RELATION BETWEEN THE VISCOSITY OF BITUMINOUS MATERIALS AND THEIR ABILITY TO PENETRATE ABSORBENT SURFACES

THESIS FOR THE DEGREE OF B. S.

V. H. Donaldson

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THESIS

Pavements, Asphalt

RELATION BETWEEN THE VISCOSITY OF BITUMINOUS MATERIALS AND THEIR ABILITY TO PENETRATE ABSORBENT SURFACES

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THESIS

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ACKNOWLEDGMENT

For the topic of this thesis I am indebted to Primost Hubbard of The Asphalt Institute; for suggestions on procedure to F. H. Jackson, Senior Engineer of Tests, Bureau of Public Roads; for materials to the Standard Oil Company of Indiana, to The Texas Company, New York, and to the American Tar Products Company Inc., Pittsburgh. For aid and guidance in my work I wish to thank Mr. E. A. Finney, member of Engineering Faculty of Michigan State College.

V. H. Donaldson

OBJECTS OF THESIS

1. Measure specific viscosity of various bituminous materials.

2. Penetration of bituminous materials in mixtures of soils and soils.

3. Determine relation, if any, between viscosity and penetration.

DISCUSSION OF NEED FOR IMPROVED ROADS.

Due to the high cost of hard surfaced roads and lack of funds for their construction, improved dirt roads are being studied, and built. Most states have a hard roads program, but it is extended over a long period of years, and can only be constructed as money is obtained for that purpose. Meanwhile there are about 2,500,000 miles of roads that are not hard surfaced, and have very little care. Farmers are taxed for roads, and the roads are built so that only a few, comparatively, benefit from them directly. The farmer who lives back from the main highway is handicapped in taking his produce to market by bad roads. He cannot always take advantage of high market prices, because he is dependent on the roads and their condition, which in turn is dependent on the weather.

Tourists do not get off the good roads to travel on unimproved, dusty, or muddy ones. Consequently, the farmer does not benefit by the direct tourist trade. A good improved road will attract a tourist, if he wants to get out of heavy traffic and crowded highways.

The Bureau of Public Roads and several private concerns have taken up the study of low cost improved roads. It has been found that applications of bituminous materials in the form of oils will serve to keep the dust down. Oiling binds the surface materials together and prevents movement or blowing. The cost of maintenance of a road of this type has been found to be considerably less than the cost of keeping an ordinary dirt read in good condition. Material does not have to be replaced, and water runs off preventing mud from forming. The oil acts as a waterproofing and a dust layer.

The dirt road mileage in the entire United States today is about 2,524,000. This is about twenty times the amount of hard surfaced roads. It is important that these roads be improved. It is important that various methods of improvement be studied. The types of oils should be analyzed, and tested by method approved by the Bureau of Public Roads. Methods of application should be, and are being developed to give the most effective and economical construction.

It is hoped that this thesis will contribute a small part to the general knowledge and perhaps help in improved dirt road construction.

PROCEDURE AND DATA

The topic of investigation was suggested by Primost Hubbard, Chemical Engineer at The Asphalt Institute, New York. In answer to a letter written to the Bureau of Public Roads the following letter was received, outlining a general plan to follow in the investigation:

"We have your letter of April 1, requesting that we send you methods to be used in conducting experiments in connection with the topic which you have chosen for your thesis, "The Relation between the Viscosity of Bituminous Materials and their Ability to Penetrate Absorbent Surfaces."

"This is a very interesting subject and one which we believe can be made productive of valuable information. It is, however, quite a broad and involved subject and there are many details which may influence the results obtained. The following general outline of procedure, however, may be of assistance to you. Make a sand-clay mixture having the following composition by weight: sheet asphalt sand 43 per cent, concrete sand 43 per cent, clay 14 per cent; mix sufficient of this material so as to fill a box approximately 6" long, 6" wide, and 2" deep. After the material is thoroughly mixed and placed in the box, add water and stir the mixture thoroughly in order to wet the entire mass. The surface should then be smoothed and the material air dried to remove excess of moisture. To the surface of the specimens thus prepared add tars and oils and asphalt cut-backs in some definite amount. We suggest for trial, applications at the rate of one-third gallon per square yard. The appearance of the sample at stated intervals should be noted.

"The following bituminous materials could be included for use in surface treating the specimens: tars of 5-8, 8-13, 13-18, 18-25, and 25-35 specific viscosities, Engler, at 40°C., and the corresponding viscosity ranges for petroleum products including asphalts, cut-back with kerosene for one series and with gasolene for another series. In addition to noting by visual inspection the condition of the surface of the specimens at stated intervals, measurements of the maximum penetration of the bituminous materials should be taken by coring the specimens.

"We believe that this procedure should give an indication of the comparative rates of absorption, by this sand-clay mixture, of various bituminous materials. The temperature of the mineral aggregate of the road, of course, varies considerably and it would be interesting to include in the experiments the application of bituminous materials to the mineral aggregate maintained at temperatures such as 77, 100, and 140°F.

"Doubtless Mr. W. J. Emmons, Director of the Michigan

State Highway Laboratory, Ann Arbor, could give you many valuable suggestions relative to the procedure for carrying on this research work with special reference to its application to the road surfaces of Michigan."

The instructions in the letter were followed as to soil mixture. One box was made one foot wide and six feet long divided into six compartments of one square foot each. A second box was made three feet long containing three compartments of one square foot. The method of mixture was followed exactly, and the amount applied was as suggested, being one twenty-seventh of a gallon per square foot. The sand and clay was all dried before mixing and the clay was added in a pulverized condition. The sieve analysis of the sands and clay are as follows:

	Gravel Sand	Sheet-Asphalt Sand	Clay
Contained on No. 8	94.5 gms.	35.8 gms.	None
" " " 10	67.9 "	20.5 "	6.3 gms.
" " " 20	92.7 "	25.7 "	11.0 "
" " " 28	68.0 "	16.4 "	17.4 "
" " " 40	117.2 "	44.9 "	38.4 "
" " " 48	33.4 "	53.7 "	52.6 "
" " " 80	19.3 "	161.8 "	132.7 "
" " " 100	2.8 "	53.5 "	41.5 "
" " " 200	2.7 "	65.9 "	84.7 "
" " Pan	1.5 "	21.8 "	115.4 "
Total	500.0 "	500.0 "	500.0 "

The mixture of 3 parts gravel sand, 3 parts sheet asphalt sand and 1 of clay makes a very compact mix; suitable for the tests as applied.

Oils and tars were the bituminous materials used. Thirteen different samples were obtained and used. They are listed below with short descriptions of each.

1. Texaco No. 45 Surfacing Material.

   Contains a minimum of 45 per cent of asphalt of 100 penetration. It is made for cold application, and is used chiefly as a light surface treatment or as a dust layer on resilient surfaces.

2. Texaco No. 55 Surfacing Material.

   Contains a minimum of 55 per cent asphalt of 100 penetration. It is used for the construction of sand asphalt surfaces by cold application. It is slow drying, and can be worked or mixed after application.

3. Standard Asphaltic Road Oil No. 3.

   Contains at least 30 per cent asphaltum.

4. Standard Asphaltic Road Oil. No. 4.

   Contains at least 40 per cent asphaltum.

5. Standard Asphaltic Road Oil No. 5.

   Contains at least 50 per cent asphaltum.

6. Standard Asphaltic Road Oil No. 6.

   Contains at least 60 per cent asphaltum.

7. Tarmac P Special Grade.

8. Tarmac P Grade No. 1

9. Tarmac P Grade No. 2

10. Tarmac P Grade No. 3

11. Tarmac P Grade No. 4

12. Water gas tar - small viscosity

13. Water gas tar - large viscosity.

The viscosities of the first six listed were measured by an Engler viscosimeter 40°C, 200 cubic centimeter samples. The last seven were determined by an Engler viscosimeter 40°C, 50 cubic centimeter samples. They were determined by the doner and shipped with the samples.

In determining the specific viscosity by the 200 cc Engler viscosimeter it was found that the time of passage of 200 ccs of distilled water at 25°C was 49.9 seconds. The viscosities obtained are listed with those furnished.

Name	Viscosity
1. Texaco No. 45 Surfacing Material	12.7
2. Texaco No. 55 Surfacing Material	39.0
3. Standard Asphaltic Road Oil No. 3	9.0
4. Standard Asphaltic Road Oil No. 4	15.6
5. Standard Asphaltic Road Oil No. 5	40.0 ?
6. Standard Asphaltic Road Oil No. 6	164.0 ?
7. Tarmac P Special Grade	5.9
8. Tarmac P Grade No. 1	9.0

9. Tarmac P Grade No. 2	14.9
10. Tarmac P Grade No. 3	20.1
11. Tarmac P Grade No. 4	29.9
12. Water Gas Tar No. 1	1.8
13. Water Gas Tar No. 2	9.3

The first five grades of Tarmac P have viscosities that fit in the ranges suggested in Mr. Jackson's letter.

The sand-clay mix was placed in the boxes, each having an area of one square foot, and was mixed with water. After drying for several days, a dry compact cohesive block of the mix was left, and the oil was applied, one-twenty seventh of a gallon (140 ccs.) per square foot. To avoid the oil soaking into the wood it was applied on squares in each box of about 100 square inches. Therefore the rate of application is more than one-third gallon per square yard (140 ccs. per 100 square inches.)

The samples were allowed to set four days in a temperature averaging about 75°F.

The water gas tar No. 2 specific viscosity 9.3, penetrated one inch, acted slightly cohesive and coated the sand particles thinly.

Tarmac P Grade 4 viscosity 29.9, penetrated one-half inch, and formed a compact surface coating the particles thickly and filling the voids.

Tarmac P Grade 3 viscosity 20.1, penetration of nine-sixteenth inch. It is not quite as compact as the grade 4 sample but appears about the same.

Tarmac P Grade 2 viscosity of 14.9, penetration five-eighths inch, not quite as cohesive as before nor as compact.

Tarmac P Grade 1 viscosity 9.0 penetration three-fourths inch. The bituminous material penetrated to about nine-sixteenth inch, the color changed then and was not so black, the fluxing material penetrating the last three-sixteenth inch, fairly compact but less so than the previous sample.

Tarmac P Special Grade viscosity of 5.9, penetration one inch. The oil gradually tinned out as it penetrated, the color varying from black to light brown at the bottom. The particles were cemented together with the same variation, quite well at the top, merely oil soaked at the bottom.

Standard No. 4 viscosity 15.6, penetration fifteen-sixteenth inch, much lighter in color, has good cohesive qualities.

Standard No. 3 viscosity 9.0, penetration one and three-sixteenth inches, light brown color, uniform coloring for about one inch with lighter shade from there on. Cementing qualities quite good.

Texaco No. 45 viscosity 12.7, penetration three-fourth inch, uniformly colored from top to bottom. Good cohesive qualities.

Texaco No. 55 viscosity 39.0, penetration eleven-sixteenth inch, uniform coating from bottom to top, very slightly cohesive.

Standard No. 5 viscosity 40.0 (?), penetration one-half inch. Material thickly coated near top, thinning out towards the bottom. Slightly cohesive.

Standard No. 6 viscosity 164 (?), penetration seven-sixteenth inch, very cohesive, but not cemented hard, still soft and thickly coated on the particles. Penetrated unevenly.

Water Gas Tar No. 1 viscosity 1.8, penetration one and nine-sixteenth inches. Slightly coated particles; very little cohesion. The oil was dry and was a light brown shade, lighter brown at the bottom than at the top, grading evenly down.

Kerosene Cut-back Asphalt. - A cut-back asphalt material was prepared by adding kerosene to asphalt. Samples of Refined Bermudez Lake Asphalt were used. 200 Grams of asphalt were mixed with kerosene; starting with 125 grams of kerosene, and to each sample adding 25 grams more until 225 grams were used for the last mixture. The asphalt was allowed to soak in the kerosene over night. It was then put over a flame and heated until all the asphalt was melted and the mix was of uniform consistency. It was then set off to cool, and it was found that it was necessary to stir it quite often as it cooled to keep the asphalt from settling out of the kerosene, and forming a thick viscous mix on the bottom. Stirring while cooling kept the mixture at a uniform viscosity until cool, and then it remained that way.

The viscosity of each of these samples was measured at 40°C Engler. The results were as follows:

Kerosene	Asphalt	Viscosity
125 gms.	200 gms.	44.8
150 "	200 "	22.5
175 "	200 "	14.4
200 "	200 "	6.3
225 "	200 "	3.8

A curve was then drawn (Plate II) showing the relation between the amount of kerosene used and the specific viscosity. Using this curve, samples were prepared having viscosities in the ranges 0-5, 5-8, 8-13, 13-18, 18-25, 25-35. These samples were applied to the same sand mixture as used in previous tests. After standing four days at a temperature of about 75°F the penetration was measured. Results are tabulated below:

Viscosity	Penetration
3.8	1-1/16"
6.3	7/8
10.1	3/4
14.4	5/8
22.5	1/2
31.0	7/16

This material gave a penetration of a uniform color from top to bottom. There was no separation of the asphalt and kerosene. The samples were slow in drying out and at the time measurements were taken there was very little cohesion between particles.

A gasoline cut-back material was not attempted due to lack of time in which to prepare the material and perform the tests.

CONCLUSION

The outstanding fact determined is that there is with most materials a relation between specific viscosity and penetration; also that the relation differs with the different kinds of materials. (Plate I)

The Texaco oils only, seemed to show little difference. The two samples had widely separated viscosities, yet the difference in penetration was only one-sixteenth of an inch. It appears that, while there was variation in penetration in the right direction, viscosity does not effect the penetrating ability of these oils. The reason for this is probably due to the composition of the material. Composition was not considered in this thesis.

The remaining types of oils show definite tendencies for the penetration to vary inversely as the viscosities, the higher the viscosity the smaller the penetration.

The water gas tar showed a definite variation of penetration due to different viscosities. There was a difference in viscosities of 7.5 and difference in penetration of nine-sixteenth inch. This tar has the ability to penetrate to comparatively large distances. A very good dust layer, but not a binding material.

The standard oils gave a good curve for showing the relation between penetration and viscosity. The curve as shown in Plate I gives a good standard to use as a general relation, that is, it curves sharply downward in the smaller viscosities, flattening out as the viscosities become greater until there is very little difference due to different viscosities.

The Tarmac oils show a general curve that is relatively the same as the Standard oils.

The Standard oils penetrate quite a little more in the smaller viscosity ranges, and about the same in the larger viscosity ranges. This is no doubt due to the different materials used in the manufacture of the oils.

The kerosene cut-back asphalt shows a good general curve somewhat similar to the Standard oil and the Tarmac.

These all go to show that there is a relation between viscosity and penetration, and that it is of the same general shape regardless of material. The difference in penetration is uniformly about the same for the same viscosities. Differences in material cause the measurements to be different.

If a sufficient number of tests were run to corroborate the figures given in this thesis, no doubt formulae could be obtained for a curve for each material. Also curves could be plotted to control the various mixes to give the desired viscosity. It is believed that there are other elements that have some control over the penetration. The fluxing material used, the properties of the bitumen, and the kind of bitumen all cause different results.

The comparison of viscosities and of the resulting penetration of these materials is a very small beginning in the study of road oils. There is a great amount of work to be done yet on this subject. Due to the necessity for the proper materials for surfacing dirt roads, there should be a great amount of research performed on these materials and their preparation. While it appears that there are oils for every soil and climate, they can be improved in their ability to do what is required of them, and also rendered less expensive and consequently in greater demand.

Kerosene Cutback Asphalt Curve

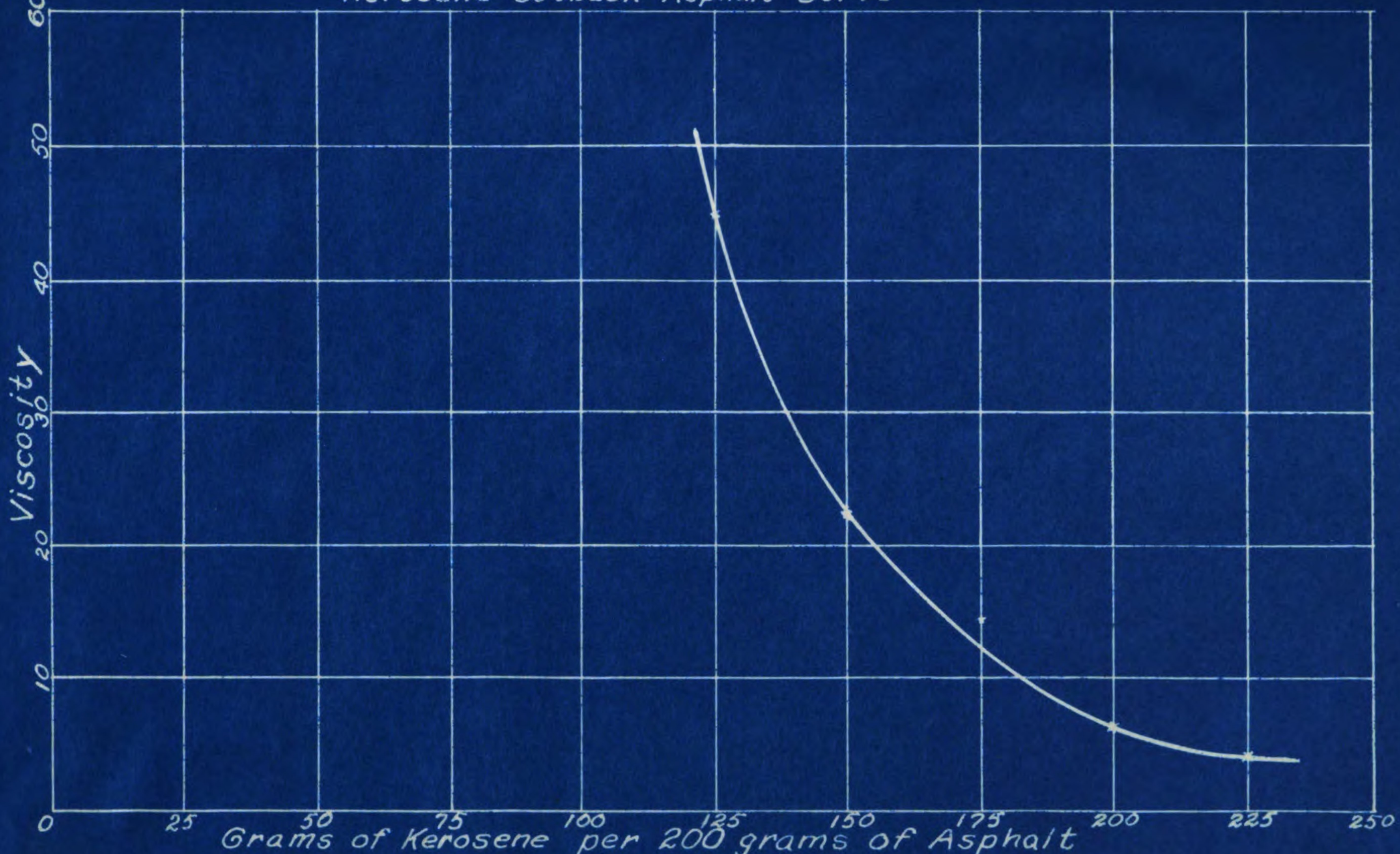


PLATE II

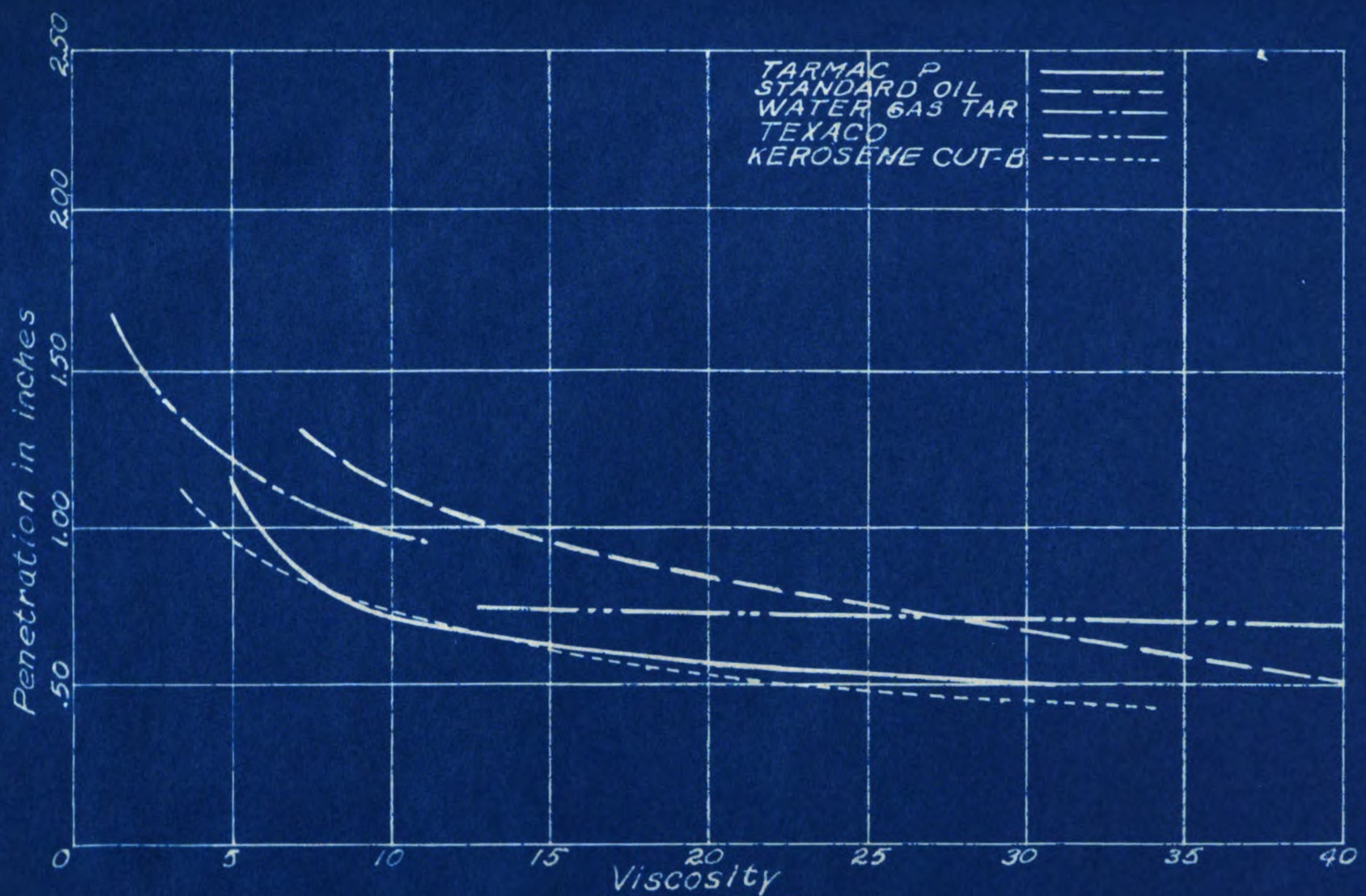
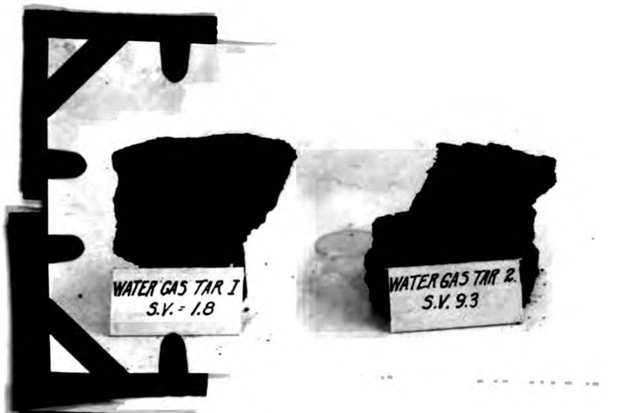
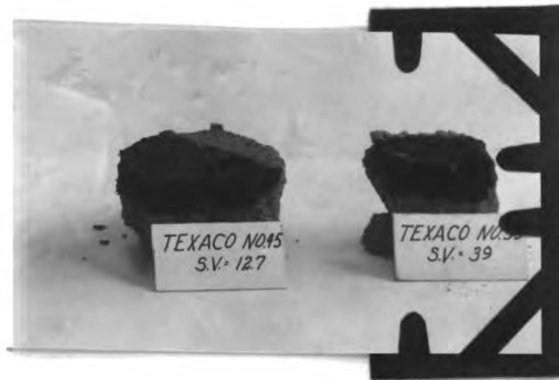
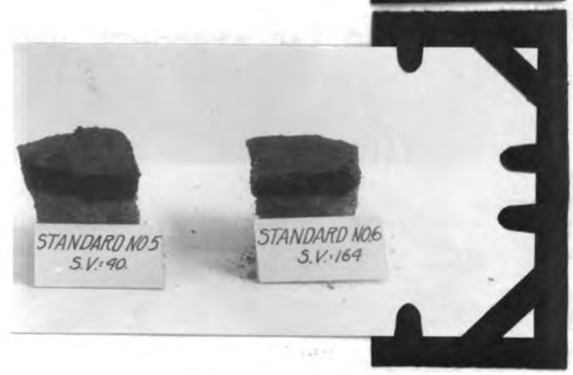
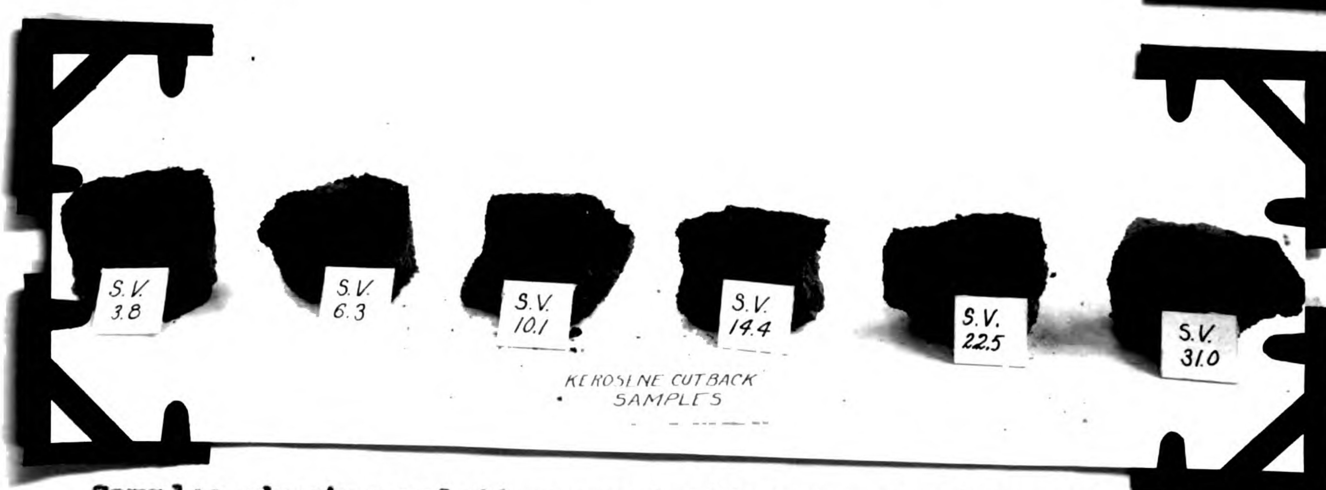

TARMAC P
STANDARD OIL
WATER GAS TAR
TEXACO
KEROSENE CUT-B
Penetration in inches
2.50
2.00
1.50
1.00
.50
0
5
10
15
20
25
30
35
40
Viscosity

PLATE I









Samples showing relative penetration due to different viscosities.

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