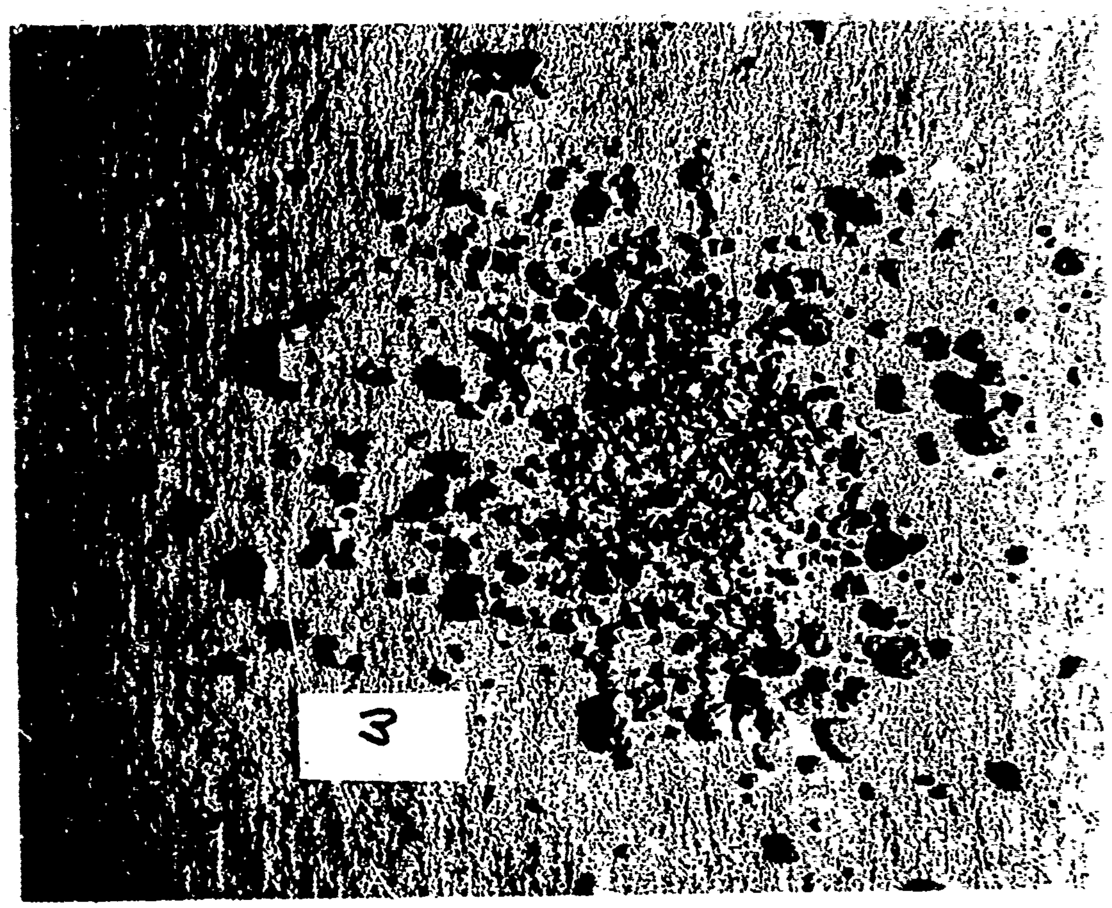


Photo F2. SOM-3, calcined clay, ×2

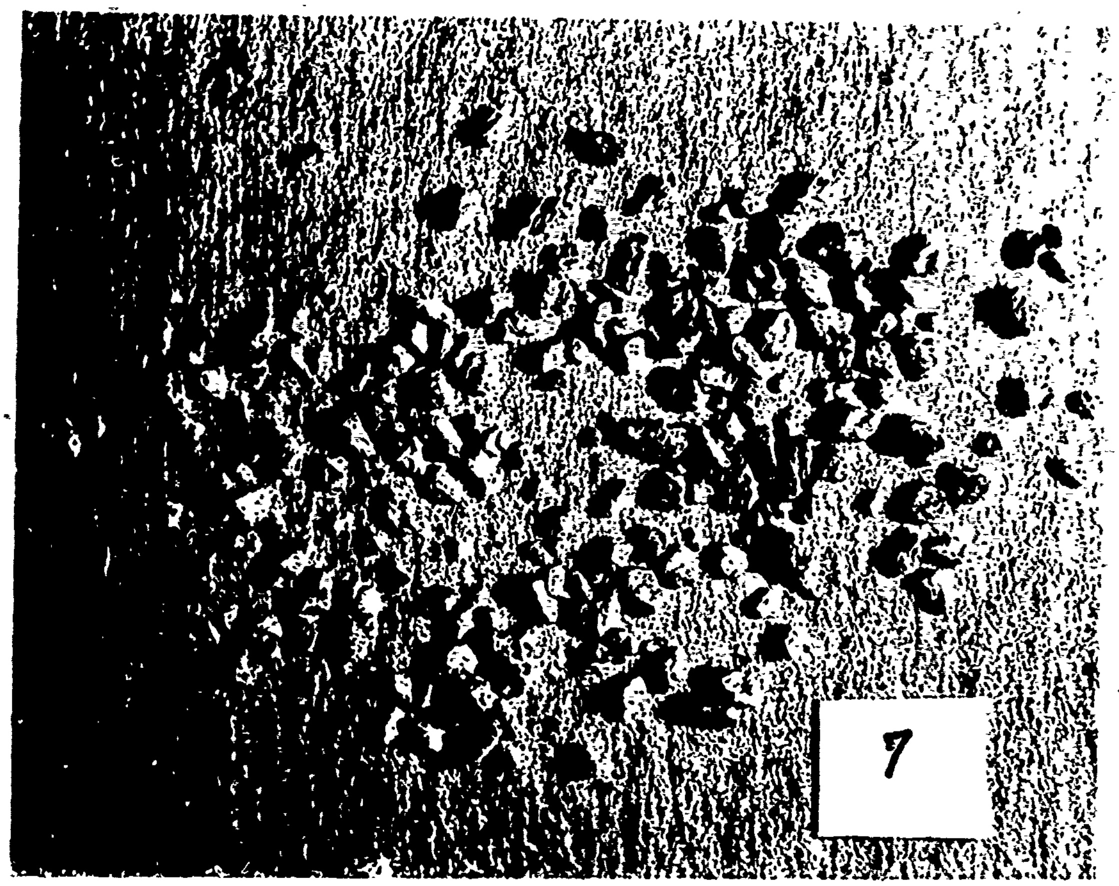


Photo F3. SOM-7, expansive clay, ×2

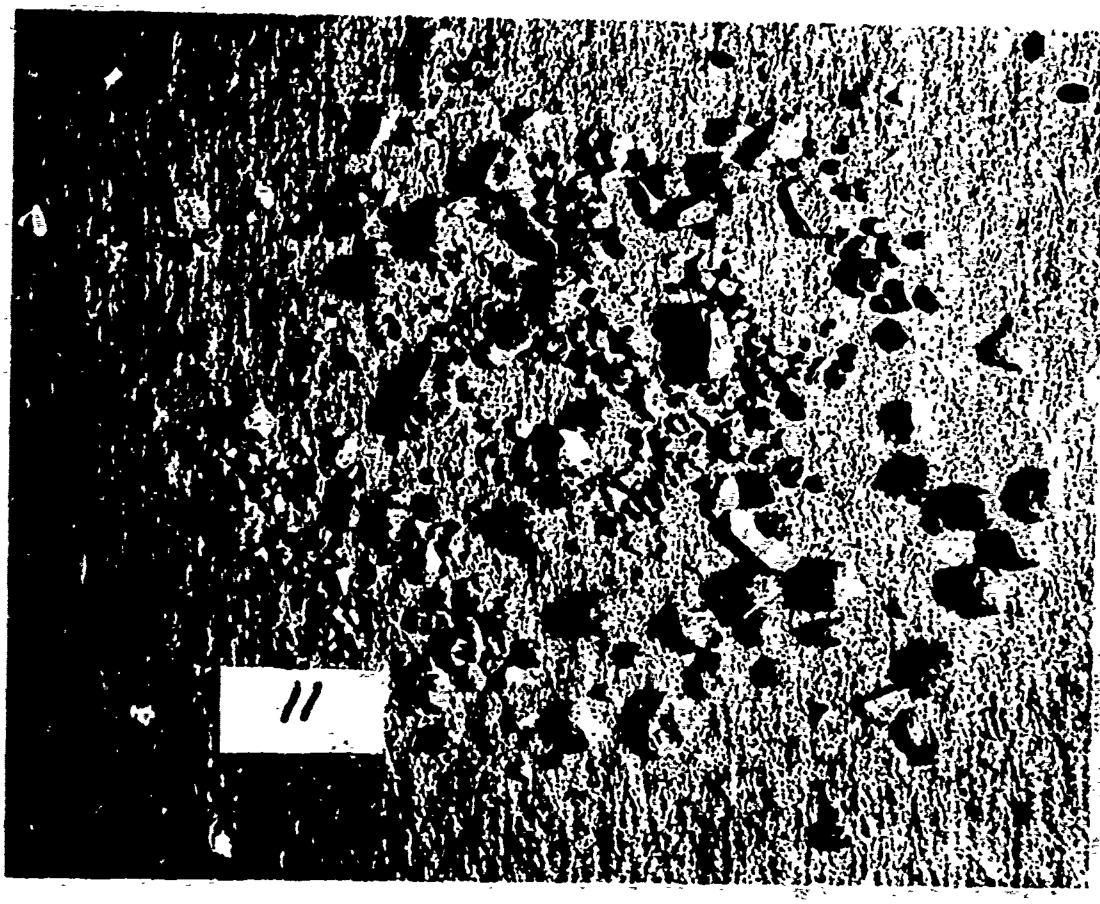


Photo F4. SOM-11, magnesium aluminum silicate, ×2

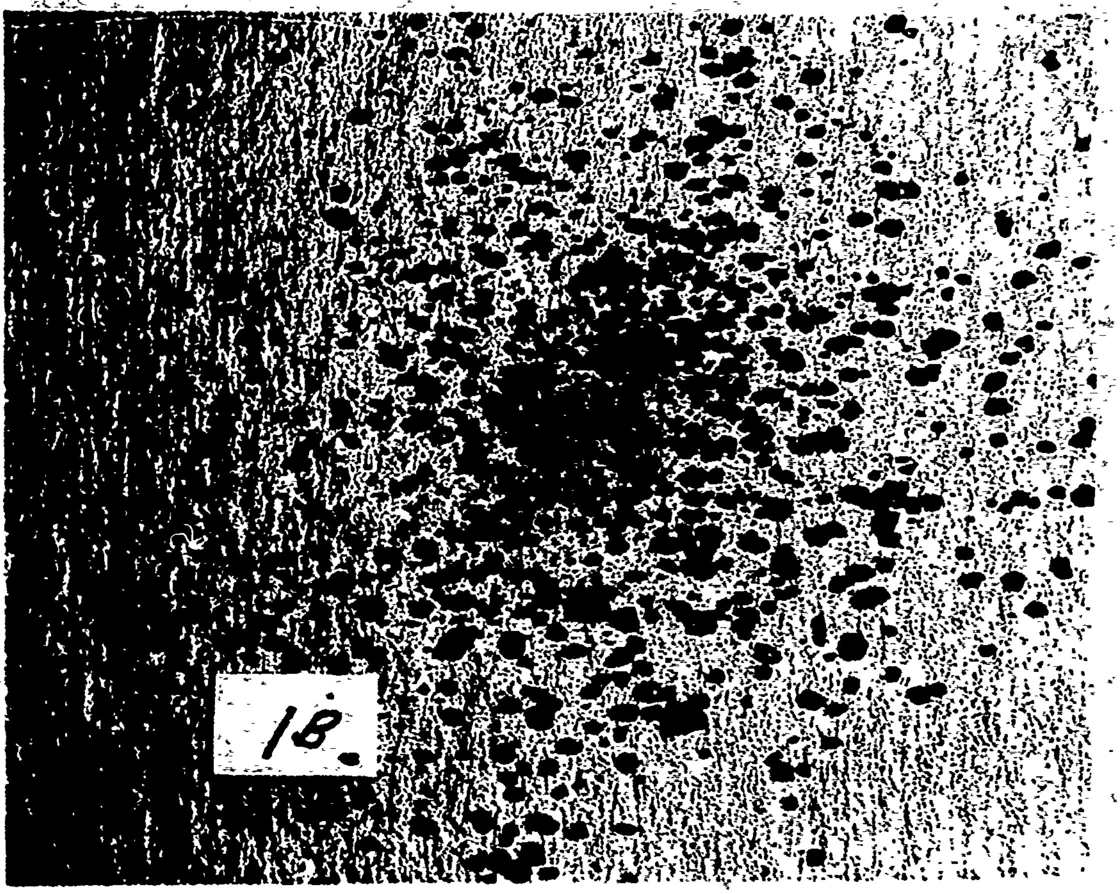


Photo F5. SOM-13, carbonized sand, ×2

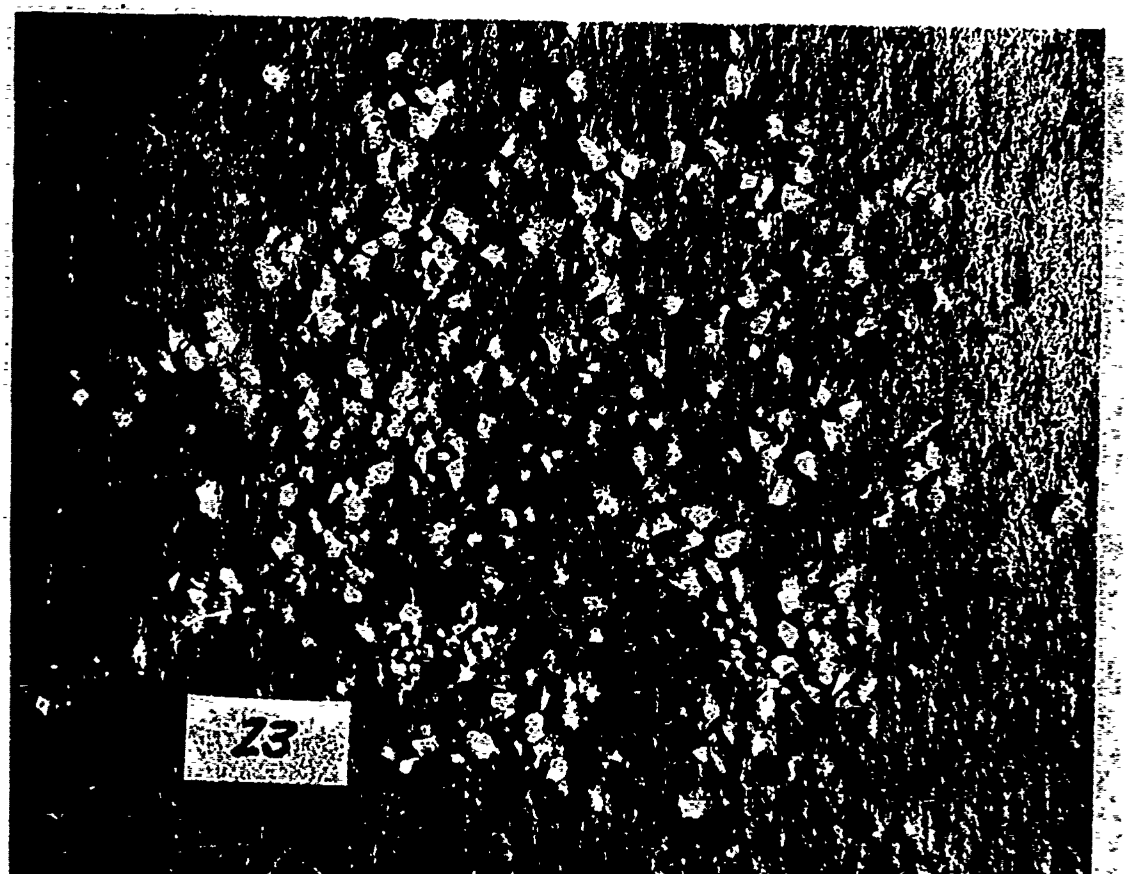


Photo F6. SOM-23, treated sand, ×2

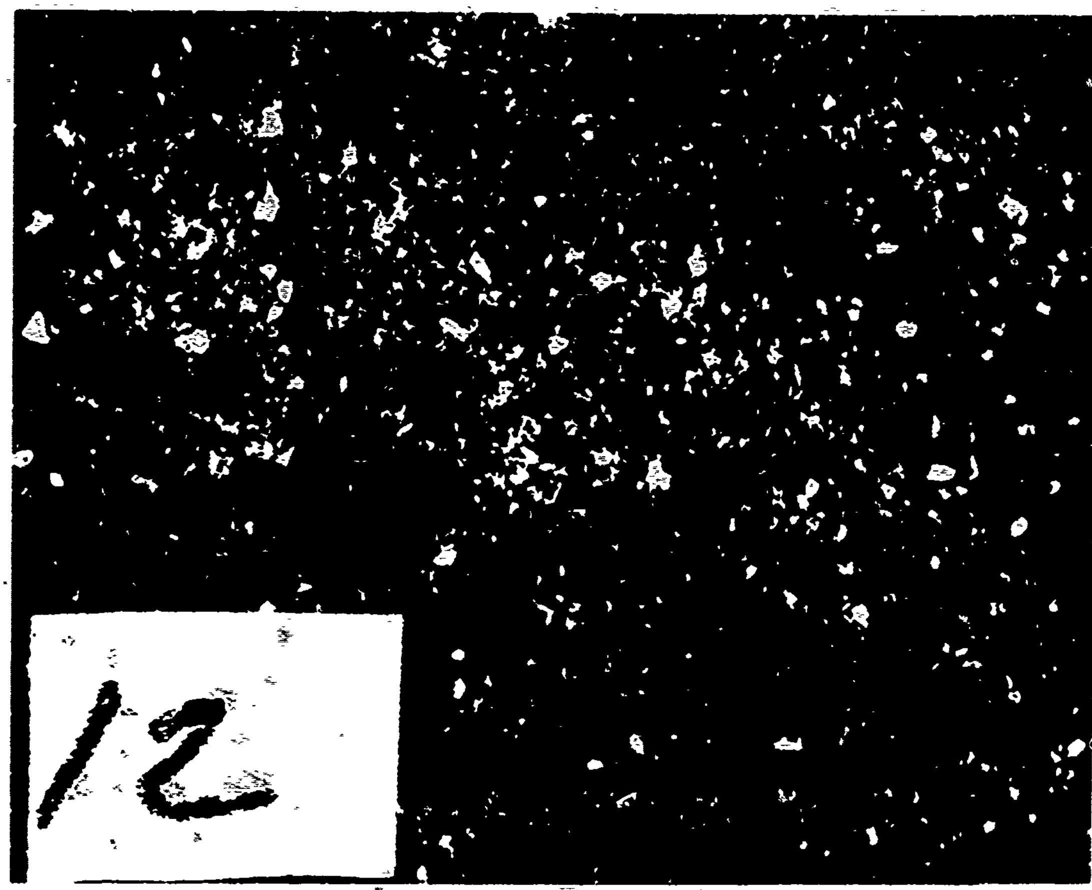


Photo F7. SOM-12, natural clay, ×10

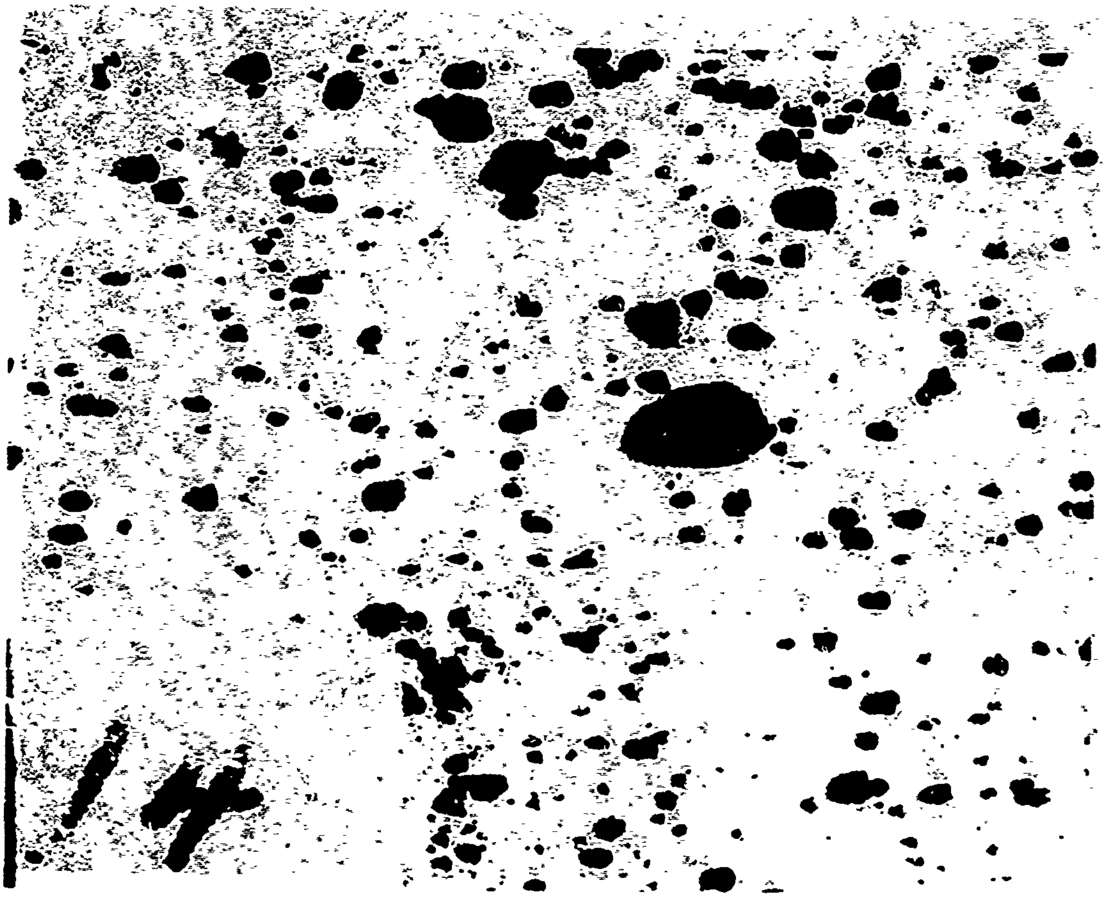


Photo F8. SOM-14, silicone treated fly ash, ×10

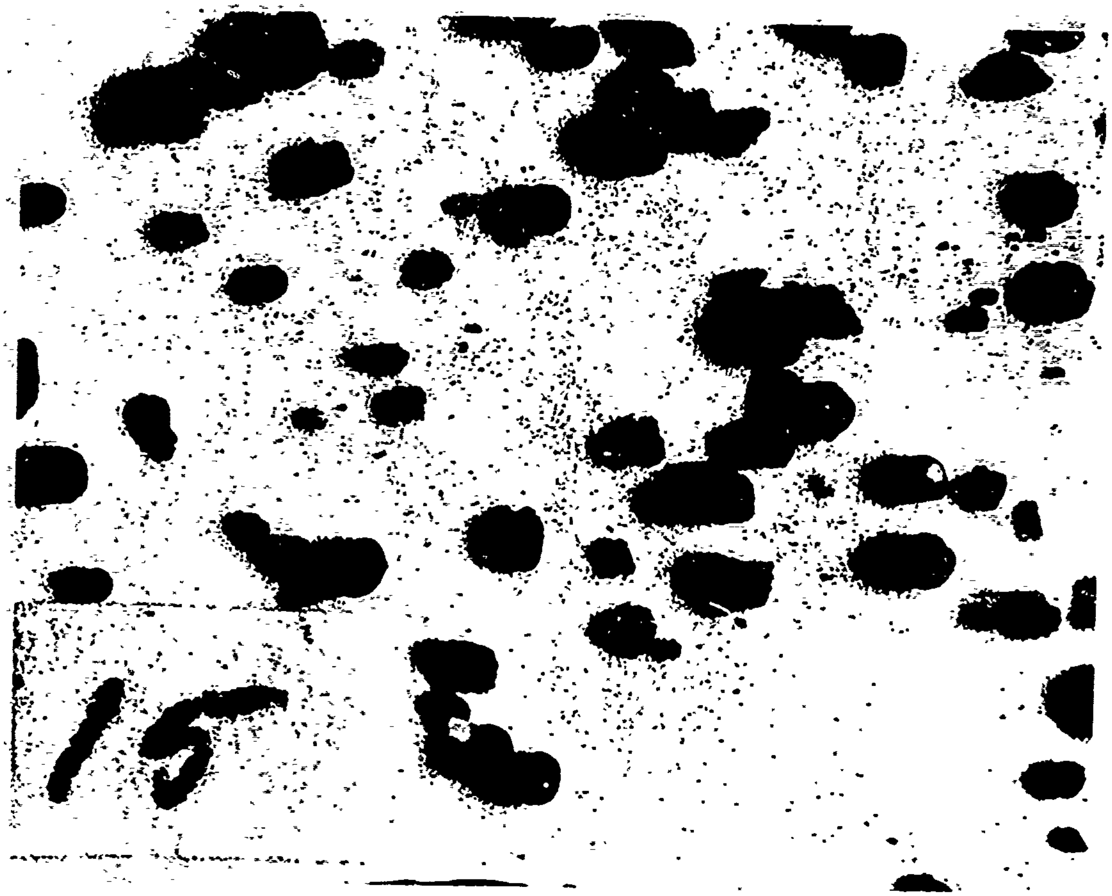


Photo F9. SOM-15, silicone treated fly ash, ×10

Photo F10. SOM-16, silicone treated sand, ×10

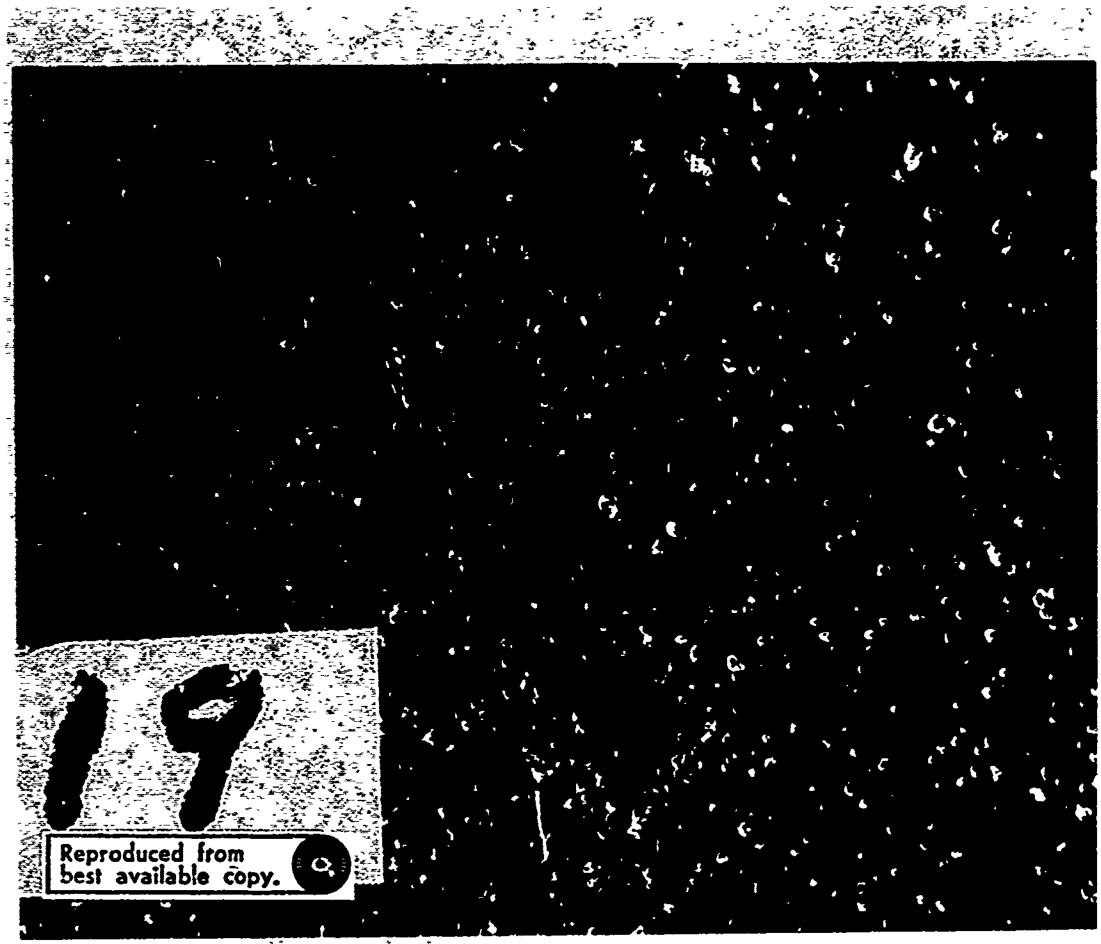


Photo F11. SOM-19, treated sand, ×10

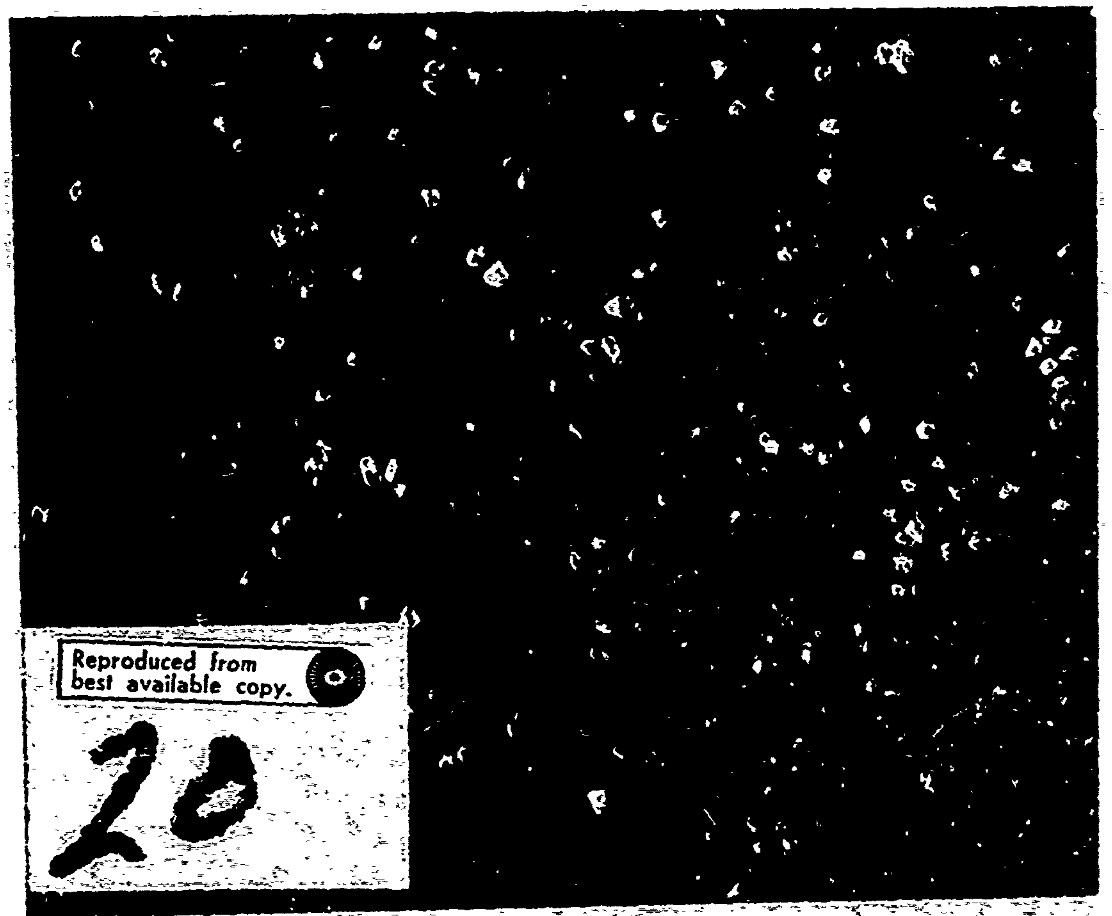


Photo F12. SOM-20, treated sand, ×10

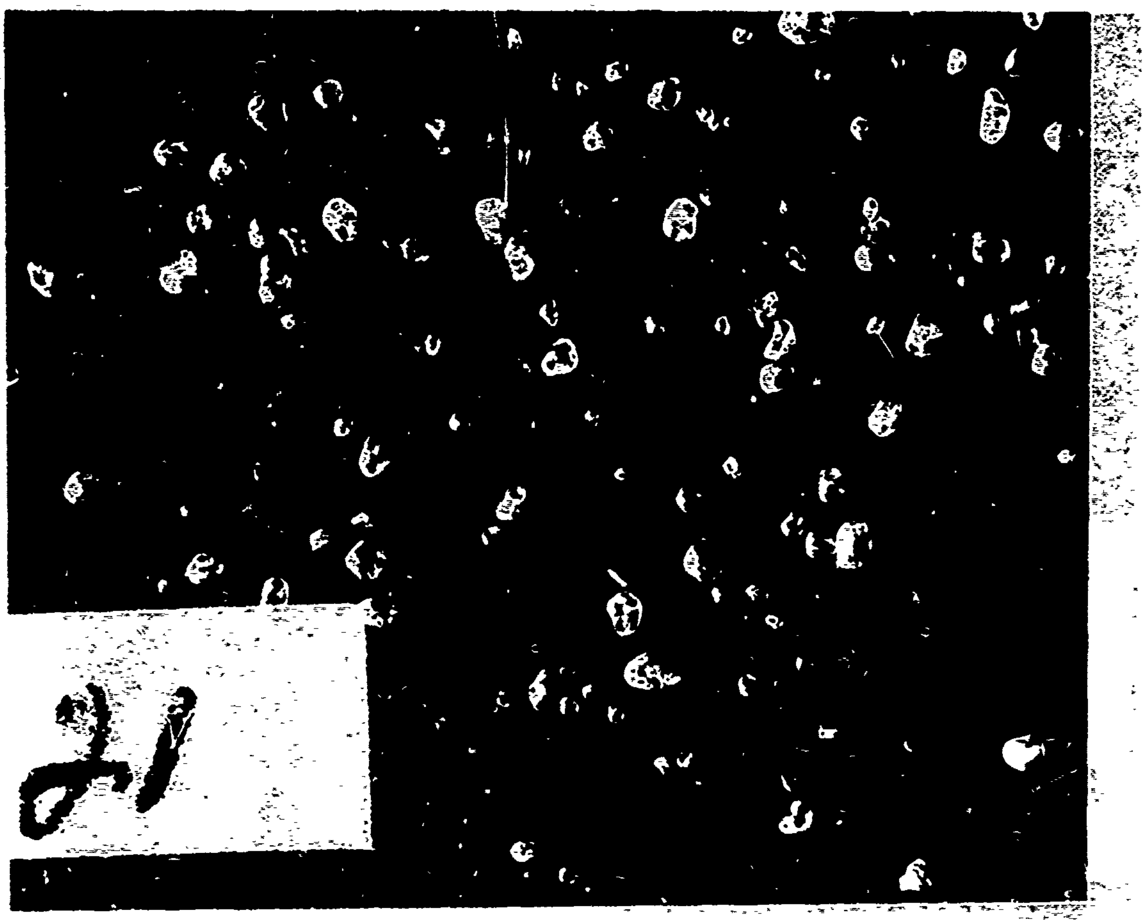


Photo F13. SOM-21, treated sand, ×10

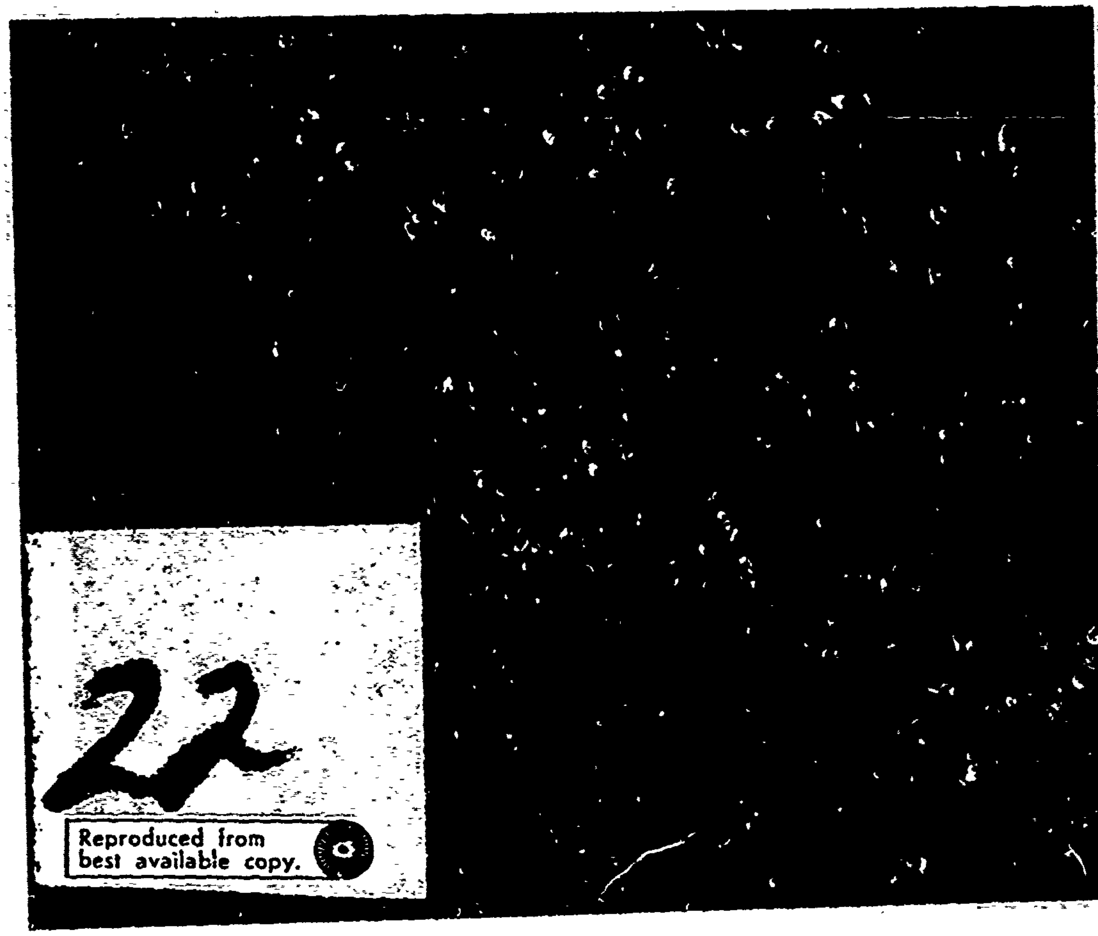


Photo F14. SOM-22, treated sand, ×10

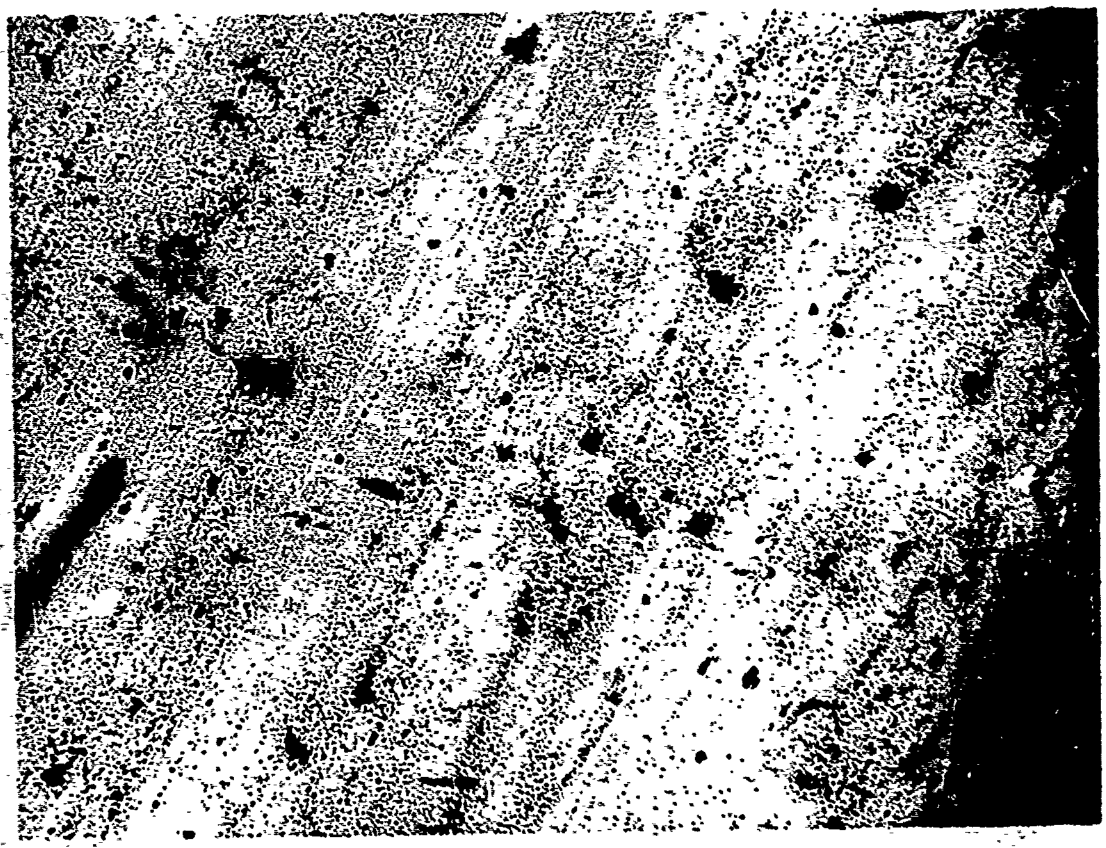


Photo F15. SOM-1, latex-coated barite, ×100

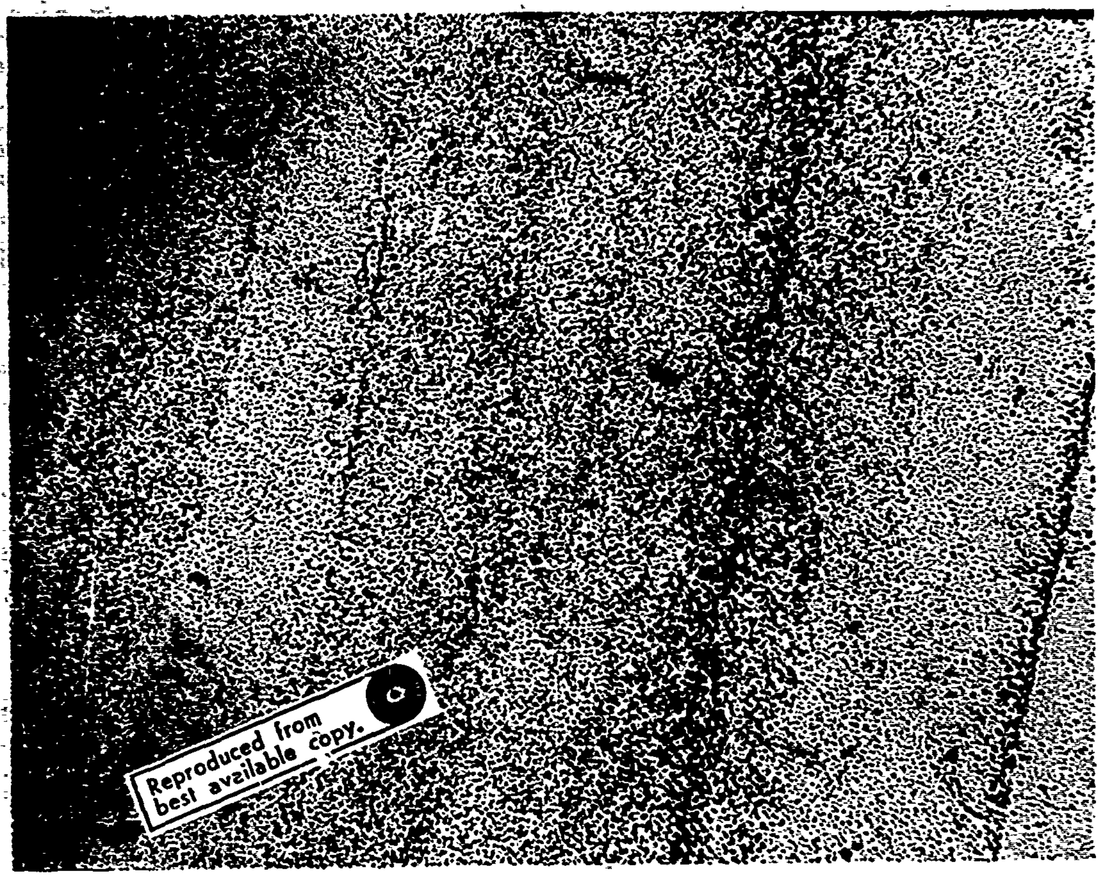


Photo F16. SOM-2, treated chalk, ×100

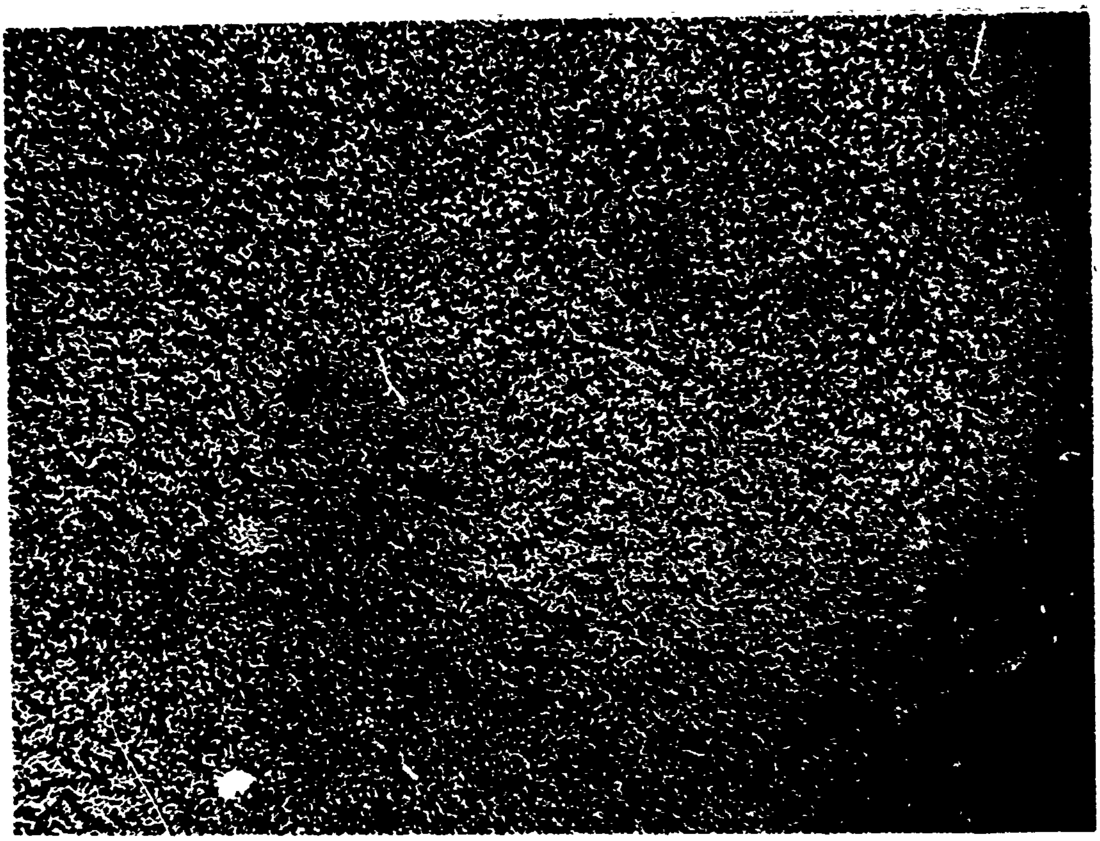


Photo F17. SOM-4, untreated talc, ×100

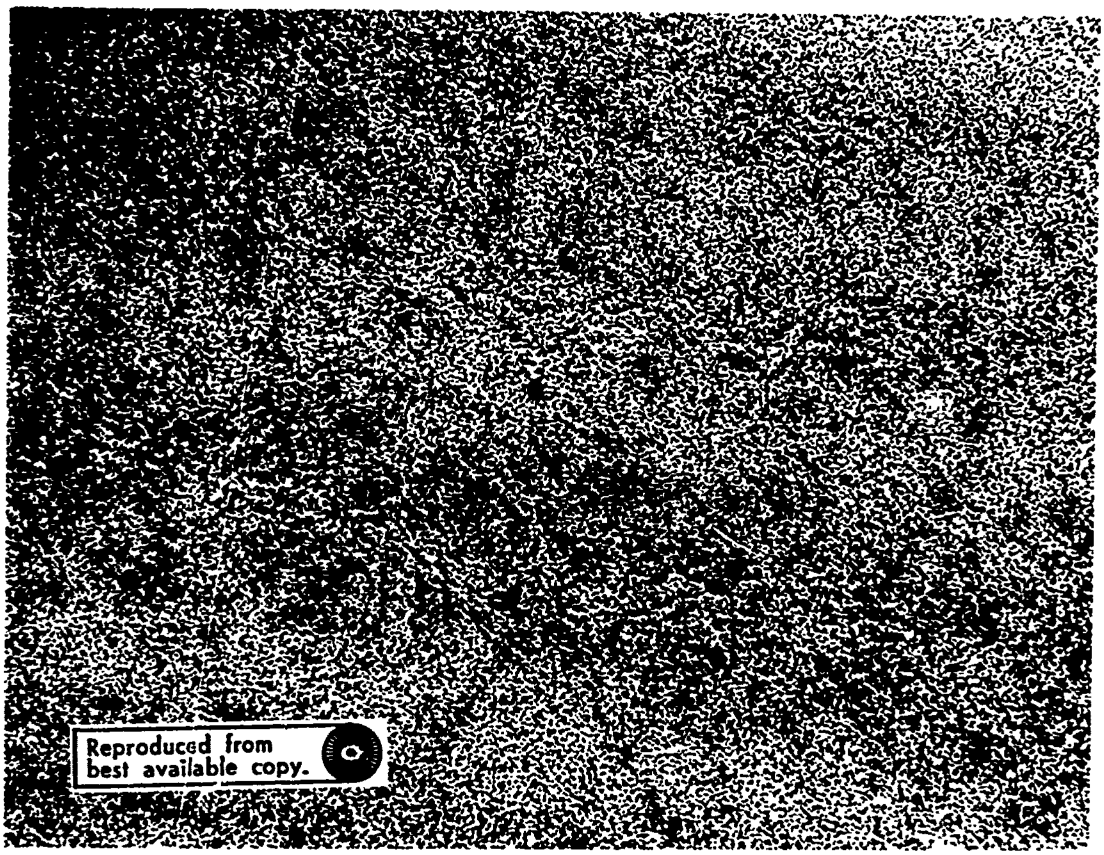


Photo F18. SOM-5, treated talc, ×100

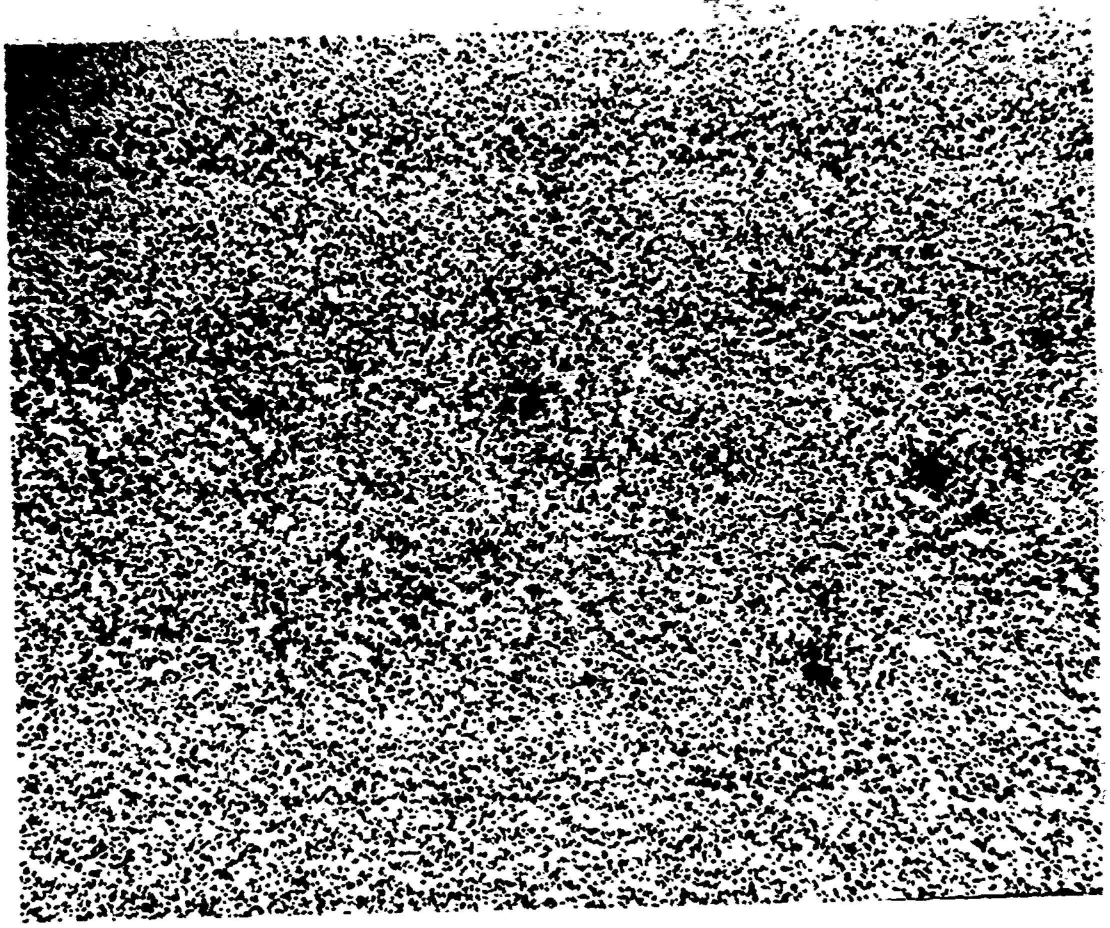


Photo F19. SOM-6, untreated talc, ×100

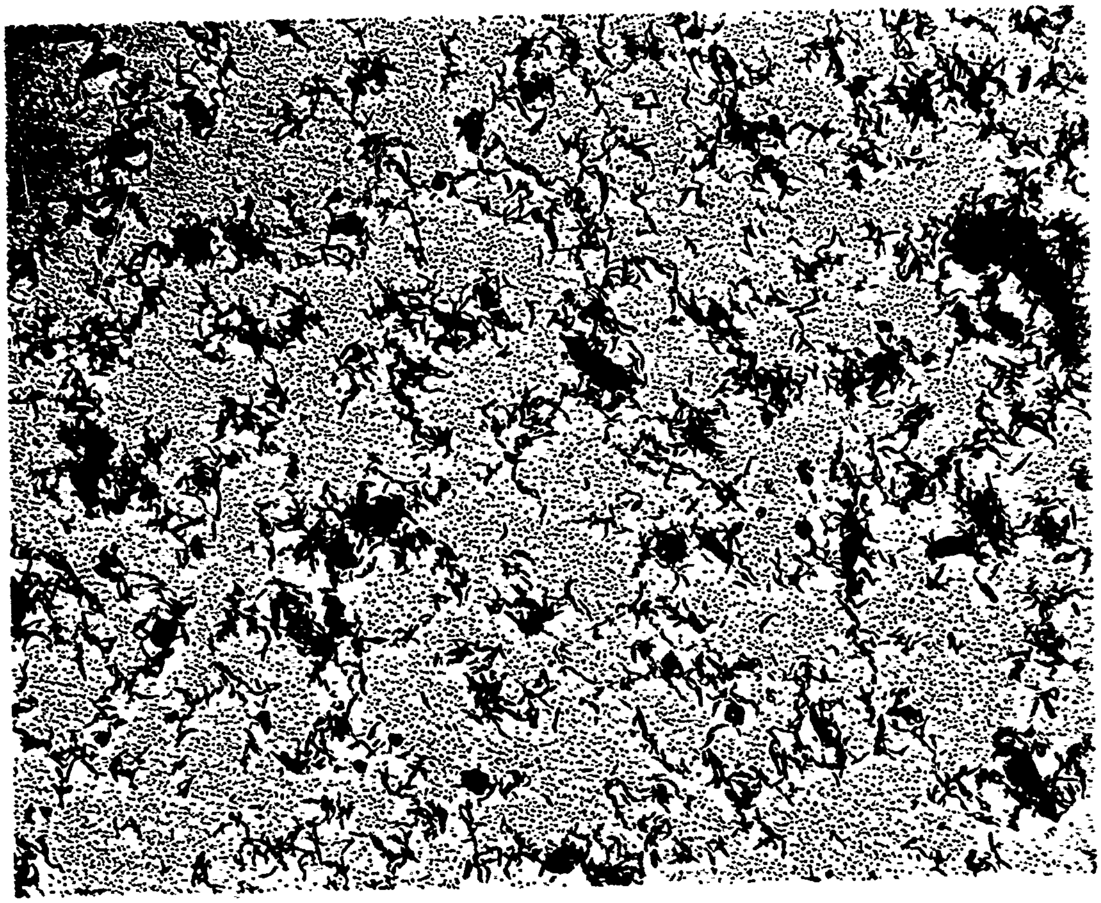


Photo F20. SOM-8, treated asbestos, ×100

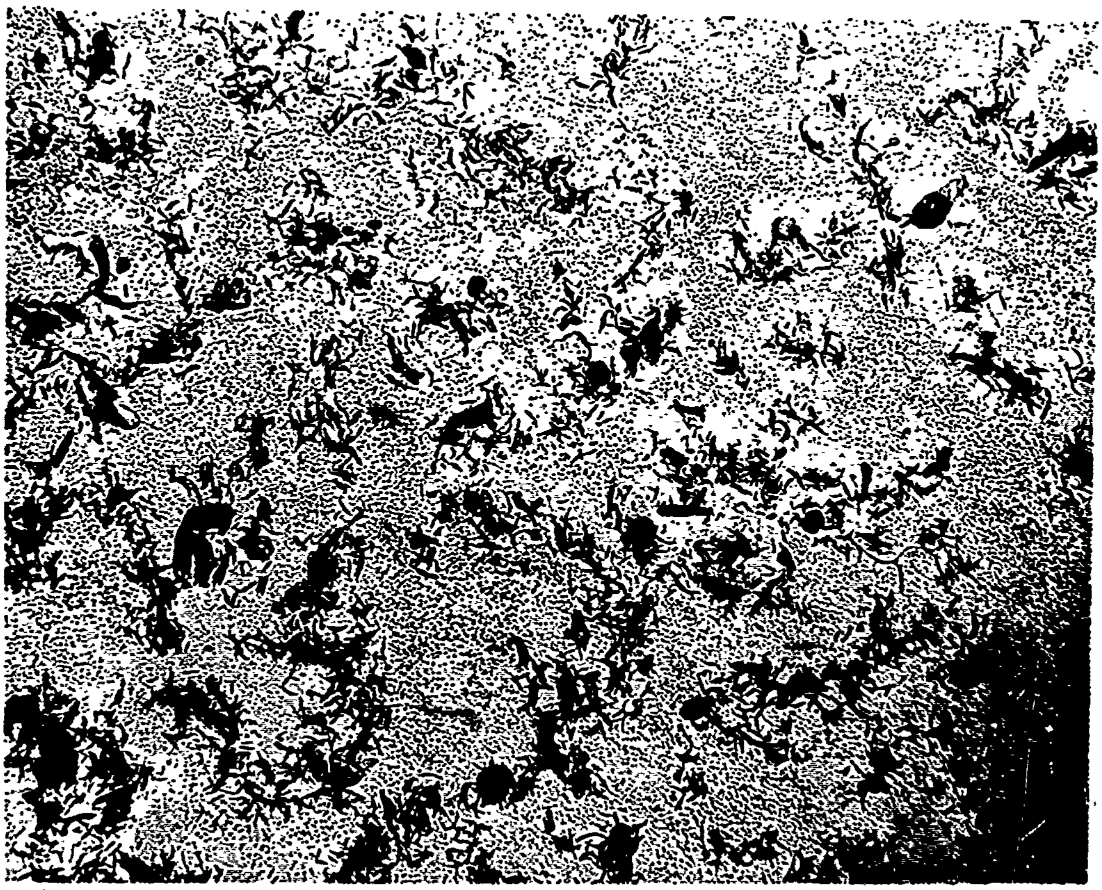


Photo F21. SOM-9, treated asbestos, ×100

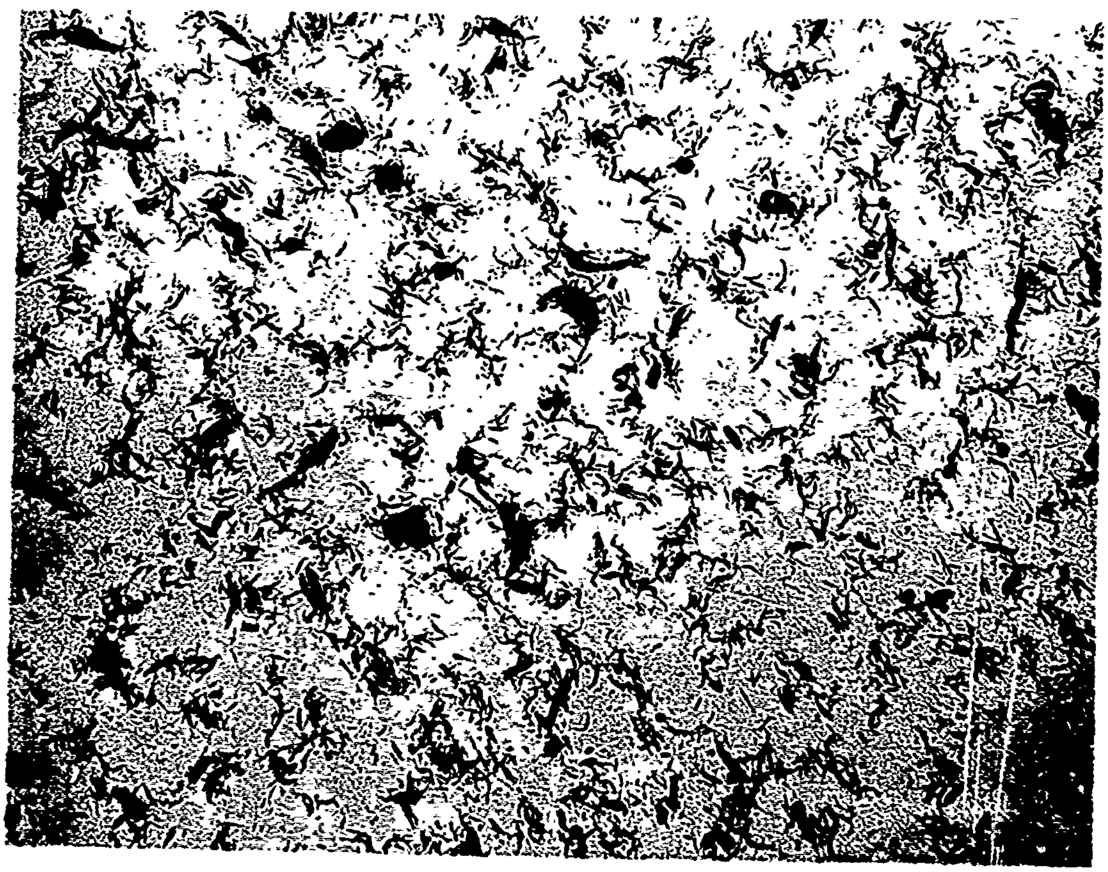


Photo F22. SOM-10, cationic asbestos, ×100

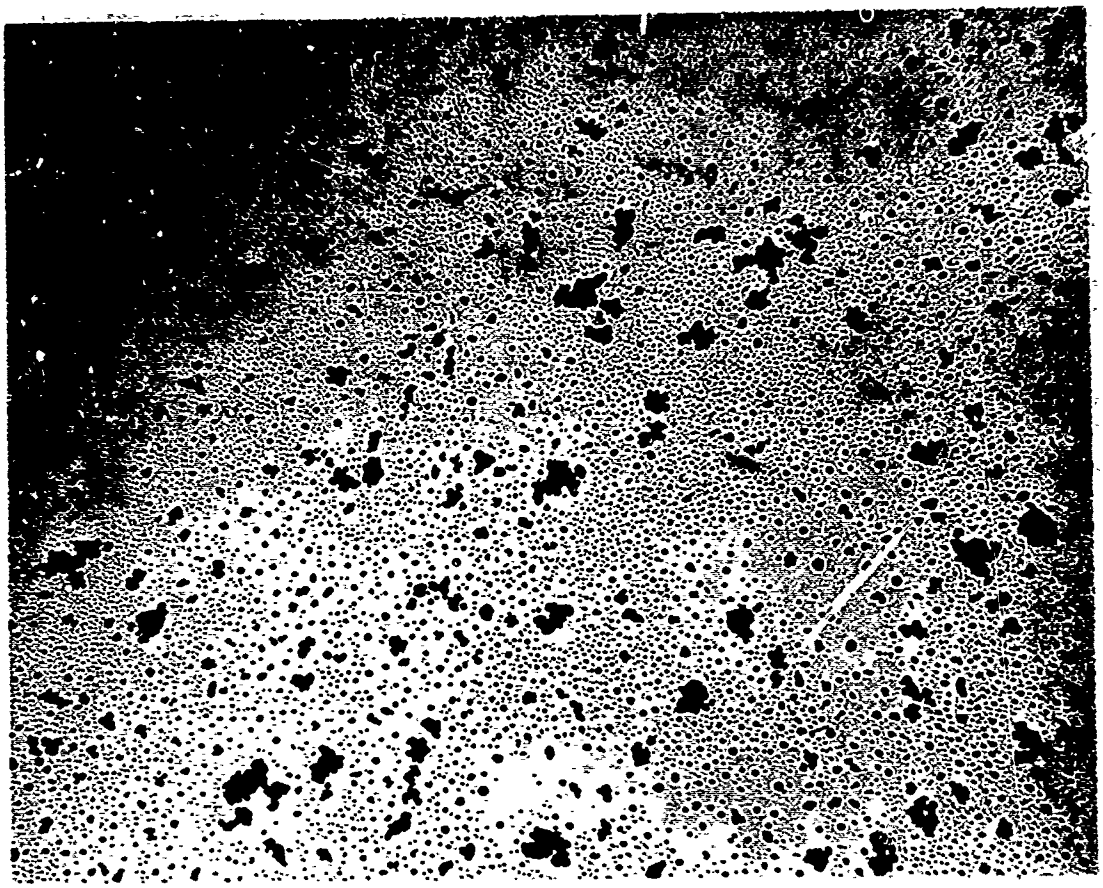


Photo F23. SOM-17, cement byproduct, ×100

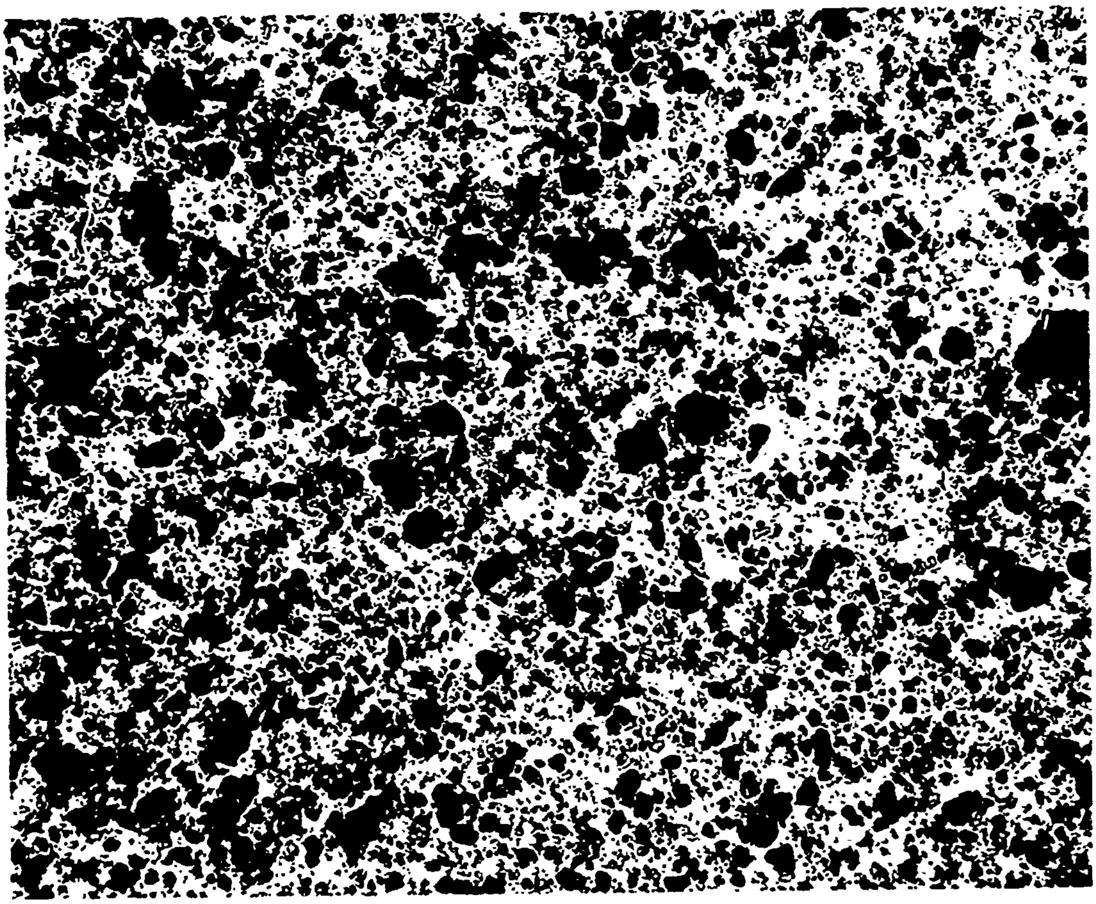
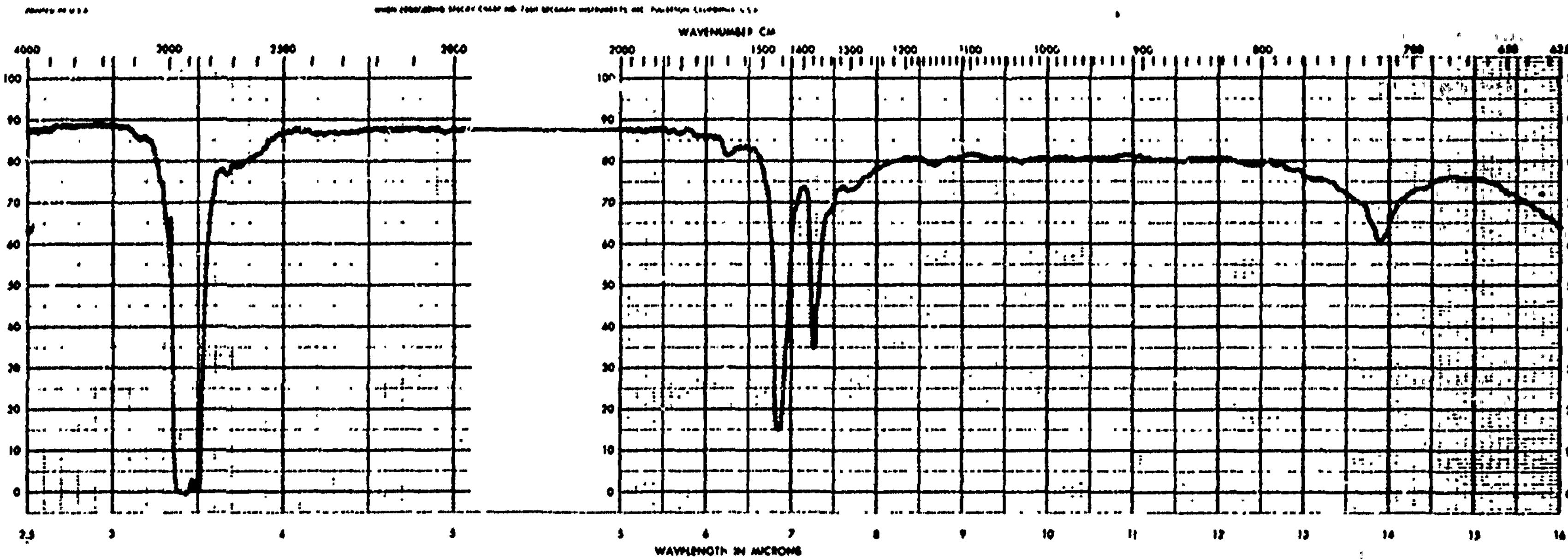


Photo F24. SOM-18, kaolinite clay, ×100

APPENDIX G: SPECTRA OF OILS USED

G1a

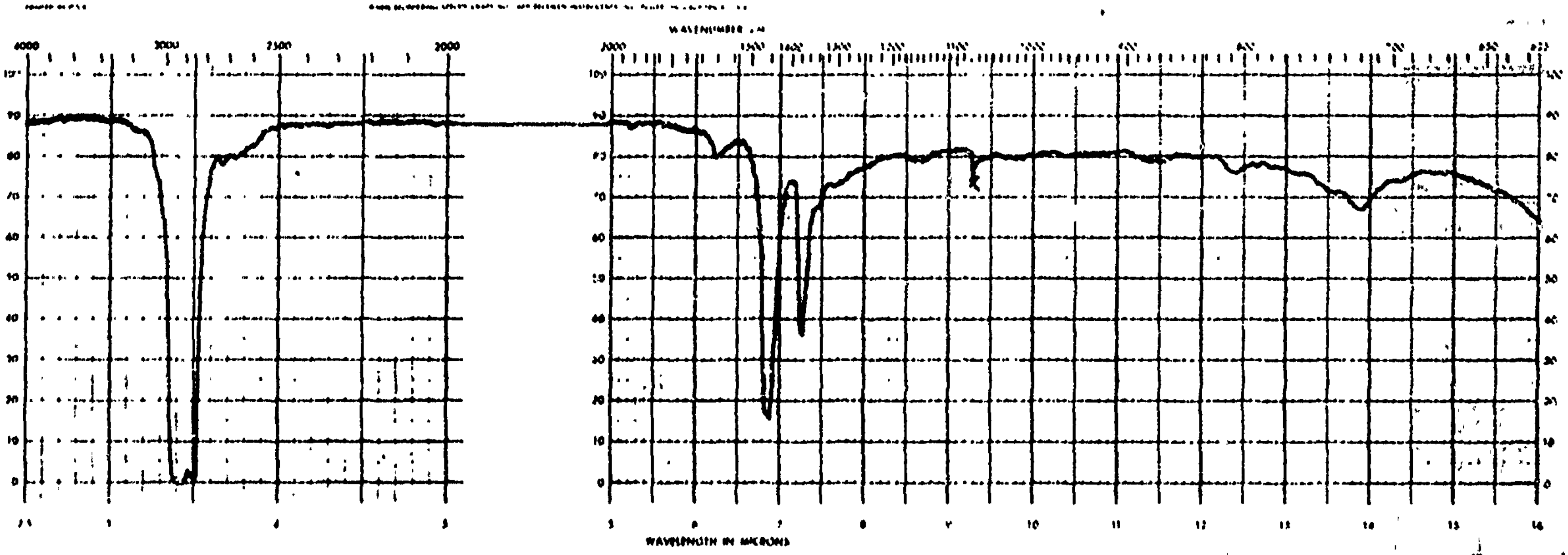


SPECTRUM NO. 18
DATE 29 April 1972
SAMPLE Crude oil from north Louisiana (oil 1)
SOURCE Humble Refinery Baton Rouge
STRUCTURE

PATH IR mm 0.015
SOLVENT None
CONCENTRATION As received
PHASE
COMMENTS
ANALYST

Beckman
INFRARED SPECTROPHOTOMETER

G1b



SPECTRUM NO.

DATE

SAMPLE

SOURCE

STRUCTURE

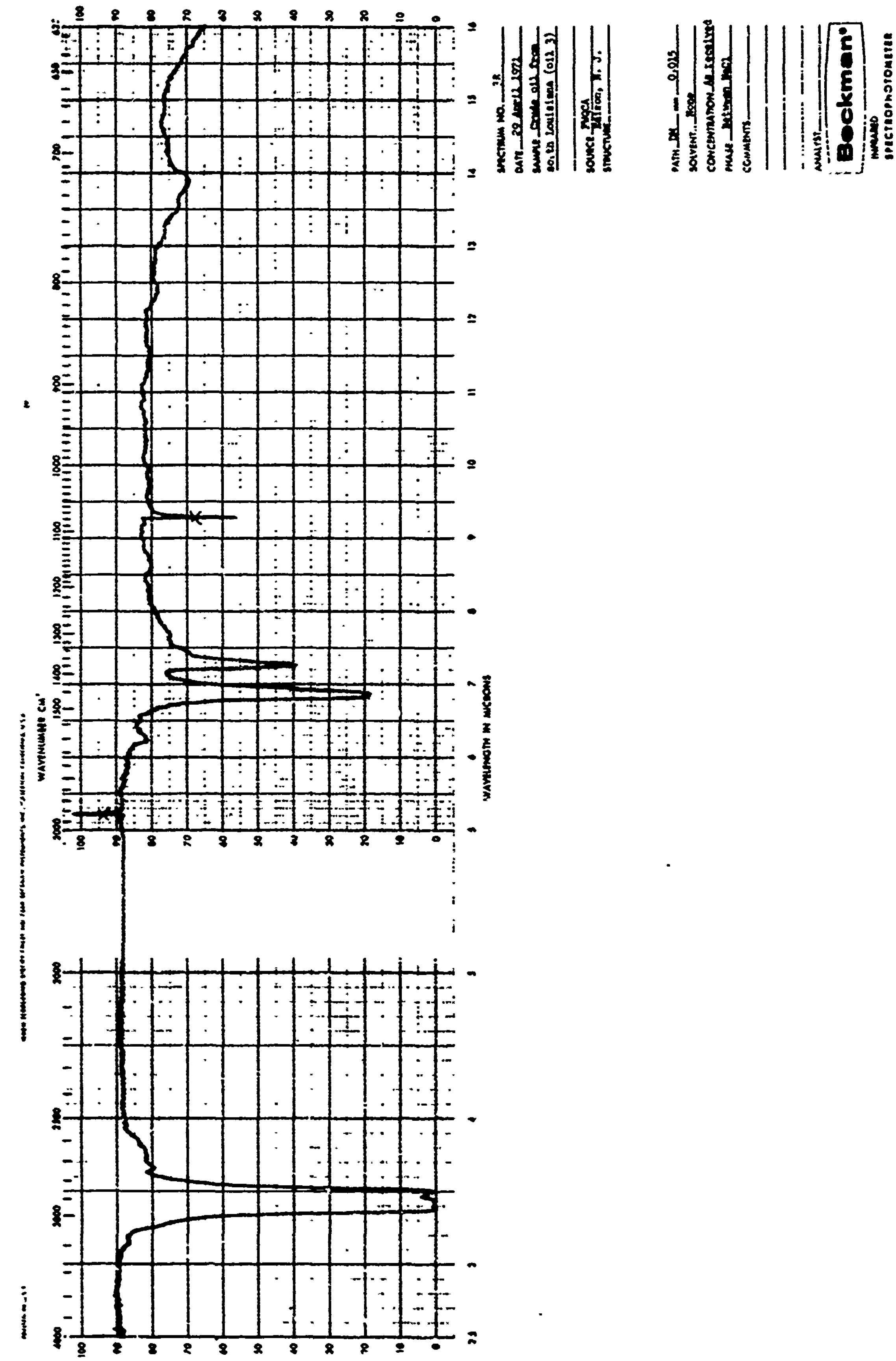
CONCENTRATION

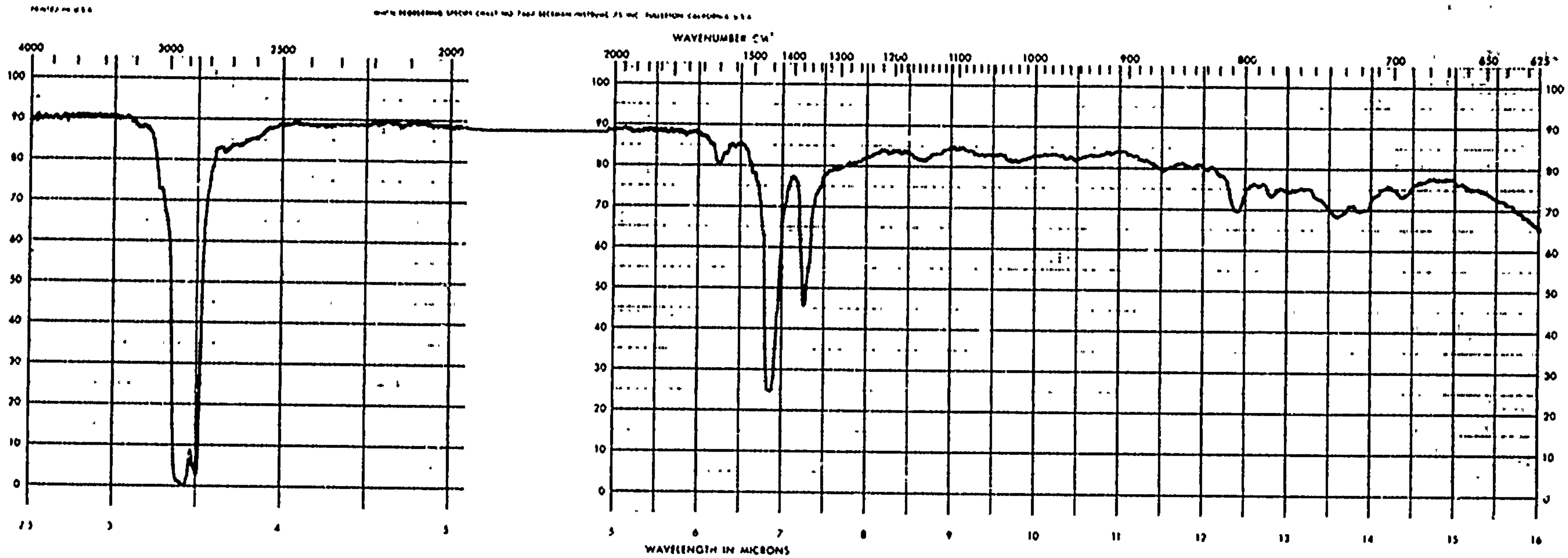
COMMENTS

ANALYST

Beckman®

INFRARED SPECTROPHOTOMETER


WAVENUMBER CM⁻¹
WAVELENGTH IN MICRONS
SPECTRUM NO. IR
DATE 29 April 1972
SAMPLE Crude oil from
South Louisiana (oil 3)
SOURCE FWQA
Edison, N. J.
STRUCTURE
PATH 0.025
SOLVENT None
CONCENTRATION As received
PHASE between NaCl
COMMENTS
ANALYST
Beckman®
INFRARED
SPECTROPHOTOMETER



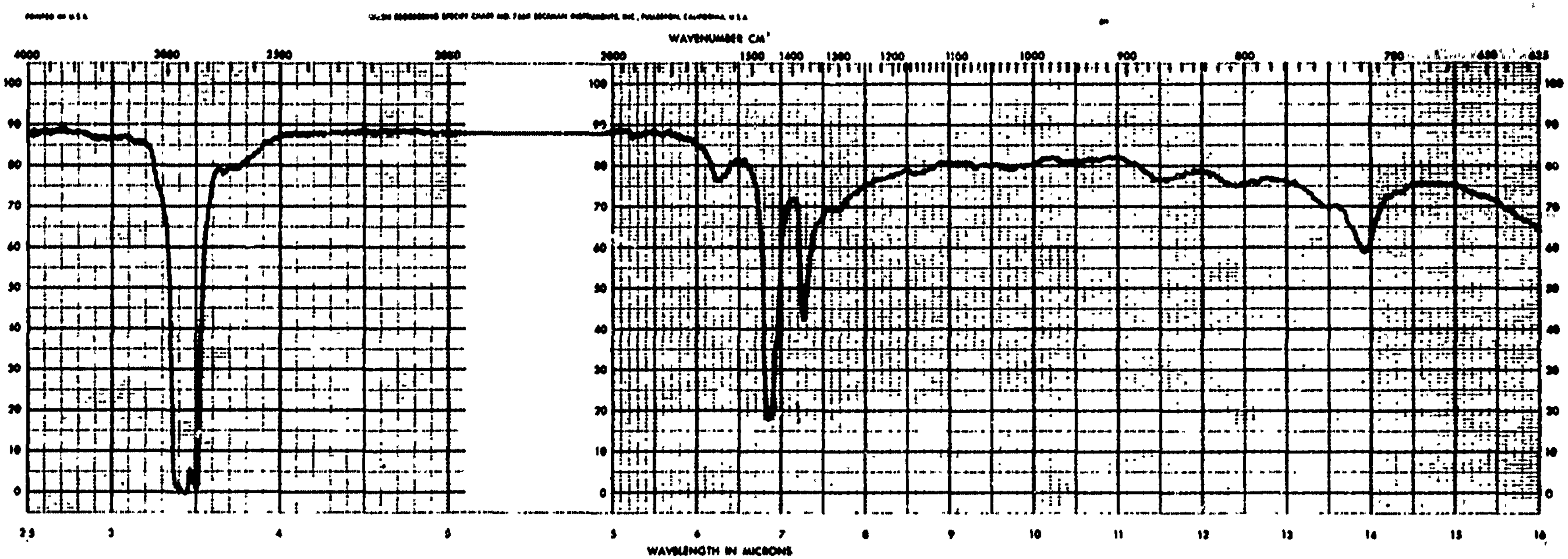
SPECTRUM NO 4P
DATE 29 April 1971
SAMPLE Diel oil 2 (oil 4)

SOURCE FAQCA
Edison, N. J.
STRUCTURE

PATH DM mm 0.015
SOLVENT None
CONCENTRATION As received
PHASE Between NaCl
COMMENTS

ANALYST

Beckman®
INFRARED
SPECTROPHOTOMETER



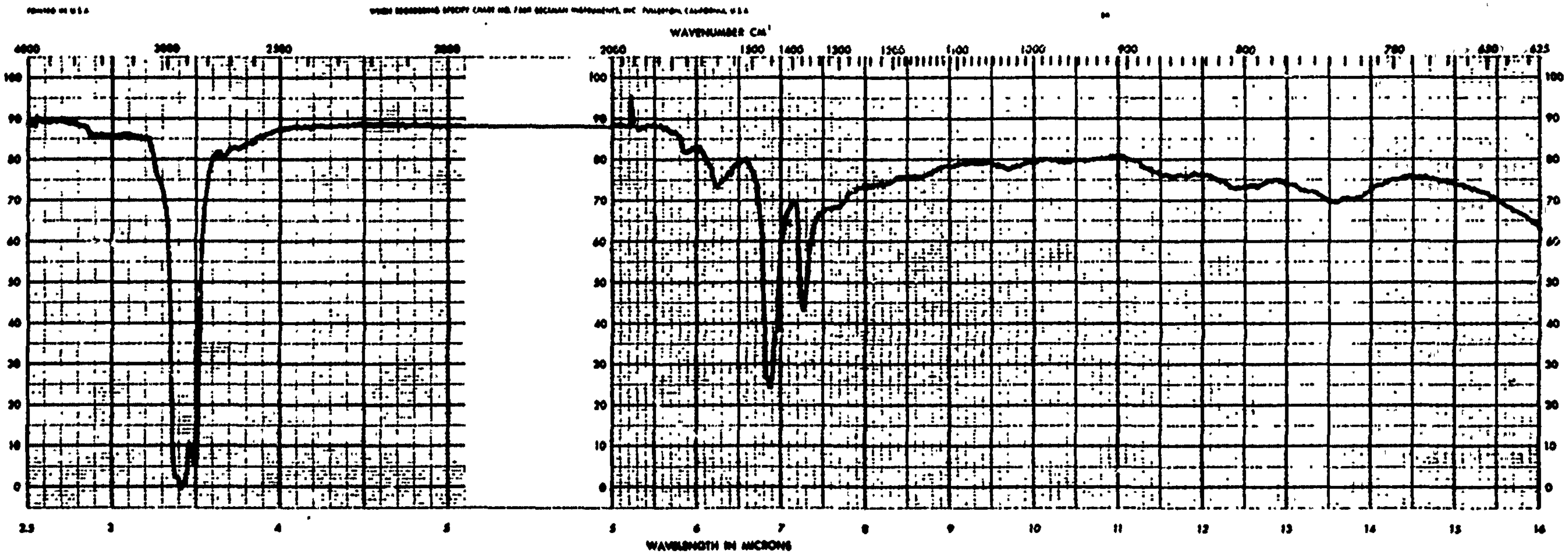
SPECTRUM NO. 5R
DATE 29 April 1971
SAMPLE Fuel oil 6 (oil 5)

SOURCE PV2CA Edison, N. J.
STRUCTURE

PATH IM mm --
SOLVENT None
CONCENTRATION As received
PHASE Between NaCl
COMMENTS Black, very thick

ANALYST

Beckman®
INFRARED
SPECTROPHOTOMETER



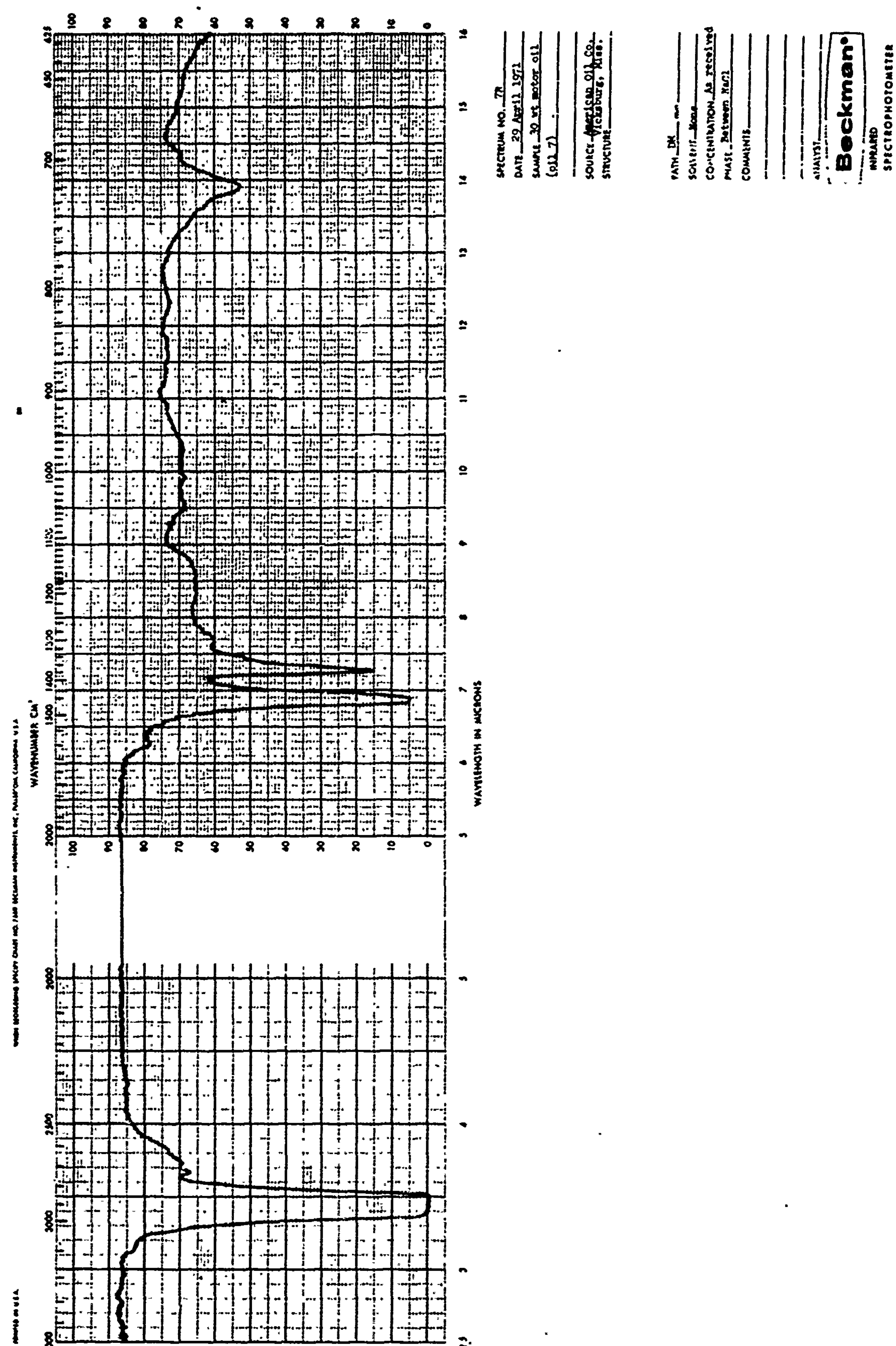
SPECTRUM NO. G6
DATE 29 April 1971
SAMPLE Crude oil (oil 6)

SOURCE Tia Juana
STRUCTURE Venezuela

PATH
SOLVENT None
CONCENTRATION As received
PHASE Between NaCl
COMMENTS

ANALYST

Beckman®
INFRARED
SPECTROPHOTOMETER


WAVENUMBER CM⁻¹
WAVELENGTH IN MICRONS
SPECTRUM NO. 78
DATE 29 April 1971
SAMPLE 30 wt motor oil
(oil 7)
SOURCE American Oil Co.
Vicksburg, Miss.
STRUCTURE
PATH DK
SOLVENT None
CONCENTRATION As received
PHASE Between NaCl
COMMENTS
ANALYST
Beckman
INFRARED
SPECTROPHOTOMETER