STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

NEW TEST METHODS FOR STUDYING THE EFFECT OF WATER ACTION ON BITUMINOUS MIXTURES

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Synopsis

The influence of water on the service performance of bituminous pavements has been the object of extensive research for many years. There appears to be a continuing need for tests which will provide a more positive measure of this influence. These tests should be performed on paving mixtures containing the entire aggregate gradation with the design binder content. Preferably, the test should also be performed on compacted specimens that closely simulate the pavement in place on the road.

This report describes four new test methods in use by the California Division of Highways, which measure the effects of water on bituminous pavements. One of the tests involves the use of the dye technique for providing a quantitative measure of the degree of stripping of the loose mixture. The other three tests are performed on compacted specimens, and

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provide methods for measuring the change in physical properties when subjected to moisture vapor or free water exposure.

Results from investigations concerned with the variables affecting the resistance of bituminous pavements when subjected to the influence of water are presented. These studies indicate the importance of the consistency of the bituminous binder in preventing failures from action of moisture. They also indicate that additives vary in their effectiveness depending on the aggregate source.

This study, to date, clearly indicates the importance of including the entire mix gradation in any water action test. The fine portion of the aggregate combination is of fundamental importance, and tests performed on the coarser fraction only may provide results of little value in determining the service performance of the pavement.

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Introduction

The influence of water on the service performance of bituminous pavements has been the subject of extensive research for many years. The literature on the subject is voluminous as can be seen from Bibliography #17 on this subject published by the Highway Research Board in 1954. From the amount of study performed over the past years, one might assume that knowledge of the subject should be on a sound basis. However, the present status is still open for debate, and recently R. N. Traxler (1) stated, "The development of a fundamentally sound test for adhesion is probably one of the greatest challenges in the field of bituminous technology." The authors agree with Dr. Traxler's statement on the need of tests that will provide a measure of the effect of water on pavement performance, and the major part of our research effort has been concerned with test development. The purpose of this report is to describe our studies on this phase of the problem.

The action of water may induce partial to serious raveling and disintegration at the surface of a pavement. The entrance of water into the pavement may cause stripping of the asphalt followed by partial emulsification of the bituminous binder. In any case, such action may alter the properties of the pavement to the extent that failures will occur under traffic action. Further, water in the form of vapor may cause serious

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distress in certain types of pavements, a fact that does not seem to have attracted sufficient attention.

It appears that the most desirable method for studying the effect of water on pavement performance is by tests which duplicate field conditions as closely as possible. This requires the use of realistic test specimens and measurement of property changes that influence the field performance of the pavement.

In this report are described four test methods; namely,

1. The Quantitative Dye Stripping Test.
2. The Moisture Vapor Susceptibility Test (MVS).
3. Water Susceptibility Test.
4. Surface Water Abrasion Test.

All of these tests are presently in use in the Materials and Research Department of the California Division of Highways. The MVS test has been for some years a specification requirement in our Standard Specifications for asphaltic concrete. The other three tests are used for research and special investigation purposes, particularly in analyzing failures of bituminous pavements. One or two of these special tests may be included in our Standard Specifications in the near future.

Test Methods

The Quantitative Dye Stripping Test

Tests for stripping action are normally performed on only part of the total aggregate gradation and the film thickness of

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the bituminous binder of these laboratory prepared specimens may vary considerably from that found in the actual paving mixture. Furthermore, the degree of stripping is estimated in most cases by visual means. Several methods have been developed for quantitatively determining the extent of stripping, one of the most interesting being the tracer salt and flame photometer technique now under study by Task Force I of Subcommittee B-26 of ASTM Committee D-4. Although we do not believe that any method of this type provides sufficient information on the adverse effect of water, they are of importance in certain phases of a study, and a quantitative stripping test was developed in our laboratory by the late A. R. Ebberts. This test was first described in a paper by Hveem in 1943 (2). The reasons for initiating this study were summarized by Ebberts in a departmental report, as follows: "Most of the adhesion tests that have been published are made on aggregate particles large enough to allow a visual estimation of the stripped area." "It is our experience that the fines are the controlling factor." "If the fines do not hold asphalt, adhesion to the coarse particles will not save the pavement." More recent studies by this department continue to confirm this statement. We consider it essential to develop tests that will provide a measure of the stripping tendencies of the entire aggregate gradation, with binder contents within the range used in normal paving.

After extensive experimentation Ebberts discovered that Safranine dye is preferentially adsorbed on mineral aggregates

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and by proper adjustments of original dye concentration, it is possible to measure the amount of this adsorption. Of great importance was his discovery that this dye is adsorbed by asphalt only slightly or not at all.

The original Ebbert's method had the disadvantage of using a very small sample and modifications have been made in the test method. The present procedure is detailed in Appendix A and outlined as follows: 250 grams of the entire uncoated aggregate mix gradation, used in the experimental study or the proposed gradation called for in the contract, is introduced into an apparatus and dye solution is added. After equilibrium is attained, the dye strength change due to adsorption is obtained by means of a photometer. Another identical 250 gram sample is coated with the design percentage of asphalt and cured for a designated period. After curing, the sample is stripped by rolling action in our regular stripping machine, Fig. 1, for a 30 minute period. The contents are then placed in the testing vessel, dye is added, and the change in dye strength determined. The ratio of the change in dye strengths between the uncoated and coated samples provides a measure of the degree of stripping.

In order to bring the dye solution into intimate contact with the aggregate system an apparatus was constructed, Figs. 2 and 3 which permits the attainment of satisfactory equilibrium in a relatively short period of time. The uncoated aggregate is placed on the #4 sieve of a sieve assembly, contained within

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a 1500 ml. beaker. The sieve assembly is made up of a #4, 8, 30 and 100 sieve. A quantity of dye solution is added, and controlled vacuum is applied to the funnel. The dye is drawn upward into the funnel to a fixed height, and then released by opening the vacuum line through use of a magnetic valve accentuated by an automatic cycle timer. Thus, the dye solution is kept in active movement as it flows through the material on each sieve size. The material passing the 100 mesh sieve is in constant movement, and is vigorously churned during each release cycle by the rapid downward movement of the solution.

Studies with a number of aggregate sources and application of principles reported for the adsorption phenomena indicate that true adsorption equilibrium is taking place under conditions of test. These studies indicated that it is necessary to use "equal strength" end points for both coated and uncoated samples. Trials indicated that the final dye concentration should range between 0.2 to 0.7 mg/ml. in order to attain proper equilibrium, and to insure sufficient accuracy in terms of dilution factors.

The method appears to be repeatable, one operator attaining duplicate results within 4%. No information is available on the reproducibility factor.

There are two basic variables involved in the dye technique. The total dye that is adsorbed by the "raw" aggregate during the equilibrium period will depend on the nature of the mineral surface and the total surface area of the sample. Certain types of minerals will adsorb a relatively small amount of the Safranine

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dye and in some cases it may be necessary to use methylene blue. This dye works best on crushed quartz. In general, the Safranine dye is adsorbed to a sufficient degree by almost all types of stone that have been studied to date. However, it should be noted that aggregate combinations involving materials having very low adsorption and high stripping combined with those having high adsorption and no stripping may provide misleading final results, especially when considering the use of the test for controlling the amount of stripping from various aggregate sources.

Some typical studies involving the dye technique are described below. In all cases the entire mix gradation and design asphalt content were used. A typical example from a study of the effectiveness of additives in reducing the stripping tendency of two aggregate sources is shown in Fig. 4. The importance of the consistency factor is again confirmed. There should be no doubt of the marked effectiveness of the harder grades of asphalt in definitely reducing the stripping tendencies of an aggregate combination. The 85-100 penetration paving asphalt was more effective in preventing stripping than the combination of any of the additives tried with an SC-4 liquid asphalt. Results also confirm past experience that the effectiveness of any asphalt additive will depend on the nature of the individual aggregate.

The influence of asphalt source is shown in Table A. The results confirm the work reported by Gzemski (3), and definitely

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indicate that there are differences within the asphalts themselves depending on the source or methods of manufacture. Although the surface properties of aggregates are the major factor in the water action problem, the results indicate that a stripping tendency may be aggravated by certain asphalts.

A most serious problem with even quantitative stripping tests is the difficulty of proper interpretation of results in terms of actual pavement performance. The amount of actual stripping in a properly constructed tight pavement may never correlate exactly with changes in pavement properties sufficient to cause failure even though the aggregates showed relatively serious stripping in the uncompacted state. Furthermore, partial emulsification may occur in pavements without substantial evidence of stripping of the asphalt film in the test and such emulsification may accompany serious failures. It seems preferable that we attempt to develop tests which will provide a measure of the potential changes in pavement physical properties when subjected to water action. One of the known methods, in this connection, is the Immersion Compression Test, (4). We believe that this test does provide some information, but that other physical properties of the pavement may be measured or evaluated to provide better and more complete evidence on the effect of water action than the simple loss in compressive strength criteria used in this method. The following methods have been developed in the hope of providing such information. One of the methods is now being used on a routine

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basis while another also shows promise of being useful for routine control. The third should be considered only as a research test.

All of the methods use specimens having specification mix gradations with recommended asphalt contents. Samples are fabricated in the kneading compactor to produce a specimen that closely simulates the actual pavement. In two of the methods, changes in physical properties are followed with normal routine tests used by the California Division of Highways in the design of asphaltic mixtures.

Moisture Vapor Susceptibility Test

Water in the form of vapor may cause serious distress in old pavements that have been overlaid by an impervious blanket or sealed. Previous reports (5) and (6) have noted that pavements, performing in a satisfactory manner, have shown distress after application of a heavy seal coat. Water in the form of vapor enters the pavement from the underlying layers and not being able to escape, will condense on the surface of the aggregate particles and may cause a marked drop in stability leading to "bleeding" and the formation of corrugations.

A test has been devised in order to aid in the design of paving mixtures which will be resistant against the effects of moisture vapor. The test was developed in the late 30's. A number of compacted specimens, including cutbacks, slow curing products, emulsions and paving asphalt, one specimen of each sealed at the surface and a duplicate not sealed which

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permitted moisture to escape, were placed on a damp subgrade on the laboratory roof. After about six months exposure the specimens were tested and it was noted that in all cases, the sealed specimens showed considerably lower stability than the unsealed specimens although the absorbed moisture was about the same. With some correlation from actual pavement performance, and some modification the present Moisture Vapor Susceptibility Test evolved. It should be pointed out, however, that at that time the Division of Highways made extensive use of the SC oils and cutbacks. With the present almost exclusive use of paving grade asphalts in overlays, the adverse effects of moisture or stripping action is not often experienced. The test, detailed in Appendix B, may be briefly described as follows: A sample of the design mix is compacted under the kneading compactor and is sealed on the top surface while still in the steel mold. The bottom surface is covered with a felt pad which is in contact with a short felt strip wick leading from a water supply. The entire assembly is placed in a 140°F oven for a period of 75 hours. The test conditions permits moisture vapor to move upward into the specimen. At the conclusion of the test, the stability is determined and compared to the routine stability test of specimens not subjected to this moisture test. A marked drop in stability indicates a drop in internal friction of the mixture caused by moisture vapor. Specification requirements for minimum stabilometer values after completion of the Moisture Vapor test have been

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set. Our present specifications require a minimum stability of 30 for Type A asphalt concrete, 25 for Type B and 20 for Type C.

Water Susceptibility Test

This test was developed as a research method for studying the various factors affecting the resistance of a bituminous mixture to moisture. The test involves measurement of changes in the physical properties of the mixture during periods of controlled water action.

The test setup is shown in Fig. 5. A standard specimen compacted with a 1/2" hole through the center is fabricated by the use of the kneading compactor. A slight modification of the tamping foot and a bottom plate with a 1/2" diameter vertical stem or mandrel is required. The final specimen resembles a normal sample in all respects except for the center hole. The specimen is inverted and cemented to the bottom test plate "A" by means of high melting point wax, and the swell plate "B" is cemented to the top of the sample. The necessary tubes are attached to the reservoir "C" and the entire assembly is placed in the container "D". The container and its contents are placed in a constant temperature bath and the reservoir chamber "C" is attached to a vacuum manifold.

The test is performed as follows: A quantity of distilled water is placed in the container "D" sufficient to cover the specimen at all times during the vacuum cycle. Tap water, or water of varying pH or water containing salts may be used for

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test purposes, thereby making it possible to depict almost any field condition in terms of active agents involved in the local water (3). Vacuum is applied to reservoir "C" to the extent necessary to move 50 ml of water laterally through the specimen in a 15 second period. When vacuum is applied, the one way ball valve "E" closes. At the end of the 15 second period, the vacuum is released through a solenoid valve controlled by a cycle timer. This causes ball valve "E" to open and water returns to container "D", within an interval of 10 seconds. This completes a cycle.

The stability and cohesion are determined on a set of specimens prior to water action. Specimens are removed after 2, 4 and 6 hours at 100°F and tested for stability and cohesion. Swell readings and amount of water within the specimen are also determined at the end of these periods.

There is reason to believe that the method might also provide information on the extent of stripping within the compacted mix. There does not appear to be any published evidence on the relation between the percentage of stripping and decrease in physical properties of the pavement. This factor was studied by determining the original Safranine dye consumption of a standard 250 gram sample of the aggregate grading used in the test specimens. With this information, the total dye consumption for the aggregate used in the test specimen could be determined. At the conclusion of a water action test period a known quantity of dye was introduced into reservoir "D", and the diluted

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solution drawn through the specimen until dye equilibrium was attained as measured with a photometer. The dye consumption was determined and the percentage of stripped area calculated in the manner used in the normal dye test, previously described in this report.

Typical test results on aggregate sources are shown in Fig. 6. There is some reduction in stability values for all paving mixtures including those known to have a satisfactory performance in terms of resistance to water action, Samples C and E. However, the reduction in stability, cohesion and gain in swell is most pronounced in sources where pavement failures from water action occurred. In the case of Samples D and I, serious failures were evident on the road during the first winter after construction. One of the factors aggravating the failure of Sample I was the tendency of the binder to partially emulsify during periods of wet weather, resulting in marked changes in the physical properties of the pavement. Our test results tend to confirm the field performance. Although there are marked changes in physical properties during the water action test, there is virtually no stripping in the compacted state as measured by the dye technique, Table B. Such results again confirm our contention that water may detrimentally influence the service performance of a pavement without clear indication of stripping action in a laboratory test.

The amount of stripping is very small for all the aggregate sources with the crushed quartz showing the highest percentage.

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It is logical that the percentage of stripped area should be small since the figure is based on the total surface area of the aggregate, and the actual area available for stripping is quite small in the compacted specimen. On the basis of these preliminary studies one may conclude that the rate of change in such physical tests as stability, cohesion and swell are more important in measuring the detrimental effect of water action than is the area or percentage of stripping. This apparatus has only been used for preliminary studies, but it appears to offer an excellent means for studying the various factors that may be involved in the water action problem.

Surface Water Abrasion Test

Raveling of a newly completed pavement may require costly maintenance repair or even the placement of an additional asphaltic concrete blanket or a screening seal coat. Raveling in the early stages of service life may be caused by a deficiency of asphalt, lack of compaction or the effect of water and tire action. In properly controlled construction operations the mechanism of failure is the removal of the susceptible matrix of the mix by tire action in the presence of water.

As noted previously, it is our contention that the properties of the matrix or fine portion of the paving mixture are of prime importance in determining resistance to water action. We have some asphaltic pavements in which the coarse aggregate consists primarily of quartz with very high stripping tendencies. After several winters the light appearance of the surface, from

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a distance, closely resembles a concrete pavement, but there are only slight signs of raveling even after ten years of heavy traffic, Fig. 7. The reason for this appearance is the high resistance to water of the finer portion of the mix. This development has also been demonstrated in laboratory studies with the aggregates used in these pavements.

In order to determine the resistance of a pavement surface to tire action in the presence of water, we have developed a relatively simple apparatus which provides a quantitative figure for the degree of raveling. The method involves equipment for subjecting the surface of a test specimen to dynamic water action together with simulated tire action of vehicles. This is done by clamping a standard 4" diameter compaction mold containing the preconditioned specimen, in a special shaking unit. A quantity of water together with four 1-1/8" diameter solid rubber balls is added. The specimen is then subjected to a shaking period of 15 minutes at 1200 cycles per minute with a vertical stroke of 1". The assembly is maintained at 100°F during the test period. Photographs of the test equipment are shown in Figs. 8 and 9. Details of the method are presented in Appendix C. The action of this test produces a surface that closely resembles a badly raveled pavement as shown in Fig. 10.

Since consistency of the binder has an important effect on the final result, it was necessary to establish an average test temperature that would be expected to represent pavement

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conditions during inclement weather. A pavement temperature of 100°F was selected. Some tests were performed at 140°F and provided an accelerated procedure for paving asphalts, but caused serious failure with all SC-4 mixes, including those known to be made from excellent water resistant materials. Furthermore, the 140°F pavement temperature is not realistic for periods of rainy weather.

The shaking period of 15 minutes was established to give measurable differentiation between various available aggregate sources at a temperature of 100°F.

The factors involved in the resistance of asphaltic pavements to raveling under water and tire action appear to be the nature of the fine material, consistency and source of asphalt, and percentage of asphalt. External factors such as type and volume of traffic together with the amount of rainfall are also of great importance in the degree of severity of the raveling, and must be considered in terms of possible specification requirements.

The surface abrasion loss for different aggregate sources are shown in Table C. Some of the factors causing this variation have been studied.

1. Relation between abrasion loss and percentage of stripping.

   Specimens were fabricated from a single aggregate source and different binder sources and grades. The results are shown in Table D and Fig. 11. For

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this specific aggregate source, there is a good relation between the percentage of stripping as determined by the dye technique and surface abrasion loss. It is logical to assume that such a relation should also exist for the fine portions of aggregates derived from different sources.

2. Effect of asphalt content on abrasion loss.

   The results are ahown in Fig. 12 and indicate that rapid changes in abrasion loss occur below a minimum asphalt content, especially for high abrasion loss mixes.

3. Effect of compaction on abrasion loss.

   As expected, higher kneading compaction pressures produce specimens having lower abrasion losses for given aggregate sources, Fig. 13. However, it appears that the amount of improvement by increasing compaction pressure is not as important as the effect of aggregate source.

In studies to date, it appears that some additives definitely improve the resistance of susceptible aggregates to surface abrasion loss, Fig. 14. In the case of aggregate A, the loss was very high with even an 85-100 grade paving asphalt. For this specific aggregate only, additives improved the resistance with definite differences between the various agents.

Based on preliminary studies, and subject to field correlation, we have tentatively decided that the maximum limit for

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the abrasion loss under the present specified test condition should be 15 grams.

We are presently engaged in further laboratory and field studies of this test method. Additional factors being studied are the effect of the soaking treatment prior to test and length of cure. Four inch cores of recently completed pavements are also being obtained from areas of different rainfall and traffic intensity. We are able to place these cores into the standard molds and perform the test in a normal manner. Further evaluation of the pavement surfaces should provide information for a field correlation and confirm the reliability of our tentative specification requirement.

Summary

This report describes four test methods for determining the effect of water action on asphalt paving mixtures. All of the methods are based on the premise that in order to be meaningful it is necessary to perform such tests on the complete aggregate gradation with the design asphalt content and preferably in a compacted state.

The results from these tests indicate the complexity of the water action problem, and the fact that the percentage of stripping, determined by presently available tests on a reference aggregate or one portion of the job aggregate gradation, may not provide sufficient information to predict performance. It appears necessary to measure the effect of water action on the engineering properties of the compacted paving mixture and

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to establish minimum criteria for specification purposes.

Conclusions

The Quantitative Stripping Test will provide a measure of the stripping tendencies of the entire mix gradation for any source where all aggregate surfaces have approximately equal dye adsorption. The test is not applicable, at present, to sources where a sizeable portion of the total aggregate combination is composed of very low adsorption material. Such a system will produce results that cannot be compared on a common basis with other sources.

The results of studies with the dye technique indicates the importance of asphalt consistency in the prevention of stripping and that different additives vary in their effectiveness depending on the aggregate source. The results also confirm the findings of other investigators that the source of the crude oil and method of production of the binder has an influence on the degree of stripping. This factor does not appear to be as important as the aggregate source, however, stripping tendencies on the part of the aggregate could be aggravated in the final pavement by a susceptible binder.

The influence of moisture vapor may be evaluated by means of the Moisture Vapor Susceptibility Test. Specification requirements now in use appear to be an adequate safeguard against failure from this form of water action.

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Results from the Water Susceptibility Test appear to indicate that serious pavement failures may result from water action with little evidence of internal stripping as measured by the dye technique. Physical properties such as Swell, Stability and Cohesion appear to be better indicators. Changes in these properties were definitely greater in cases where early pavement failures occurred than for satisfactory jobs.

A test procedure has been developed for determining the resistance of a pavement to raveling caused by water and tire action. In the aggregate sources studied, additives appear to improve the resistance to raveling.

The great importance of the matrix of the paving mixture in the resistance of the pavement to water action has been stressed in the introduction. The results of these studies support the contention that water action test methods must include this fine portion of the aggregate in the test specimen or very misleading results may be attained.

Acknowledgments

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Special acknowledgment is due Mr. Glenn Kemp who performed many of the laboratory tests concerned with this study.

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TABLE A

Influence of Asphalt Source on Percentage of Stripping, as Measured by the Dye Technique.

Aggregate Source	Asphalt Source	Grade	Curing Time Hrs. at 140°F	Film Stripping Test			Dye Test % Stripping
				Method	Test Temp. °F	Test Time Min.	
A	1	85-100	15	Calif. 302 B	77	30	35
"	2	"	"	"	"	"	45
"	3	"	"	"	"	"	53
"	4	"	"	"	"	"	65
"	5	"	"	"	"	"	71

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TABLE B

Percentage of Stripping During Water Susceptibility Test on Various Aggregate Sources.

Aggregate Source	% Binder	Grade of Binder	Test Period Hours	% Stripping Dye Technique
B	4.6	SC6	2 4 6	1.5 3 3
C	5.3	85-100	2 4 6	0.3 0.3 0.3
D	6.4	SC3	2 4 6	0.2 0.2 0.2
E	3.8	85-100	2 4 6	1.3 1.7 2.7
F	4.1	SC4	2 4 6	0.5 0.2 0.4
G Crushed Quartz	3.2	200-300	2 4 6	3.4 3.4 3.4
H	6.5	200-300	2 4 6	0.6 0.7 0.7
I	9.0	200-300	2 4 6	0.4 0.2 0.2

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TABLE C

Surface Abrasion Losses for Various Aggregate Sources Using Bituminous Binder From Producer 2

Aggregate Source	Material Abraded - Gms. at 100°F		
	SC4	200-300	85-100
T	0.5	None	None
M	5	None	None
P	8	None	None
C	17	None	None
N	22	None	None
O	33	None	None
L	57	None	None
J	81	4	None
B	89	23	None
K	93	None	None
A	187	88	19
U	240	14	8
R	264	80	43
S	287	128	94
V	331	39	6
Q	340	11	6

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TABLE D

Comparison of Surface Abrasion Results
and Percentage of Stripping.
Aggregate Source = A

Asphalt Source	Grade	Material Abraded Gms. at 100°F	% Stripping Dye Technique
2	60-70	17	34
	85-100	19	44
	120-150	56	44
	200-300	88	57
	SC4	187	91
3	60-70	11	27
	85-100	20	41
	120-150	27	59
	200-300	52	62
4	60-70	14	32
	85-100	22	37
	120-150	27	48
	200-300	41	50
5	60-70	21	48
	85-100	58	51
	120-150	60	62
	SC4	502	91

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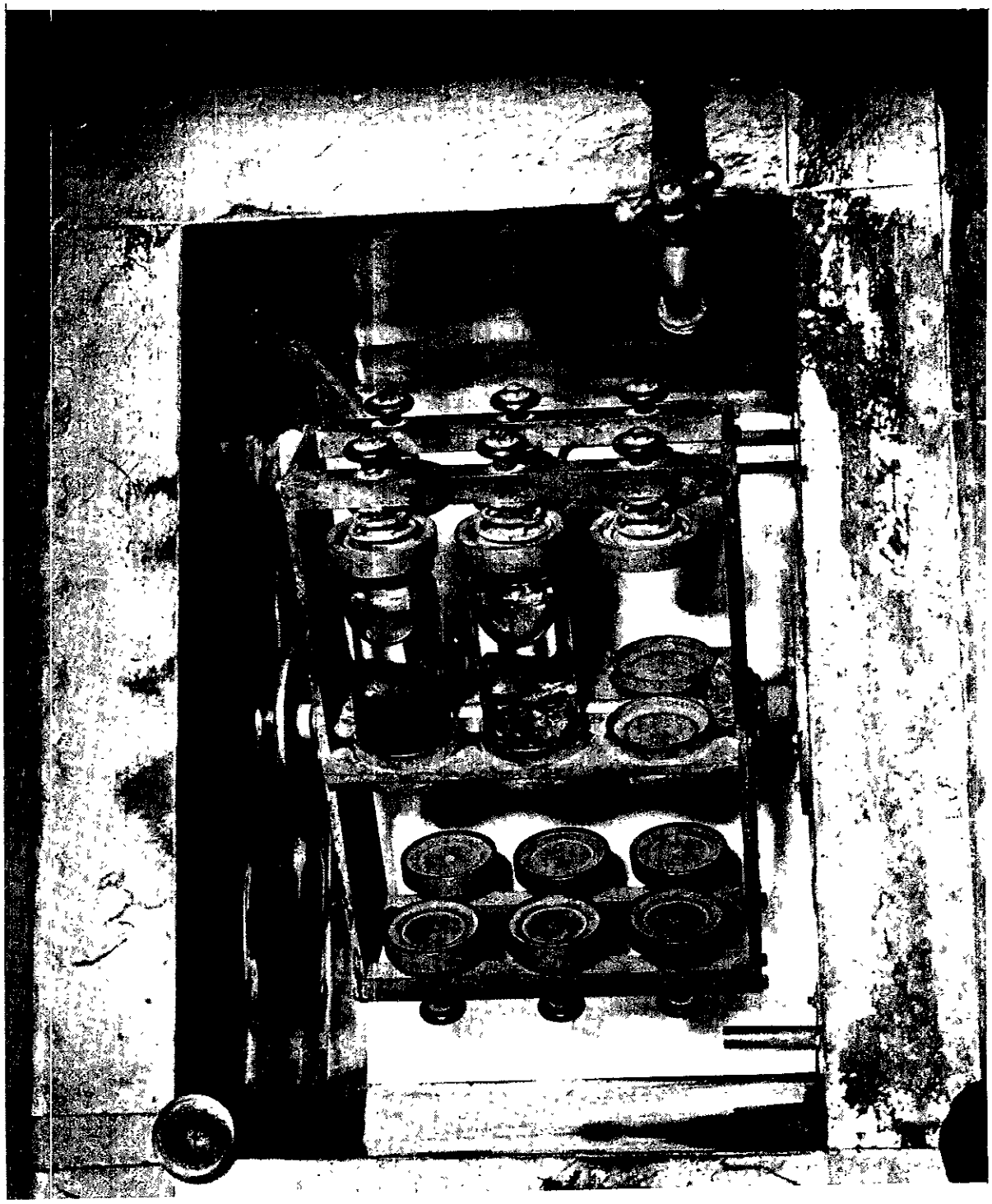
FIGURE 1



FILM STRIPPING APPARATUS

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FIGURE 2

DYE CIRCULATION UNIT FOR QUANTITATIVE DYE STRIPPING TEST

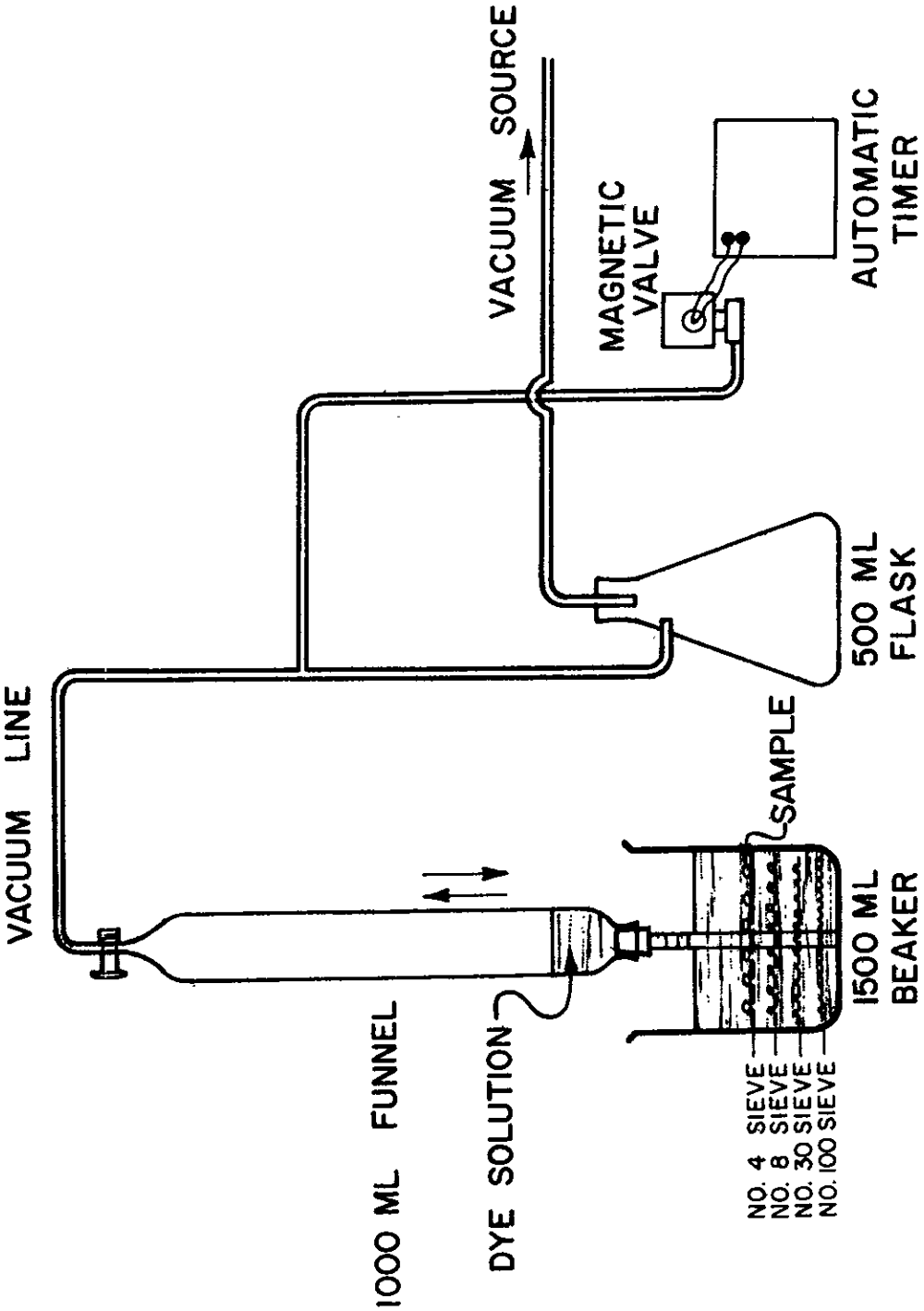

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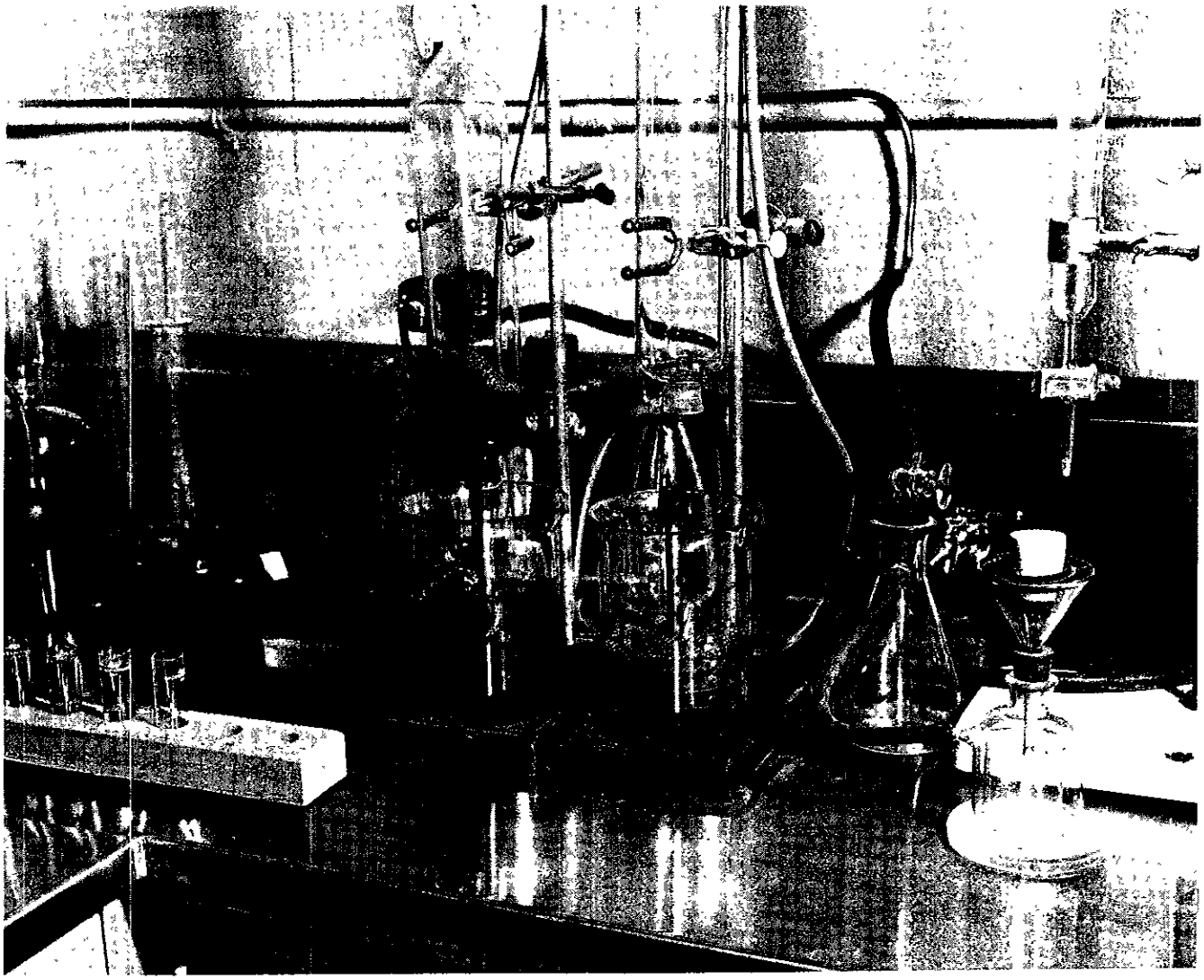
FIGURE 3



DYE CIRCULATION UNIT

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FIGURE 4

EFFECT OF ADDITIVES ON STRIPPING RESISTANCE

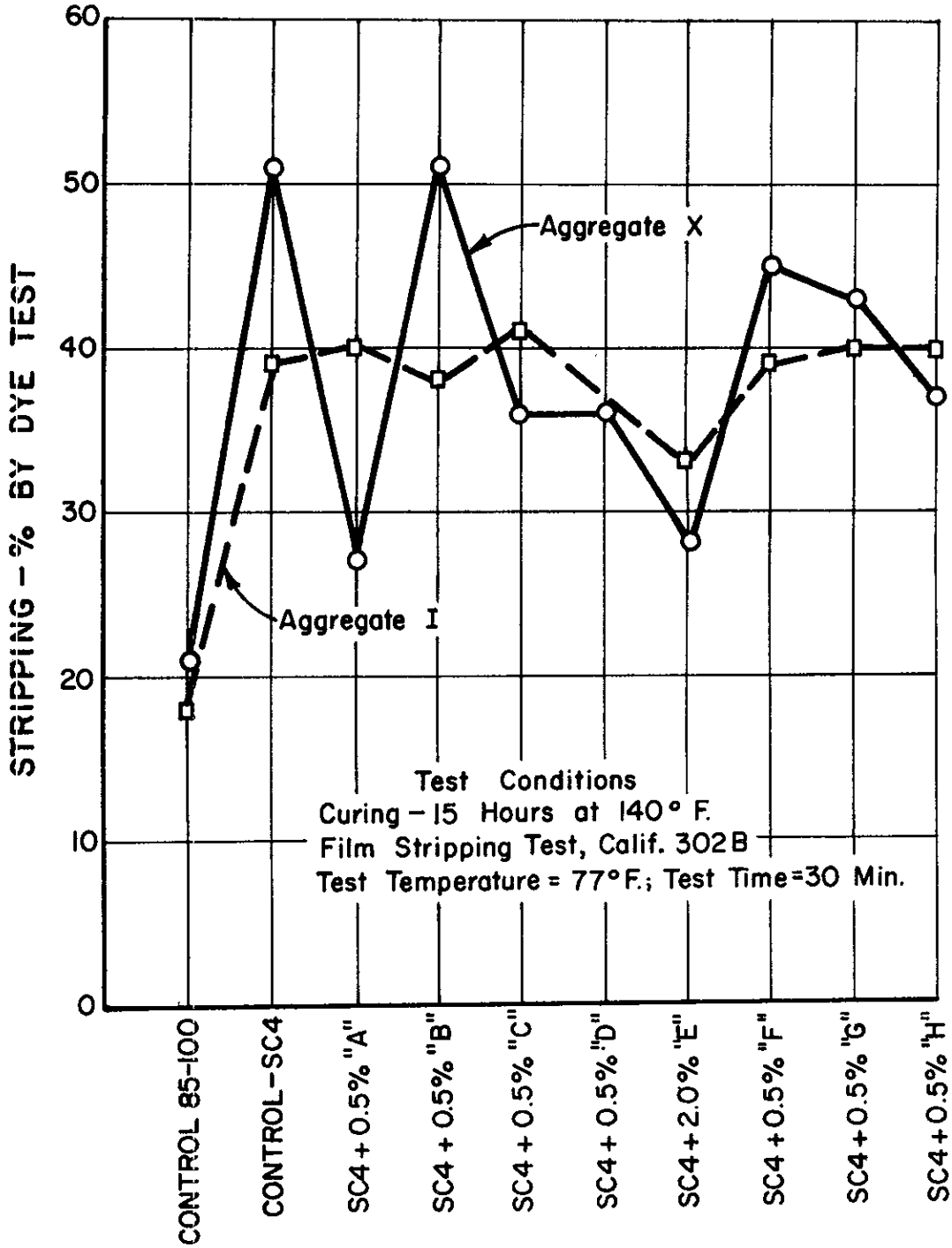

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FIGURE 5

WATER SUSCEPTIBILITY TEST EQUIPMENT

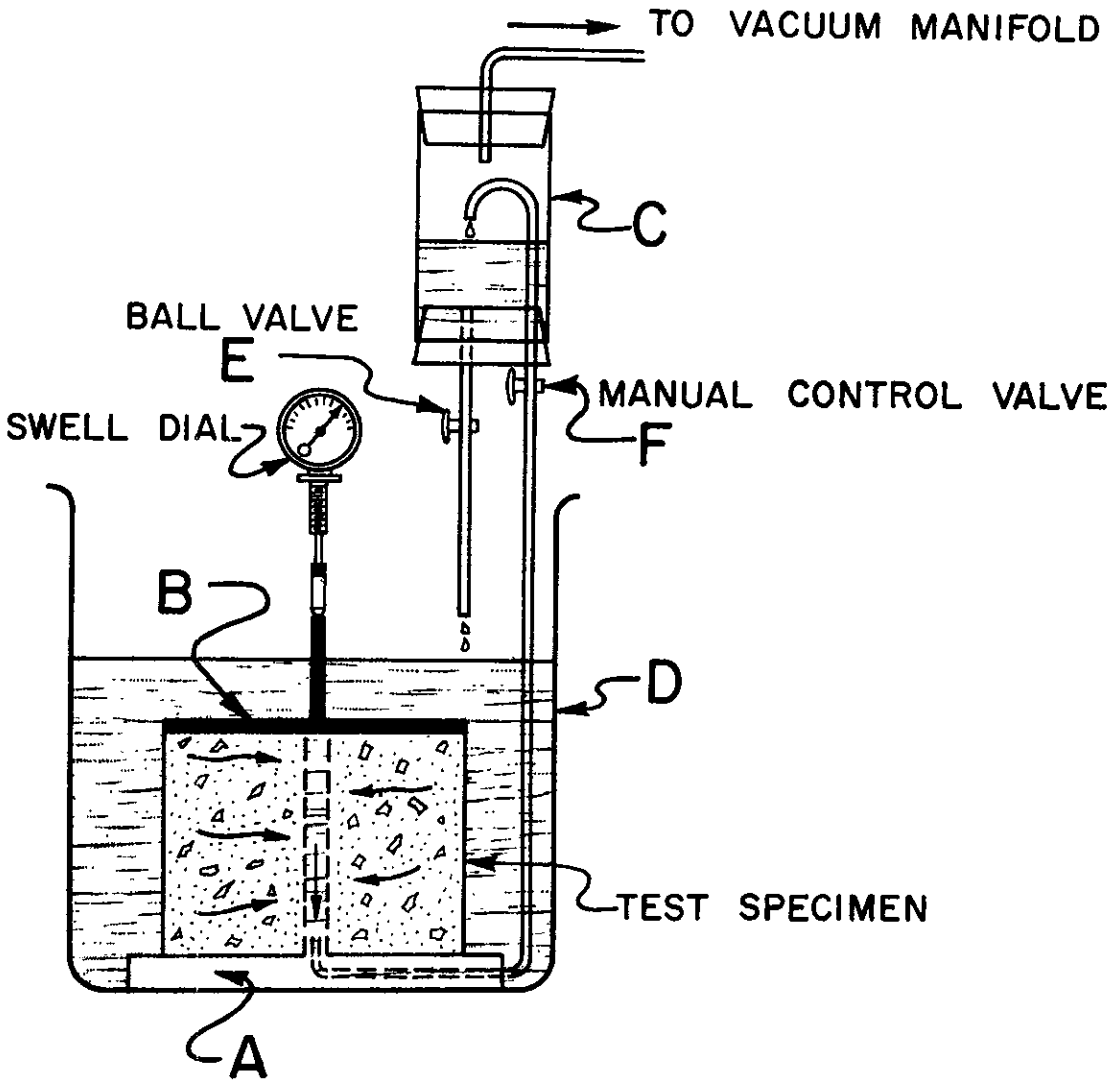

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FIGURE 6

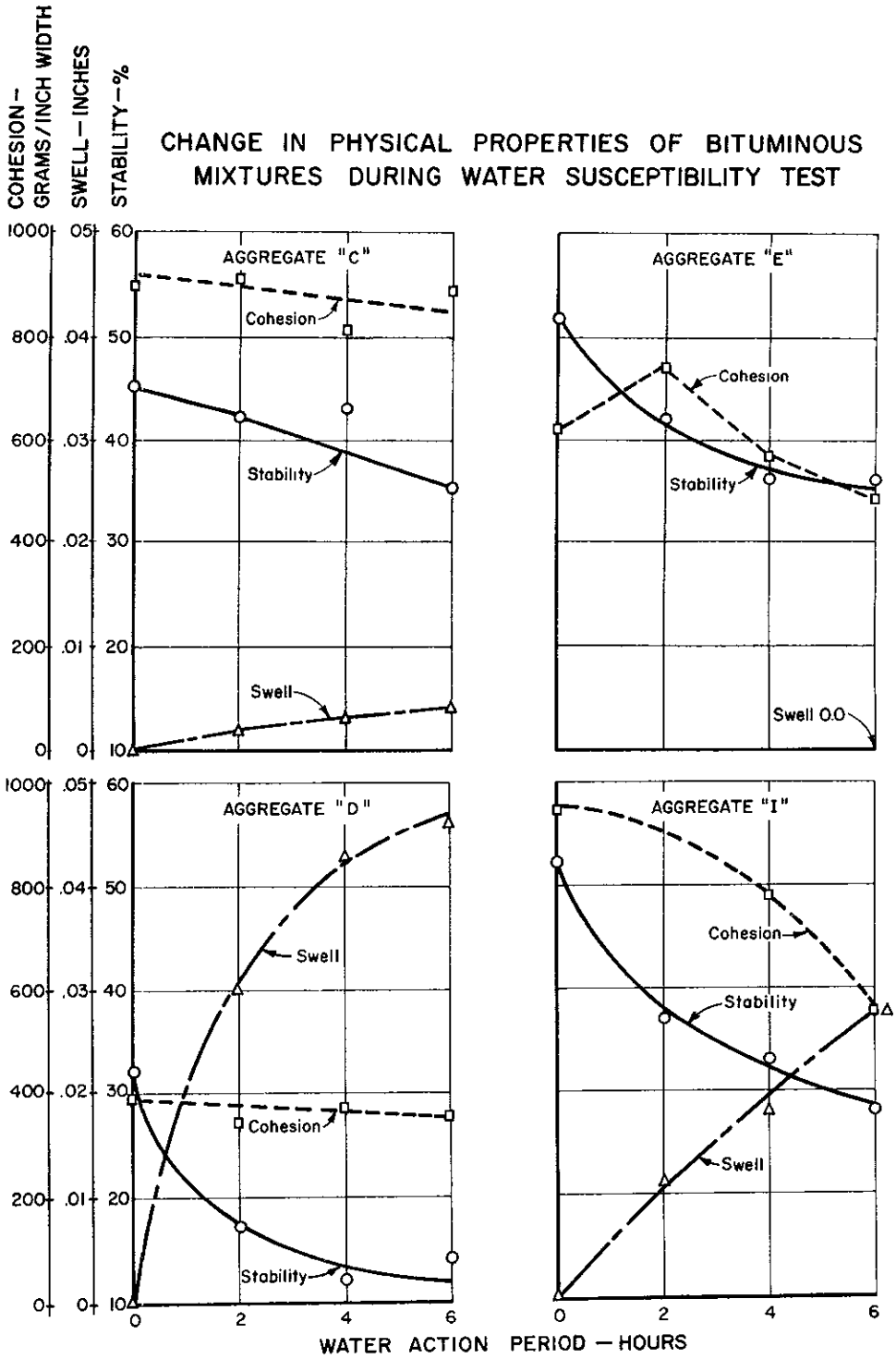

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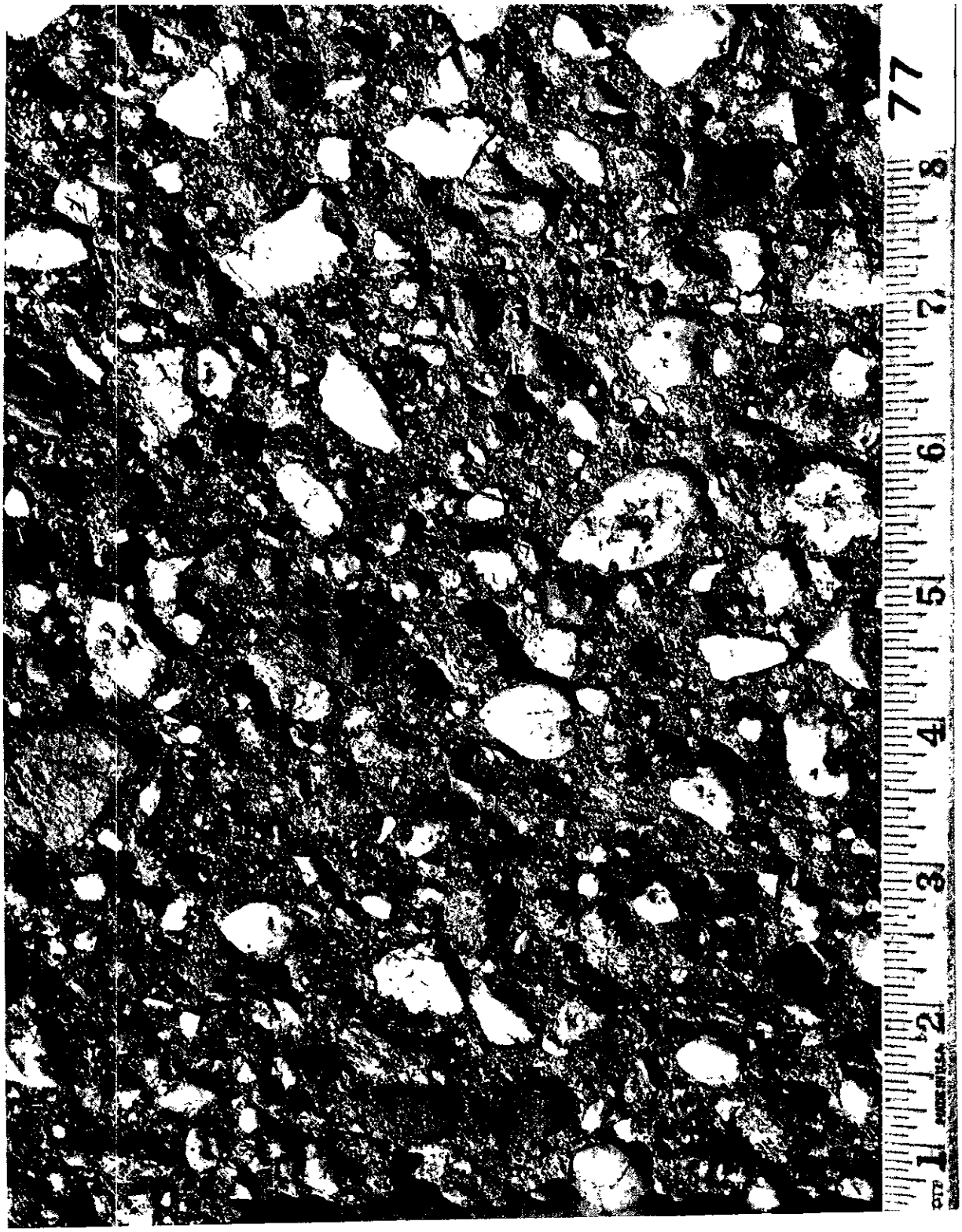
FIGURE 7



PAVEMENT TEXTURE AFTER TEN YEARS OF SERVICE LIFE
COARSE AGGREGATE PRIMARILY QUARTZ

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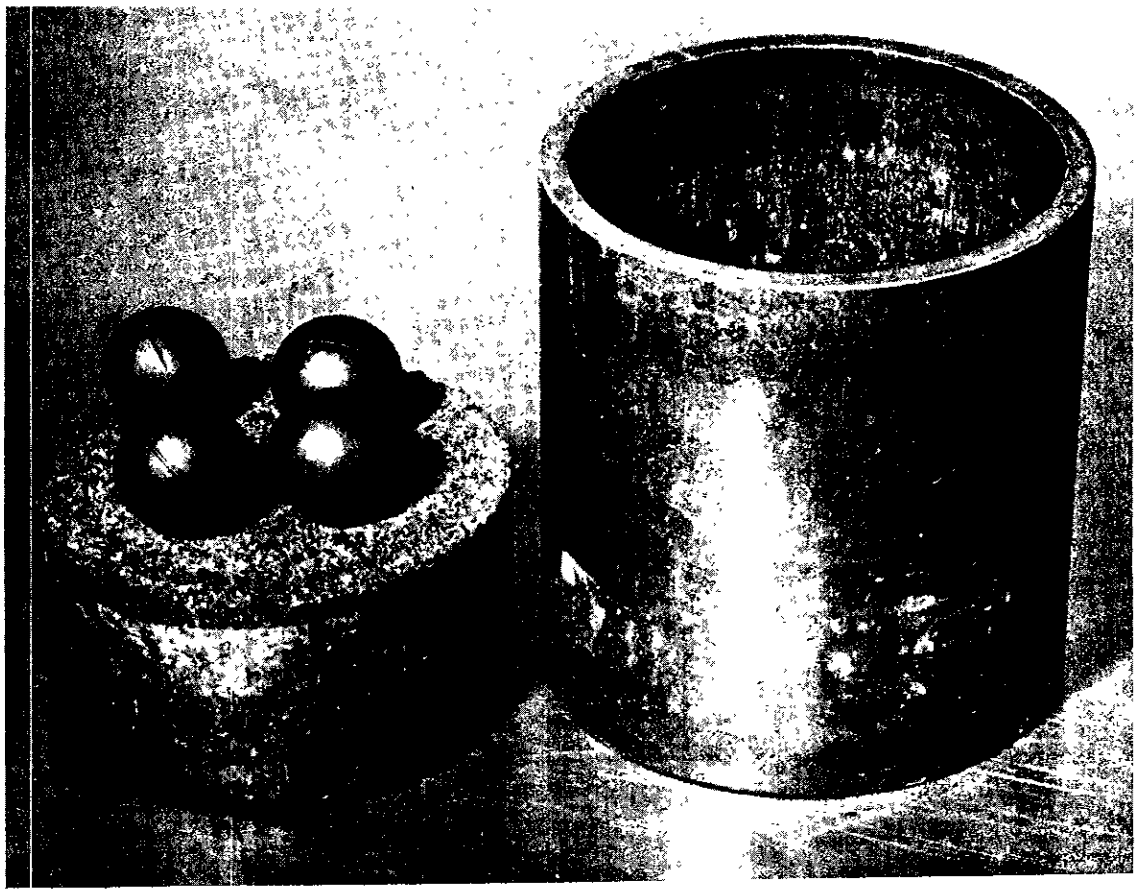
FIGURE 8

SURFACE WATER ABRASION TEST UNIT



TEST SPECIMEN, 1-1/8" SOLID RUBBER BALLS AND TEST MOLD

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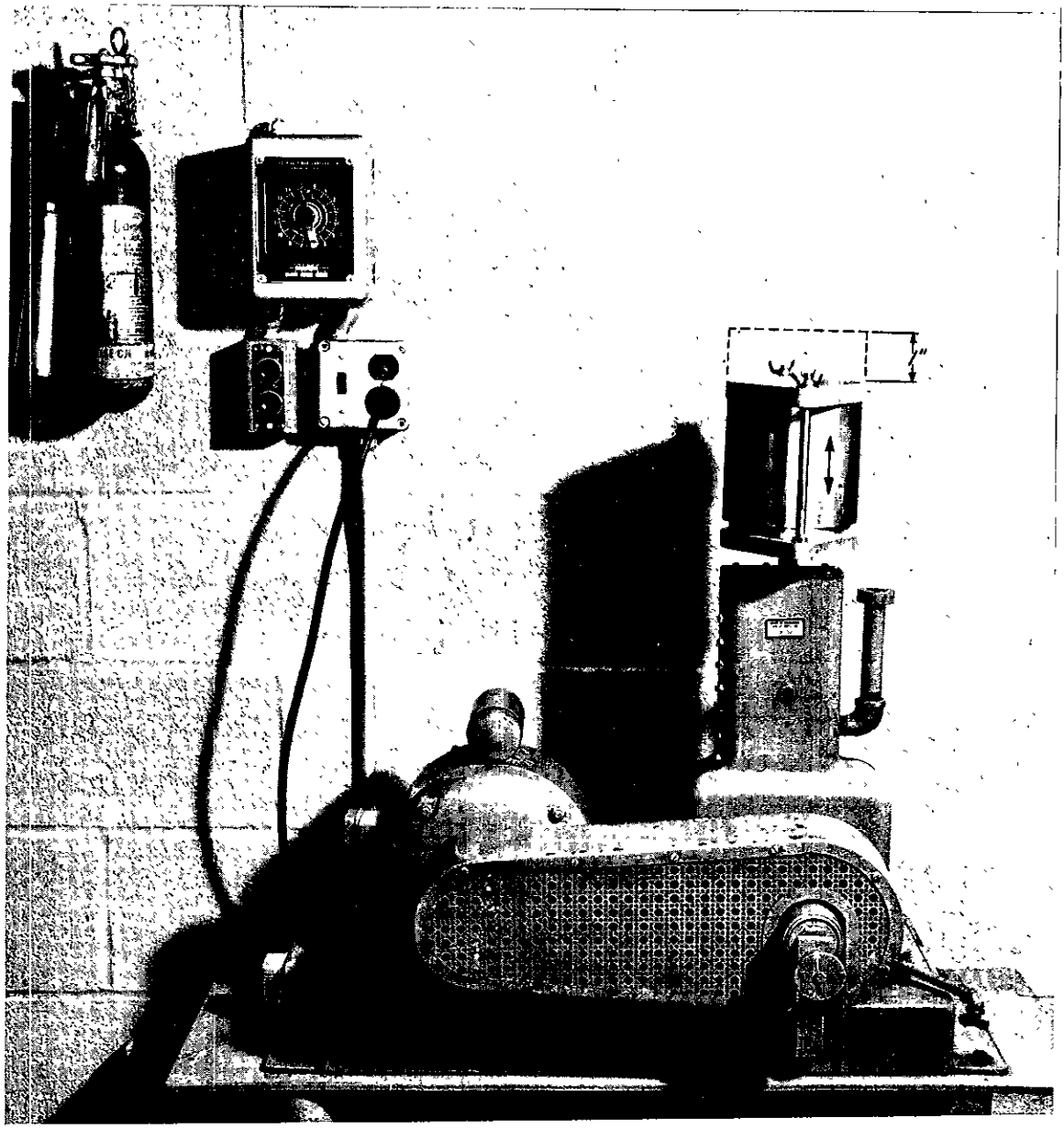
FIGURE 9



SURFACE WATER ABRASION TEST EQUIPMENT

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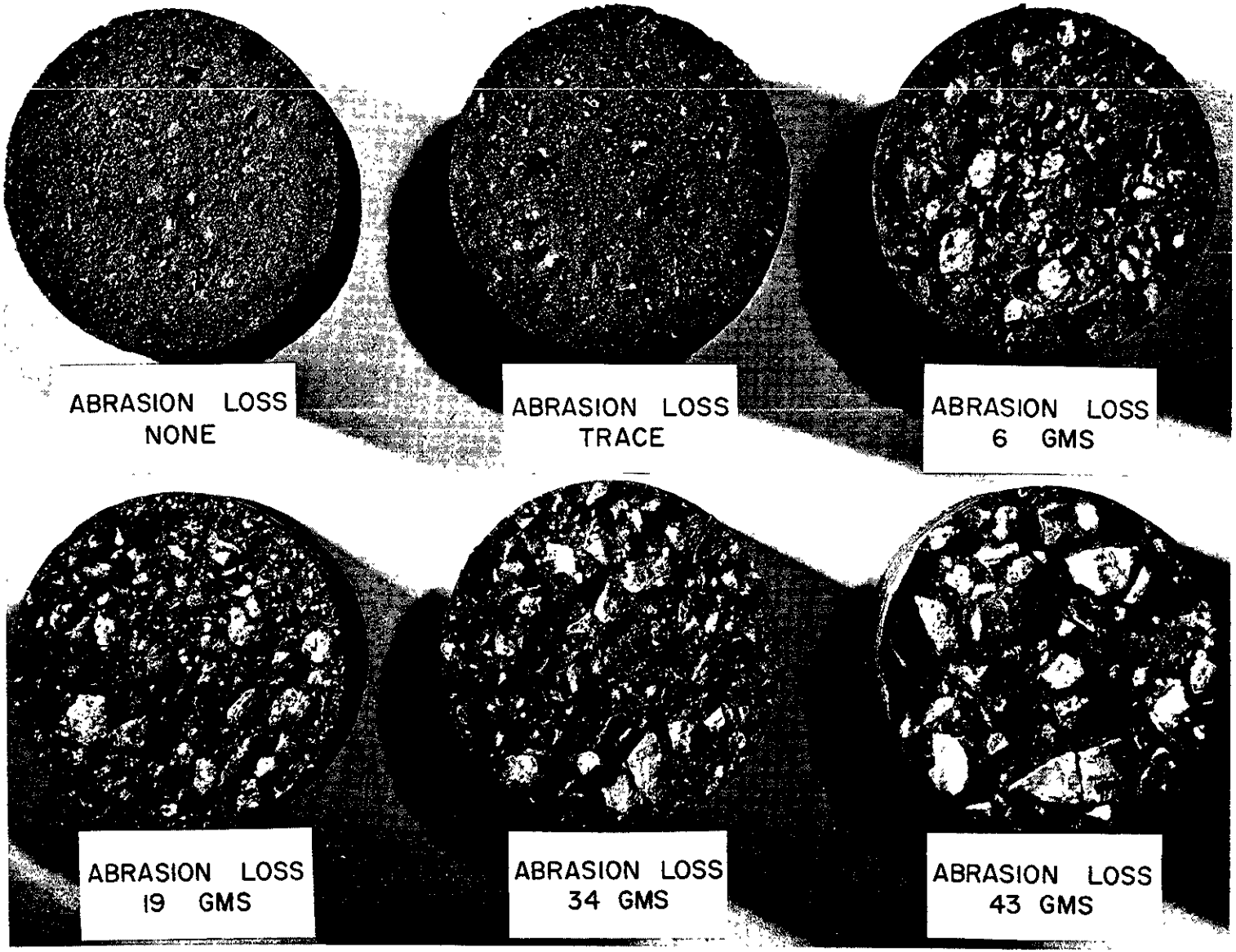

SURFACE ABRASION RESISTANCE OF VARIOUS AGGREGATE SOURCES
(ALL SPECIMENS CONTAIN 85-100 GRADE PAVING ASPHALT. EQUIVALENT TEST CONDITIONS)

FIGURE 10

FIGURE 11

RELATION BETWEEN ABRASION LOSS AND PERCENTAGE OF STRIPPING

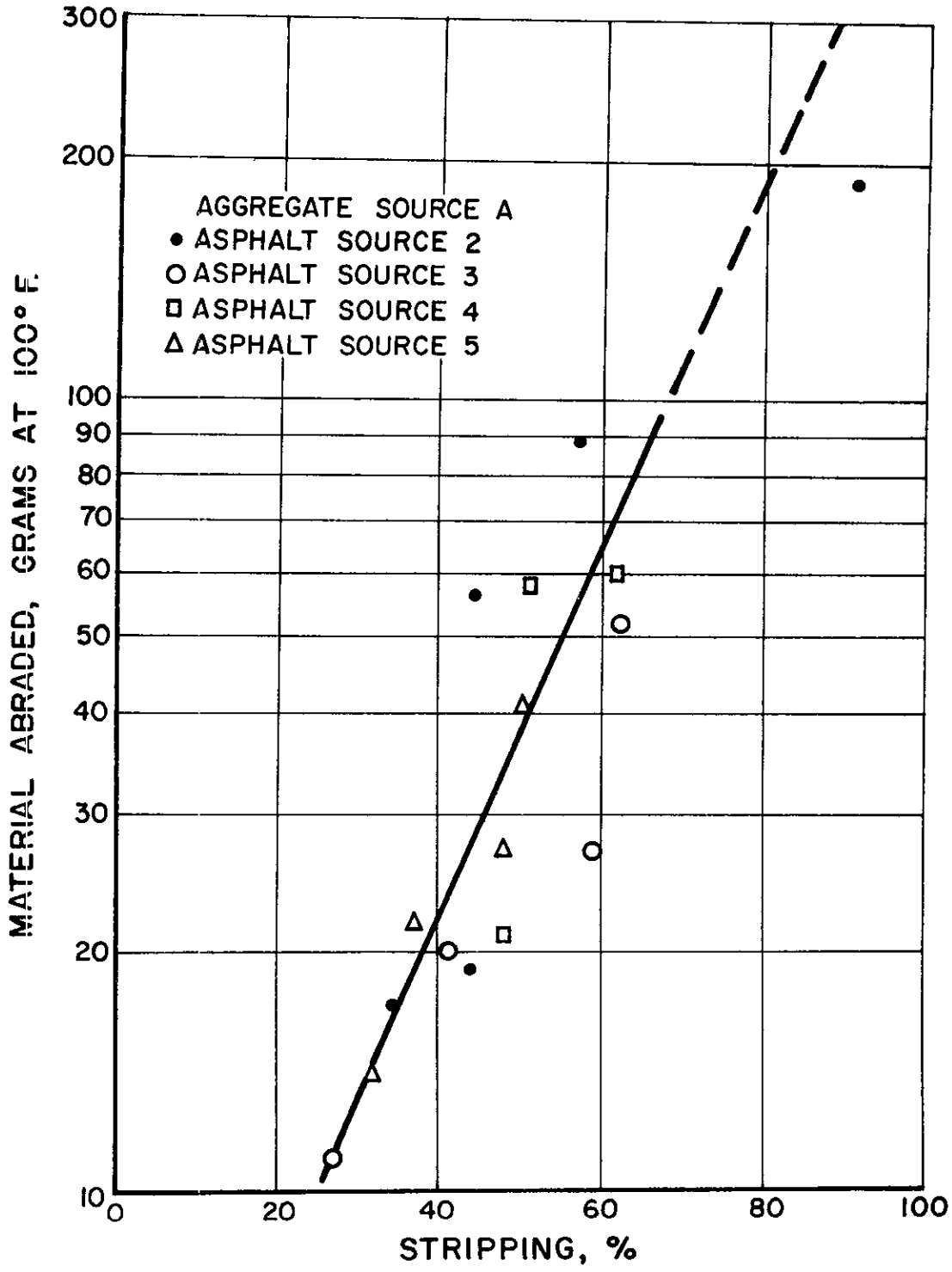

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FIGURE 12

EFFECT OF ASPHALT CONTENT ON ABRASION LOSS

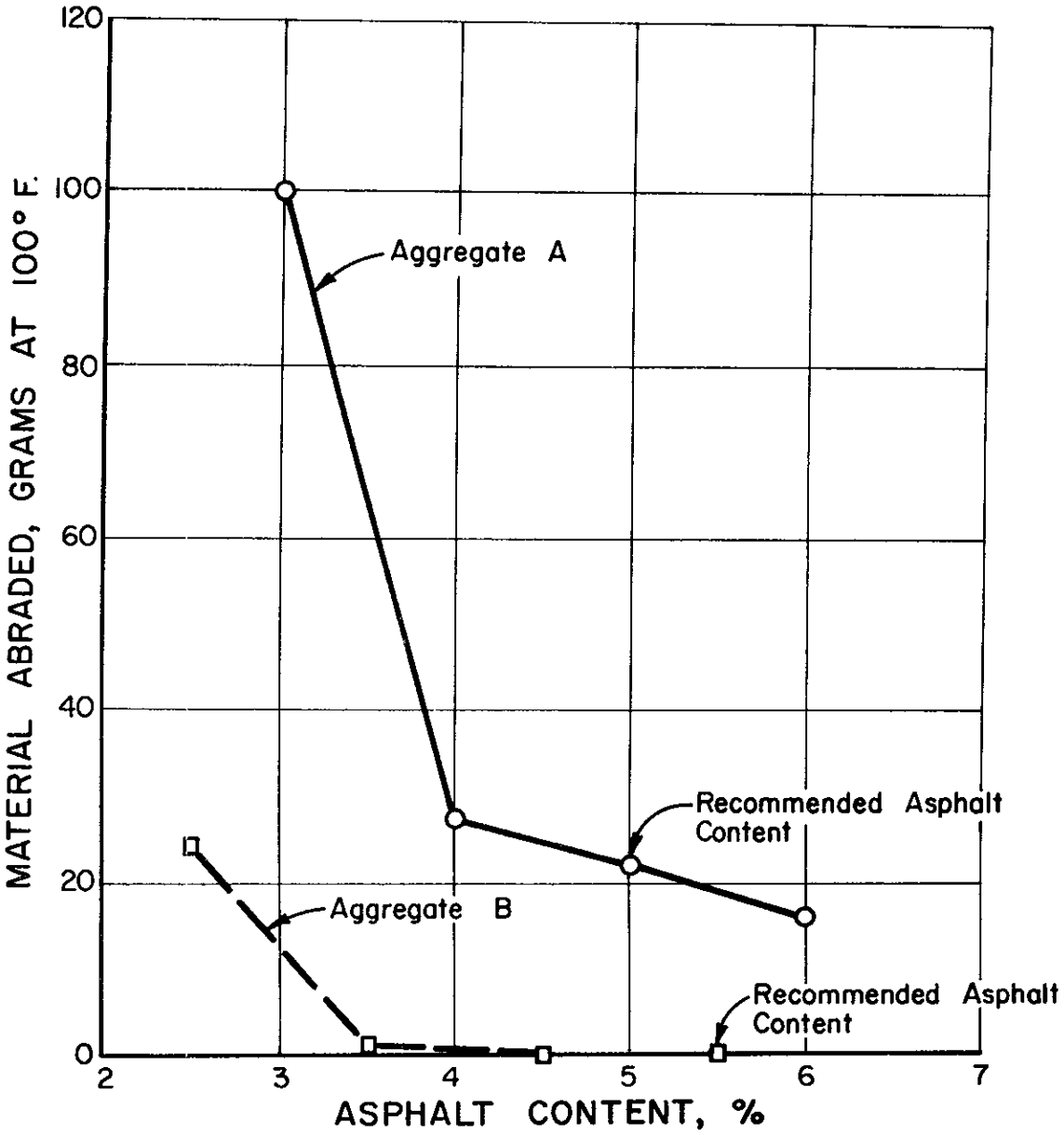

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FIGURE 13

EFFECT OF LABORATORY COMPACTION PRESSURE ON ABRASION LOSS

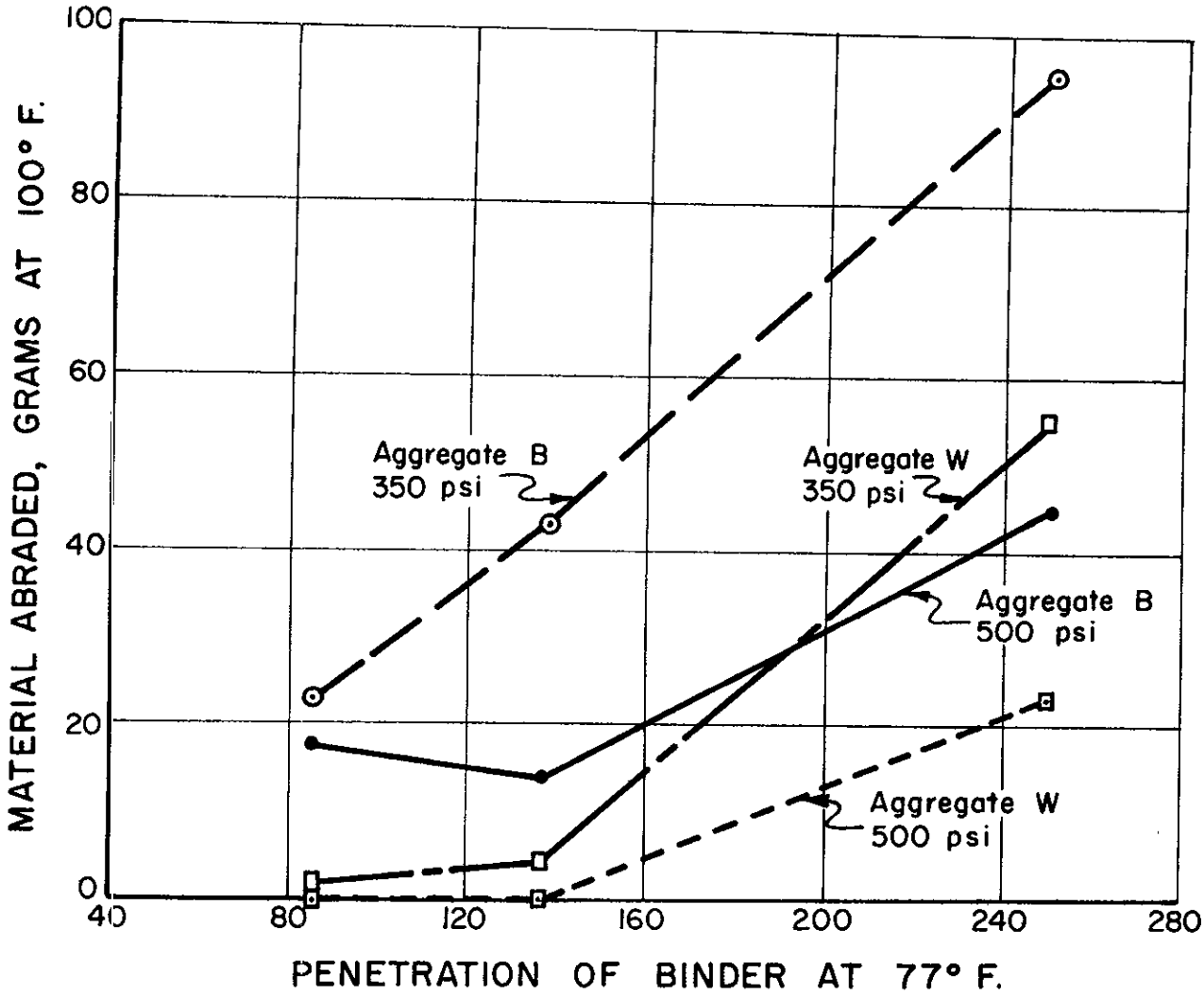

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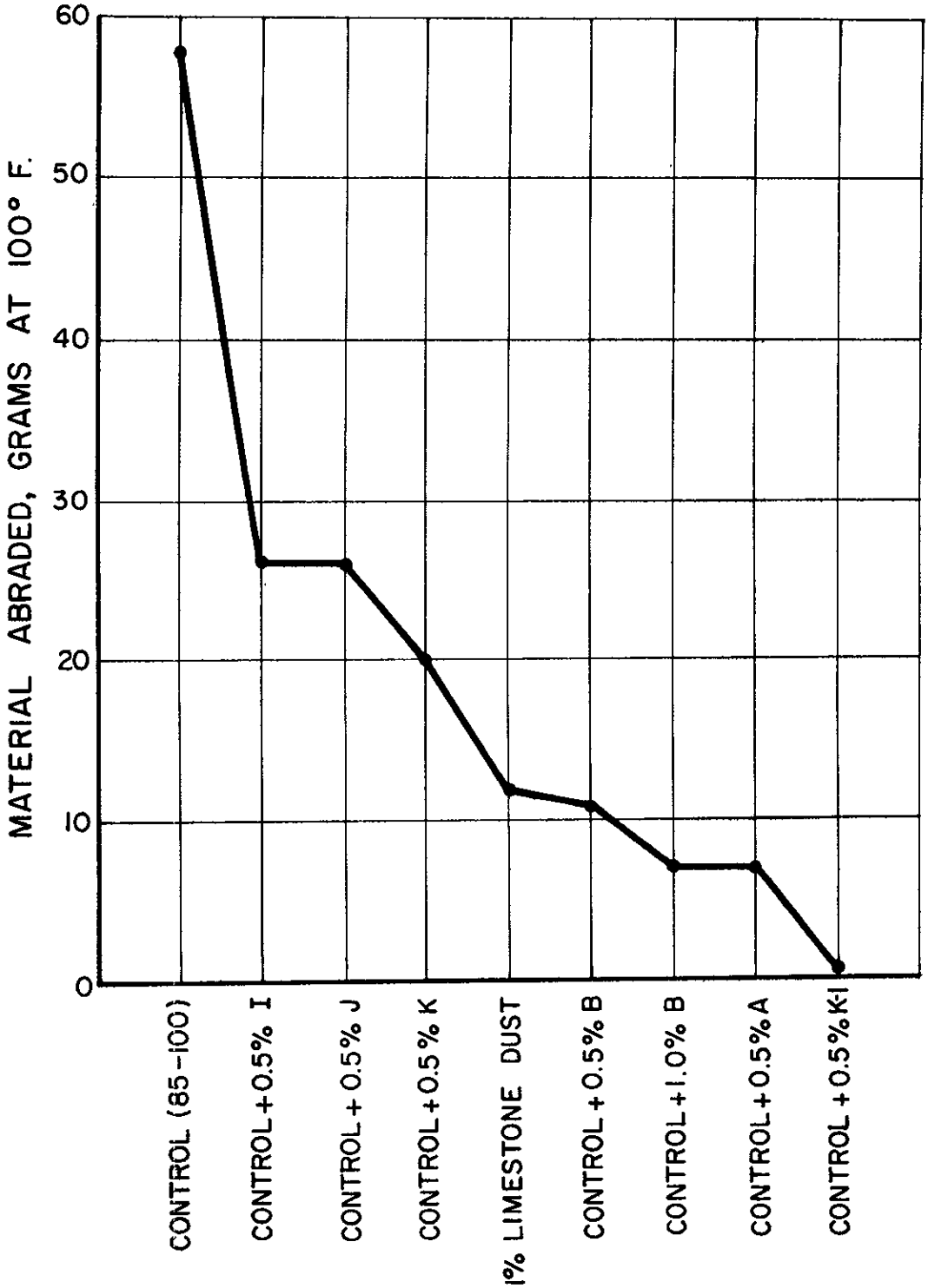
FIGURE 14

EFFECT OF ADDITIVES ON ABRASION LOSS
AGGREGATE A



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APPENDIX

A. Quantitative Stripping Test by Dye Technique.

B. Moisture Vapor Susceptibility Test.

C. Surface Water Abrasion Test.

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TENTATIVE METHOD OF TEST FOR QUANTITATIVE DETERMINATION OF FILM STRIPPING.

Scope:

This method provides a means for the quantitative determination of the resistance of bituminous mixtures to stripping of the asphalt from the aggregate particles, through the use of a dye adsorption technique for indicating the extent of stripped surface.

Procedure:

A. Apparatus

1. Dye Equilibrium Apparatus, Fig. 1.

2. California Type Mechanical Stripping Machine with special adaptors to hold 16 oz. bottles, Test Method No. Calif. 302-B.

3. Mechanical Mixing Machine (optional), Test Method No. Calif. 304-C.

4. Photometer, including tubes and filters.

B. Materials

1. Safranine Dye A

C. Preparation of Stock Dye Solution

Safranine in a concentration of 6 grams per liter of distilled water is prepared by thoroughly mixing with a mechanical mixer. The solution is filtered to eliminate a turbidity effect. A calibration curve is then determined with the photometer using an appropriate filter. (Filter 425B is used with a Fisher Type Photometer.)

D. Preparation of Samples

Process the aggregate in a manner comparable to construction processing, i.e., wash if washing is to be employed; otherwise, test as received. Prepare 2-250 gram samples, representing the entire combined grading.

E. Mixing

Coat one 250 gram sample of aggregate with the design bitumen content and cure for 15 hours at 140°F.

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F. Tests and Calculations

1. Procedure for Determining Dye Adsorption of Uncoated Aggregate.

(a) The starting dye strength should be sufficient to satisfy the adsorptive capacity of the sample and have an end strength in the range of 0.2 to 0.7 mg./ml. The strength must be determined by trial, however, only one determination should be necessary. The desired dye strength is prepared by diluting a sample of the stock solution with distilled water to a total volume of 700 ml.

(b) The uncoated 250 gm. sample is poured into the beaker containing the series of sieves in the dye equilibrium apparatus and 700 ml. of dye solution is added. The beaker is then swirled by hand until the material is graded on the series of sieves. The 1000 ml. funnel is then attached to the rubber cork on the brass tube of the sieve series. The timing motor is started and the vacuum is adjusted so that all of the dye solution is raised into the funnel in a period of approximately 8 seconds. The vacuum is then released for an 8 second period, permitting the solution to drain back into the beaker. The solution is cycled for a period of 1-1/2 hours.

(c) At the end of the 1-1/2 hour period, 20 ml. of dye solution is removed, filtered through a Gooch crucible containing a glass fiber filter. The solution is then diluted, placed in the Photometer and the dye strength determined. This procedure is repeated at 15 minute intervals until. Photometer readings do not vary by more than 2 points. The final reading provides the end strength of the dye remaining in solution. This range should be between 0.2-0.7 mg./ml.

(d) If the solution does not have an end strength, between 0.2-0.7 mg./ml. then the procedure is repeated with a fresh sample of uncoated aggregate, adjusting the original dye strength on the basis of the final results from the first sample.

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2. Procedure for Stripping the Coated Samples.

   (a) The cured bitumen coated sample is placed in a 16 oz. jar and allowed to cool. 200 ml. of distilled water is added, and the jar is placed in the stripping machine for 30 minutes.

3. Procedure for Determining Dye Adsorption of Stripped Sample.

   (a) Perform a rough estimate of the amount of stripping by visual means. On the basis of the amount of stripping and the initial dye strength required for the uncoated sample, estimate the initial dye strength required for the stripped sample. Example: If the uncoated sample, required 2.0 mg./gm. of dye to satisfy adsorption to equilibrium and the estimated percent of stripping is 50%, then the required amount of dye is 1 mg./gm. of dye. Then since 250 gm. of aggregate is used, the total dye needed for the sample is (1.0)(250) or 250 mg. of dye. The total amount of initial solution is 700 ml. and the final range of dye strength after equilibrium should be 0.2-0.7 mg./ml. Therefore, assuming an average value of 0.5 mg./ml. for final strength, we have (0.5)(700) or 350 mg. dye required for final solution strength after total dye adsorption by stripped aggregate surface. Then total dye needed for this test is 250+350 or 600 mg. dye. Since the stock solution contains 6.0 gm./liter of dye, $\frac{600}{6}$ = 100 ml. of stock solution. Then 600 ml. of distilled water should be added to the 100 ml. of stock solution to make 700 ml. of required dye solution. However, in the case of the stripped sample, the 200 ml. of stripping water is included in the total volume of 700 ml. and therefore only 400 ml. of additional distilled water is added to the stock solution.

   (b) The stripped sample and water is poured onto the sieve assembly, and the dye adsorption to equilibrium is determined in the same manner as described for the uncoated material.

4. Calculation of Percentage of Stripping.

   (a) For original and stripped sample calculate total dye adsorbed as follows:

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Dye adsorbed, mg./gm. =

$$\frac{\text{mg. of Dye Used-mg. of Dye in Solution}}{\text{Sample Weight, gm.}}$$

(b) Calculate Percentage of Stripping.

Stripping, % =

$$\frac{\text{Dye Adsorbed, mg./gm., Stripped Sample}}{\text{Dye Adsorbed, mg./gm., Original Sample}} \times 100$$

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DYE CIRCULATION UNIT FOR QUANTITATIVE DYE STRIPPING TEST

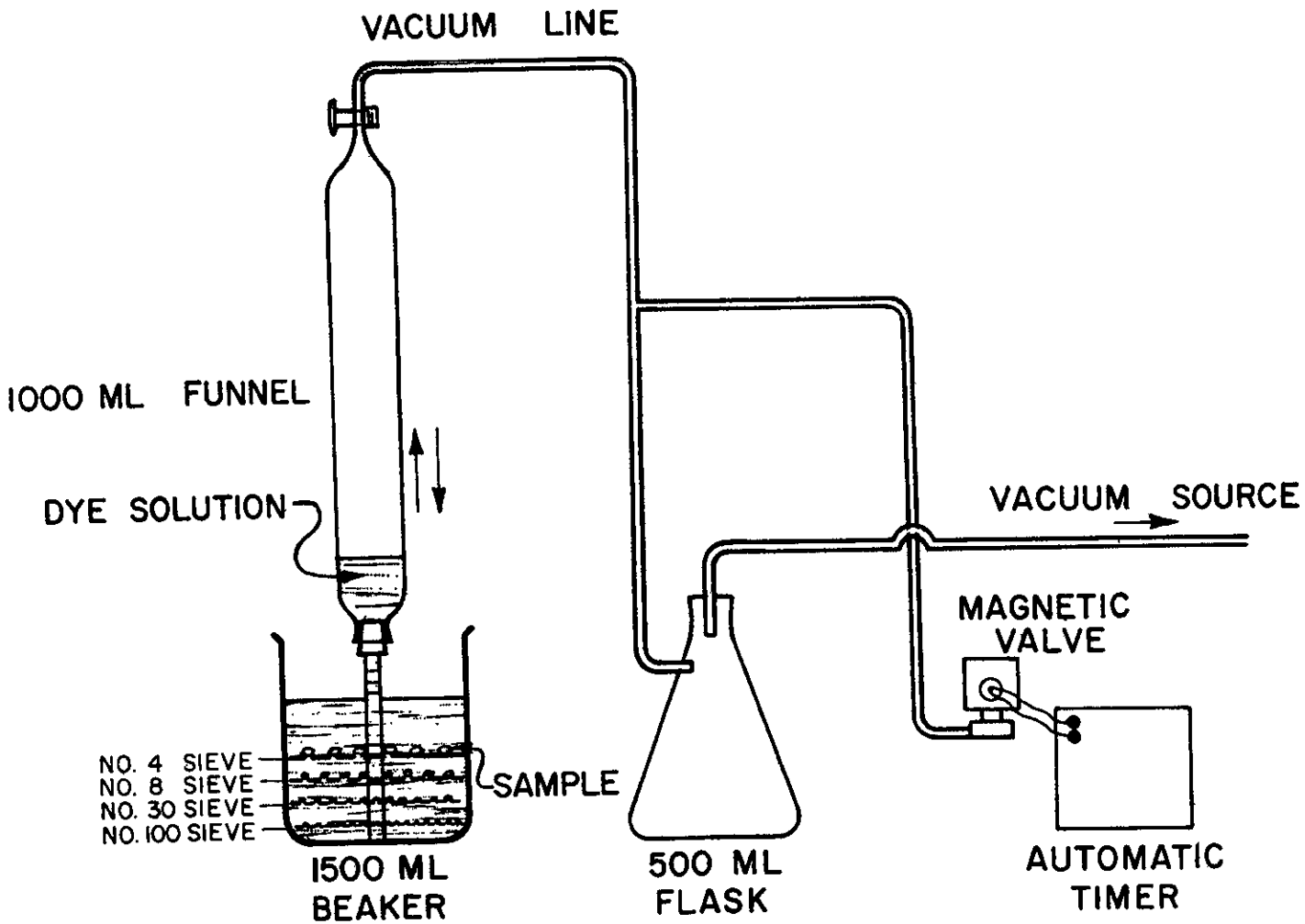


FIGURE 1

Test Method No. Calif. 307-B
January 3, 1956
(3 pages)

State of California
Department of Public Works
Division of Highways

MATERIALS AND RESEARCH DEPARTMENT

METHOD OF TEST FOR MOISTURE VAPOR SUSCEPTIBILITY OF BITUMINOUS MIXTURES

Scope

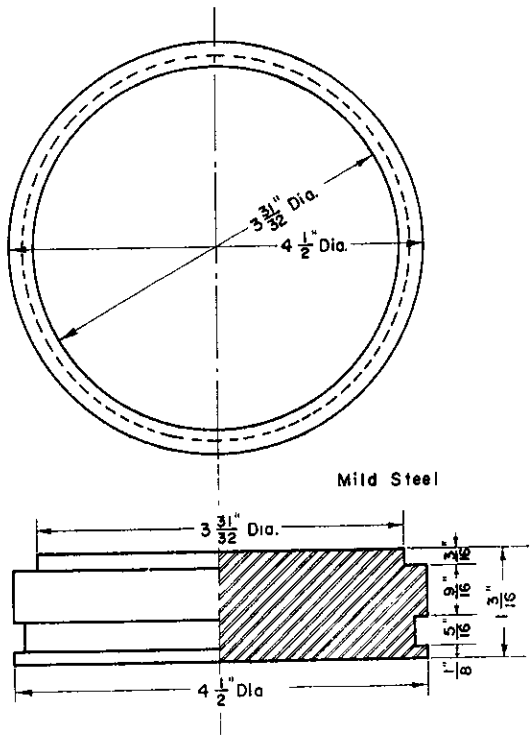
The moisture vapor susceptibility test indicates the extent to which stabilometer values of bituminous mixtures are affected by moisture, in the vapor state, entering the mixture from a wet subgrade or from other sources.

Procedure

A. Apparatus

1. Hveem stabilometer and accessories.
2. Testing Machine, 50,000-lb. capacity (minimum).
3. Weathering machine or oven conforming to either of the following:
   a. Weathering machine, designed to subject bituminous mixtures, either loose or in a compacted state to alternate cycles of heating and cooling. The samples shall receive the effect of heating and cooling by slowly moving through various heated and aerated sections of the machine on trays fastened to an endless chain. One section of the machine shall be maintained at approximately 140 F., another at approximately 180 F., with a section between each open to atmospheric temperature. The heating effect shall be developed by infra-red lamps. One complete cycle for a sample shall consist of it being moved at a constant rate of speed through the heated and cooled areas of the machine in the following sequence:
      (1) Atmospheric temperature.
      (2) Approximately 180 F.
      (3) Atmospheric temperature.
      (4) Approximately 140 F.

      The complete cycle requires 5 hr.
   b. Oven, capable of maintaining a temperature of 140 ± 5 F. with provision for free circulation of air through the oven.
4. Aluminum seal cap, 4-in. diameter, 18-20 gauge, $\frac{1}{8}$-in. lip.
5. Circular felt pad, 4-in. diameter, $\frac{1}{4}$-in. thick.
6. Felt strip wick, $\frac{1}{4}$ in. x 2 in. x $7\frac{1}{2}$ in.
7. Metal spring retaining clamp.
8. Tin-plated pan, $1\frac{1}{4}$ in. high, $3\frac{7}{8}$ in. in diameter.
9. Special pressing standard for applying aluminum seal caps (see Figure I).



M.V.S. PRESSING STANDARD

FIGURE I

B. Test Record Form

Use "Test Record" sheet, Form T-315, for recording test data. After test is completed, transfer result to work card, Form T-302.

C. Preparation of Sample

1. Mix, fabricate and compact the test specimen as described in Test Method No. Calif. 304, with the exception that the specimen shall be compacted in a stainless steel mold.
2. Before application of the 1,000 psi static load, force the specimen upward through the mold so that the surface of the specimen is $\frac{1}{4}$ in. below the top of the mold.
3. Place aluminum seal cap on the compacted surface, invert mold so that the seal cap rests on the special pressing standard, and apply a vertical load of 1,000 psi.

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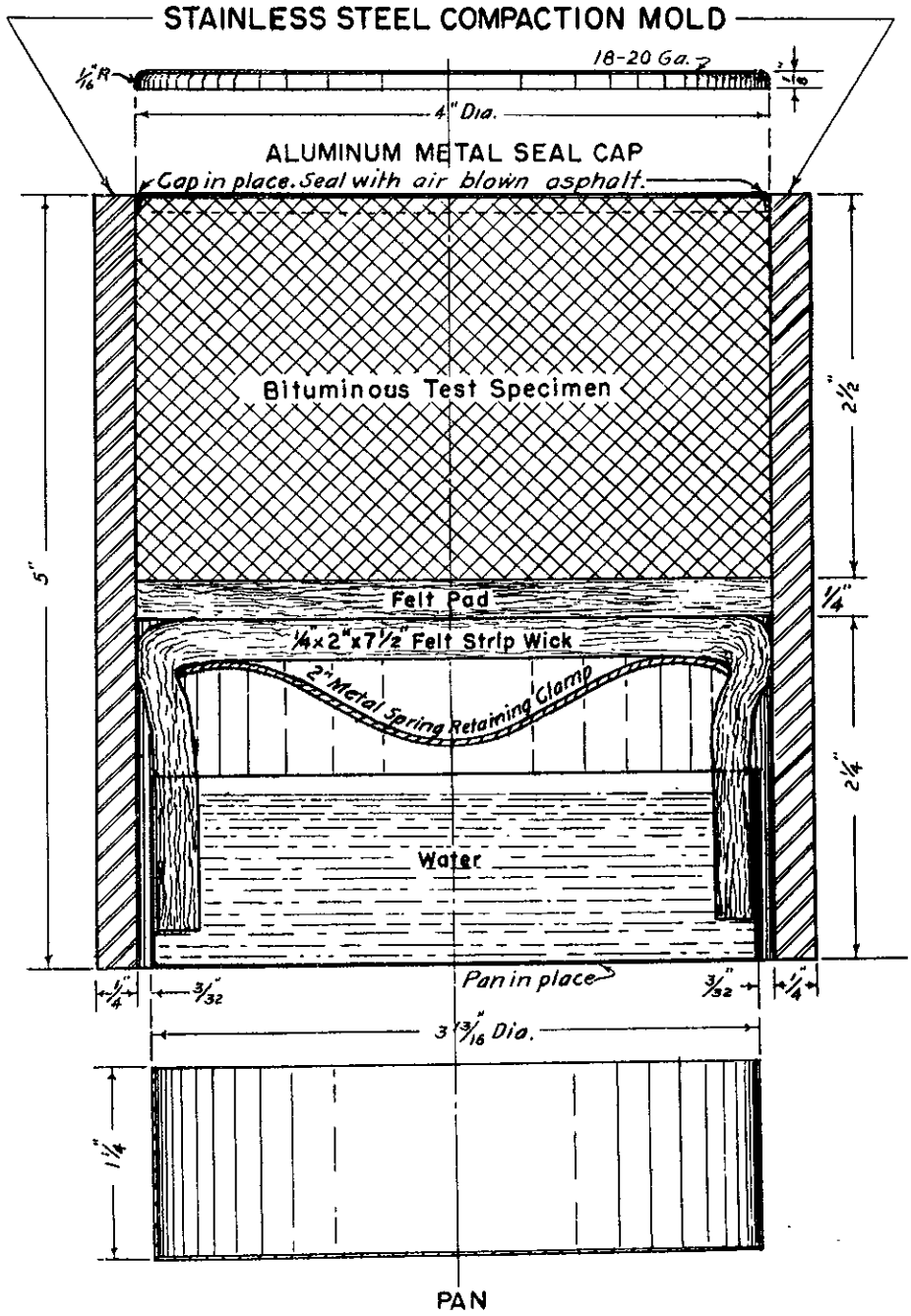

STATE OF CALIFORNIA
MATERIALS & RESEARCH DEPARTMENT
MOISTURE VAPOR SUSCEPTIBILITY
TEST ASSEMBLY
FULL SCALE

FIGURE II

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TENTATIVE METHOD OF TEST FOR DETERMINING THE SURFACE ABRASION OF LABORATORY COMPACTED BITUMINOUS MIXTURES IN THE PRESENCE OF WATER

Scope:

The surface abrasion test measures the ability of a compacted bituminous mixture to resist surface abrasion or raveling in the presence of water.

Procedure:

A. Apparatus

1. 1-Mechanical shaker for shaking mold containing sample, water and rubber balls in a vertical direction at 1200 cycles per minute with a 1" stroke. Drawings are available from the Materials and Research Department.

2. 1-140°F Oven

3. 1-230°F Oven

4. 4-Rubber balls 1-1/8" diameter 15.5 grams ±0.7 grams each. These balls may be obtained from vendors of plumbing supplies as #1542 Solid Rubber balls, Medium consistency.

5. 1-250 ml. graduated cylinder

6. 1-Polyethylene wash bottle

7. Steel Pan 6-in. diameter 1-1/2" deep

8. Aluminum Pan 7-1/2" in diameter 2-1/2" deep

9. 1-Balance having capacity 4,500 gm. and sensitive to 0.1 gm.

B. Mixing and Fabrication

Mix and fabricate the specimen as described for swell test in Test Method No. Calif. 304-B.

C. Test Procedure

1. Place mold containing specimen in the aluminum pan.

2. After the specimen has been allowed to cool, pour exactly 500 ml. of water on specimen in mold, and allow to stand undisturbed for 20 hours.

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4. Seal the edges of the aluminum seal cap, to prevent the escape of moisture vapor, with a solution consisting of air blown asphalt that has been dissolved in sufficient ethylene dichloride to produce a consistency comparable to that of ordinary paint.
5. Place circular felt pad, which has previously been soaked in water, against the bottom surface of the test specimen. Place presoaked felt strip wick in contact with felt pad, the wick to be held in place with a metal spring clamp (see Figure II).
6. Insert pan of water up into the mold making certain that the free ends of the wick are immersed.

D. Test Procedure

1. Place assembly in weathering machine and subject to 15 cycles of treatment as described under Section A, paragraph 3, or place assembly in a 140 F. oven for a continuous period of 75 hr.
2. Obtain the stabilometer and cohesiometer values as described under Methods of Test for Stabilometer Value, Test Method No. Calif. 304, and Cohesiometer Value, Test Method No. Calif. 306, with the exception that the cohesiometer test should be performed immediately following the stabilometer test. The 2-hr. reheating period in the 140 F. oven is eliminated to preserve the moisture absorbed during the 75-hr. moisture vapor treatment.
3. Determine percent of moisture absorbed by the specimen by subjecting 500 g. of the mixture to the Xylene Reflux Distillation Test, Test Method No. Calif. 311.

Notes

Materials showing a stabilometer value of 30 or more after 15 cycles of moisture vapor action in the weathering machine, or 75 hr. in a 140 F. oven, are considered satisfactory for the higher types of bituminous mixtures. Correspondingly lower stabilometer values of 25 minimum and 20 minimum, respectively, for the intermediate and lower types of bituminous mixtures are considered to be acceptable.

Reporting of Results

Report results as numerical values obtained in the stabilometer and cohesiometer tests and as percent of moisture obtained in the xylene reflux distillation test.

Report results on Test Report Form T-374.

REFERENCE

A California Method.
Test Method Nos. Calif. 304, 306, and 311

End of Text on Calif. 307-B

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3. Pour any water which has permeated through the sample during the 20 hour soaking period back into the mold containing the specimen and place mold with sample and pan into 100°F oven for four to six hours. Surface of specimen must be covered with water during this heating period.

4. Remove all water from mold and measure 250 ml. of the heated water in a graduated cylinder and pour onto the surface of the specimen.

5. Place the four rubber balls in the mold, the insulating jacket over the mold, and lock mold into place on mechanical shaker with wing nuts.

6. Shake sample at 1200 C.P.M. for 15 minutes and remove from mechanical shaker.

7. Remove rubber balls and pour contents from mold into the preweighed steel pan. Wash all fines from the surface of the sample into the pan with wash bottle.

8. Let pan stand for one hour and decant as much of the clear water off as possible.

9. Place pan in 230°F oven until all water has been evaporated.

10. Weigh pan containing abraded material and record its weight. The difference between this weight and the original weight of the pan is the amount of abrasion loss in grams.

D. Precautions

1. The sample should be transferred from the 100°F oven to the shaking device as quickly as possible.

Reporting Results:

Report the amount of abrasion loss in grams of material abraded and this amount shall be an average of <u>three</u> test specimens.

Note:

The rubber balls shall be free of asphalt prior to testing. The asphalt shall be cleaned from the rubber balls with a white gasoline soaked rag.

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