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White, R.M.; Mitten, W.R.; and Skog, John B.

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16. ABSTRACT

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Four asphalts, of different chemical composition and from different geographical origin (California, Venezuela, Arkansas, Alberta) were separated into concentrates of five components: asphaltenes, nitrogen bases, first acidaffins, second acidaffins, and paraffins. The components were blended in various proportions to determine the composition limits within which the reconstituted asphalts were free of syneresis.

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FRACTIONAL COMPONENTS OF ASPHALTS-- COMPATIBILITY AND INTERCHANGEABILITY OF FRACTIONS PRODUCED FROM DIFFERENT ASPHALTS

R. M. White,[1] W. R. Mitten,[1] and John B. Skog[2]

SYNOPSIS

It has been established previously that the durability of highway asphalts depends on their chemical composition expressed as the ratio of reactive to non-reactive components. It has also been postulated as a result of the previous work that imbalance of components is the cause for the lack of internal compatibility in asphalts which exhibit syneresis or flocculation. The work presented here was undertaken to establish quantitatively the effect of each component on compatibility and on interchangeability of components isolated from different asphalts.

Four asphalts, of different chemical composition and from different geographical origin (California, Venezuela, Arkansas, Alberta) were separated into concentrates of five components: asphaltenes, nitrogen bases, first acidaffins, second acidaffins, and paraffins. The components were blended in various proportions to determine the composition limits within which the reconstituted asphalts were free of syneresis.

Two test procedures were devised to observe syneresis of the blends made from the asphalt components. In one, a thin film of asphalt was examined under the microscope; in the other test a spot of asphalt on filter paper was

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(1) Materials Research & Development, Inc., Oakland, California.

(2) California Division of Highways, Sacramento, California.

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examined under ultraviolet light. Blends of the components from all four asphalts were made up in a wide range of compositions and tested by these methods. The results obtained on several hundred blends are presented in tables and graphs.

In the absence of asphaltenes, all fractional components are compatible. In the presence of asphaltenes, compatibility was found to depend primarily on the proportions of nitrogen bases and paraffins. The relative proportions of these two components, as represented by the parameter $\frac{N}{P}$, appears to be the most important factor governing syneresis. The two test methods were found to measure compatibility of somewhat different types, but the ratio $\frac{N}{P}$ seems to govern compatibility measured by either method. The presence of some minimal amount of fraction "N" appears essential. Some variation was found from one asphalt to another in the ratio of nitrogen bases to paraffins necessary to insure compatibility of the blend. The molecular weight of fraction "A" and its content of chemical compounds of the nature of nitrogen bases appear primarily responsible for the effect of fraction "A" on compatibility.

The interchangeability of fractional components originating from the different asphalts was studied by reconstituting asphalts stepwise from their fractions. It was first established that all four asphalts could be reblended from the component concentrates to match, within acceptable limits, the properties of the original asphalt, thus assuring that the components in these concentrates had not been appreciably altered during the preparative procedures from the components originally present in the asphalt. Crossblending of the five components produced from the four asphalts showed that, with the exception of the asphaltenes fraction, components from different asphalts are sufficiently similar in properties to be interchangeable. By matching the percentage

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composition of components existing in a durable asphalt, an asphalt of good durability could be produced from components of an asphalt of poor durability. Conversely, blending components from an asphalt of good durability to the percentabe composition of an asphalt of poor durability resulted in an asphalt of poor durability. The durability of an asphalt, as measured by embrittlement, has thus been shown to be dependent on the proportions of fractional components present, and the effect of the source of the components was shown to be minor.

The findings of the study demonstrate that asphalt quality can be improved by blending to change the proportions of maltenes components to desirable composition ratios.

Crossblending of asphaltenes and maltenes fractions among the four asphalts studied indicated that the asphaltenes fractions are not equally as interchangeable as the maltenes components and that the effect of both the molecular weight and the chemical nature of the asphaltenes must be taken into account to predict properties of asphalts from chemical composition.

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INTRODUCTION

The overall purpose of this study was to investigate the validity of postulates made on the basis of previous research regarding the interdependence of asphalt behavior and chemical composition of asphalt as determined by the precipitation method. In examining the results obtained in this study, it is important first to consider findings and postulates derived from previous work pertinent to this investigation. These preceding findings can be summarized as follows:

(1) The analytical procedure originally developed for characterization of rubber extender oils was found applicable to all high boiling petroleum oils independent of their origin or composition[1].

(2) After minor modification, the analysis was later adopted for identification of asphalts[2,3]. A flow sheet of the analytical procedure, which is based on stepwise precipitation of the maltenes fraction after removal of asphaltenes, is shown in Figure 1.

(3) The characteristics of the five primary fractional components of asphalts, A, N, A_1, A_2, and P, and their function in asphalts have been defined and demonstrated[3,4]. A summary of these findings is presented in Table I.

(4) The composition parameter of the maltenes, $\frac{N+A_1}{P+A_2}$, expressive of the ratio of more reactive to less reactive fractional components, has been shown to govern the durability of asphalts as measured by tendency of asphalts to harden (embrittle) during aging. Table II summarizes these findings, which permit prediction of asphalt durability from analysis of a one-gram sample of the original asphalt.

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(5) In interpreting the graph shown in Figure 11 of reference (3) for durability against the maltenes parameter, $\frac{N+A_1}{P+A_2}$, it was postulated that the parameter is only a first approximation and that it must have a bearing on durability which components are preponderant in the numerator and in the denominator of the fraction[3].

(6) In rating asphalt durability by the parameter, $\frac{N+A_1}{P+A_2}$, it was also found that a parameter of less than 0.4 was characteristic of a "cheesy" consistency, putty-like properties and syneresis caused by exudation of paraffins. It was therefore concluded that a product of this type should not be considered as belonging in the classification of highway asphalts. The postulate made in (5) also applies to compatibility, and the limiting value of 0.4 should therefore also be considered only a first approximation of the rule.

(7) On the basis of the observations described above under (3) and (5) it was concluded that all highway asphalts must contain, in addition to fraction "A", a minimum of fraction "N", and can tolerate only a certain amount of fraction "P".

(8) Analysis of 347 asphalt specimens comprising all the highway asphalts used in studies by the BPR and some asphalt specimens originating from other studies showed that no asphalt has been commercially available or used which did not contain all of the five primary fractional components. Table III shows the range of compositions encountered in all asphalts previously investigated[3,5].

(9) Other important characteristics suspected to influence asphalt properties, in addition to chemical reactivity, were molecular weight of the fractional components, their structural characteristics and their molecular association as expressed in viscosity characteristics.

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(10) When investigating bituminous products for their potential utility as highway asphalts, all compositions containing less than 5% asphaltenes, or having a penetration value of higher than 300, or containing materials volatile under construction or service conditions need not be considered.

The above given recapitulation of previous findings and postulates constitutes the background of the present investigation. In this study, four 60 - 70 penetration grade asphalts of different origin were separated into concentrates of the five fractional components.

The principal procedures used in the preparation of the fractional components employ sulfuric acid of increasing strength, as does the analytical procedure. However, while in the analytical procedure recovery of the fractions is not the objective, but their quantitative determination, the opposite is the case in the preparative procedure.

In order to utilize sulfuric acid in the preparative procedure certain precautionary steps were required, taking into account that sulfuric acid interacts with the component fractions in three stages. In the first stage the acid forms adducts; in the second, the adducts are dissolved in the excess acid; and in the third stage the acid reacts chemically and possibly irreversibly with the fractions precipitated. Since the chemical reactions, which are primarily oxidation and sulfonation, are time reactions, speeded up by heat, care was taken in the preparative procedures to work fast and to carry out all operations in the presence of free sulfuric acid in the cold, thus forestalling the occurrence of stage three.

Some of the concentrates were prepared by use of chromatographic techniques. Pentane asphaltenes were separated into fractions of widely different molecular weights by use of paraffinic hydrocarbons of higher molecular weight than pentane.

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The results achieved in the first phase of the investigation provided the methods for producing asphalt components in sufficient quantities for future work and confirmed in part the postulates made, in that blends of fractions produced for the purpose of verification of the preparative methods gave reconstituted products identical with the starting material from which the fractions originated. The four asphalts used as starting material are defined in Table IV. Table V shows the analyses of concentrates of fractional components produced and used for preparing the blends examined.

The concentrates of the fractional components were compared as to color under ultraviolet light. Spots of the asphalts and their fractional components were made on filter paper for this comparison, observed and photographed in color. Figure 2 is a black and white photograph. (Color slide used in oral presentation.) It is noteworthy that all concentrates except those of A_1 are very similar. The difference in A_1 might be attributable to the amount of the other components present in the concentrates.

The reconstituted asphalts tested were prepared by mixing at room temperature benzene solutions of the component concentrates in calculated proportions, and evaporating the benzene from the mixture. This procedure was adopted to permit the use of small amounts, to increase the accuracy of composition, to assure complete initial homogeneity, and to forestall aging of the reconstituted asphalts by hot mixing.

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COMPATIBILITY OF FRACTIONS

The purpose of this phase of the investigation was to establish the minimum concentration (if any) of each component required, or the maximum concentration allowable, for the resulting blend to be free of syneresis.

Two semi-quantitative test procedures for syneresis and solubility limits were employed:

(1) Depositing of a drop of the blend on a microscope slide and examination of the homogeneity of the film, and

(2) Depositing of a drop of asphalt on filter paper and observation of the spot thus formed under UV light for separation of an oil phase.

Both tests were semi-quantitative in that blends were prepared quantitatively, but the amounts of deposits were not exactly controlled. It was more expedient to run these semi-quantitative tests on a great number of blends than to develop and use an elaborate quantitative test on a few blends.

The spot test on the microscope slide reveals whether or not the homogeneous benzene solution of the components blend is compatible after removal of the benzene, and is possibly indicative of segregation in bulk storage. The filter paper spot test reveals whether or not syneresis occurs in the presence of an interfering substrate, and is believed indicative of asphalt separation when in contact with aggregate. This hypothesis is admittedly speculative, but can serve as a theoretical concept in tentatively interpreting the difference in behavior in the test procedures.

Two types of segregation causing phase separation can be observed in both tests. One is simply separation as it occurs in supersaturated solutions when components are ejected because of insufficient solvent; the other is rejection of a component when its amount exceeds the mutual compatibility limit. Flocculation, observable

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particularly in blends of high asphaltenes content, is typical for rejection of components because of insufficient solvent, and appears to occur as the last traces of benzene are being removed. The second type of phase separation occurring in asphalts is true syneresis in the form of physical ejection of a liquid from a gel. The two test methods, detailed in the Appendix, take both these phenomena into account.

In the test on the microscope slide, flocculation of an asphaltenes phase can be seen with the naked eye; ejection of an oil phase is visible under suitable magnification in the form of oil droplets. In the filter paper test, flocculation can be seen under ordinary light as a separate deposit on top of the paper; segregation is seen under UV light in the form of fluorescent rings of oil surrounding the deposit. The main cause for exudation is rejection of paraffins. The exudate is visible under UV light because of dissolved trace amounts of other components, primarily second acidaffins, which fluoresce strongly. Paraffins by themselves do not fluoresce. The intensity of fluorescence is, therefore, not significant for the amount of segregation, only the width of the ring.

The degree of syneresis in the filter paper test was rated independently by three different observers from "1" to "5". A rating of "1" (severe syneresis) or "2" (definite syneresis) is an expression of a positive test, indicative of substantial migration of an oil phase. A rating of "4" (trace of syneresis) or "5" (no syneresis) is considered a negative test. A rating of "3" (slight syneresis) is expressive of borderline cases, i.e., slight oil migration, detectible as a very narrow ring of exudate. Figure 3 shows spots with each of these ratings. (Color slide used in oral presentation.)

RESULTS OF FILTER PAPER TESTS

The test series reported below were designed to detect specific limiting factors suspected to govern

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compatibility due to the functions of the fractional components.

Series 1 - Dependence of syneresis on durability parameter, $\frac{N+A_1}{P+A_2}$:

Fraction "P" was added to each of the four asphalts until syneresis occurred. The results of these tests are shown in Table VI. A parameter of 0.4 was in all cases the limiting factor for tolerance of paraffins.

In a second set of experiments, fraction "A_2" was added to each of the four asphalts in an attempt to cause syneresis. The results of this set of tests, shown in Table VII, revealed that a parameter of 0.4 does not constitute the limiting factor for tolerance of second acidaffins. In both sets of tests the concentration of fraction "A" was kept constant at the concentration in the original asphalt.

Another series of tests was carried out to determine the influence of adding fraction "N" to compositions showing syneresis. For this purpose, fraction "N" was added incrementally to blends consisting of asphaltenes and maltenes freed of fraction "N". The results of these tests with each asphalt are shown in Table VIII. The tests evidence that blends containing only minimal amounts of fraction "N" show syneresis, and that in each case a noncompatible blend could be made compatible by addition of fraction "N".

The data reported in Tables VI through VIII confirm that the two fractions having the greatest influence on compatibility are fractions "P" and "N". The parameter, $\frac{N}{P}$, reported in the tables, is indicative of this fact.

Series 2 - Significance of the parameter, $\frac{N}{P}$:

In order to confirm these primary findings, blends were prepared from the components listed in Table V to

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give wide variation in composition. Tables IX through XII list these blends, together with their composition, calculated from the composition of the concentrates, and results of filter paper spot tests. These results are expressed as ratings, described earlier, with an "f" after the number indicating some degree of flocculation. Results of microscope tests, discussed later, are also reported.

Figure 4 shows for each asphalt the relationship of syneresis to the composition of the maltenes, plotted on trilinear coordinates. Blends containing more than 50 percent asphaltenes have been omitted from the graphs, since all these blends showed flocculation severe enough to render the test results unreliable; i.e., the spot failed to spread on the paper under the test conditions. Although theoretically of interest, these materials are all of a consistency too high to be considered highway asphalts. Blends with less than 50 percent asphaltenes which showed flocculation are shown in the figures as small points. The results with blends showing flocculation were weighed less heavily in drawing the dividing lines for syneresis than the results with blends where the spot spread evenly on the paper. A study of the results presented in Tables IX through XII indicates that the amount of asphaltenes has little effect on the mutual compatibility of the components below the point where flocculation occurs. Therefore, all blends having asphaltenes content ranging from as low as 8 percent up to 50 percent were plotted in these graphs.

The graphs for all four asphalts confirm that the principal governing factor for compatibility is the ratio, $\frac{N}{P}$, which could be shown graphically on these triangular coordinates as a straight line from the bottom of the triangle to the apex. In all cases, syneresis, as represented by exudation of an oily phase, appears to be strictly dependent on this parameter when the content of N and P

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together is at least 30 percent of the maltenes. When the acidaffins constitute more than 70 percent of the maltenes, additional nitrogen bases appear to be necessary, as indicated by the fact that curves representing limits of compatibility all tend to curve to the right in the upper portion of the graph.

In the composite graph in Figure 5 the curves indicating compatibility limits for all four asphalts show that the ratio of nitrogen bases to paraffins in the maltenes necessary to insure compatibility of the reblended asphalt is not the same. On this graph there is also marked the area representing the range of maltenes composition found in all asphalts previously investigated, showing that practically all incompatible blends of components fall outside the range of composition to be expected in highway asphalts commercially available at present.

RESULTS OF MICROSCOPE SLIDE TESTS

The results of observation of films of asphalt blends on microscope slides have been related to maltenes composition in the same manner as for the filter paper test in Figures 6 and 7. These results of the microscope slide tests reveal primarily that the phenomenon being observed in these tests is not quite the same as that observed in the filter paper tests. With the Valley, Boscan and Arkansas asphalts, the test appears to measure the same type of segregation, but the tendency for an oil layer to separate appears much less under the conditions of this test than in the filter paper test. In other words, although the ratio, $\frac{N}{P}$, still appears to govern compatibility, a much lower ratio seems necessary to effect compatibility than in the presence of the interfering substrate represented by the filter paper. If the assumption is correct that the filter paper spot test

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represents behavior in contact with aggregate, while the microscope slide test indicates tendency for the blend to segregate in storage, the tests on these three asphalts suggest that compatibility of asphalt components in storage does not necessarily mean there will be no bleeding of oil in use.

One phenomenon could be observed under the microscope which is not visible in the filter paper spot test - the separation of crystalline wax from the blend. Thus in the case of the blends of the Boscan asphalt components, wax crystals could be observed in most of the mixtures having high paraffins content. This is to be expected since a high amount of crystalline wax is evident in the paraffins fraction from Boscan asphalt.

The behavior in the microscope test of the blends made from Canadian asphalt components is different from what would be expected from the filter paper spot tests and from the behavior of the other asphalts. Blends of Canadian asphalt components revealed a greater tendency to segregation observable under the microscope than blends of the same composition prepared from components of the other three asphalts. The Canadian asphalt differs from the other three tested in that crystalline wax is observable in the second acidaffins fraction, and shows up in the microscope slide test in those blends having a high second acidaffins content. It is possible that this crystalline wax is responsible for the disproportionately high sensitivity to syneresis of blends of Canadian asphalt components. Although the presence of wax in the paraffins fraction, as in the Boscan asphalt, did not appear to contribute significantly to syneresis, crystalline wax in the second acidaffins seems to disturb mutual compatibility of asphalt components.

Another peculiarity of the blends of Canadian asphalt components observable under the microscope was that blends of high second acidaffins content tended to coalesce into beads on the slide rather than spreading out into a film. This has been indicated alongside the points in the graph.

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Comparison of the dividing lines in Figure 5 and Figure 7 between compatible and noncompatible blends of the four asphalts shows, except for Canadian asphalt in the microscope slide tests, that the curves for the limiting ratio of nitrogen bases to paraffins are in the same relative position by both tests. This leads to the conclusion that, even though the amount of asphaltenes fraction does not appear consequential, the nature of the asphaltenes fraction cannot be ignored in considerations involving mutual compatibility of asphalt components. One test was run to check on this assumption, as shown in Table XIII. In this test fraction "A" and maltenes freed of nitrogen bases from Valley and Canadian asphalts were crossblended. Both blends made with the Canadian asphaltenes showed segregation, while neither blend made with Valley asphaltenes showed evidence of syneresis.

It is noteworthy that the amount of nitrogen bases required to make a compatible blend with each of the four asphalts is in inverse order to the nitrogen bases content of the original asphalt. This seeming influence of source of the asphalt is brought about by the analytical separation of asphaltenes and maltenes, which defines the asphaltenes arbitrarily as the components of high enough molecular weight to be insoluble in pentane. All the pentane-asphaltenes contain materials of intermediate molecular weight, which are soluble in heptane. It is logical to assume that in asphalts of high nitrogen bases content the pentane-asphaltenes contain materials of chemical make-up similar to nitrogen bases, and that these materials contribute to mutual compatibility in the same manner as the nitrogen bases fraction, or, stated differently, that high molecular weight nitrogen bases are separated in the routine analytical procedure as part of fraction "A". This assumption appears justified since blends of Valley asphalt components were compatible in microscope slide tests even when containing appreciable

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amounts of paraffins and little or no nitrogen bases isolated from maltenes (See Tests No. V-30-, V-31, V-32, V-36, V-37, V-40, V-41, V-42 and V-56 in Table IX). Blends of this type made with the components from Arkansas asphalt all showed syneresis even in the microscope slide test.

Some of the segregation phenomena shown here would certainly also show up in the Oliensis Spot Test and Negative Period Test. The discussion of the paper quoted as reference (5) left somewhat in mid air the question whether or not ratings by the parameter $\frac{N+A_1}{P+A_2}$ are also borne out by the two Oliensis tests. Members of the AAPT who read the earlier discussion might be interested in the results which Dr. Oliensis obtained on the specimens supplied to him at his request, quoted from a letter (6) of Dr. Oliensis to the Secretary of the AAPT, as follows:

> "I had found myself unable to complete more than one-third of my Negative Period tests. However, it is true that in spite of that, my complete series of Hexane-Resistance tests and the one-third of my Negative Period tests that I did complete, both do agree in bringing out the rather significant fact that the Group V asphalts of the 60-70, 85-100 and 120-150 penetration, that by Dr. Rostler's test would have ranked as poorest in performance, also turned out as ranking poorest in stability of internal structure by both the Hexane-Resistance and Negative Period modification of the spot test. This may be of interest to many members of the AAPT."

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INTERCHANGEABILITY OF FRACTIONS

The purpose of this phase of the investigation was to determine the relation between the fractional composition of asphalts and their engineering properties. Blends made from the component concentrates were designed to give the greatest possible amount of information with a minimum number of tests. These blends made up for comparing with the original asphalts were:

1. Blends in which each asphalt was reconstituted from its components by
   (a) Blending asphaltenes and maltenes, and
   (b) Blending concentrates of all five components to the original percentage composition,
2. Crossblends of asphaltenes and maltenes in which the asphaltenes of each asphalt were replaced by asphaltenes of each of the other three,
3. Blends of components derived from an asphalt of good durability and of those from an asphalt of poor durability by blending the components of each asphalt to the percentage composition of the other, and
4. Blends made up from component concentrates of each of the four asphalts in which the maltenes were reconstituted in a stepwise progression from the blends of 1(a) to those of 1(b).

The tests carried out were as follows:

Component analysis;

Pellet abrasion test before and after 7 days' aging;

Viscosity at 77°F, 140°F, and 275°F;

Stain test; and

Viscosity at 77°F and microductility of specimens aged in the California durability test.

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One minor modification of the component analysis method was made as a result of tests carried out on the asphaltenes separation. It was found that the technique previously used in the analysis (3) for dissolving the maltenes from the asphalt (digestion without agitation except for occasional swirling) failed to remove all the maltenes in the case of high amounts of relatively high molecular weight asphaltenes, as present in the Boscan asphalt, thus resulting in an erroneously high analytical value for the asphaltenes content of this asphalt. The analytical results given throughout the tables of the present paper were obtained by carrying out the initial pentane digestion under constant agitation, effected by a glass ball in the flask, which was placed on a rotating, slanted turntable.

Pellet abrasion tests, and preparation and aging of the asphalt-sand mixes for these tests were performed by the procedure described by Rostler and White (2). Essentially, the test consists of measuring the weight loss resulting from tumbling under specified conditions a cylindrical 2-gram pellet of standard size prepared from a mixture of 2 parts asphalt and 100 parts Ottawa sand. Aging of the asphalt-sand mixtures was carried out for 7 days in an infra-red oven at 140°F.

Viscosity at 77°F was measured according to Test Method No. Calif. 348-A using a sliding plate microviscometer at shear rates of 0.05 and 0.001 sec^{-1}. Viscosities at 140° and 275°F were measured with capillary viscometers according to ASTM Designations D2171 and D2170, respectively. Temperature susceptibility was calculated from the viscosity measurements in the range of 140° to 275°F, and in the range of 77° to 140°F, using the formula:

$$\text{Temperature susceptibility} = \frac{\log\log \eta_2 - \log\log \eta_1}{\log T_2 - \log T_1}$$

where the viscosity is expressed in centistokes and T is the absolute temperature.

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The stain test was a modification of ASTM Designation D1328. Test conditions of 120 hours at 140°F were used in place of the 18 hours at 210°F specified in the ASTM procedure. The value reported is the number of sheets of cigarette paper stained, and is a measure of the tendency for oily constituents to exude from the asphalt.

Aging of specimens for the durability test consisted of oven-aging a 20-micron film for 24 hours at 210°F. The procedure followed was as described in Test Method No. Calif. 347-A, except that the asphalt was not first subjected to the Rolling Thin Film test as specified in the test method.

The microductility measurements on the durability test residue were made by Test Method No. Calif. 349-A.

COMPARISON OF REBLENDED ASPHALTS WITH ORIGINAL

The four series of blends, listed in Tables XIV through XVII, were made to determine with each of the asphalts whether any of the components had been altered during preparative manipulations, and, if so, in which concentrates this had occurred. The results of these tests are shown in Table XIV for Valley asphalt blends and in the following tables for the other three asphalts.

In Table XVIII are presented the tests comparing the four original asphalts with the asphalts reconstituted from the five individual components. The properties measured on the reblended asphalts matched those of the other asphalts within the expected limits of experimental error. It can thus be concluded that the components contained in the concentrates had not been significantly altered in the preparative isolation from the original asphalts.

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EFFECT OF INTERCHANGING ASPHALTENES FROM DIFFERENT ASPHALTS

In Table XIX are presented the results of interchanging the asphaltenes fractions of the four asphalts. In all cases the percentage content of asphaltenes was approximately the same as in the original asphalt.

The data obtained on the four sets of blends, and depicted in Figures 8 through 13, show that asphaltenes fractions obtained from different asphalts are not equivalent when used part for part. Even though the predominant factor governing asphalt properties remains the composition of the maltenes, substitution of one asphaltenes fraction for another caused marked variation in both viscosity and abrasion resistance.

Figure 8 shows the effect on abrasion loss. The effect of the asphaltenes originating from the four asphalts is in the same order of decreasing abrasion resistance with each of the maltenes; i.e., Valley asphaltenes < Canadian asphaltenes < Boscan asphaltenes < Arkansas asphaltenes. This order is in direct relation to molecular weight of the asphaltenes; the higher the molecular weight of the asphaltenes, the greater the abrasion resistance of the blend.

Figure 9, depicting the effect of interchanging asphaltenes on the viscosity of the blend at 275°F, indicates that this property is also related to the molecular weight of fraction "A". In this case the use of the two asphaltenes fractions of higher molecular weight resulted in higher asphalt viscosity than the use of the asphaltenes fractions of lower molecular weight. This is confirmed by the fact shown in the second set of bars in Figure 9 that substitution of a higher molecular weight asphaltenes fraction from the Canadian asphalt (heptane asphaltenes, having a molecular weight of 4200) in the Arkansas asphalt resulted in a viscosity of the same order as resulted from asphaltenes from the Arkansas and Boscan asphalts.

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Figure 10 shows graphically the effect of the four different asphaltenes on the temperature susceptibility of viscosity between 140° and 275°F of the blends containing them. In this temperature range, there appears to be a trend for lower molecular weight asphaltenes to result in greater temperature susceptibility of the blend. The temperature susceptibility of the maltenes, shown for comparison, appears to have less effect on the temperature susceptibility of the blend than the molecular weight of fraction "A", except for the blends made with Valley maltenes, which contain only 11% of fraction "A" and 89% maltenes of very high viscosity. It is logical that the maltenes viscosity overshadows the effect of the asphaltenes in this case.

Temperature susceptibility of viscosity in the lower temperature range of 77° to 140°F, depicted in Figure 11, also varies with the asphaltenes fraction. The trend appears again to be that the lower molecular weight asphaltenes increase temperature susceptibility. However, in this range, where the four maltenes fractions vary widely in temperature susceptibility, maltenes appear to be more influential in affecting temperature susceptibility of the asphalt viscosity than asphaltenes. This again is logical, as was the case, depicted in Figure 10, with the minor effect of small amounts of asphaltenes on the highly viscous Valley maltenes.

The viscosities of the blends at 140° and 77°F recorded in Figures 12 and 13 are also affected by the nature of the asphaltenes fraction. There is a fairly consistent order to the effect of the asphaltenes on each of the maltenes. However, the relative effect is in different order at each temperature. At these two lower temperatures this order seems unrelated to molecular weight of the asphaltenes, which is not surprising when considering that the effect of molecular weight of the asphaltenes on viscosity at 275°F and on temperature

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susceptibility of the viscosity below this temperature is in inverse order. Additionally, the effect is overshadowed by the temperature susceptibility of the maltenes.

Abrasion resistance has previously been shown to be influenced by the viscosity of the asphalt at the abrasion test temperature as well as by the maltenes composition[5]. In order to determine whether the change in abrasion resistance on changing asphaltenes was due to a corresponding change in viscosity, additional blends were made with the Valley and Arkansas asphaltenes, which had resulted in highest and lowest abrasion loss, respectively. In these blends, lower amounts of Valley fraction "A" were added to the Arkansas maltenes, and higher amounts of Arkansas fraction "A" were added to the Valley maltenes in order to match the original asphalt viscosities. A comparison of the data obtained on these blends, presented in Table XX, with those obtained on the original asphalts discloses that the variation in abrasion resistance on changing asphaltenes was caused primarily by the difference in viscosity of the blends. When the Arkansas asphaltenes were substituted in the Valley asphalt in an amount to duplicate the Valley asphalt viscosity, the abrasion resistance was also duplicated. These test results reveal that the influence of the source of asphaltenes on durability, as measured by the pellet abrasion test, is minimal, provided viscosities of the asphalts are the same at the test temperature.

In general, it has been found that asphaltenes produced from different crude oils by pentane precipitation are not interchangeable part for part because of differences in molecular weight. However, by taking into account the molecular weight, the source of the fraction becomes inconsequential.

The results reported for microductility of the maltenes-asphaltenes blends in Table XIX suggest that the asphaltenes isolated from the Arkansas asphalt have a beneficial effect on this property, but the evidence for

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this conclusion is rather meager. Further study of asphaltenes fractions will be necessary to determine whether this result is consistent, and, if so, in what manner these asphaltenes differ from the other three examined. Since the blends made from Valley maltenes consistently showed microductility figures far above those for blends with any of the other maltenes, this property appears to depend more on the nature of the maltenes fraction than on the nature of the asphaltenes.

It is not surprising to find that the pentane-asphaltenes fractions from different crude oils are not quantitatively interchangeable. The analytical identification of the individual maltenes fractions is based on the response of each fraction to a specific reagent -- sulfuric acid of a specified strength. These fractions are, therefore, chemically well defined as to reactivity, and are each made up of very similar groups of organic compounds. The analytical procedure identifies the asphaltenes fraction merely as those complex components of an asphalt having sufficiently high molecular weight to be insoluble in pentane. Thus, the fractions separated from various asphalts as fraction "A" may vary widely in both chemical character and average molecular weight.

The need for subdividing the pentane-asphaltenes has been well recognized and pointed out in previous work. The experiments described in the study of compatibility revealed that the lower molecular weight portions of the pentane-asphaltenes are actually components of a nature and behavior similar to fraction "N" but of higher molecular weight. For routine analysis, the separation by pentane offers a great advantage because of the ease of removing the low-boiling pentane between steps of the separation, but for research purposes separation of asphalt into heptane-asphaltenes and maltenes would provide valuable additional information.

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COMPLETE INTERCHANGING OF ASPHALT COMPONENTS

To investigate the relationship between chemical composition of the maltenes and asphalt properties, particularly durability, blends were made in which components of one asphalt were reblended to the maltenes composition of another. Two asphalts were selected for these blends -- the Boscan asphalt, which shows poor durability in terms of embrittlement, and the Arkansas asphalt, which exhibits excellent durability in this respect. Both these asphalts have asphaltenes of about the same molecular weight (5000 to 6000), so that this variable was eliminated.

To satisfy the purpose of the tests, the maltenes composition of each asphalt was matched as closely as possible in these blends from component concentrates of the other. Since room temperature viscosity has been found to have considerable effect on abrasion resistance, the blends were compounded by adding asphaltenes to match as nearly as possible the viscosity of the other asphalt, rather than the percentage of asphaltenes.

In Table XXI are presented the composition and test results for two blends made from Arkansas asphalt component concentrates to match the maltenes composition and viscosity of the Boscan asphalt, and two blends made from Boscan asphalt component concentrates to match the maltenes composition and viscosity of the Arkansas asphalt. Also presented for comparison are the composition and test results for the two original asphalts and for each asphalt reblended from its own components.

The results of the test on these blends show that the durability of these reblended asphalts as measured by the pellet abrasion test is primarily dependent on the maltenes composition. The poor durability of the Boscan asphalt could be duplicated with components of the Arkansas asphalt by reblending these components to

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the same maltenes composition as the Boscan asphalt. Conversely, the components of the Boscan asphalt when reblended in the proportions of the Arkansas maltenes resulted in an asphalt of excellent durability. In all cases the abrasion resistance paralleled the paramenter, $\frac{N+A_1}{P+A_2}$.

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CONCLUSIONS

Incompatibility of components in an asphalt, which causes syneresis and failure of asphaltenes to remain in homogeneous solution, depends on the composition of the maltenes portion of the asphalt as determined by fractional component analysis. More specifically, mutual compatibility appears to be governed primarily by the ratio of nitrogen bases to paraffins, which can be approximated by the parameter, $\frac{N}{P}$. The numerical value of the parameter which limits compatibility differs from one asphalt to another. Since a lower amount of nitrogen bases is needed in asphalts of higher original nitrogen bases content, it can be deduced that the lower molecular weight fractions of the asphaltenes of these asphalts contain appreciable amounts of material similar to the nitrogen bases fraction of the maltenes, and that these materials assist in increasing the tolerance of an asphalt for paraffins.

A general interdependence of fractional chemical composition of asphalts and their engineering properties has been shown. Rheological properties of asphalts have been shown to depend on percentage composition of fractional components, as do durability phenomena. The effect of molecular weight of fraction "A", chemical composition of that fraction, and molecular weight or viscosity of maltenes are also important factors in engineering properties of asphalts.

The basic principles developed in this study should prove of assistance to manufacturers of highway asphalt in selecting suitable petroleum fractions (maltenes) for blending with asphaltenes concentrates (low penetration asphalts) to assure high quality products. Previous work has shown that the fractions "P" and "A_2" are desirable in such blending materials to increase durability of the

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asphalt. The present work has shown that there is a limit to the amount of fraction "P" which can be tolerated in an asphalt blend without syneresis, depending on the amount of fraction "N" present. However, addition of fraction "A_2" seems to be tolerated without syneresis up to high amounts. Thus, blending low penetration asphalts with materials high in second acidaffins appears highly desirable from the standpoints of both durability and compatibility. The exception to this general rule appears to be that if the second acidaffins fraction contains crystalline wax, it has much more limited compatibility with the other asphalt fractions.

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Microductility, durability and stain tests, and most of the viscosity determinations on the reconstituted asphalts, were performed in the laboratory of the California Division of Highways under the supervision of G. R. Kemp; all other laboratory preparation and testing was performed by Materials Research & Development, Inc. J. W. Newton assisted in separation and purification of the components, Mrs. C. C. Chiao in preparation and testing of the reconstituted asphalts, and Mrs. K. S. Rostler in analysis and interpretation of data.

The opinions, findings and conclusions expressed here are those of the authors and not necessarily those of the Division of Highways or the Bureau of Public Roads.

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APPENDIX

MICROSCOPE SLIDE SEGREGATION TEST

Scope

1. When the components of an asphalt or a blend of asphalt components are not mutually compatible, this incompatibility or separation can be observed in a thin layer under the microscope. The procedure described provides a method of preparing such a film for observation.

2. The method is semi-quantitative, since neither the amount nor film thickness of the deposit is exactly controlled.

Apparatus

3. (a) Hot plate
   (b) Microscope slides
   (c) Micropipettes, disposable, 100 microliter size*
   (d) Miscroscope, 100X to 400X magnification.

Procedure

4. Using a micropipette transfer to a microscope slide 15 to 20 microliters of a blended 4% benzene solution of asphalt components or a benzene solution of asphalt, containing approximately 4 grams per 100 ml solution. Tilt the slide to form a film about 5 to 10 mm in diameter, and let dry. Heat the dried film at about 150 C on the hot plate for about 5 minutes, let cool, and examine the film under the microscope at 100X magnification using transmitted light.

5. If a clear film is observed, with no structure or network of segregated phases, report a negative result.

6. Report as positive any widespread irregularity of appearance, which may appear as a coarse or fine pattern

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* Drummond "Microcaps".

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in the film. A dull surface on the film when viewed by reflected light may be observed with the naked eye when severe segregation has occurred.

7. In borderline cases, re-examine daily for one week, using 400X magnification if needed.

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FILTER PAPER SPOT TEST FOR ASPHALT COMPATIBILITY

Scope

1. This procedure provides a means of observing syneresis in an asphalt or blend of asphalt components in the presence of an interfering substrate which increases the tendency of the blend to separate into phases. The material is applied to the paper in solution and the solvent evaporated by applying heat from the periphery of the spot to avoid chromatographic separation from the solution. A drop of an asphalt blend of mutually compatible components will spread evenly with heating on a filter paper, without any type of striation. Where incompatibility of the components exists, there occurs either a flocculation of unblended material on top of the spot, or a bleeding out of a separated oily phase around the periphery of the spot. The first type of segregation, flocculation, is visible under ordinary light. The latter type of separation, exudation of oil layer, becomes visible when viewed under ultraviolet light, because of the strong fluorescence of the acidaffins fractions present in small amounts in the exudate.

2. The method is semi-quantitative in that neither the amount of material applied to the paper nor the size of the spot is exactly controlled. In order to minimize the subjective element in rating the degree of syneresis, five standard spots, judged to represent five rankings, are used for comparison with the test spots, and the test spots are rated independently by three observers and their ratings averaged.

Apparatus

3. (a) Filter paper, #1 Whatman, 11 cm diameter
   (b) Pipette, 1 ml, graduated in 0.01 ml
   (c) Rubber bulb and screw clamp
   (d) Ring stand with small clamp

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(e) Ring oven*

(f) Hot plate**

(g) Asbestos plates, two 6"x6"x½", with 2" diameter holes in center

(h) Ultraviolet lamp, 15-watt fluorescent type, with reflector

(i) Filter paper spot test ranking chart.

Procedure

4. Preparation of Spot - Adjust the ring oven to 170 C with the 5/8" diameter round rings in place. Adjust the vacuum tube beneath the lower ring about 1/16" below the top surface of the ring. Keep the two rings in contact before and between tests to maintain their temperature as steady as possible. Adjust the vacuum source to give a slow stream of air into the tube, leaving the shutter hole opposite the thermometer open.

5. One to two minutes before starting test place an 11-cm Whatman No. 1 paper centered between the rings. Using the rubber bulb on the 1-ml pipette like a medicine dropper, draw about 0.2 to 0.3 ml of a 4% benzene solution of asphalt or blended asphalt components up into the graduated portion of the pipette. Clamp the pipette over the center of the paper with its tip close to the paper surface. Using the tubing clamp (screw pinch clamp) gently compress the rubber bulb to deliver about 0.1 ml of solution onto the paper in a slow stream. Let the spot dry about 1 minute.

6. Remove the paper containing the dried spot of asphalt and place paper between the two asbestos blocks, centering the spot in the 2" opening. Heat the assembly for about 10 minutes on a hot plate using about 150 C hot plate surface temperature.

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* Nurnberg Scientific, Model RO-31.

** Temco HP-A-1915B.

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7. Rating of Spots - Rate the spots from independent evaluations of three observers comparing the peripheral rings under ultraviolet light with those of the standard spots and observing presence or absence of flocculation under ordinary light.

8. Rate the degree of syneresis by observing the spot under the ultraviolet light and noting the size of the fluorescent ring surrounding it, disregarding the intensity of the fluorescence. Using the following numerical rating denote degrees of syneresis:

1 = Severe syneresis; i.e., broad ring or series of rings surrounding the central spot (ring can usually be observed under ordinary light in specimens rated as "1").

2 = Definite syneresis; i.e., distinct ring, 1 to 2 mm wide.

3 = Slight syneresis; i.e., thin ring, less than 1 mm wide.

4 = Trace of syneresis; i.e., very fine hair-line ring.

5 = No syneresis; i.e., no observable ring.

9. Note presence of flocculation, observed under ordinary light as heavy black material in the center or around the outer portion of the central black spot, and report by the notation "f" after the numerical rating.

10. When three observers have rated the tests independently, average their numerical ratings. Write an "f", indicating flocculation, after the rating average if flocculation has been noted by more than one of the observers.

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TABLE I

CHARACTERISTICS OF ASPHALT COMPONENTS

Fraction	General Description	Specific Chemical Reactivity	TYPICAL ANALYTICAL DATA								Significant Function
			Elementary Composition					n_D^{25}	d_4^{20}	I No.	
			C	H	N	S	O				
A Asphaltenes	Higher molecular weight condensation products	Insoluble in n-pentane	86.5	8.3	2.3	1.5	1.4	--	--	--	Bodying agent
N Nitrogen Bases	Petroleum resins containing nitrogen bases and other highly reactive compounds	Precipitable with 85% H_2SO_4	86.1	9.3	3.0	0.7	0.9	1.642	1.08	--	Peptizer for asphaltenes
A_1 First Acidaffins	Resinous hydrocarbons	Precipitable with concentrated H_2SO_4	90.0	7.8	0.3	1.9	--	1.613	1.07	65-100	Solvent for peptized asphaltenes
A_2 Second Acidaffins	Slightly unsaturated hydrocarbons	Precipitable with fuming H_2SO_4 (30% SO_3)	88.8	9.6	0.0	0.9	0.7	1.558	1.01	5	Solvent for peptized asphaltenes
P Paraffins	Saturated hydrocarbons	Non-reactive with fuming H_2SO_4 (30% SO_3)	86.5	13.5	--	--	--	1.486	0.90	--	Gelling agent

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TABLE II

DURABILITY CLASSIFICATION OF HIGHWAY ASPHALTS--85-100 PENETRATION GRADE

GROUP	$\frac{N + A_1}{P + A_2}$ (1)		AVERAGE ABRASION (2)		DURABILITY
	Range	Average (3)	Range	Average (3)	
0 (4)	<0.4	0.28		50	Decreasing durability with decreasing parameter value
I	0.4-1.0	0.82	0-10	5.7	Superior
II	1-1.2	1.09	5-15	8.9	Good
III	1.2-1.5	1.34	10-40	29.6	Satisfactory
IV	1.5-1.7	1.58	30-60	45.4	Fair
V	>1.7	1.84	50+	52.7	Inferior

1. Composition of original (unaged) asphalt.
2. Average of % abrasion (pellet method) before and after aging.
3. Calculated from measured data (reported AAPT XXI, pp. 35-89 (1962)).
4. Cheesy and putty-like products of consistency not associated with highway asphalt.

TABLE III

RANGE OF COMPOSITION AND CONSISTENCY OF HIGHWAY ASPHALTS COLLECTED AND TESTED AS REPRESENTATIVE OF COMMERCIALLY AVAILABLE ASPHALT CEMENTS (347 SPECIMENS)

	Lowest	Highest	Number Tested
A, %	5.0	35.9	301
N, %	7.8	42.9	301
A_1, %	13.1	33.0	301
A_2, %	12.4	33.0	301
P, %	6.1	23.6	301
Penetration @ 77°F., 100 g, 5 sec, dmm	14	193	347
Viscosity @ 77°F., megapoises @ 0.05 sec^{-1}	0.29	27.7	105
@ 140°F., poises	680	5537	90
@ 275°F., cst	146	870	332

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TABLE IV

CHEMICAL COMPOSITION AND VISCOSITY OF ASPHALTS AND MALTENES

Asphalt, 60/70 penetration	Valley (1)	Boscan (2)	Arkansas (3)	Canadian (4)
Component Analysis, %				
A	10.9	27.8	23.6	21.0
N	41.5	26.6	14.3	20.8
A_1	14.2	21.5	21.5	17.1
A_2	20.7	17.8	27.9	29.9
P	12.7	6.3	12.7	11.2
$(N + A_1)/(P + A_2)$	1.67	2.00	0.88	0.92
Average molecular weight				
Asphalt	757	886	1083	899
Asphaltenes	2900	5430	5920	3315
Maltenes	725	705	900	780
Asphalt viscosity at 77°F (5)				
At 0.05 sec^{-1}, poises	2,600,000	3,100,000	3,300,000	2,530,000
At 0.001 sec^{-1}, poises	2,650,000	4,800,000	4,400,000	3,020,000
Shear Angle, °	0.3	6.4	4.3	2.6
Tangent	0.0052	0.11	0.075	0.045
Maltenes viscosity (6)				
At 77°F, poises	162,000	3,313	1,582	20,912
At 140°F, poises	374	35.6	33.5	36.3
At 275°F, poises	1.206	0.536	0.650	0.580
Temperature susceptibility,				
140° - 275°F	-3.872	-3.540	-3.271	-3.455
77° - 140°F	-4.102	-3.973	-3.500	-5.172

(1) Poso Crude - California
(2) Boscan Crude - Venezuela
(3) Smackover Crude - Arkansas
(4) Redwater Crude - Alberta
(5) Microviscometer
(6) Valley asphalt at 77°F measured with microviscometer, 0.05 sec^{-1} shear rate; all others measured with capillary viscometer.

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TABLE V

CONCENTRATES OF FRACTIONAL COMPONENTS USED IN BLENDS

Source	Valley			Boscan			Arkansas			Canadian		
Fraction "A"												
Reference No. WRM-	111	116	67	111	116	67	116	67		111	116	67
Component Analysis, %												
A	95.4	97.4	91.8	96.1	97.6	93.8	97.6	93.3		95.6	96.9	90.8
N	3.7	2.1	6.6	3.0	1.8	4.3	1.8	2.9		2.5	1.9	3.6
A_1+A_2+P	0.9	0.5	1.6	0.9	0.6	1.9	0.6	3.8		1.9	1.2	5.6
Molecular weight	3220	3390	2625	5570	6340	4740	6620	4670		3490	3910	2725
Maltenes												
Reference No. WRM-	67			67			67			67		
Component Analysis, %												
N	47.3			35.3			18.3			25.7		
A_1	15.2			31.5			29.5			23.6		
A_2	24.1			24.0			37.5			35.9		
P	13.4			9.2			14.7			14.8		
N-Bases-free Maltenes												
Reference No. WRM-	107			107	106		107	106		107		
Component Analysis, %												
N	0.3			2.1	8.6		3.3	7.2		0.3		
A_1	29.1			44.8	43.1		29.4	32.7		25.1		
A_2	42.3			39.1	33.8		48.8	42.6		53.5		
P	28.3			14.0	14.5		18.5	17.5		21.1		
Fraction "N"												
Reference No. WRM-	88	144		88	144		144			144		
Component Analysis, %												
A	0.2	0.7		1.0	--		--			--		
N	91.2	87.5		90.7	76.5		65.2			62.2		
A_1	3.1	7.0		5.3	16.1		23.2			22.8		
A_2	3.8	3.7		2.8	5.6		10.0			11.7		
P	1.4	1.1		1.2	1.8		1.6			3.3		
Fraction "A_1"												
Reference No. WRM-	95			103			144	136		127		
Component Analysis, %												
N	0.5			5.7			24.0	14.9		6.0		
A_1	89.5			81.3			61.4	58.1		69.6		
A_2	6.9			9.1			10.5	26.2		24.0		
P	3.1			3.9			4.1	0.8		0.4		
Concentrate, Fractions "A_2"+"P"												
Reference No. WRM-	145			145			145			145		
Component Analysis, %												
N	2.9			--			1.6			1.0		
A_1	0.0			4.7			7.5			8.0		
A_2	60.5			68.1			64.4			62.5		
P	36.6			27.2			26.5			28.5		
Fraction "A_2"												
Reference No. WRM-	92-98			103			118	140		135	113	
Component Analysis, %												
N	} 2.6			--			} 2.4	2.3		3.9	1.7	
A_1				3.2				9.1		4.5	3.7	
A_2	93.7			95.2			92.8	87.0		89.3	88.5	
P	3.7			1.6			4.8	1.6		2.3	6.1	
Fraction "P"												
Reference No. WRM-	92			103			118	119	140	119		
Component Analysis, %												
N	--			--			} 0.1	--	0.5	--		
A_1	--			--				--	--	0.5		
A_2	2.9			2.6			2.9	6.8	9.5	4.7		

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TABLE VI

EFFECT OF ADDING FRACTION "P" TO ASPHALT

(Fraction "A" Added Simultaneously to Hold Asphaltenes Content Constant)

Test No.	Asphalt Used	Composition, %					$\frac{N + A_1}{P + A_2}$	$\frac{N}{P}$	Filter Paper Spot Test Rating*
		A	N	A_1	A_2	P			
Original	Valley	10.9	41.5	14.2	20.7	12.7	1.67	3.27	5
V-87	Valley	10.9	33.2	11.3	17.1	27.5	1.00	1.21	4
V-89	Valley	10.9	29.5	10.1	15.5	34.0	0.80	0.87	3
V-91	Valley	10.9	24:9	8.5	13.4	42.3	0.60	0.59	3
V-93	Valley	10.9	18.7	6.4	10.8	53.2	0.39	0.35	2
Original	Boscan	27.8	26.6	21.5	17.8	6.3	2.00	4.22	5
B-35	Boscan	27.8	20.0	16.1	13.8	22.3	1.00	0.90	4
B-37	Boscan	27.8	17.8	14.3	12.5	27.6	0.80	0.64	4
B-39	Boscan	27.8	15.0	12.1	10.9	34.2	0.60	0.44	3
B-41	Boscan	27.8	11.4	9.2	8.7	42.9	0.40	0.27	2
Original	Arkansas	23.6	14.3	21.5	27.9	12.7	0.88	1.13	3
A-3	Arkansas	23.6	11.4	17.2	22.3	25.5	0.60	0.45	2f
A-5	Arkansas	23.6	8.7	13.1	17.0	37.6	0.40	0.23	1f
A-7	Arkansas	23.6	7.0	10.6	13.8	45.0	0.30	0.16	1f
A-9	Arkansas	23.6	5.1	7.6	9.9	53.8	0.20	<0.1	1f
Original	Canadian	21.0	20.8	17.1	29.9	11.2	0.92	1.86	4
C-5	Canadian	21.0	16.2	13.4	23.4	26.0	0.60	0.62	3
C-7	Canadian	22.4	12.2	10.0	17.5	37.9	0.40	0.32	3f
C-9	Canadian	21.0	10.0	8.2	14.4	46.4	0.30	0.22	1f

* Average of three observers:

1 = Severe syneresis; 2 = Definite syneresis;

3 = Slight syneresis; 4 = Trace of syneresis;

5 = No syneresis; f = Flocculation

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TABLE VII

EFFECT OF ADDING FRACTION "A_2" TO ASPHALT

(Fraction "A" Added Simultaneously to Hold Asphaltenes Content Constant)

Test No.	Asphalt Used	Composition, %					$\frac{N + A_1}{P + A_2}$	$\frac{N}{P}$	Filter Paper Spot Test Rating*
		A	N	A_1	A_2	P			
Original	Valley	10.9	41.5	14.2	20.7	12.7	1.67	3.27	5
V-88	Valley	10.9	33.2	11.8	33.3	10.8	1.02	3.07	5
V-90	Valley	10.9	29.5	10.8	38.8	10.0	0.83	2.95	4
V-92	Valley	10.9	24.9	9.5	45.8	8.9	0.63	2.80	4
V-94	Valley	10.9	18.7	7.7	55.2	7.5	0.42	2.49	4
Original	Boscan	27.8	26.6	21.5	17.8	6.3	2.00	4.22	5
B-36	Boscan	27.8	20.0	16.7	30.5	5.0	1.03	4.00	4
B-38	Boscan	27.8	17.8	15.0	34.8	4.6	0.83	3.87	4
B-40	Boscan	27.8	15.0	13.1	40.0	4.1	0.64	3.66	4
B-42	Boscan	27.8	11.4	10.6	46.9	3.3	0.44	3.45	4f
Original	Arkansas	23.6	14.3	21.5	27.9	12.7	0.88	1.13	3
A-2	Arkansas	23.6	11.4	17.2	37.6	10.2	0.60	1.12	2
A-4	Arkansas	23.6	8.7	13.1	46.8	7.8	0.40	1.12	2
A-6	Arkansas	23.6	7.0	10.6	52.5	6.3	0.30	1.11	2
A-8	Arkansas	23.6	5.1	7.6	59.2	4.5	0.20	1.14	2
Original	Canadian	21.0	20.8	17.1	29.9	11.2	0.92	1.86	4
C-4	Canadian	21.0	16.2	13.4	40.6	8.8	0.60	1.84	3
C-6	Canadian	22.4	12.2	10.0	48.9	6.5	0.40	1.88	3
C-8	Canadian	21.0	10.0	8.2	55.4	5.4	0.30	1.85	3

* Average of three observers:

1 = Severe syneresis; 2 = Definite syneresis;
3 = Slight syneresis; 4 = Trace of syneresis;
5 = No syneresis; f = Flocculation

TABLE VIII

EFFECT OF ADDING FRACTION "N" TO ASPHALT

Test No.	Asphalt	Composition, % A	N	A_1	A_2	P	$\frac{N + A_1}{P + A_2}$	$\frac{N}{P}$	Filter Paper Spot Test Rating*
V-0	Valley	10.9	41.5	14.2	20.7	12.7	1.67	3.27	5
V-56	Valley fractions reblended	20.0	0.2	23.3	33.9	22.6	0.42	<0.1	3
V-57		20.0	4.4	22.2	32.0	21.4	0.50	0.21	3
V-58		20.0	8.2	21.3	30.3	20.2	0.58	0.41	4
V-59		20.0	14.5	19.7	27.5	18.3	0.75	0.79	4
V-60		20.0	37.8	12.2	19.3	10.7	1.67	3.53	5
B-0	Boscan	27.8	26.6	21.5	17.8	6.3	2.00	4.22	5
B-18	Boscan fractions reblended	20.0	1.7	35.8	31.3	11.2	0.88	0.15	2
B-19		20.0	5.2	34.5	29.7	10.6	0.99	0.49	3
B-20		20.0	8.3	33.3	28.3	10.1	1.08	0.82	3
B-21		20.0	13.6	31.2	25.9	9.3	1.27	1.46	4
B-22		20.0	28.2	25.2	19.2	7.4	2.01	3.81	5
A-0	Arkansas	23.6	14.3	21.5	27.9	12.7	0.88	1.13	3
A-37	Arkansas fractions reblended	20.0	2.6	23.5	39.1	14.8	0.48	0.18	2
A-38		20.0	5.5	23.3	37.2	14.0	0.56	0.39	2
A-39		20.0	8.1	23.0	35.6	13.3	0.64	0.61	3
A-40		20.0	12.6	22.5	32.8	12.1	0.78	1.04	3
A-41		20.0	14.6	23.6	30.0	11.8	0.91	1.24	4
C-0	Canadian	21.0	20.8	17.1	29.9	11.2	0.92	1.86	4
C-21	Canadian fractions reblended	20.0	0.2	20.1	42.8	16.9	0.34	<0.1	2
C-22		20.0	3.2	20.0	40.8	16.0	0.41	0.20	3
C-23		20.0	5.7	19.9	39.1	15.3	0.47	0.37	3
C-24		20.0	10.2	19.7	36.1	14.0	0.60	0.73	3
C-25		20.0	20.6	18.9	28.7	11.8	0.98	1.75	4

* Average of three observers:

1 = Severe syneresis; 2 = Definite syneresis;
3 = Slight syneresis; 4 = Trace of syneresis;
5 = No syneresis; f = Flocculation

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TABLE IX

COMPATIBILITY TESTS ON BLENDS OF VALLEY ASPHALT COMPONENTS

Test No.	Concentrates Blended, Parts: Asphalt	Fraction "A"	Maltenes	Fraction "N"	N-free Maltenes	Fraction "A_1"	Concentrate A_2 + P	Fraction "A_2"	Fraction "P"	Composition of Blend, %: A	N	A_1	A_2	P	$\frac{N}{P}$	Filter Paper Spot Test Rating*	Microscope Test Segregation
V-0	100	----	----	----	----	----	----	----	----	10.9	41.5	14.2	20.7	12.7	3.27	5	-
V-1	---	50	----	----	50	----	----	----	----	50.0	0.1	14.6	21.2	14.1	<0.1		-
V-2	---	50	----	----	----	----	----	----	50	50.0	----	----	1.4	48.6	<0.1		+
V-3	---	50	----	5	----	----	----	----	50	47.6	4.3	0.3	1.5	46.3	<0.1		+
V-4	---	50	----	10	----	----	----	----	50	45.5	8.1	0.6	1.5	44.3	0.18		+
V-5	---	50	----	----	----	----	----	50	----	50.0	----	1.3	46.9	1.8	<0.1		-
V-6	---	50	----	----	----	----	50	----	----	50.0	0.2	44.8	3.5	1.5	<0.1		-
V-7	---	40	----	20	----	----	----	----	40	40.0	17.9	1.3	1.7	39.1	0.46		+
V-8	---	30	----	40	----	----	----	----	30	30.0	35.7	2.7	1.9	29.7	1.20		-
V-9	---	20	----	60	----	----	----	----	20	20.0	53.6	4.1	2.1	20.2	2.65		-
V-10	---	35	----	30	----	----	----	----	35	35.0	26.8	2.0	1.8	34.4	0.78		-
V-11	---	37.5	----	25	----	----	----	----	37.5	37.5	22.3	1.7	1.7	36.8	0.61		-
V-12	---	40	----	40	----	----	----	----	20	40.0	35.7	2.7	1.6	20.0	1.78		-
V-13	---	50	----	25	----	----	----	----	25	50.0	22.3	1.7	1.3	24.7	0.90		-
V-14	---	60	----	10	----	----	----	----	30	60.0	8.9	0.7	1.1	29.3	0.30		-
V-15	---	65	----	2.5	----	----	----	----	32.5	65.0	2.2	0.2	1.0	31.6	<0.1		+
V-16	---	65	----	5	----	----	----	----	32.5	63.4	4.4	0.3	1.0	30.9	0.14		+
V-17	---	20	----	40	----	----	----	----	40	20.0	35.7	2.7	2.2	39.4	0.91		-, + one week
V-18	---	30	----	10	----	----	----	----	60	30.0	8.9	0.7	2.0	58.4	0.15		+
V-19	---	25	----	25	----	----	----	----	50	25.0	22.3	1.7	2.1	48.9	0.46		-, + one week
V-20	---	30	----	15	----	----	----	----	60	28.6	12.8	0.9	2.0	55.7	0.23		+
V-21	---	30	----	20	----	----	----	----	60	27.3	16.3	1.2	2.0	53.2	0.31		+
V-22	---	50	----	40	----	----	----	----	10	50.0	35.7	2.7	1.3	10.3	3.47		-
V-23	---	75	----	10	----	----	----	----	15	75.0	8.9	0.7	0.7	14.7	0.61		+
V-24	---	75	----	3	----	----	----	----	15	80.6	2.9	0.2	0.6	15.7	0.18		-
V-25	---	75	----	2.5	----	----	----	----	15	81.1	2.4	0.2	0.5	15.8	0.15		- (?)
V-26	---	75	----	----	----	----	----	----	15	83.3	----	----	0.5	16.2	<0.1		- (?)
V-27	---	50	----	----	----	----	----	----	50	50.0	----	----	1.4	48.6	<0.1		+
V-28	---	25	----	----	----	50	----	----	25	25.0	0.2	44.8	4.2	25.8	<0.1		+
V-29	---	25	----	----	----	20	----	----	25	35.7	0.1	25.6	3.0	35.6	<0.1		?
V-30	---	25	----	----	----	100	----	----	25	16.7	0.3	59.7	5.1	18.2	<0.1		-
V-31	---	25	----	----	----	60	----	----	25	22.7	0.3	48.8	4.4	23.8	<0.1		-
V-32	---	25	----	----	----	70	----	----	25	20.8	0.3	52.2	4.6	22.1	<0.1		-
V-33	---	20	----	----	----	----	----	----	40	33.3	----	----	1.9	64.8	<0.1		+
V-34	---	20	----	----	----	12	----	----	40	27.8	0.1	14.9	2.8	54.4	<0.1		+
V-35	---	20	----	----	----	24	----	----	40	23.8	0.1	25.6	3.4	47.1	<0.1		+
V-36	---	20	----	----	----	60	----	----	40	16.7	0.2	44.8	4.4	33.9	<0.1		-
V-37	---	20	----	----	----	36	----	----	40	20.8	0.2	33.7	3.6	41.7	<0.1		-, + three
V-38	---	20	----	----	----	48	----	----	40	18.5	0.2	39.8	4.1	37.4	<0.1		-, + three
V-39	---	40	----	----	----	----	----	----	20	66.7	----	----	0.9	32.4	<0.1		+
V-40	---	40	----	----	----	60	----	----	20	33.3	0.2	44.8	3.9	17.8	<0.1		-
V-41	---	40	----	----	----	120	----	----	20	22.2	0.3	59.7	4.9	12.9	<0.1		-
V-42	---	40	----	----	----	30	----	----	20	44.4	0.2	29.8	3.0	22.6	<0.1		-
V-43	---	40	----	----	----	70	----	----	20	30.8	0.2	48.2	4.2	16.6	<0.1		+
V-44	---	40	----	----	----	50	----	----	20	36.4	0.2	40.7	3.6	19.1	<0.1		+
V-45	---	4	----	----	----	----	----	----	20	16.7	----	----	2.4	80.9	<0.1		+
V-46	---	4	----	9.6	----	----	----	----	20	11.9	25.5	1.9	2.5	58.2	0.44		-
V-47	---	4	----	14.4	----	----	----	----	20	10.4	33.5	2.6	2.4	51.1	0.66		-
V-48	---	4	----	19.2	----	----	----	----	20	9.3	39.7	3.0	2.4	45.6	0.87		-
V-49	---	4	----	2.4	----	----	----	----	20	15.2	8.1	0.6	2.4	73.7	0.11		+
V-50	---	4	----	4.8	----	----	----	----	20	13.9	14.9	1.1	2.4	67.7	0.22		+
V-51	---	4	----	7.2	----	----	----	----	20	12.8	20.6	1.6	2.4	62.6	0.33		+
V-52	---	2	----	----	----	----	----	----	20	9.1	----	----	2.6	88.3	<0.1		+
V-53	---	2	----	2.2	----	----	----	----	20	8.3	8.1	0.6	2.6	80.4	0.10		+
V-54	---	2	----	6.6	----	----	----	----	20	7.0	20.6	1.6	2.6	68.2	0.30		+
V-55	---	2	----	11	----	----	----	----	20	6.1	29.8	2.2	2.6	59.3	0.50		-
V-56	---	20	----	----	80	----	----	----	----	20.0	0.2	23.3	33.9	22.6	<0.1	3	-
V-57	---	20	----	4.7	75.3	----	----	----	----	20.0	4.4	22.2	32.0	21.4	0.21	3	-
V-58	---	20	----	8.9	71.1	----	----	----	----	20.0	8.2	21.3	30.3	20.2	0.41	4	-
V-59	---	20	----	16.0	64.0	----	----	----	----	20.0	14.5	19.7	27.5	18.3	0.79	4	-
V-60	---	20	80	----	----	----	----	----	----	20.0	37.8	12.2	19.3	10.7	3.53	5	-
V-61	---	25	80	----	----	----	----	----	20	20.0	30.3	9.7	15.9	24.1	1.26	3	-
V-62	---	28	80	----	----	----	----	----	32.5	20.0	26.9	8.6	14.4	30.1	0.89	3	-
V-63	---	33	80	----	----	----	----	----	53.3	20.0	22.7	7.3	12.5	37.5	0.61	2	-
V-64	---	44	80	----	----	----	----	----	95	20.0	17.3	5.6	10.1	47.0	0.37	2	+

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TABLE IX (Continued)

COMPATIBILITY TESTS ON BLENDS OF VALLEY ASPHALT COMPONENTS

Test No.	Concentrates Blended, Parts: Asphalt	Fraction "A"	Maltenes	Fraction "N"	N-free Maltenes	Fraction "A_1"	Concentrate A_2 + P	Fraction "A_2"	Fraction "P"	Composition of Blend, %: A	N	A_1	A_2	P	$\frac{N}{P}$	Filter Paper Spot Test Rating*	Microscope Test Segregation
V-65	---	20	----	----	----	----	----	80	----	20.0	----	2.1	75.0	2.9	<0.1	3	-
V-66	---	20	----	10	----	----	----	70	----	20.0	8.9	2.5	65.9	2.7	3.30	4	-
V-67	---	20	----	20	----	----	----	60	----	20.0	17.9	2.9	56.7	2.5	7.16	4	-
V-68	---	20	----	30	----	----	----	50	----	20.0	26.8	3.3	47.6	2.3	11.7	4	-
V-69	---	35	----	----	----	----	----	65	----	35.0	----	1.7	60.9	2.4	<0.1	4	-
V-70	---	50	----	----	----	----	----	50	----	50.0	----	1.3	46.9	1.8	<0.1	5f	-
V-71	---	----	----	----	----	----	80	----	----	20.0	2.3	----	48.4	29.3	<0.1	2	-
V-72	---	20	----	10	----	----	----	----	70	20.0	8.9	0.7	2.3	68.1	0.13	1f	+
V-73	---	20	----	10	----	----	----	21	49	20.0	8.9	1.2	21.4	58.5	0.18	1	+
V-74	---	20	----	10	----	----	----	35	35	20.0	8.9	1.6	34.1	35.4	0.25	2	+ slight
V-75	---	20	----	10	----	----	----	49	21	20.0	8.9	1.9	46.8	22.4	0.40	3	-
V-76	---	20	----	10	----	----	----	70	----	20.0	8.9	2.5	65.9	2.7	3.30	4	-
V-77	---	20	----	10	----	13	----	----	57	20.0	9.0	12.3	2.8	55.9	0.16	1	+
V-78	---	20	----	10	----	13	----	17	40	20.0	9.0	12.8	18.2	40.0	0.22	2	+ slight
V-79	---	20	----	10	----	13	----	28.5	28.5	20.0	9.0	13.1	28.7	29.2	0.31	2	-
V-80	---	20	----	10	----	13	----	40	17	20.0	9.0	13.4	39.1	18.5	0.49	3	-
V-81	---	20	----	10	----	13	----	57	----	20.0	9.0	13.8	54.6	2.6	3.46	4	-
V-82	---	20	----	10	----	20	----	----	50	20.0	9.0	18.6	3.1	49.3	0.18	2	+
V-83	---	20	----	10	----	20	----	15	35	20.0	9.0	19.0	16.7	35.3	0.25	2	-
V-84	---	20	----	10	----	20	----	25	25	20.0	9.0	19.2	25.8	26.0	0.35	2	-
V-85	---	20	----	10	----	20	----	35	15	20.0	9.0	19.5	34.9	16.6	0.54	3	-
V-86	---	20	----	10	----	20	----	50	----	20.0	9.0	19.9	48.5	2.6	3.46	4	-
V-87	100	2.7	----	----	----	----	----	----	22.3	10.9	33.2	11.3	17.1	27.5	1.21	4	-
V-88	100	2.7	----	----	----	----	----	22.3	----	10.9	33.2	11.8	33.3	10.8	3.07	5	-
V-89	100	4.45	----	----	----	----	----	----	36.2	10.9	29.5	10.1	15.5	34.0	0.87	3	-
V-90	100	4.45	----	----	----	----	----	36.2	----	10.9	29.5	10.8	38.8	10.0	2.95	4	-
V-91	100	7.3	----	----	----	----	----	----	59.5	10.9	24.9	8.5	13.4	42.3	0.59	3	-
V-92	100	7.3	----	----	----	----	----	59.5	----	10.9	24.9	9.5	45.8	8.9	2.80	4	-
V-93	100	13.3	----	----	----	----	----	----	108.4	10.9	18.7	6.4	10.8	53.2	0.35	2	-
V-94	100	13.3	----	----	----	----	----	108.4	----	10.9	18.7	7.7	55.2	7.5	2.49	4	-

* Average of three observers:

1 = Severe syneresis; 2 = Definite syneresis;
3 = Slight syneresis; 4 = Trace of syneresis;
5 = No syneresis; f = Flocculation

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TABLE X

COMPATIBILITY TESTS ON BLENDS OF BOSCAN ASPHALT COMPONENTS

Test No.	Concentrates Blended, Parts: Asphalt	Fraction "A"	Maltenes	Fraction "N"	N-free Maltenes	Fraction "A_1"	Concentrate A_2 + P	Fraction "A_2"	Fraction "P"	Composition of Blend, %: A	N	A_1	A_2	P	$\frac{N}{P}$	Filter Paper Spot Test Rating*	Microscope Test Segregation
B-0	100	----	----	----	----	----	----	----	----	27.8	26.6	21.5	17.8	6.3	4.22	5	-
B-1	---	50	----	----	50	----	----	----	----	50.0	1.0	22.4	19.6	7.0	0.14		-
B-2	---	50	----	----	----	----	----	----	50	50.0	----	----	1.3	48.7	<0.1		+
B-3	---	50	----	----	----	----	----	50	----	50.0	----	1.6	47.6	0.8	<0.1		-
B-4	---	50	----	----	----	50	----	----	----	50.0	2.8	40.7	4.6	1.9	1.47		-
B-5	---	45	----	10	----	----	----	----	45	45.0	7.7	1.6	1.7	44.0	0.18		+ wax
B-6	---	40	----	20	----	----	----	----	40	40.0	15.3	3.2	2.2	39.3	0.39		+ wax
B-7	---	30	----	40	----	----	----	----	30	30.0	30.6	6.4	3.0	30.0	1.02		- wax
B-8	---	25	----	50	----	----	----	----	25	25.0	38.3	8.0	3.4	25.3	1.51		- wax
B-9	---	35	----	30	----	----	----	----	35	35.0	23.0	4.8	2.6	34.6	0.66		+ wax
B-10	---	35	----	35	----	----	----	----	35	33.3	25.5	5.4	2.7	33.1	0.77		-, + one week
B-11	---	40	----	40	----	----	----	----	20	40.0	30.6	6.4	2.8	20.2	10.9		-
B-12	---	50	----	25	----	----	----	----	25	50.0	19.1	4.0	2.1	24.8	0.77		-
B-13	---	60	----	10	----	----	----	----	30	60.0	7.7	1.6	1.3	29.4	0.26		+
B-14	---	60	----	15	----	----	----	----	30	57.1	10.9	2.3	1.6	28.1	0.39		-
B-15	---	25	----	25	----	----	----	----	50	25.0	19.1	4.0	2.7	49.2	0.39		+ wax
B-16	---	15	----	55	----	----	----	----	30	15.0	42.1	8.8	3.9	30.2	1.39		-
B-17	---	25	----	35	----	----	----	----	50	22.7	24.4	5.1	3.0	44.8	0.54		+ wax
B-18	---	20	----	----	80	----	----	----	----	20.0	1.7	35.8	31.3	11.2	0.15	2	-
B-19	---	20	----	4.7	75.3	----	----	----	----	20.0	5.2	34.5	29.7	10.6	0.49	3	-
B-20	---	20	----	8.9	71.1	----	----	----	----	20.0	8.3	33.3	28.3	10.1	0.82	3	-
B-21	---	20	----	16.0	64.0	----	----	----	----	20.0	13.6	31.2	25.9	9.3	1.46	4	-
B-22	---	20	80	----	----	----	----	----	----	20.0	28.2	25.2	19.2	7.4	3.81	5	-
B-23	---	26.7	80	----	----	----	----	----	27	20.0	21.1	18.8	14.9	25.2	0.84	4	-
B-24	---	30	80	----	----	----	----	----	40	20.0	18.8	16.8	13.5	30.9	0.61	4	- wax
B-25	---	35.6	80	----	----	----	----	----	62.4	20.0	15.9	14.1	11.7	38.3	0.42	3	- slight, wax
B-26	---	46.6	80	----	----	----	----	----	106.4	20.0	12.1	10.8	9.4	47.7	0.25	2	+
B-27	---	20	----	----	----	----	----	80	----	20.0	----	2.5	76.2	1.3	<0.1	2	-
B-28	---	20	----	5	----	----	----	80	----	19.0	3.7	3.2	72.8	1.3	2.85	2	
B-29	---	20	----	10	----	----	----	70	----	20.0	7.7	3.8	67.2	1.3	5.92	3	
B-30	---	20	----	20	----	----	----	60	----	20.0	15.3	5.1	58.3	1.3	11.8	3	
B-31	---	35	----	----	----	----	----	65	----	35.0	----	2.1	61.9	1.0	<0.1	3f	-
B-32	---	50	----	----	----	----	----	50	----	50.0	----	1.6	47.6	0.8	<0.1	4f	-
B-33	---	65	----	----	----	----	----	35	----	65.0	----	1.1	33.3	0.6	<0.1	5f	-
B-34	---	20	----	----	----	----	80	----	----	20.0	----	3.7	54.5	21.8	<0.1	2	- wax
B-35	100	9.3	----	----	----	----	----	----	24	27.8	20.0	16.1	13.8	22.3	0.90	4	-
B-36	100	9.3	----	----	----	----	----	24	----	27.8	20.0	16.7	30.5	5.0	4.00	4	-
B-37	100	13.9	----	----	----	----	----	----	36	27.8	17.8	14.3	12.5	27.6	0.64	4	-
B-38	100	13.9	----	----	----	----	----	36	----	27.8	17.8	15.0	34.8	4.6	3.87	4	-
B-39	100	21.7	----	----	----	----	----	----	56	27.8	15.0	12.1	10.9	34.2	0.44	3	-
B-40	100	21.7	----	----	----	----	----	56	----	27.8	15.0	13.1	40.0	4.1	3.66	4	-
B-41	100	37.0	----	----	----	----	----	----	96	27.8	11.4	9.2	8.7	42.9	0.27	2	- wax
B-42	100	37.0	----	----	----	----	----	96	----	27.8	11.4	10.6	46.9	3.3	3.45	4f	-
B-43	---	20	----	10	----	----	----	----	70	20.0	7.7	1.6	2.4	68.3	0.11	1f	+ spreads
B-44	---	20	----	10	----	----	----	21	49	20.0	7.7	2.3	21.8	48.2	0.16	2	+ wax
B-45	---	20	----	10	----	----	----	35	35	20.0	7.7	2.7	34.8	34.8	0.22	2	- wax
B-46	---	20	----	10	----	----	----	49	21	20.0	7.7	3.2	47.7	21.4	0.36	2	-
B-47	---	20	----	10	----	----	----	70	----	20.0	7.7	3.8	67.2	1.3	5.92	3	-
B-48	---	20	----	10	----	13	----	----	57	20.0	8.4	12.2	3.2	56.2	0.15	2	+
B-49	---	20	----	10	----	13	----	17	40	20.0	8.4	12.7	19.0	39.9	0.21	2	+ wax
B-50	---	20	----	10	----	13	----	28.5	28.5	20.0	8.4	13.1	29.6	28.9	0.29	2	- trace wax
B-51	---	20	----	10	----	13	----	40	17	20.0	8.4	13.5	40.2	17.9	0.47	2	- trace wax
B-52	---	20	----	10	----	13	----	57	----	20.0	8.4	14.0	56.0	1.6	5.25	3	-
B-53	---	20	----	10	----	20	----	----	50	20.0	8.8	17.9	3.7	49.6	0.18	1	+ wax
B-54	---	20	----	10	----	20	----	15	35	20.0	8.8	18.3	17.6	35.3	0.25	2	+ wax
B-55	---	20	----	10	----	20	----	25	25	20.0	8.8	18.7	26.8	25.7	0.34	2	wax
B-56	---	20	----	10	----	20	----	35	15	20.0	8.8	19.0	36.1	16.1	0.55	3	wax
B-57	---	20	----	10	----	20	----	50	----	20.0	8.8	19.5	50.0	1.7	5.18	3	-
B-58	---	72	----	10	----	----	----	----	18	72.0	7.7	1.6	1.0	17.7	0.44	5f	-
B-59	---	60	----	25	----	----	----	----	15	60.0	19.1	4.0	1.8	15.1	1.26	5f	-
B-60	---	48	----	40	----	----	----	----	12	48.0	30.6	6.4	2.6	12.4	2.47	5f	-
B-61	---	44	----	45	----	----	----	----	11	44.0	34.4	7.3	2.8	11.5	2.99	5f	-
B-62	---	40	----	50	----	----	----	----	10	40.0	38.3	8.0	3.1	10.6	3.61	5f	-
B-63	---	36	----	55	----	----	----	----	9	36.0	42.1	8.8	3.3	9.8	4.30	5f	-
B-64	---	32	----	60	----	----	----	----	8	32.0	45.9	9.7	3.6	8.8	5.22	5f	-

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TABLE X (Continued)

COMPATIBILITY TESTS ON BLENDS OF BOSCAN ASPHALT COMPONENTS

Test No.	Concentrates Blended, Parts: Asphalt	Fraction "A"	Maltenes	Fraction "N"	N-free Maltenes	Fraction "A_1"	Concentrate A_2 + P	Fraction "A_2"	Fraction "P"	Composition of Blend, %: A	N	A_1	A_2	P	$\frac{N}{P}$	Filter Paper Spot Test Rating*	Microscope Test Segregation
B-65	---	24	----	70	----	----	----	----	6	24.0	53.5	11.3	4.1	7.1	7.53	5	-
B-66	---	16	----	80	----	----	----	----	4	16.0	61.2	12.9	4.6	5.3	11.5	5	-
B-67	---	54	----	10	----	----	----	----	36	54.0	7.6	1.6	1.5	35.3	0.22	4f	+
B-68	---	45	----	25	----	----	----	----	30	45.0	19.1	4.0	2.2	29.7	0.64	4	-
B-69	---	30	----	50	----	----	----	----	20	30.0	38.3	8.0	3.3	20.4	1.88	5	-
B-70	---	24	----	60	----	----	----	----	16	24.0	45.9	9.7	3.8	16.6	2.76	5	-
B-71	---	18	----	70	----	----	----	----	12	18.0	53.6	11.3	4.2	12.9	4.15	5	-
B-72	---	15	----	75	----	----	----	----	10	15.0	57.4	12.1	4.4	11.1	5.17	5	-
B-73	---	10	----	10	----	----	----	----	80	10.0	7.6	1.6	2.7	78.1	0.10	1f	+
B-74	---	10	----	20	----	----	----	----	70	10.0	15.3	3.2	2.9	68.6	0.22	1	+
B-75	---	10	----	40	----	----	----	----	50	10.0	30.6	6.4	3.5	49.5	0.62	4	+
B-76	---	10	----	60	----	----	----	----	30	10.0	45.9	9.7	4.1	30.3	1.51	4	-
B-77	---	10	----	70	----	----	----	----	20	10.0	53.6	11.3	4.4	20.7	2.59	5	-
B-78	---	10	----	80	----	----	----	----	10	10.0	61.2	12.9	4.7	11.2	5.46	5	-
B-79	---	12	----	----	----	10	----	----	78	12.0	0.6	8.1	2.9	76.4	<0.1	1f	+
B-80	---	12	----	----	----	22	----	----	76	10.9	1.1	16.3	3.6	68.1	<0.1	1	+
B-81	---	12	----	----	----	40	----	----	48	12.0	2.3	32.5	4.9	48.3	<0.1	1	+
B-82	---	12	----	----	----	60	----	----	28	12.0	3.4	48.8	6.2	29.6	0.11	2	+ slight
B-83	---	12	----	----	----	70	----	----	18	12.0	4.0	56.9	6.8	20.3	0.20	2	-
B-84	---	8	----	----	----	80	----	----	12	8.0	4.6	65.0	7.6	14.8	0.31	2	-
B-85	---	15	----	----	----	80	----	----	5	15.0	4.6	65.1	7.4	7.9	0.58	2	-
B-86	---	18	----	----	----	76	----	----	6	18.0	4.3	61.8	7.1	8.8	0.49	2	-
B-87	---	24	----	----	----	68	----	----	8	24.0	3.9	55.3	6.4	10.4	0.37	2	-
B-88	---	30	----	----	----	60	----	----	10	30.0	3.4	48.8	5.7	12.1	0.28	3	+
B-89	---	42	----	----	----	44	----	----	14	42.0	2.5	35.8	4.4	15.3	0.16		+
B-90	---	54	----	----	----	28	----	----	18	54.0	1.6	22.8	3.0	18.6	<0.1	5f	+
B-91	---	60	----	----	----	20	----	----	20	60.0	1.1	16.3	2.3	20.3	<0.1	5f	+
B-92	---	69	----	----	----	8	----	----	23	69.0	0.5	6.5	1.3	22.7	<0.1	5f	+
B-93	---	60	----	----	----	----	----	10	30	60.0	----	0.3	10.3	29.4	<0.1	5f	+
B-94	---	50	----	----	----	----	----	25	25	50.0	----	0.8	24.4	24.8	<0.1	4f	+
B-95	---	40	----	----	----	----	----	40	20	40.0	----	1.3	38.6	20.1	<0.1	3	? wax
B-96	---	30	----	----	----	----	----	55	15	30.0	----	1.8	52.7	15.5	<0.1	2	? wax
B-97	---	24	----	----	----	----	----	64	12	24.0	----	2.1	61.2	12.7	<0.1	2	? wax
B-98	---	18	----	----	----	----	----	73	9	18.0	----	2.3	69.7	10.0	<0.1	2	
B-99	---	10	----	----	----	----	----	85	5	10.0	----	2.7	81.1	6.2	<0.1	2	

* Average of three observers:

1 - Severe syneresis; 2 - Definite syneresis;

3 - Slight syneresis; 4 - Trace of syneresis;

5 - No syneresis; f - Flocculation

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TABLE XI

COMPATIBILITY TESTS ON BLENDS OF ARKANSAS ASPHALT COMPONENTS

Test No.	Concentrates Blended, Parts: Asphalt	Fraction "A"	Maltenes	Fraction "N"	N-free Maltenes	Fraction "A_1"	Concentrate A_2 + P	Fraction "A_2"	Fraction "P"	Composition of Blend, %: A	N	A_1	A_2	P	$\frac{N}{P}$	Filter Paper Spot Test Rating*	Microscope Test Segregation
A-0	100	----	----	----	----	----	----	----	----	23.6	14.3	21.5	27.9	12.7	1.13	3	-
A-1	---	50	----	----	50	----	----	----	----	50.0	1.7	14.7	24.4	9.2	0.18		-
A-2	100	5.9	----	----	----	----	----	19.1	----	23.6	11.4	17.2	37.6	10.2	1.12	2	
A-3	100	5.9	----	----	----	----	----	----	19.1	23.6	11.4	17.2	22.3	25.5	0.45	2f	
A-4	100	15.1	----	----	----	----	----	48.9	----	23.6	8.7	13.1	46.8	7.8	1.12	2	
A-5	100	15.1	----	----	----	----	----	----	48.9	23.6	8.7	13.1	17.0	37.6	0.23	1f	
A-6	100	24.3	----	----	----	----	----	78.6	----	23.6	7.0	10.6	52.5	6.3	1.11	2	
A-7	100	24.3	----	----	----	----	----	----	78.6	23.6	7.0	10.6	13.8	45.0	0.16	1f	
A-8	100	42.5	----	----	----	----	----	138.4	----	23.6	5.1	7.6	59.2	4.5	1.14	2	-
A-9	100	42.5	----	----	----	----	----	----	138.4	23.6	5.1	7.6	9.9	53.8	<0.1	1f	+
A-10	---	23.6	----	----	----	----	----	----	12.7	65.0	----	----	3.3	31.7	<0.1	4f	
A-11	---	23.6	----	5	----	----	----	----	12.7	57.1	7.9	2.8	4.1	28.1	0.28	2f	
A-12	---	23.6	----	10	----	----	----	----	12.7	51.0	14.1	5.0	4.7	25.2	0.56	3f	
A-13	---	23.6	----	20	----	----	----	----	12.7	41.9	23.2	8.2	5.7	21.0	1.10	3f	
A-14	---	23.6	----	----	----	5	----	----	12.7	57.1	1.8	7.1	6.1	27.9	<0.1	2f	
A-15	---	23.6	----	----	----	10	----	----	12.7	51.0	3.2	12.5	8.3	25.0	0.13	3f	
A-16	---	23.6	----	----	----	20	----	----	12.7	41.9	5.3	20.7	11.4	20.7	0.26	3f	
A-17	---	35	----	----	----	----	----	----	65	35.0	----	----	6.5	58.5	<0.1		+
A-18	---	35	----	5	----	----	----	----	65	33.3	3.1	1.1	6.7	55.8	<0.1		+
A-19	---	35	----	10	----	----	----	----	65	31.8	5.9	2.1	6.8	53.4	0.11		+
A-20	---	35	----	20	----	----	----	----	65	29.2	10.7	3.9	7.1	49.1	0.22		+
A-21	---	35	----	25	----	----	----	----	65	28.0	13.1	4.6	7.2	47.1	0.28		+
A-22	---	35	----	30	----	----	----	----	65	26.9	15.0	5.4	7.3	45.4	0.33		+
A-23	---	35	----	35	----	----	----	----	65	25.9	16.9	6.0	7.4	43.8	0.39	1f	+
A-24	---	35	----	40	----	----	----	----	65	25.0	18.6	6.6	7.5	42.3	0.44	1f	+
A-25	---	35	----	45	----	----	----	----	65	24.1	20.2	7.2	7.6	40.9	0.49	1f	+
A-26	---	35	----	50	----	----	----	----	65	23.4	21.7	7.7	7.7	39.5	0.55	1	+
A-27	---	35	----	60	----	----	----	----	65	21.9	24.4	8.7	7.8	37.2	0.66	2	-
A-28	---	20	----	----	----	----	----	80	----	20.0	----	1.9	74.3	3.8	<0.1	2	-
A-29	---	20	----	5	----	----	----	80	----	19.1	3.1	2.9	71.2	3.7	0.84	2	-
A-30	---	20	----	10	----	----	----	80	----	18.2	5.9	3.9	68.4	3.6	1.64	2	-
A-31	---	20	----	20	----	----	----	80	----	16.7	10.9	5.4	63.5	3.5	3.11	2	-
A-32	---	35	----	----	----	----	----	65	----	35.0	----	1.6	60.3	3.1	<0.1	2f	-
A-33	---	50	----	----	----	----	----	50	----	50.0	----	1.2	46.4	2.4	<0.1	3f	-
A-34	---	20	----	20	----	----	----	60	----	20.0	13.0	6.1	57.7	3.2	4.06	2	-
A-35	---	20	----	30	----	----	----	50	----	20.0	19.6	8.2	49.4	2.8	7.00	3	-
A-36	---	20	----	40	----	----	----	40	----	20.0	26.1	10.2	41.1	2.6	10.0	4	-
A-37	---	20	----	----	80	----	----	----	----	20.0	2.6	23.5	39.1	14.8	0.18	2	-
A-38	---	20	----	4.7	75.3	----	----	----	----	20.0	5.5	23.3	37.2	14.0	0.39	2	-
A-39	---	20	----	8.9	71.1	----	----	----	----	20.0	8.1	23.0	35.6	13.3	0.61	3	-
A-40	---	20	----	16.0	64.0	----	----	----	----	20.0	12.6	22.5	32.8	12.1	1.04	3	-
A-41	---	20	80	----	----	----	----	----	----	20.0	14.6	23.6	30.0	11.8	1.24	4	-
A-42	---	21.8	80	----	----	----	----	----	7.1	20.0	13.5	21.7	27.7	17.1	0.79	3	-
A-43	---	25.6	80	----	----	----	----	----	23.1	20.0	11.3	18.3	23.8	26.6	0.42	2	-
A-44	---	33.9	80	----	----	----	----	----	55.4	20.0	8.7	13.9	18.7	38.7	0.22	1	+
A-45	---	20	----	----	----	----	80	----	----	20.0	1.3	6.0	51.5	21.2	<0.1	1	-
A-46	---	20	----	10	----	----	----	----	70	20.0	6.5	2.3	3.1	68.1	0.10	1f	+
A-47	---	20	----	10	----	----	----	21	49	20.0	6.5	2.8	22.0	48.7	0.13	1f	+
A-48	---	20	----	10	----	----	----	35	35	20.0	6.5	3.2	34.5	35.8	0.18	1	+ very slight
A-49	---	20	----	10	----	----	----	49	21	20.0	6.5	3.5	47.1	22.9	0.28	1	-
A-50	---	20	----	10	----	----	----	70	----	20.0	6.5	4.0	66.0	3.5	1.86	2	-
A-51	---	20	----	10	----	13	----	----	57	20.0	8.5	9.9	6.1	55.5	0.15	1f	+
A-52	---	20	----	10	----	13	----	17	40	20.0	8.5	10.2	21.4	39.9	0.21	1	+ slight
A-53	---	20	----	10	----	13	----	28.5	28.5	20.0	8.5	10.5	31.7	29.3	0.29	2	-
A-54	---	20	----	10	----	13	----	40	17	20.0	8.5	10.8	42.0	18.7	0.45	2	-
A-55	---	20	----	10	----	13	----	57	----	20.0	8.5	11.2	57.3	3.0	2.83	3	-
A-56	---	20	----	10	----	20	----	----	50	20.0	9.5	14.0	7.7	48.8	0.19	1f	+
A-57	---	20	----	10	----	20	----	15	35	20.0	9.5	14.3	21.2	35.0	0.27	2	-
A-58	---	20	----	10	----	20	----	25	25	20.0	9.5	14.5	30.2	25.8	0.37	2	-
A-59	---	20	----	10	----	20	----	35	15	20.0	9.5	14.8	39.2	16.5	0.58	3	-
A-60	---	20	----	10	----	20	----	50	----	20.0	9.5	15.2	52.6	2.7	3.52	4	-
A-61	---	72	----	10	----	----	----	----	18	72.0	6.5	2.3	2.2	17.0	0.38	5f	-
A-62	---	60	----	25	----	----	----	----	15	60.0	16.3	5.8	3.5	14.4	1.13	5f	-
A-63	---	48	----	40	----	----	----	----	12	48.0	26.1	9.3	4.8	11.8	2.21	4f	-
A-64	---	40	----	50	----	----	----	----	10	40.0	32.6	11.6	5.7	10.1	3.22	5f	-

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TABLE XI (Continued)

COMPATIBILITY TESTS ON BLENDS OF ARKANSAS ASPHALT COMPONENTS

Test No.	Concentrates Blended, Parts: Asphalt	Fraction "A"	Maltenes	Fraction "N"	N-free Maltenes	Fraction "A_1"	Concentrate A_2 + P	Fraction "A_2"	Fraction "P"	Composition of Blend, %: A	N	A_1	A_2	P	$\frac{N}{P}$	Filter Paper Spot Test Rating*	Microscope Test Segregation
A-65	---	32	----	60	----	----	----	----	8	32.0	39.1	13.9	6.5	8.5	4.60	5	-
A-66	---	16	----	80	----	----	----	----	4	16.0	52.2	18.5	8.3	5.0	10.4	5	-
A-67	---	10	----	10	----	----	----	----	80	10.0	6.5	2.3	6.4	74.8	<0.1	1f	+
A-68	---	10	----	20	----	----	----	----	70	10.0	13.0	4.6	6.8	65.6	0.20	1f	+
A-69	---	10	----	40	----	----	----	----	50	10.0	26.1	9.3	7.4	47.2	0.55	2	+
A-70	---	10	----	60	----	----	----	----	30	10.0	39.1	13.9	8.0	29.0	1.34	2	-
A-71	---	10	----	70	----	----	----	----	20	10.0	45.6	16.2	8.4	19.8	2.30	3	-
A-72	---	10	----	80	----	----	----	----	10	10.0	52.2	18.5	8.7	10.6	4.92	4	-
A-73	---	54	----	10	----	----	----	----	36	54.0	6.5	2.3	3.5	33.7	0.19	3f	+
A-74	---	45	----	25	----	----	----	----	30	45.0	16.3	5.8	4.5	28.4	0.57	3f	+
A-75	---	30	----	50	----	----	----	----	20	30.0	32.6	11.6	6.4	19.4	1.68	3f	-
A-76	---	24	----	60	----	----	----	----	16	24.0	39.1	13.9	7.1	15.9	2.46	4	-
A-77	---	18	----	70	----	----	----	----	12	18.0	45.7	16.2	7.8	12.3	3.72	4f	-
A-78	---	12	----	80	----	----	----	----	8	12.0	52.2	18.6	8.5	8.7	6.00	5f	-
A-79	---	12	----	----	----	10	----	----	78	12.0	1.5	5.8	7.9	72.8	<0.1	1f	+
A-80	---	12	----	----	----	20	----	----	68	12.0	3.0	11.6	9.9	63.5	<0.1	1f	+
A-81	---	12	----	----	----	40	----	----	48	12.0	6.0	23.2	13.7	45.1	0.13	2	-
A-82	---	12	----	----	----	60	----	----	28	12.0	8.9	34.9	17.6	26.6	0.33	3	-
A-83	---	12	----	----	----	70	----	----	18	12.0	10.4	40.7	19.6	17.3	0.60	3	-
A-84	---	8	----	----	----	80	----	----	12	8.0	11.9	46.5	21.8	11.8	1.01	3	-
A-85	---	66	----	----	----	12	----	----	22	66.0	1.8	7.0	4.6	20.6	<0.1	4f	-
A-86	---	54	----	----	----	28	----	----	18	54.0	4.1	16.3	8.6	17.0	0.24	4f	+
A-87	---	42	----	----	----	44	----	----	14	42.0	6.5	25.6	12.5	13.4	0.48	5f	-
A-88	---	33	----	----	----	56	----	----	11	33.0	8.3	32.6	15.4	10.7	0.78	5f	-
A-89	---	24	----	----	----	68	----	----	8	24.0	10.1	39.5	18.4	8.0	1.26	5f	-
A-90	---	15	----	----	----	80	----	----	5	15.0	11.9	46.5	21.3	5.3	2.24	5f	-
A-91	---	60	----	----	----	----	----	10	30	60.0	----	0.2	11.3	28.5	<0.1	4f	+
A-92	---	50	----	----	----	----	----	25	25	50.0	----	0.6	24.9	24.5	<0.1	3f	+
A-93	---	40	----	----	----	----	----	40	20	40.0	----	1.0	38.5	20.5	<0.1	2f	+
A-94	---	30	----	----	----	----	----	55	15	30.0	----	1.3	52.1	16.6	<0.1	2	+
A-95	---	24	----	----	----	----	----	64	12	24.0	----	1.5	60.2	14.3	<0.1	1	+
A-96	---	18	----	----	----	----	----	73	9	18.0	----	1.7	68.4	11.9	<0.1	2	-
A-97	---	10	----	----	----	----	----	85	5	10.0	----	2.0	79.2	8.8	<0.1	1	-

* Average of three observers:

1 = Severe syneresis; 2 = Definite syneresis;
3 = Slight syneresis; 4 = Trace of syneresis;
5 = No syneresis; f = Flocculation

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TABLE XII

COMPATIBILITY TESTS ON BLENDS OF CANADIAN ASPHALT COMPONENTS

Test No.	Concentrates Blended, Parts: Asphalt	Fraction "A"	Maltenes	Fraction "N"	N-free Maltenes	Fraction "A_1"	Concentrate A_2 + P	Fraction "A_2"	Fraction "P"	Composition of Blend, %: A	N	A_1	A_2	P	N/P	Filter Paper Spot Test Rating*	Microscope Test Segregation
C-0	100	----	----	----	----	----	----	----	----	21.0	20.8	17.1	29.9	11.2	1.86	4	
C-1	---	50	----	----	50	----	----	----	----	50.0	0.1	12.6	26.8	10.5	<0.1		+
C-2	---	50**	----	----	50	----	----	----	----	50.0	0.1	12.6	26.8	10.5	<0.1		-
C-3	---	50	----	----	50**	----	----	----	----	50.0	0.1	14.6	21.2	14.1	<0.1		+
C-4	100	5.9	----	----	----	----	----	22.1	----	21.0	16.2	13.4	40.6	8.8	1.84	3	- wax
C-5	100	5.9	----	----	----	----	----	----	22.1	21.0	16.2	13.4	23.4	26.0	0.62	3	- wax
C-6	100	17.3	----	----	----	----	----	53.7	----	22.4	12.2	10.0	48.9	6.5	1.88	3	- wax
C-7	100	17.3	----	----	----	----	----	----	53.7	22.4	12.2	10.0	17.5	37.9	0.32	3f	+
C-8	100	22.7	----	----	----	----	----	85.2	----	21.0	10.0	8.2	55.4	5.4	1.85	3	- wax
C-9	100	22.7	----	----	----	----	----	----	85.2	21.0	10.0	8.2	14.4	46.4	0.22	1f	+
C-10	---	20	----	----	----	----	----	80	----	20.0	1.3	3.0	70.8	4.9	0.27		beads
C-11	---	35	----	----	----	----	----	----	65	35.0	----	0.3	3.1	61.6	<0.1	1f	+
C-12	---	35	----	20	----	----	----	----	65	29.2	10.4	4.0	4.5	51.9	0.20	2f	+
C-13	---	35	----	40	----	----	----	----	65	25.0	17.8	6.7	5.5	45.0	0.40	2f	+
C-14	---	35	----	60	----	----	----	----	65	21.9	23.3	8.7	6.3	39.8	0.59	3f	+
C-15	---	35	----	80	----	----	----	----	65	19.4	27.7	10.3	6.9	35.7	0.78	3	+
C-16	---	35	----	100	----	----	----	----	65	17.5	31.1	11.6	7.4	32.4	0.96	3	-
C-17	---	35	----	120	----	----	----	----	65	15.9	33.9	12.6	7.8	29.8	1.14	3	-
C-18	---	35	----	----	----	----	----	65	----	35.0	1.1	2.4	57.5	4.0	0.28	2f	
C-19	---	50	----	----	----	----	----	50	----	50.0	0.8	1.9	44.3	3.0	0.27	4f	-
C-20	---	65	----	----	----	----	----	35	----	65.0	0.6	1.3	31.0	2.1	0.29	5f	-
C-21	---	20	----	----	80	----	----	----	----	20.0	0.2	20.1	42.8	16.9	<0.1	2	+
C-22	---	20	----	4.7	75.3	----	----	----	----	20.0	3.2	20.0	40.8	16.0	0.20	3	+
C-23	---	20	----	8.9	71.1	----	----	----	----	20.0	5.7	19.9	39.1	15.3	0.37	3	-
C-24	---	20	----	16.0	64.0	----	----	----	----	20.0	10.2	19.7	36.1	14.0	0.73	3	-
C-25	---	20	80	----	----	----	----	----	----	20.0	20.6	18.9	28.7	11.8	1.75	4	-
C-26	---	22.2	80	----	----	----	----	----	8.7	20.0	18.5	17.1	26.3	18.1	1.02	3	-
C-27	---	26.3	80	----	----	----	----	----	25.1	20.0	15.6	14.5	22.8	27.1	0.58	3	+
C-28	---	28.2	80	----	----	----	----	----	32.9	20.0	14.6	13.5	21.4	30.5	0.49	2	+
C-29	---	20	----	----	----	----	80	----	----	20.0	0.8	6.4	50.0	22.8	<0.1	1f	+
C-30	---	20	----	----	----	----	80***	----	----	20.0	1.3	6.0	51.5	21.2	<0.1		+
C-31	---	20***	----	----	----	----	80	----	----	20.0	0.8	6.4	50.0	22.8	<0.1		+ slight, wax
C-32	---	20	----	5	----	----	----	75	----	20.0	4.3	3.9	67.0	4.8	0.90	2	- beads
C-33	---	20	----	10	----	----	----	70	----	20.0	7.4	4.9	63.1	4.6	1.61	3	- beads
C-34	---	20	----	20	----	----	----	60	----	20.0	13.5	6.8	55.4	4.3	3.14	3	- beads
C-35	---	20	----	----	----	----	----	----	80	20.0	----	0.4	3.8	75.8	<0.1	1f	+
C-36	---	20	----	10	----	----	----	----	70	20.0	6.2	2.6	4.5	66.7	<0.1	1f	+
C-37	---	20	----	20	----	----	----	----	60	20.0	12.4	4.9	5.2	57.5	0.22	1f	+
C-38	---	20	----	30	----	----	----	----	50	20.0	18.7	7.1	5.8	48.4	0.39	2f	+
C-39	---	20	----	40	----	----	----	----	40	20.0	24.9	9.3	6.6	39.2	0.64	2	+
C-40	---	20	----	50	----	----	----	----	30	20.0	31.1	11.5	7.3	30.1	1.03	3	- wax
C-41	---	20	----	60	----	----	----	----	20	20.0	37.3	13.8	8.0	20.9	1.78	4	-
C-42	---	20	----	10	----	----	----	----	70	20.0	6.2	2.6	4.5	66.7	<0.1	1f	+
C-43	---	20	----	10	----	----	----	21	49	20.0	6.6	3.3	22.0	48.1	0.14	1f	+
C-44	---	20	----	10	----	----	----	35	35	20.0	6.8	3.7	33.8	35.7	0.19	1f	+
C-45	---	20	----	10	----	----	----	49	21	20.0	7.1	4.2	45.5	23.2	0.32	2	+ wax
C-46	---	20	----	10	----	----	----	70	----	20.0	7.4	4.9	63.1	4.6	1.61	3	+ wax
C-47	---	20	----	10	----	13	----	----	57	20.0	6.9	12.8	5.3	55.0	0.13	1f	+
C-48	---	20	----	10	----	13	----	17	40	20.0	7.2	13.3	19.6	39.9	0.18	2f	+
C-49	---	20	----	10	----	13	----	28.5	28.5	20.0	7.4	13.7	29.2	29.7	0.25	2f	+
C-50	---	20	----	10	----	13	----	40	17	20.0	7.6	14.1	38.8	19.5	0.39	2	+ beads
C-51	---	20	----	10	----	13	----	57	----	20.0	7.9	14.6	53.1	4.4	1.80	3	+ wax, beads
C-52	---	20	----	10	----	20	----	----	50	20.0	7.3	18.3	5.8	48.6	0.15	1f	+
C-53	---	20	----	10	----	20	----	15	35	20.0	7.5	18.7	18.4	35.4	0.21	2f	+
C-54	---	20	----	10	----	20	----	25	25	20.0	7.7	19.1	26.7	26.5	0.29	2	-
C-55	---	20	----	10	----	20	----	35	15	20.0	7.9	19.4	35.1	17.6	0.45	2	+ wax
C-56	---	20	----	10	----	20	----	50	----	20.0	8.1	19.9	47.7	4.3	1.88	3	+ wax
C-57	---	72	----	10	----	----	----	----	18	72.0	6.2	2.4	2.0	17.4	0.36	5f	+
C-58	---	60	----	25	----	----	----	----	15	60.0	15.6	5.8	3.6	15.0	1.04	4f	-
C-59	---	48	----	40	----	----	----	----	12	48.0	24.9	9.2	5.2	12.7	1.96	5f	-
C-60	---	40	----	50	----	----	----	----	10	40.0	31.1	11.5	6.3	11.1	2.80	5f	-
C-61	---	32	----	60	----	----	----	----	8	32.0	37.3	13.7	7.4	9.6	3.89	5f	-
C-62	---	16	----	80	----	----	----	----	4	16.0	49.8	18.3	9.5	6.4	7.8	4	-
C-63	---	54	----	10	----	----	----	----	36	54.0	6.2	2.5	2.9	34.4	0.18	2f	+
C-64	---	45	----	25	----	----	----	----	30	45.0	15.6	5.8	4.3	29.3	0.53	3f	+

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TABLE XII (Continued)

COMPATIBILITY TESTS ON BLENDS OF CANADIAN ASPHALT COMPONENTS

Test No.	Concentrates Blended, Parts: Asphalt	Fraction "A"	Maltenes	Fraction "N"	N-free Maltenes	Fraction "A_1"	Concentrate A_2 + P	Fraction "A_2"	Fraction "P"	Composition of Blend, %: A	N	A_1	A_2	P	$\frac{N}{P}$	Filter Paper Spot Test Rating*	Microscope Test Segregation
C-65	---	30	----	50	----	----	----	----	20	30.0	31.1	11.5	6.8	20.6	1.51	4f	+
C-66	---	24	----	60	----	----	----	----	16	24.0	37.3	13.8	7.8	17.1	2.18	5	+
C-67	---	18	----	70	----	----	----	----	12	18.0	43.5	16.0	8.8	13.7	3.17	5	+ slight
C-68	---	12	----	80	----	----	----	----	8	12.0	49.8	18.3	9.7	10.2	4.88	5	-
C-69	---	10	----	10	----	----	----	----	80	10.0	6.2	2.7	4.9	76.2	<0.1	1f	+
C-70	---	10	----	20	----	----	----	----	70	10.0	12.5	4.9	5.6	67.0	0.19	1f	+
C-71	---	10	----	40	----	----	----	----	50	10.0	24.9	9.4	7.0	48.7	0.51	2	+
C-72	---	10	----	60	----	----	----	----	30	10.0	37.3	13.9	8.4	30.4	1.23	3	+
C-73	---	10	----	70	----	----	----	----	20	10.0	43.5	16.1	9.1	21.3	2.04	4	+
C-74	---	10	----	80	----	----	----	----	10	10.0	49.8	18.3	9.8	12.1	4.12	5	-
C-75	---	12	----	----	----	10	----	----	78	12.0	0.5	8.3	4.8	74.4	<0.1	1f	+
C-76	---	12	----	----	----	20	----	----	68	12.0	1.0	16.1	5.5	65.4	<0.1	1f	+
C-77	---	12	----	----	----	40	----	----	48	12.0	2.1	31.7	6.8	47.4	<0.1	2f	+
C-78	---	12	----	----	----	60	----	----	28	12.0	3.2	47.4	8.1	29.3	0.11	3	+
C-79	---	12	----	----	----	70	----	----	18	12.0	3.7	55.2	8.8	20.3	0.18	3	+
C-80	---	8	----	----	----	80	----	----	12	8.0	4.2	63.0	9.7	15.1	0.28	4f	+
C-81	---	66	----	----	----	12	----	----	22	66.0	0.6	9.6	2.4	21.4	<0.1	3f	+
C-82	---	54	----	----	----	28	----	----	18	54.0	1.5	22.1	4.0	18.4	<0.1	3f	+
C-83	---	42	----	----	----	44	----	----	14	42.0	2.3	34.7	5.7	15.3	0.15	4f	+ slight
C-84	---	33	----	----	----	56	----	----	11	33.0	3.0	44.1	6.9	13.0	0.23	4f	+
C-85	---	24	----	----	----	68	----	----	8	24.0	3.6	53.6	8.1	10.7	0.34	4f	+
C-86	---	15	----	----	----	80	----	----	5	15.0	4.2	63.0	9.4	8.4	0.50	5f	+
C-87	---	60	----	----	----	----	----	10	30	60.0	0.2	0.5	10.3	29.0	<0.1	3f	+
C-88	---	50	----	----	----	----	----	25	25	50.0	0.4	1.1	23.3	25.2	<0.1	3f	+
C-89	---	40	----	----	----	----	----	40	20	40.0	0.7	1.6	36.3	21.4	<0.1	3f	+
C-90	---	30	----	----	----	----	----	55	15	30.0	0.9	2.1	49.4	17.6	<0.1	2	+
C-91	---	24	----	----	----	----	----	64	12	24.0	1.1	2.4	57.2	15.3	<0.1	2	+ bead
C-92	---	18	----	----	----	----	----	73	9	18.0	1.2	2.8	65.0	13.0	<0.1	2	+ bead
C-93	---	10	----	----	----	----	----	85	5	10.0	1.4	3.2	75.5	9.9	0.14	2	+ bead

* Average of three observers:
1 Severe syneresis; 2 - Definite syneresis;
3 Slight syneresis; 4 - Trace of syneresis;
5 No syneresis; f - Flocculation

** From Valley Asphalt

*** From Arkansas Asphalt

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TABLE XIII

EFFECT OF ASPHALTENES COMPOSITION ON MUTUAL COMPATIBILITY OF COMPONENTS

Test No.	V-1	C-1	C-3	C-2
Fraction "A"				
% in Blend	50	50	50	50
Source	Valley	Canadian	Canadian	Valley
Maltenes free of - Fraction "N"				
% in Blend	50	50	50	50
Source	Valley	Canadian	Valley	Canadian
Component Analysis, %				
A	50.0	50.0	50.0	50.0
N	0.1	0.1	0.1	0.1
A_1	14.6	12.6	14.6	12.6
A_2	21.2	26.8	21.2	26.8
P	14.1	10.5	14.1	10.5
Microscope Test Segregation	-	+	+	-

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TABLE XIV

EFFECT ON VISCOSITY AND ABRASION RESISTANCE OF STEPWISE SUBSTITUTION OF INDIVIDUAL COMPONENTS IN ORIGINAL MALTENES--VALLEY ASPHALT

Sample Designation	1	5	Val C-3756	Val B-3756	25R
Materials Blended, %					
Original Asphalt	100	---	----	----	----
Fraction "A"	---	11	10.9	10.9	10.9
Maltenes	---	89	----	----	----
Fraction "N"	---	---	46.5	45.4	46.4
N-bases-free Maltenes	---	---	42.6	----	----
Fraction "A_1"	---	---	----	12.4	11.8
Concentrate, Fractions "A_2" and "P"	---	---	----	31.3	----
Fraction "A_2"	---	---	----	----	19.6
Fraction "P"	---	---	----	----	11.3
Viscosity at 77°F*					
0.05 sec^{-1}, megapoises	2.60,2.07	3.03,3.0	2.80	1.66	1.27,1.34
0.001 sec^{-1}, megapoises	2.65,2.07	3.2,3.0	2.80	1.67	1.32,1.68
Shear susceptibility	0.01,0	0.01,0	0	0	0.01,0.06
Penetration at 77°F, calculated, dmm	56	53	55	70	79
Pellet Abrasion Test					
% loss in 500 revolutions**					
Unaged	24.2	33.8	55.6	22.5	10.6
Aged 7 days	98.5	100(410)	100(374)	76.5	46.3
Average	61.3	67+	78+	49.6	28.4
mg loss/revolution,					
Unaged	0.982	1.370	2.205	0.930	0.440
Aged 7 days	4.126	4.878	5.343	3.143	1.910
Average	2.554	3.124	3.774	2.032	1.175

* Duplicate data are from measurements in both MR&D and State Laboratories.

** Figure in parentheses after 100 = number of revolutions to 100% loss.

TABLE XV

EFFECT ON VISCOSITY AND ABRASION RESISTANCE OF STEPWISE SUBSTITUTION OF INDIVIDUAL COMPONENTS IN ORIGINAL MALTENES--BOSCAN ASPHALT

Sample Designation	2	9	Bos B-3757	26R
Materials Blended, %				
Original Asphalt	100	----	----	----
Fraction "A"	---	28	27.8	27.8
Maltenes	---	72	----	----
Fraction "N"	---	----	31.2	33.3
N-bases-free Maltenes	---	----	41.0	----
Fraction "A_1"	---	----	----	19.3
Concentrate, Fractions "A_2" and "P"	---	----	----	----
Fraction "A_2"	---	----	----	14.8
Fraction "P"	---	----	----	4.8
Viscosity at 77°F*				
0.05 sec^{-1}, megapoises	3.34,3.5	3.73	7.2	6.9,6.55
0.001 sec^{-1}, megapoises	4.6,4.55	7.1	12.3	11.8,14.5
Shear Susceptibility	0.09,0.07	0.16	0.14	0.14,0.20
Penetration at 77°F, calculated, dmm	50	48	35	36
Pellet Abrasion Test				
% loss in 500 revolutions**				
Unaged	34.8	21.1	36.9	25.2
Aged 7 days	100(434)	92.2	93.2	100(426)
Average	68+	56.6	65.1	63+
mg loss/revolution,				
Unaged	1.422	0.842	1.524	1.031
Aged 7 days	4.618	3.755	3.740	4.876
Average	3.020	2.298	2.632	2.954

* Duplicate data are from measurements in both MR&D and State Laboratories.

** Figure in parentheses after 100 = number of revolutions to 100% loss.

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TABLE XVI

EFFECT ON VISCOSITY AND ABRASION RESISTANCE OF STEPWISE SUBSTITUTION OF INDIVIDUAL COMPONENTS IN ORIGINAL MALTENES--ARKANSAS ASPHALT

Sample Designation	3	13	Ark A-3758	Ark B-3758	27R
Materials Blended, %					
Original Asphalt	100	----	----	----	----
Fraction "A"	---	23.5	23.6	23.6	23.6
Maltenes	---	76.5	----	----	----
Fraction "N"	---	----	19.4	14.9	14.9
N-bases-free Maltenes	---	----	57.0	----	----
Fraction "A_1"	---	----	----	27.3	27.8
Concentrate, Fractions "A_2" and "P"	---	----	----	29.3	----
Fraction "A_2"	---	----	----	----	20.5
Fraction "P"	---	----	----	4.9	13.2
Viscosity at 77°F*					
0.05 sec^{-1}, megapoises	3.30,3.3	2.2	11.8	7.6	3.2,3.02
0.001 sec^{-1}, megapoises	4.40,4.35	2.88	28.5	8.2	3.8,4.0
Shear susceptibility	0.08,0.07	0.07	0.24	0.02	0.04,0.07
Penetration at 77°F, calculated, dmm	51	61	28	34	51
Pellet Abrasion Test, % loss in 500 revolutions					
Unaged	0.32	0.02	0.08	0.46	0.28
Aged 7 days	0.46	0.26	0.14	4.04	0.76
Average	0.39	0.14	0.11	2.2	0.52
mg loss/revolution					
Unaged	0.013	0.001	0.003	0.019	0.012
Aged 7 days	0.019	0.011	0.006	0.167	0.032
Average	0.016	0.006	0.004	0.093	0.022

* Duplicate data are from measurements in both MR&D and State Laboratories.

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TABLE XVII

EFFECT ON VISCOSITY AND ABRASION RESISTANCE OF STEPWISE SUBSTITUTION OF INDIVIDUAL COMPONENTS IN ORIGINAL MALTENES--CANADIAN ASPHALT

Sample Designation	4	17	Can A-3759	Can B-3759	28R
Materials Blended, %					
Original Asphalt	100	----	----	----	----
Fraction "A"	---	21	21	21.0	21.0
Maltenes	---	79	----	----	----
Fraction "N"	---	----	30	31.8	31.4
N-bases-free Maltenes	---	----	49	----	----
Fraction "A_1"	---	----	----	9.9	12.9
Concentrate, Fractions "A_2" and "P"	---	----	----	37.3	----
Fraction "A_2"	---	----	----	----	25.7
Fraction "P"	---	----	----	----	9.0
Viscosity at 77°F*					
0.05 sec^{-1}, megapoises	2.53,2.4	2.5	4.8	9.0	4.2,3.72
0.001 sec^{-1}, megapoises	3.02,2.4	2.9	6.0	16.3	6.0,6.05
Shear susceptibility	0.04,0	0.04	0.06	0.15	0.09,0.11
Penetration at 77°F, calculated, dmm	57	57	42	32	45
Pellet Abrasion Test, % loss in 500 revolutions					
Unaged	15.9	3.9	6.3	12.4	37.2
Aged 7 days	59.2	18.3	27.7	64.1	70.1
Average	37.6	11.1	17.0	38.3	53.7
mg loss/revolution					
Unaged	0.657	0.162	0.260	0.514	1.534
Aged 7 days	2.410	0.750	1.158	2.657	2.826
Average	1.534	0.456	0.709	1.586	2.180

* Duplicate data are from measurements in both MR&D and State Laboratories.

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TABLE XVIII

COMPARISON OF ORIGINAL ASPHALTS WITH ASPHALTS REBLENDED FROM FIVE INDIVIDUAL COMPONENTS

MR&D No.	1	25R	2	26R	3	27R	4	28R
Asphalt	Valley Original	Valley Reblended	Boscan Original	Boscan Reblended	Arkansas Original	Arkansas Reblended	Canadian Original	Canadian Reblended
Composition, %, A	10.9	10.9	27.8	30.1	23.6	23.3	21.0	21.7
N	41.5	44.0	26.6	25.6	14.3	10.6	20.8	19.9
A_1	14.2	13.1	21.5	21.5	21.5	23.9	17.1	17.2
A_2	20.7	19.9	17.8	16.7	27.9	28.9	29.9	30.4
P	12.7	12.1	6.3	6.1	12.7	13.3	11.2	10.8
$(N+A_1)/(P+A_2)$	1.67	1.78	2.00	2.06	0.88	0.82	0.92	0.90
Viscosity at 77°F,								
At 0.05 sec^{-1}, megapoises	2.07	1.34	3.5	6.55	3.3	3.02	2.4	3.72
At 0.001 sec^{-1}, megapoises	2.07	1.68	4.55	14.5	4.35	4.0	2.4	6.05
Shear susceptibility	0	0.06	0.07	0.20	0.07	0.07	0	0.11
Viscosity at 77°F after aging*								
At 0.05 sec^{-1}, megapoises	20.9	8.6	49.3	46.5	12.9	8.4	24.3	19.4
At 0.001 sec^{-1}, megapoises	22.3	9.4	153	183.0	36.1	16.2	102	53.0
Shear susceptibility	0.02	0.02	0.29	0.35	0.27	0.17	0.37	0.26
Viscosity at 140°F, poises	1870	1586	4922	13,288	4699	4887	1033	2689
Viscosity at 275°F, centistokes	245	240	689	1185	669	678	227	363
Temperature susceptibility,								
140° - 275°F	-3.894	-3.844	-3.424	-3.390	-3.426	-3.431	-3.715	-3.699
77° - 140°F	-4.106	-4.023	-3.660	-3.284	-3.851	-3.598	-4.629	-4.133
Stain Number	4	4	4	5	7	6	7	8
Microductility after aging*, mm	83	75	4	3	7	18	4	5
Pellet Abrasion Test, % loss in 500 revolutions,**								
Unaged	24.2	10.6	34.8	25.2	0.32	0.28	15.9	37.2
Aged 7 days	98.5	46.3	100(434)	100(426)	0.46	0.76	59.2	70.1
Average	61.3	28.4	68+	63+	0.39	0.52	37.6	53.7
mg loss/revolution,								
Unaged	0.982	0.440	1.422	1.031	0.013	0.012	0.657	1.534
Aged 7 days	4.126	1.910	4.618	4.876	0.019	0.032	2.410	2.826
Average	2.554	1.175	3.020	2.954	0.016	0.022	1.534	2.180

* Twenty-micron film exposed 24 hours at 210°F.

** Figure in parentheses after 100 = number of revolutions to 100% loss.

TABLE XIX

EFFECT OF INTERCHANGING ASPHALTENES IN ASPHALT

Specimen No. MR&D	1	5	6	7	8	2	9	10	11	12	3	13	14	15	16	21	4	17	18	19	20
Materials Blended,																					
Asphalt	100V	------	------	------	------	100B	------	------	------	------	100A	------	------	------	------	------	100C	------	------	------	------
Asphaltenes, %	------	11	11	11	11	------	28	28	28	28	------	23.5	23.5	23.5	23.5	23.5	------	21	21	21	21
Source*		V	B	A	C		B	V	A	C		A	V	B	C	C_H		C	Y	B	A
Mol. wt.		2625	4740	4670	2725		4740	2625	4670	2725		4670	2625	4740	2725	4200		2725	2625	4740	4670
Maltenes, %	------	89	89	89	89	------	72	72	72	72	------	76.5-A	76.5-A	76.5-A	76.5-A	76.5-A	------	79-C	79-C	79-C	79-C
Source*		V	V	V	V		B	B	B	B		A	A	A	A	A		C	C	C	C
Composition, %, A	10.9	12.3	12.5	11.5	12.3	27.8	28.1	27.7	27.1	27.2	23.6	23.9	23.0	23.8	22.9	25.2	21.0	20.4	20.0	21.4	20.5
N	41.5	40.3	39.5	41.0	39.8	26.6	23.9	24.8	25.5	25.8	14.3	10.2	14.5	12.2	11.9	10.7	20.8	18.8	20.9	19.4	19.4
A_1	14.2	14.2	14.6	14.4	14.7	21.5	23.3	22.7	22.6	21.9	21.5	22.9	20.6	22.1	22.9	22.0	17.1	18.8	16.9	18.1	18.5
A_2	20.7	20.6	20.6	20.3	20.3	17.8	18.0	18.2	18.1	18.5	27.9	31.5	30.1	29.8	30.1	30.2	29.9	29.0	29.0	27.9	29.1
P	12.7	12.6	12.8	12.8	12.9	6.3	6.7	6.6	6.7	6.6	12.7	11.5	11.8	12.1	12.2	11.9	11.2	13.0	13.2	13.2	12.5
$(N+A_1)/(P+A_2)$	1.67	1.64	1.62	1.67	1.64	2.00	1.91	1.92	1.94	1.90	0.88	0.77	0.84	0.82	0.82	0.78	0.92	0.90	0.90	0.91	0.91
Viscosity at 77°F																					
At 0.05 sec^{-1}, megapoises	2.07	3.0	2.11	1.70	1.96	3.5	3.73	7.2	2.85	1.78	3.3	2.2	7.05	3.1	2.62	5.55	2.4	2.5	4.15	3.77	2.08
At 0.001 sec^{-1}, megapoises	2.07	3.0	2.37	1.73	1.96	4.55	7.1	8.2	4.05	4.35	4.35	2.88	13.3	6.1	4.3	13.8	2.4	2.9	4.15	5.05	2.82
Shear susceptibility	0	0	0.03	0	0	0.07	0.16	0.03	0.08	0.11	0.07	0.07	0.16	0.17	0.13	0.23	0	0.04	0	0.07	0.08
Viscosity at 77°F after Aging**																					
At 0.05 sec^{-1}, megapoises	20.9	15.8	10.6	6.78	8.35	49.3	34.7	72.3	17.0	26.8	12.9	5.83	16.8	13.3	7.13	10.3	24.3	13.6	20.1	20.1	8.83
At 0.001 sec^{-1}, megapoises	22.3	15.8	11.0	8.6	8.4	153	110	174	36.4	69.8	36.1	12.3	72.8	81.0	21.4	47.0	102	39.0	52.0	96.5	15.1
Shear susceptibility	0.02	0	0.01	0.06	0	0.29	0.29	0.23	0.19	0.25	0.27	0.19	0.38	0.47	0.28	0.39	0.37	0.27	0.25	0.39	0.13
Viscosity at 140°F, poises	1870	2414	2102	1826	1493	4922	5699	5725	4999	3205	4699	3285	4940	3793	2171	2712	1033	1060	1437	1996	1434
Viscosity at 275°F, centistokes	245	275	281	274	228	689	744	517	696	374	669	527	432	522	347	483	227	230	262	370	334
Temperature susceptibility,																					
140° - 275°F	-3.894	-3.892	-3.819	-3.784	-3.865	-3.424	-3.420	-3.701	-3.421	-3.742	-3.426	-3.475	-3.789	-3.538	-3.651	-3.470	-3.715	-3.715	-3.725	-3.564	-3.515
77° - 140°F	-4.106	-4.091	-4.029	-4.031	-4.251	-3.660	-3.587	-3.880	-3.554	-3.645	-3.851	-3.726	-3.973	-3.784	-4.106	-4.286	-4.629	-4.627	-4.627	-4.336	-4.307
Stain Number	4	4	5	5	5	4	7	7	7	8	7	10	12	12	14	18	7	9	10	9	8
Microductility after Aging**, mm	83	99	85	81	64	4	6	4	27	9	7	13	4	2	8	3	4	9	8	4	16
Pellet Abrasion Test,																					
% loss in 500 revolutions***																					
Unaged	24.2	33.8	21.4	6.3	46.6	34.8	21.1	46.4	9.5	40.6	0.32	0.02	0.12	0.07	0.07	0.19	15.9	3.9	7.4	2.6	1.2
Aged 7 days	98.5	100	90.6	70.2	93.9	100	92.2	100	77.9	100	0.46	0.26	0.41	0.14	0.16	0.19	59.2	18.3	50.2	18.8	9.7
		(410)				(434)		(320)		(379)											
Average	61.3	67+	56.0	38.3	70.2	68+	56.6	74+	43.7	71+	0.39	0.14	0.26	0.10	0.12	0.19	37.6	11.1	28.8	10.7	5.4
mg loss/revolution																					
Unaged	0.982	1.370	0.890	0.252	1.879	1.422	0.842	1.916	0.392	1.683	0.013	0.001	0.005	0.003	0.003	0.008	0.657	0.162	0.304	0.106	0.047
Aged 7 days	4.126	4.878	3.891	2.883	4.317	4.618	3.755	6.328	3.211	5.449	0.019	0.011	0.017	0.006	0.007	0.008	2.410	0.750	2.083	0.773	0.402
Average	2.554	3.124	2.390	1.568	3.098	3.020	2.298	4.122	1.802	3.566	0.016	0.006	0.011	0.004	0.005	0.008	1.534	0.456	1.194	0.440	0.224

* V = Valley; B = Boscan; A = Arkansas; C = Canadian; C_H = Heptane-insoluble asphaltenes from Canadian asphalt, 4200 mol. wt.

** Twenty-micron film exposed 24 hours at 210°F.

*** Figure in parentheses below 100 = number of revolutions to 100% loss.

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TABLE XX

EFFECT OF MATCHING VISCOSITY OF CROSS BLENDS BY ADJUSTING ASPHALTENES CONTENT

Specimen No. MR&D	1	5	7	7b	7c	3	13	14	14c	14b
Materials Blended*										
Asphalt	100V	------	------	------	------	100A	------	------	------	------
Asphaltenes, %	------	11	11	12.0	12.4	------	23.5	23.5	22.0	20.8
Source		V	A	A	A		A	V	V	V
Mol. Wt.		2625	4670	4670	4670		4670	2625	2625	2625
Maltenes, %	------	89	89	88.0	87.6	------	76.5	76.5	78.0	79.2
Source		V	V	V	V		A	A	A	A
Composition, % of asphalt, A	10.9	12.3	11.5	12.3	12.5	23.6	23.9	23.0	21.1	19.9
N	41.5	40.3	41.0	39.0	39.0	14.3	10.2	14.5	14.3	14.4
A_1	14.2	14.2	14.4	14.7	14.8	21.5	22.9	20.6	21.1	21.5
A_2	20.7	20.6	20.3	21.3	21.1	27.9	31.5	30.1	31.6	31.7
P	12.7	12.6	12.8	12.7	12.6	12.7	11.5	11.8	11.9	12.5
% of Maltenes, N	46.6	45.9	46.3	44.5	44.6	18.7	13.4	18.8	18.1	18.0
A_1	15.9	16.2	16.3	16.7	16.9	28.1	30.1	26.8	26.7	26.8
A_2	23.2	23.5	22.9	24.3	24.1	36.6	41.4	39.1	40.1	39.6
P	14.3	14.4	14.5	14.5	14.4	16.6	15.1	15.3	15.1	15.6
$(N + A_1)/(P + A_2)$	1.67	1.64	1.67	1.58	1.60	0.88	0.77	0.84	0.81	0.81
Viscosity at 77°F										
At 0.05 sec^{-1}, megapoises	2.07	3.0	1.70	1.89	1.92	3.3	2.2	7.05	3.67	1.88
At 0.001 sec^{-1}, megapoises	2.07	3.0	1.73	2.17	1.99	4.35	2.88	13.3	6.1	2.52
Shear susceptibility	0	0	0	0.04	0.01	0.07	0.07	0.16	0.13	0.08
Viscosity at 77°F after Aging**										
At 0.05 sec^{-1}, megapoises	20.9	15.8	6.78	8.73	9.6	12.9	5.83	16.8	11.4	7.95
At 0.001 sec^{-1}, megapoises	22.3	15.8	8.6	9.15	10.8	36.1	12.3	72.8	37.5	19.2
Shear susceptibility	0.02	0	0.06	0.01	0.04	0.27	0.19	0.38	0.31	0.23
Viscosity at 140°F, poises	1870	2414	1826	1971	1932	4699	3285	4940	2857	1690
Viscosity at 275°F, centistokes	245	275	274	289	288	669	527	432	354	300
Temperature susceptibility, 140° - 275°F	-3.894	-3.892	-3.784	-3.768	-3.763	-3.426	-3.475	-3.789	-3.743	-3.674
77° - 140°F	-4.106	-4.091	-4.031	-4.025	-4.048	-3.851	-3.726	-3.973	-4.062	-4.137
Stain Number	4	4	5	4	4	7	10	12	8	8
Microductility after Aging**, mm	83	99	81	101	64	7	13	4	6	10
Pellet Abrasion Test, % loss in 500 revolutions***, Unaged	24.2	33.8	6.3	17.8	27.0	0.32	0.02	0.12	0.09	0.02
Aged 7 days	98.5	100 (410)	70.2	85.2	100 (440)	0.46	0.26	0.41	0.54	0.36
Average	61.3	67+	38.3	51.5	64+	0.39	0.14	0.26	0.32	0.19
mg loss/revolution, Unaged	0.982	1.370	0.252	0.732	1.079	0.013	0.001	0.005	0.004	0.001
Aged 7 days	4.126	4.878	2.883	3.757	4.441	0.019	0.011	0.017	0.022	0.015
Average	2.554	3.124	1.568	2.244	2.760	0.016	0.006	0.011	0.013	0.008

* V = Valley; A = Arkansas.

** Twenty-micron film exposed 24 hours at 210°F.

TABLE XXI

ASPHALT REBLENDED FROM COMPONENTS OF OTHER ASPHALTS

Specimen No. MR&D	2 (Control 1)	26R (Control 2)	33-3773-12.6	33-3773-13.7	3 (Control 1a)	27R (Control 2a)	36-3772-29.0	36-3772-30.9
Maltenes composition and viscosity	Original Boscan Asphalt	Boscan	Boscan	Boscan	Original Arkansas Asphalt	Arkansas	Arkansas	Arkansas
Origin of asphalt or components		Boscan	Arkansas	Arkansas		Arkansas	Boscan	Boscan
Fraction "A" added, % of total	------	27.8	12.6	13.7	------	23.6	29.0	30.9
Composition, % of asphalt, A	27.8	30.1	15.7	18.7	23.6	23.3	28.5	28.8
N	26.6	25.6	24.1	23.2	14.3	10.6	13.5	13.5
A_1	21.5	21.5	29.4	29.1	21.5	23.9	20.0	19.6
A_2	17.8	16.7	22.3	21.0	27.9	28.9	26.7	26.7
P	6.3	6.1	8.5	8.0	12.7	13.3	11.3	11.4
% of maltenes, N	36.8	36.6	28.6	28.6	18.7	13.8	18.9	19.0
A_1	29.8	30.8	34.9	35.8	28.1	31.2	28.0	27.5
A_2	24.7	23.9	26.4	25.8	36.6	37.7	37.3	37.5
P	8.7	8.7	10.1	9.8	16.6	17.3	15.8	16.0
$(N + A_1)/(P + A_2)$	2.00	2.06	1.74	1.80	0.88	0.82	0.88	0.87
Viscosity at 77°F								
At 0.05 sec^{-1}, megapoises	3.5	6.55	2.48	7.75	3.3	3.02	1.66	1.72
At 0.001 sec^{-1}, megapoises	4.55	14.5	2.98	8.8	4.35	4.0	4.35	4.5
Shear susceptibility	0.07	0.20	0.05	0.03	0.07	0.07	0.25	0.25
Viscosity at 77°F after Aging*								
At 0.05 sec^{-1}, megapoises	49.3	46.5	7.6	22.1	12.9	8.4	13.9	13.7
At 0.001 sec^{-1}, megapoises	153	183.0	8.45	40.3	36.1	16.2	66.0	64.3
Shear susceptibility	0.29	0.35	0.03	0.16	0.27	0.17	0.40	0.40
Viscosity at 140°F, poises	4922	13,288	3629	7918	4699	4887	4198	3263
Viscosity at 275°F, centistokes	689	1185	615	893	669	678	540	486
Temperature susceptibility, 140° - 275°F	-3.424	-3.390	-3.393	-3.422	-3.426	-3.431	-3.550	-3.536
77° - 140°F	-3.660	-3.284	-3.714	-3.697	-3.851	-3.598	-3.421	-3.616
Stain Number	4	5	5	5	7	6	12	12
Microductility after Aging*, mm	4	3	62	48	7	18	3	2
Pellet Abrasion Test, % loss in 500 revolutions**, Unaged	34.8	25.2	3.4	39.2	0.32	0.28	0.00	0.09
Aged 7 days	100(434)	100(426)	41.0***	98.3	0.46	0.76	1.45	1.40
Average	68+	63+	22.2***	68.8	0.39	0.52	0.72	0.74
mg loss/revolution, Unaged	1.422	1.031	0.144	1.584	0.013	0.012	0.000	0.004
Aged 7 days	4.618	4.876	1.702	4.001	0.019	0.032	0.061	0.058
Average	3.020	2.954	0.923	2.792	0.016	0.022	0.030	0.031

* Twenty-micron film aged 24 hours at 210°F.

** Figure in parentheses after 100 - number of revolutions to 100% loss.

*** [illegible] attributed to the low maltenes parameter and the low

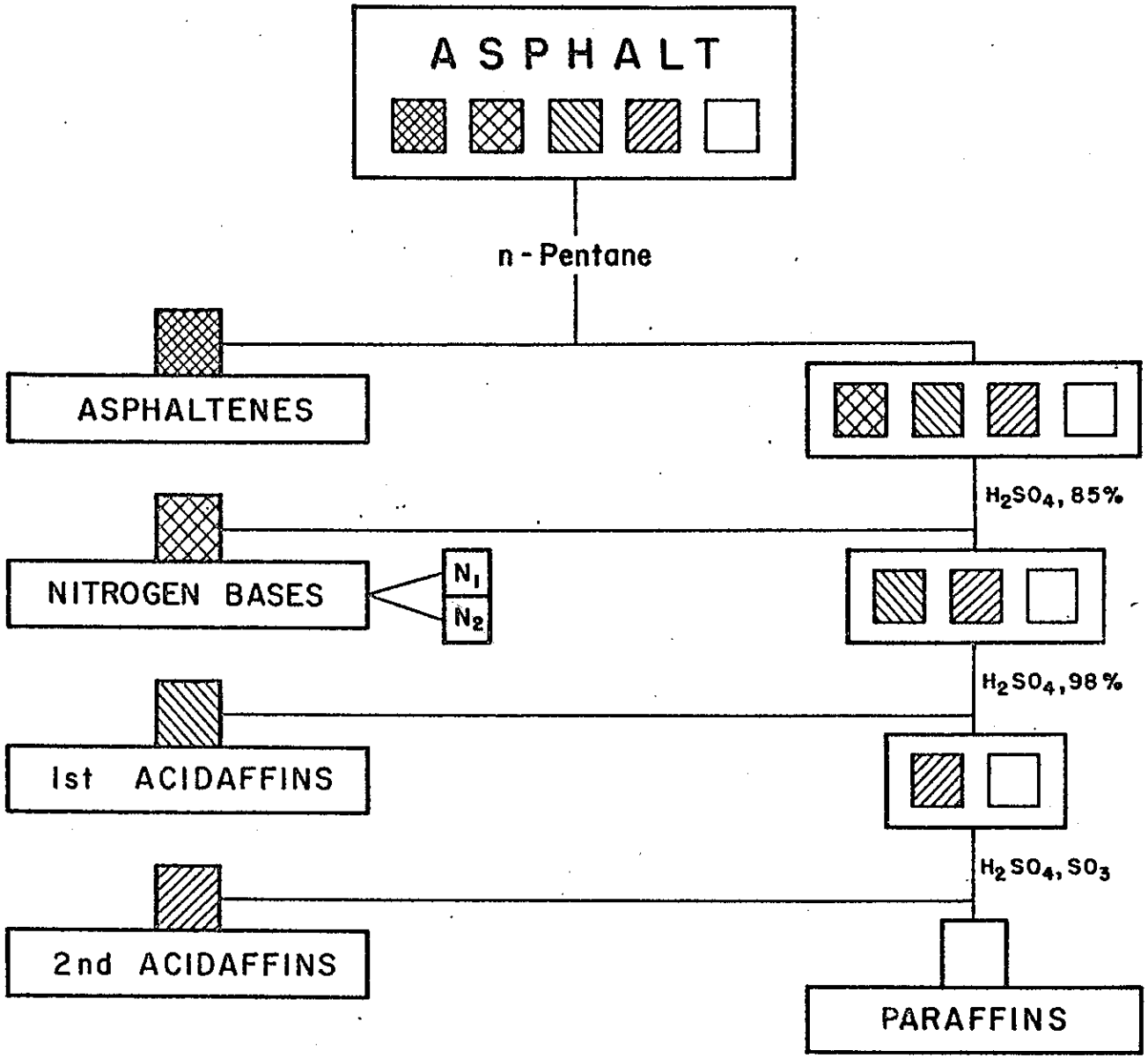

Figure 1

FLOW SHEET OF PRECIPITATION METHOD

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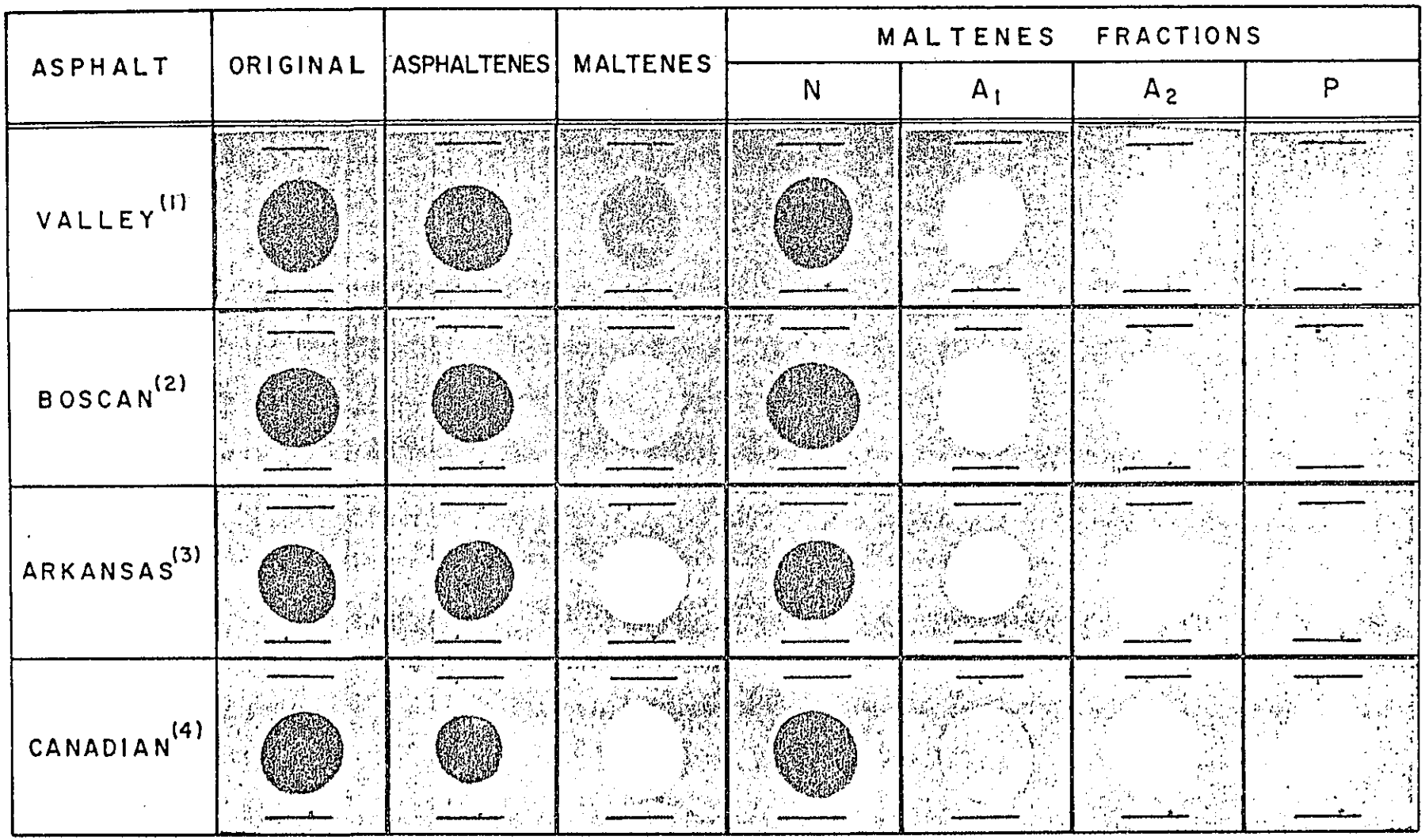
Figure 2

APPEARANCE OF ASPHALT FRACTIONS UNDER U.V. LIGHT



(1) POSO CRUDE - CALIFORNIA
(2) BOSCAN CRUDE - VENEZUELA
(3) SMACKOVER CRUDE - ARKANSAS
(4) REDWATER CRUDE - ALBERTA

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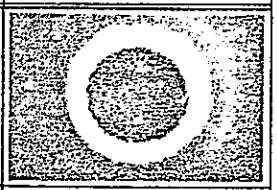
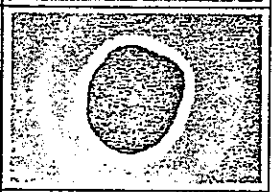
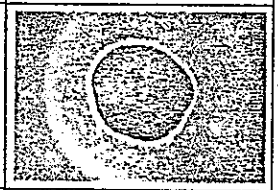
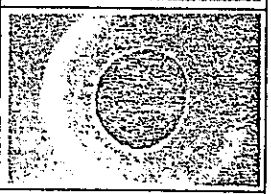
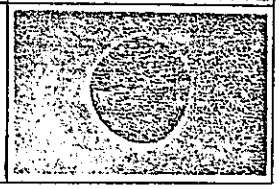
Figure 3

Filter Paper Spot Test Ranking

Rating	Syneresis	Example
1	Severe	
2	Definite	
3	Slight	
4	Trace	
5	None	

NOTE: In judging syneresis, only the ring surrounding the asphalt deposit is considered. The faint outer ring is a residue from the benzene solution and is disregarded. The ring surrounding the asphalt deposit visible in example 5 is not detectable with the naked eye. It is due to the time exposure needed in taking the photograph.

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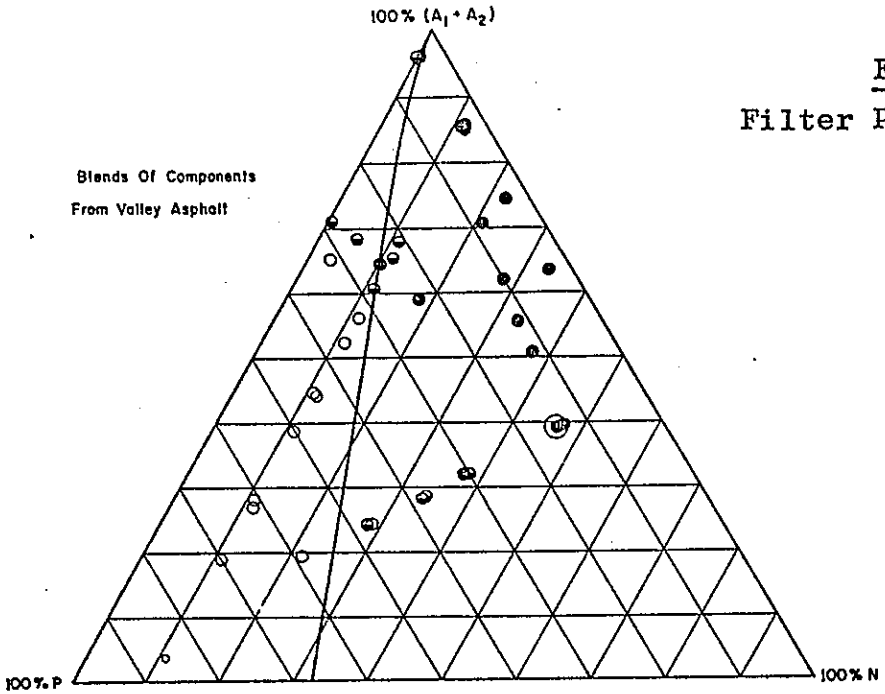
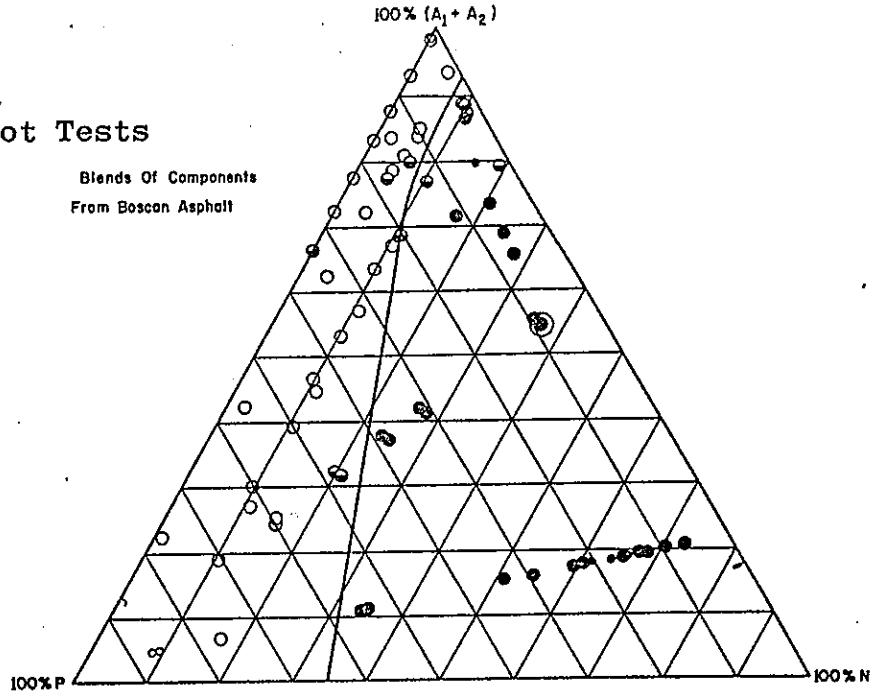
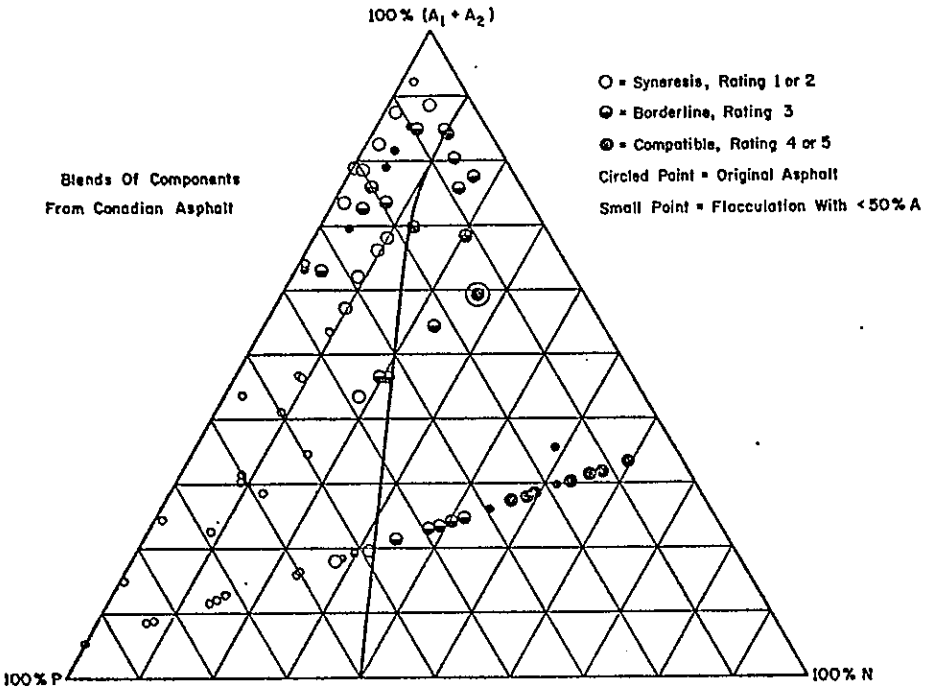
Figure 4

Filter Paper Spot Tests







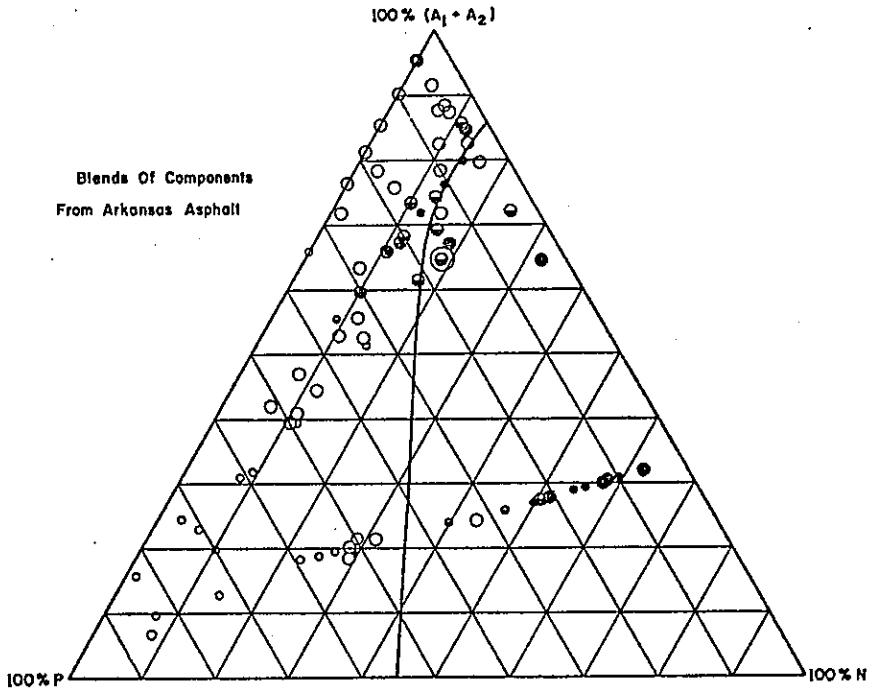


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Figure 5

Filter Paper Spot Tests

Composite Graph For

All Four Asphalts

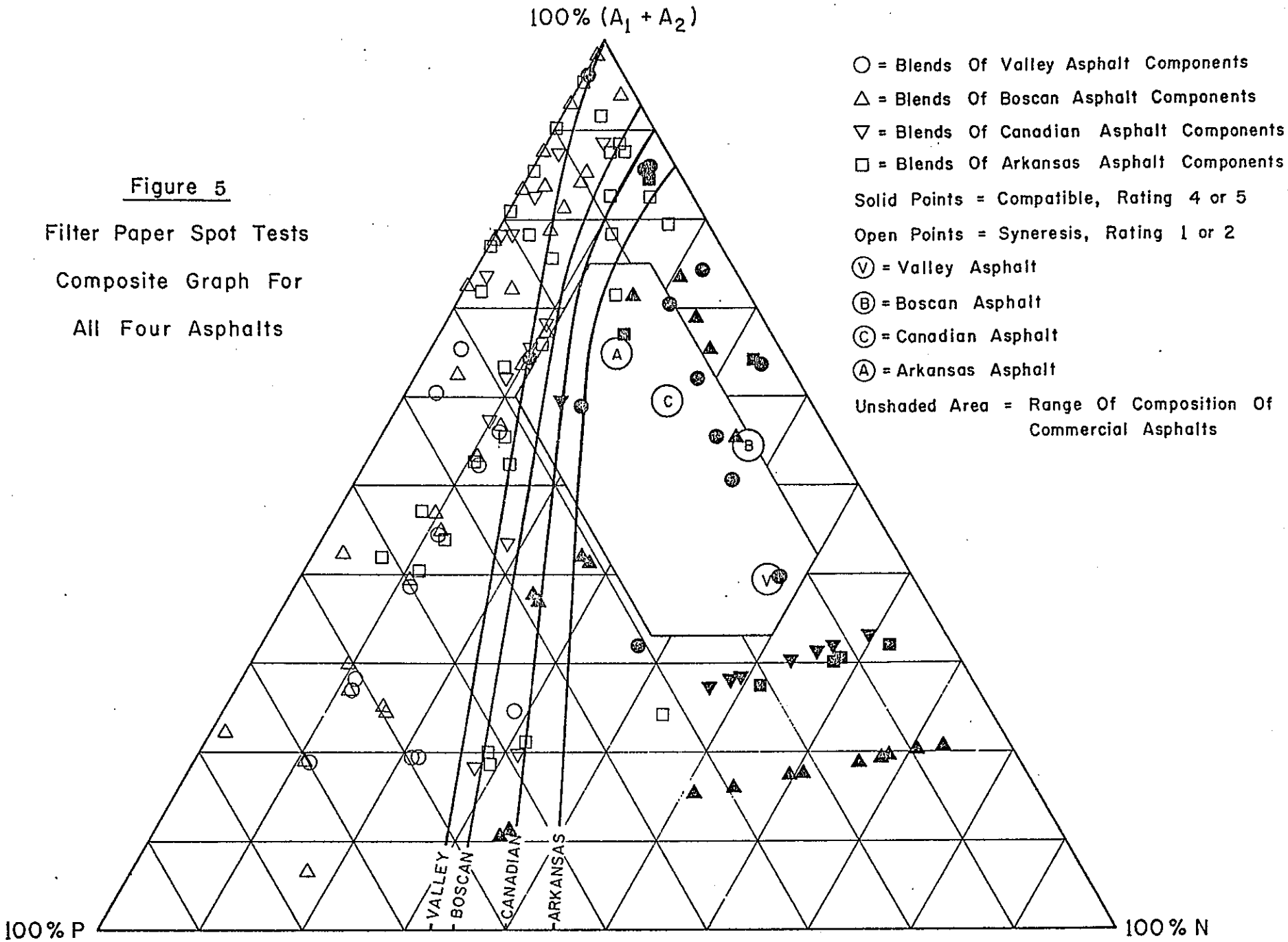

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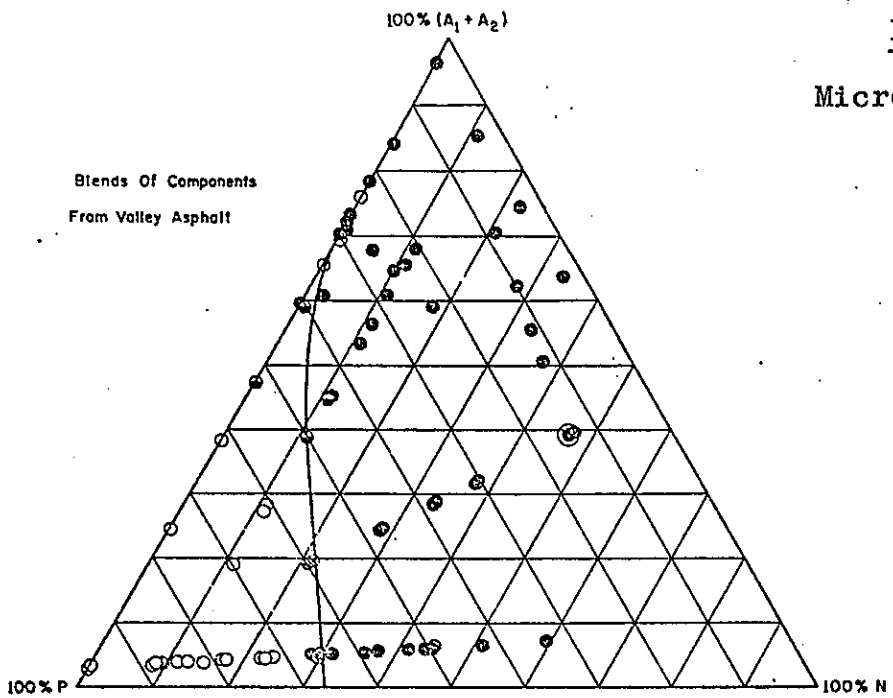
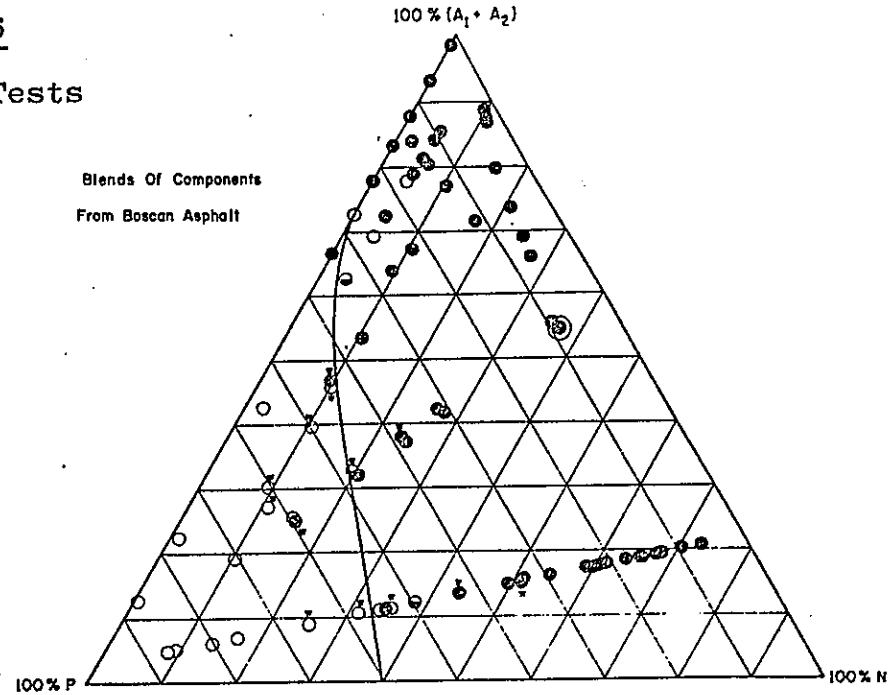
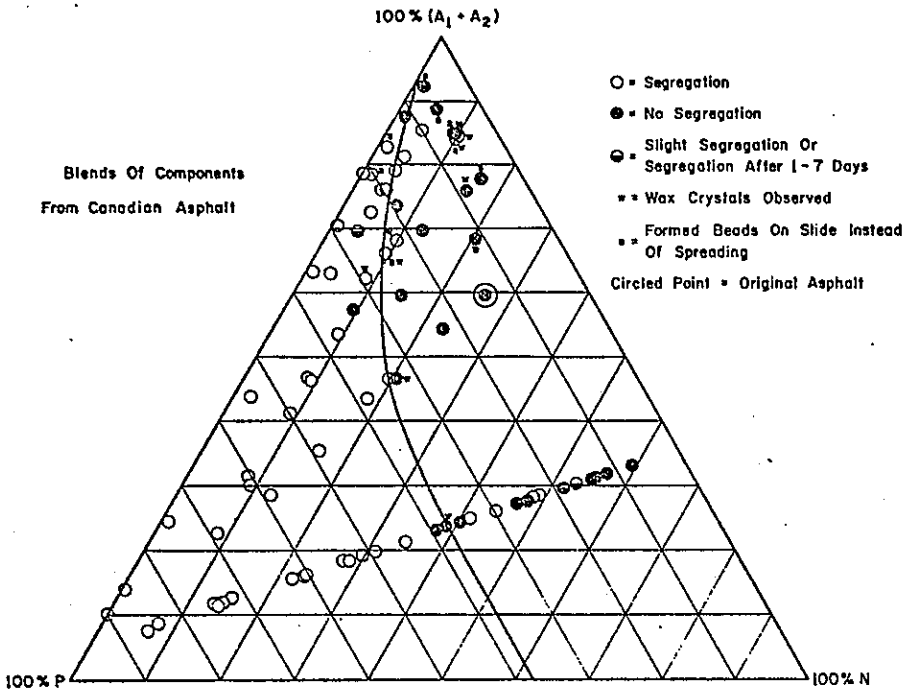
Figure 6

Microscope Tests







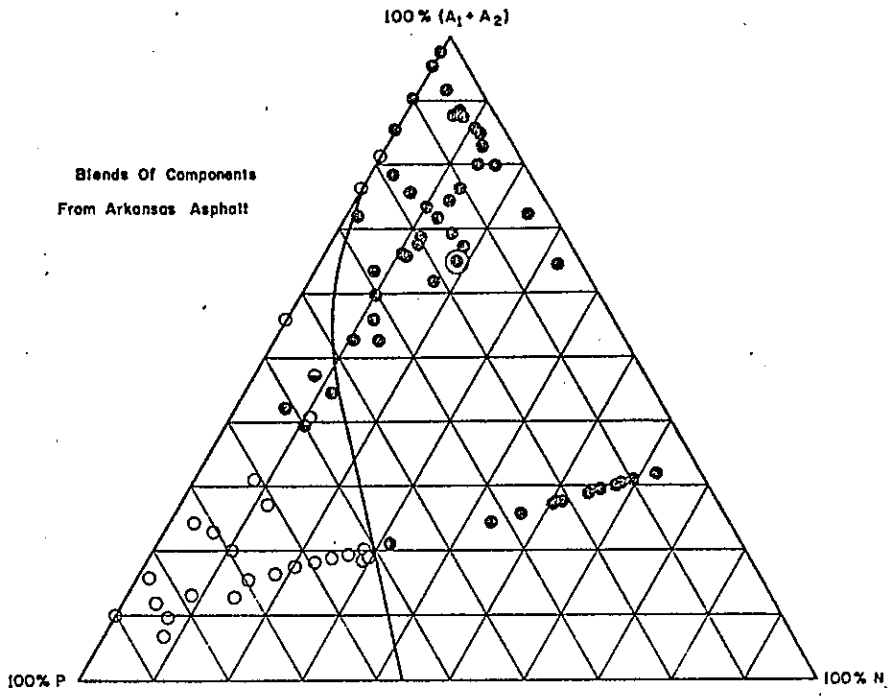


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Figure 7

Microscope Tests

Composite Graph For

All Four Asphalts

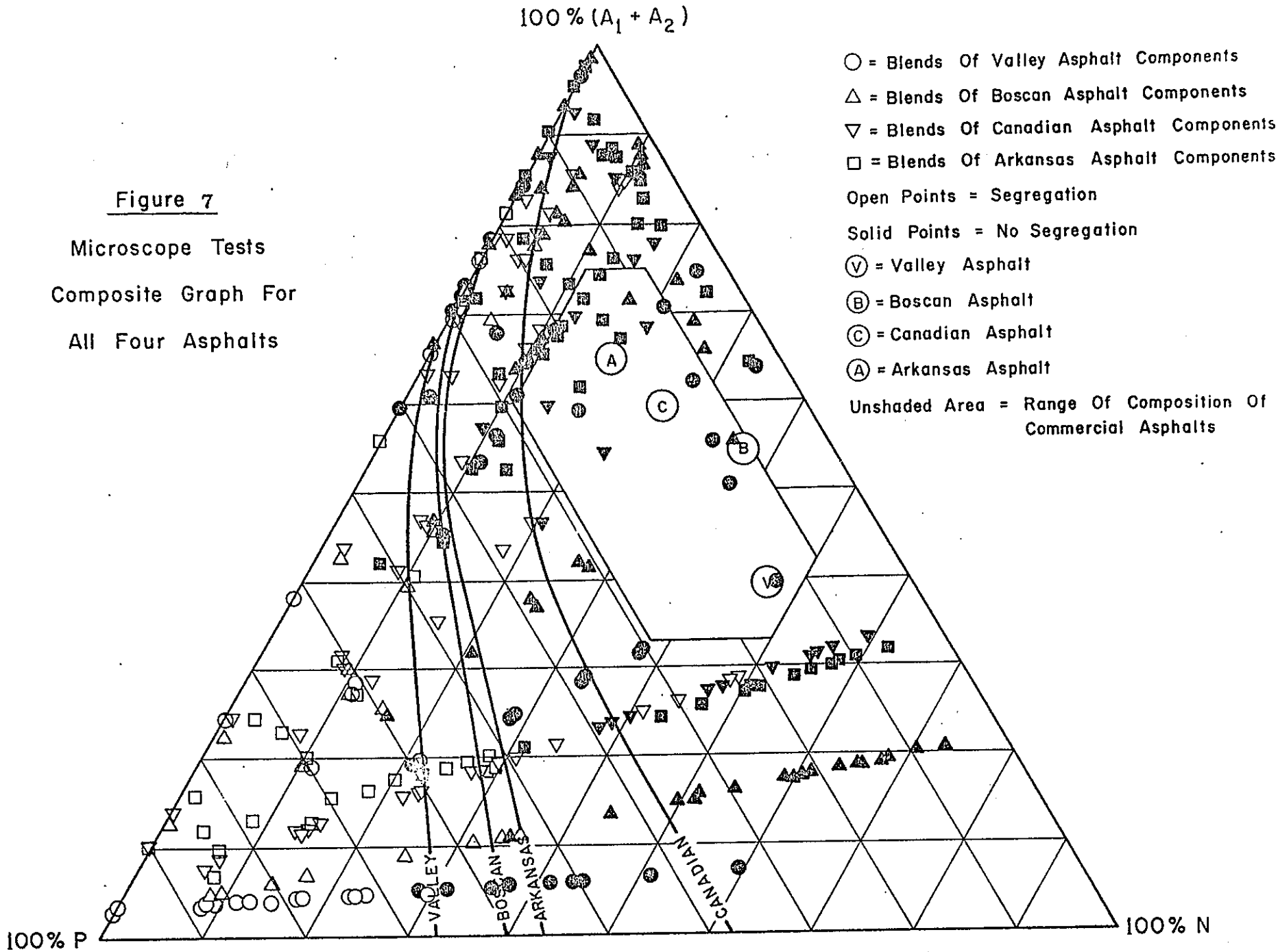

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FIGURE 8

RELATIVE EFFECT OF ASPHALTENES ON PELLET ABRASION LOSS

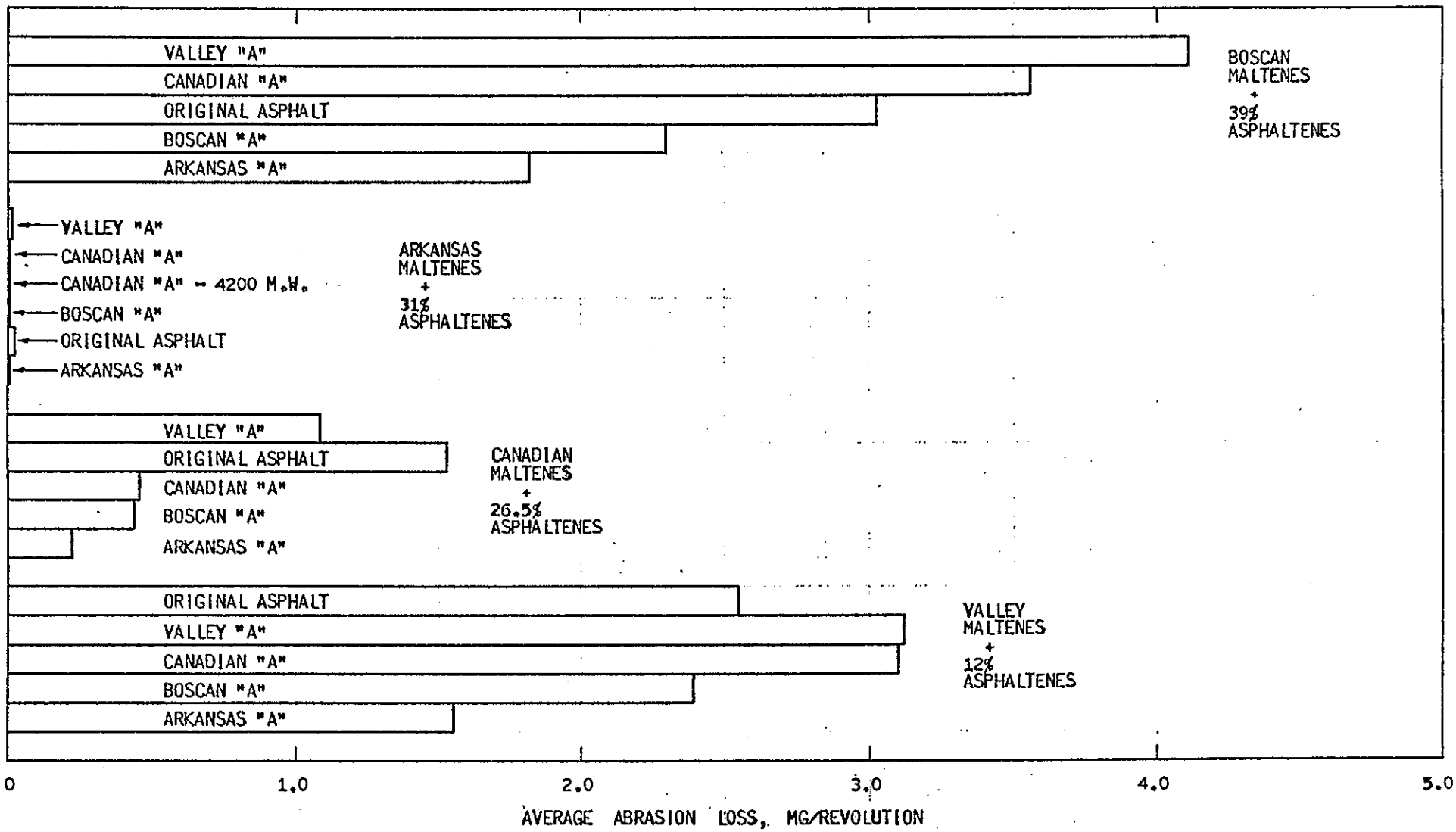

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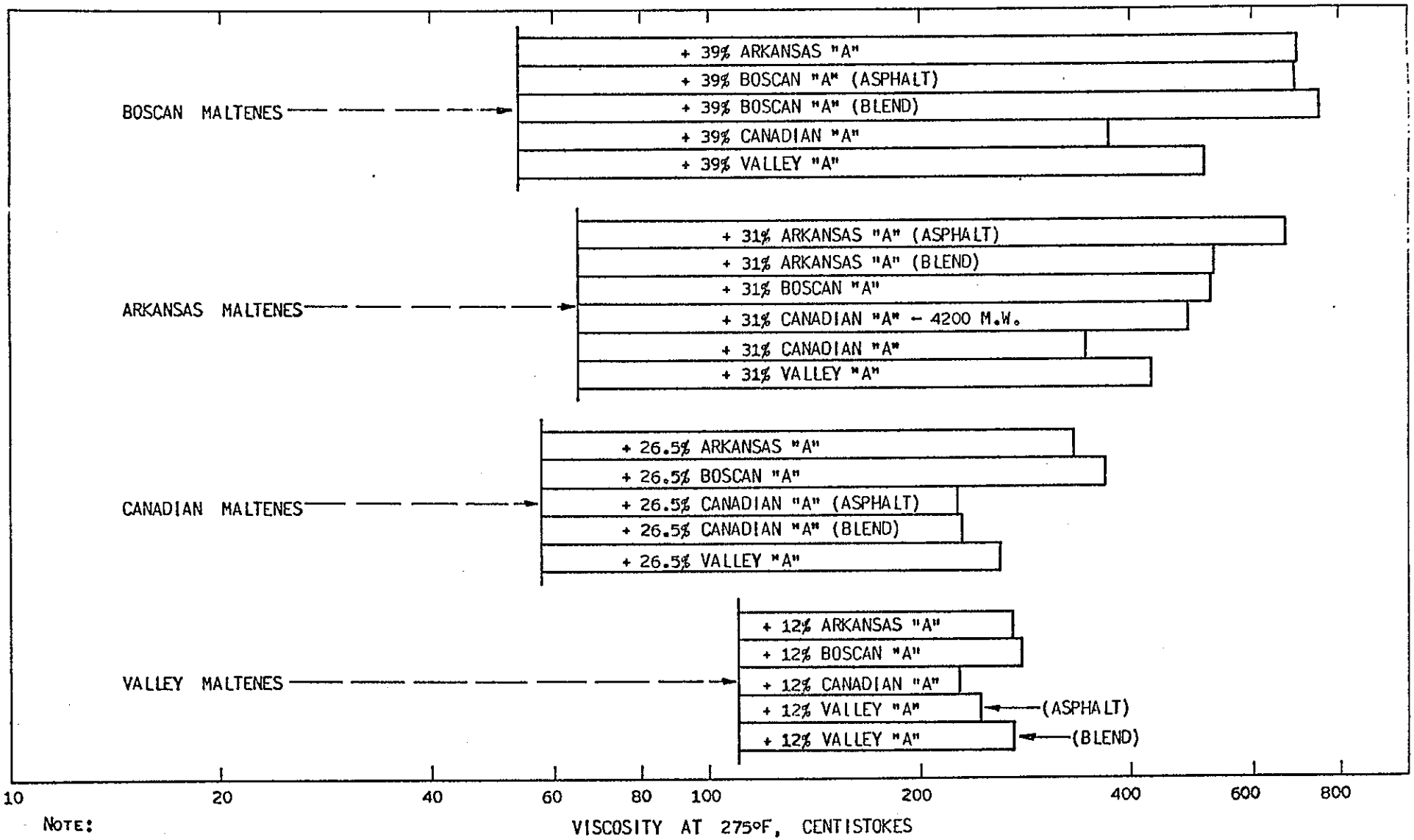
FIGURE 9

RELATIVE EFFECT OF ASPHALTENES ON VISCOSITY AT 275°F



NOTE:

BARS ORIGINATE AT VISCOSITY OF MALTENES.

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FIGURE 10

RELATIVE EFFECT OF ASPHALTENES ON TEMPERATURE SUSCEPTIBILITY OF VISCOSITY FROM 140° TO 275°F

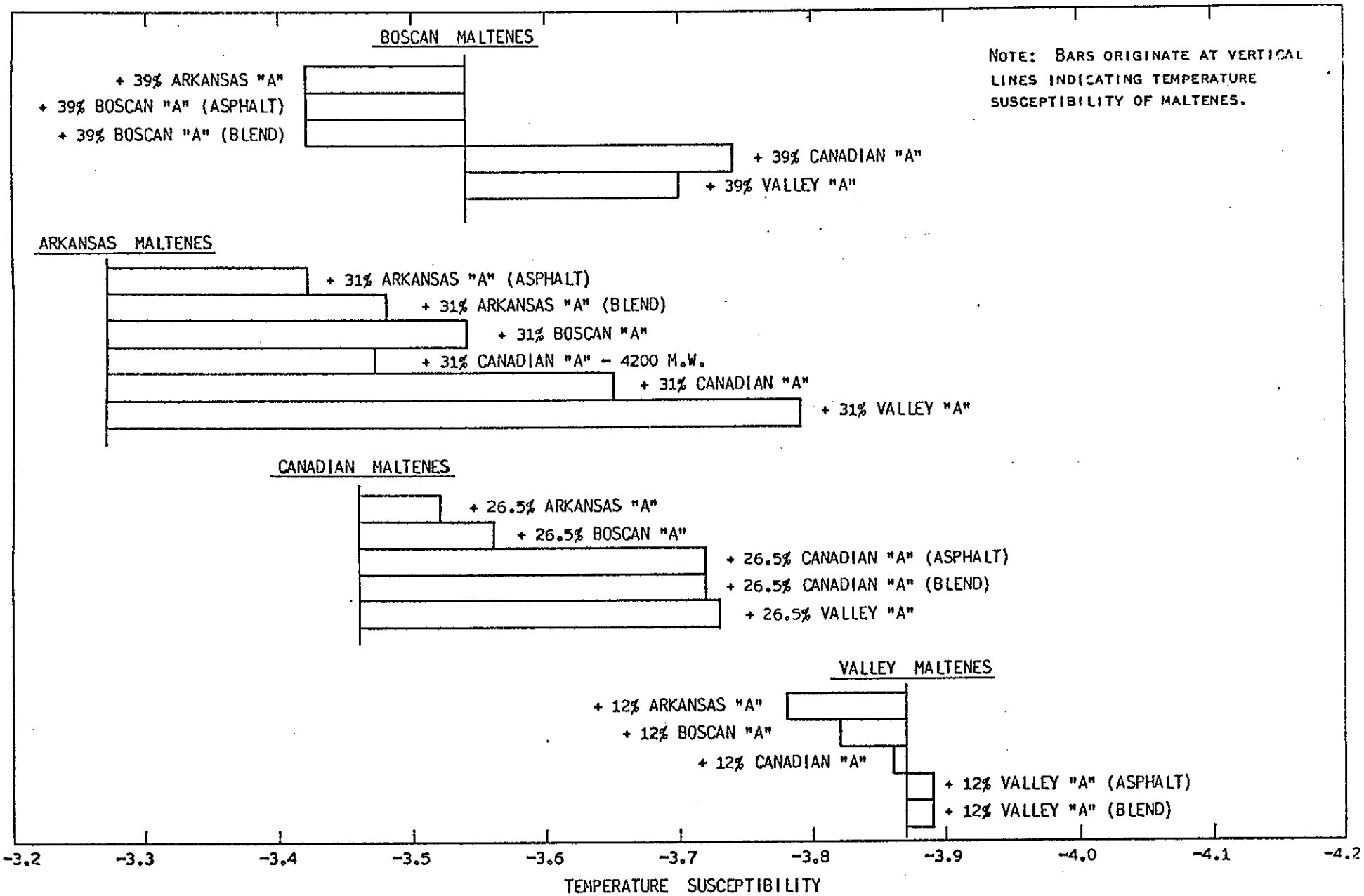

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FIGURE 11

RELATIVE EFFECT OF ASPHALTENES ON TEMPERATURE SUSCEPTIBILITY OF VISCOSITY FROM 77° TO 140°F

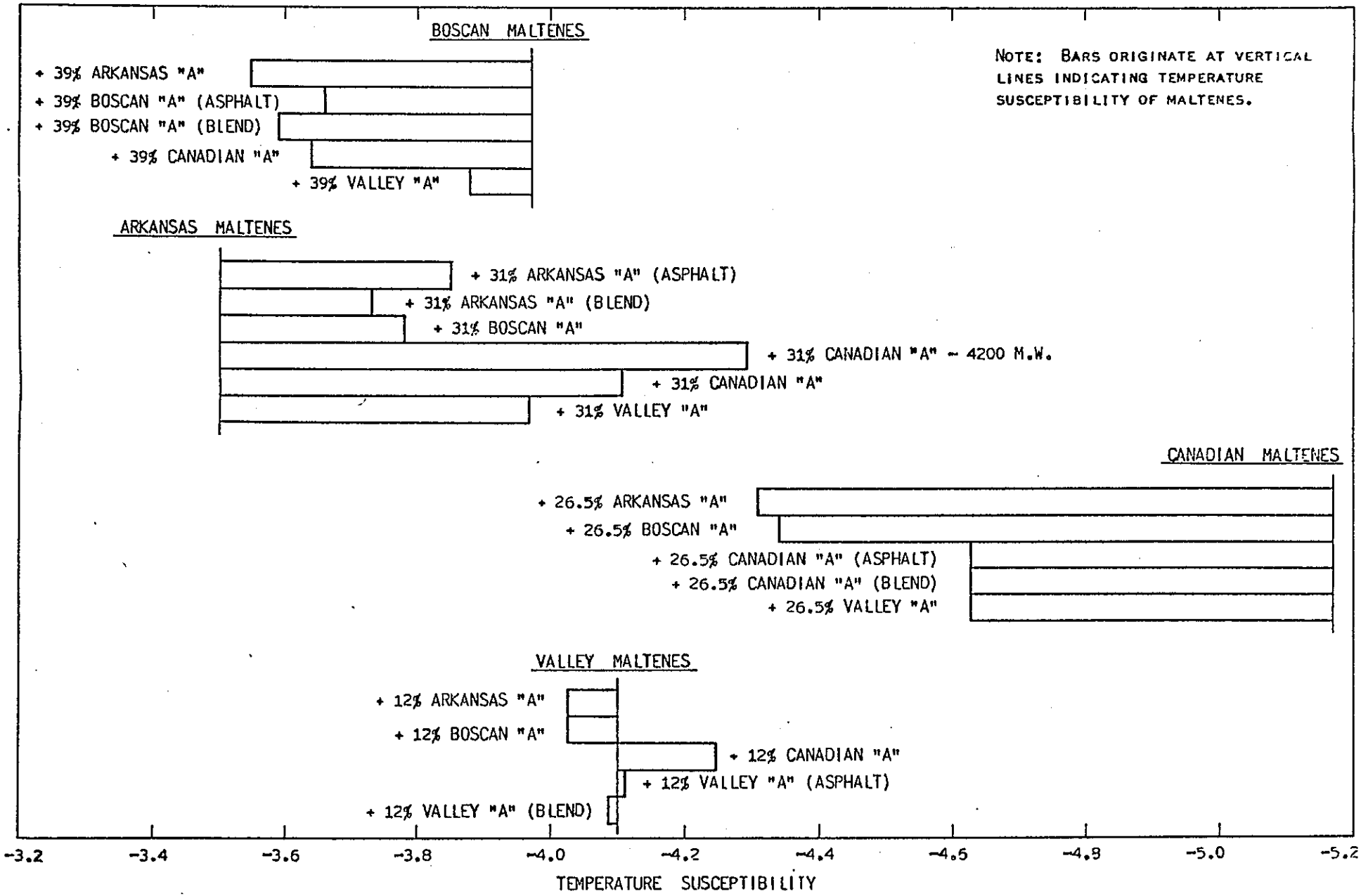

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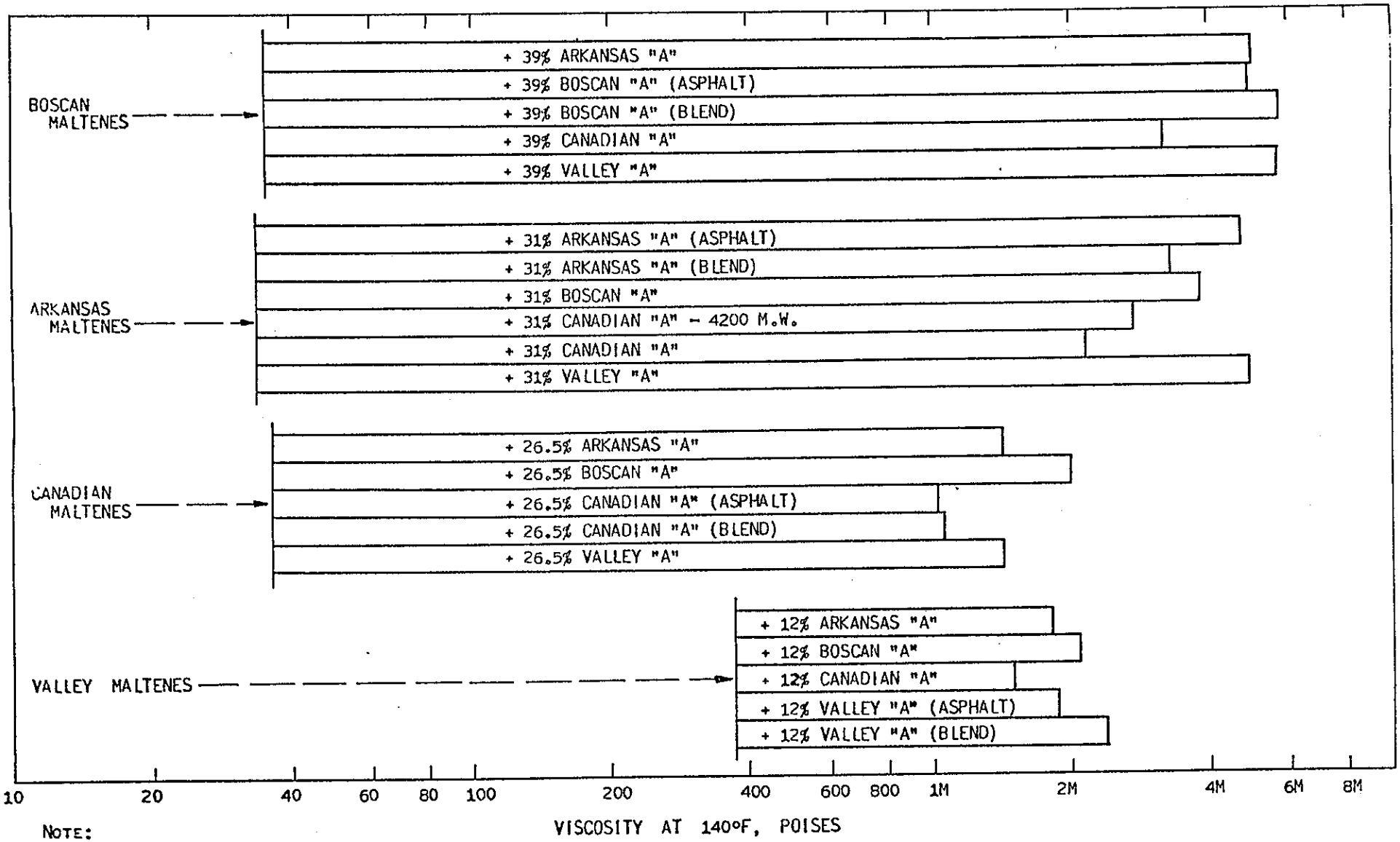
FIGURE 12

RELATIVE EFFECT OF ASPHALTENES ON VISCOSITY AT 140°F



NOTE:

BARS ORIGINATE AT VISCOSITY OF MALTENES.

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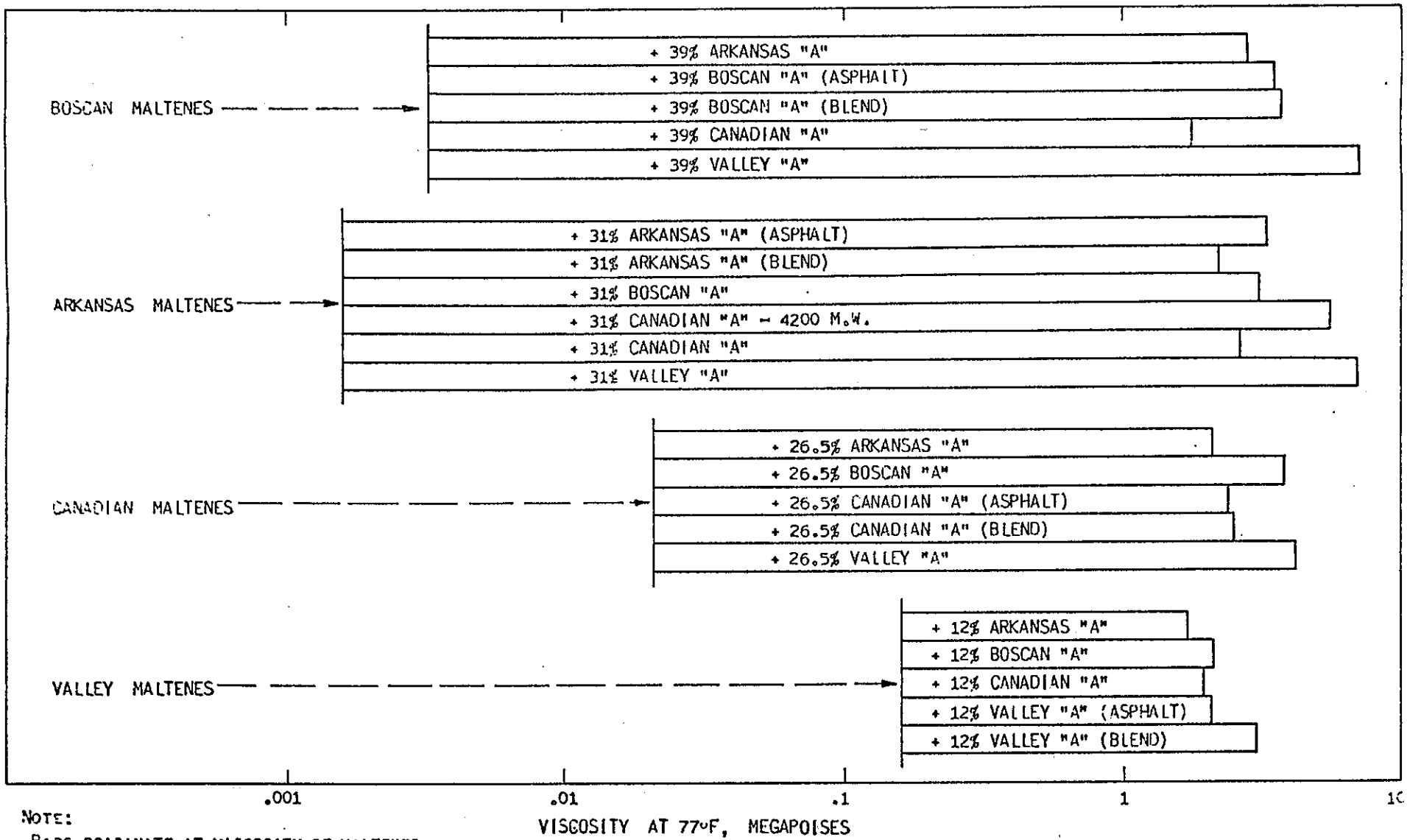
FIGURE 13

RELATIVE EFFECT OF ASPHALTENES ON VISCOSITY AT 77°F



NOTE:
BARS ORIGINATE AT VISCOSITY OF MALTENES.

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