DEVELOPMENT OF SPECIFICATIONS FOR VISCOSITY-GRADED ASPHALTS

Woodrow J. Halstead, Materials Division, Federal Highway Administration; and
J. York Welborn, Consulting Engineer

The users and producers of asphalt have conducted a comprehensive research program to develop fundamental methods for measuring the consistency of asphaltic materials and to study the flow properties of asphalt cements over the range in temperatures encountered in construction and service in pavements. Concurrently a number of specifications using requirements based on the new fundamental methods have been proposed or used as the basis for purchasing asphalt. In an attempt to give some guidance and standardization to these specifications, the Committee on Materials of the American Association of State Highway Officials (AASHO) undertook the development of specifications based on viscosity grading at 140 F. Four grades were selected, and limiting requirements were added for viscosity at 275 F. Because low-temperature viscosity tests were not perfected for national use, limiting requirements using the penetration test at 77 F were selected. Other requirements included maximum viscosity and minimum ductility limits on the residue from the thin-film oven test. Conventional solubility, flash point, and Oliensis spot test requirements also were included in the specification. The limits for the requirements of the 4 grades were set by a systematic study of test characteristics of asphalt cements produced in the United States. The specification has been adopted by AASHO, designated as Specification M 226, and published as an alternate to Specification M 20, which is based on penetration grading and remains in effect. The advantages of Specification M 226 are that it provides information on the kind of asphalt being used and a means for selecting the asphalt that should result in improved mixture design and more uniform construction practices. This should, in time, lead to improved pavement performance.

•ABOUT 10 years ago the users and producers of asphalt became keenly interested in the development of fundamental methods of measuring the flow properties of asphaltic materials. This interest was prompted by the limitations of the usual empirical tests then in use and the desire to better define the rheological or engineering properties of asphalt and to use such information for establishing more rational requirements for specifications. This interest resulted in a considerable number of studies by both producers and consumer groups, such as the Federal Highway Administration, The Asphalt Institute, state highway departments, and individual private companies producing asphalt products. During this period, test methods for measuring fundamental viscosity at temperatures ranging from 32 to 300 F have been developed and standardized by both the American Society for Testing and Materials (ASTM) and the American Association of State Highway Officials (AASHO). The fundamental flow properties of asphalts have been studied in both laboratory tests and field experimental projects. Concurrently, a number of specifications have been proposed and in some instances used as the basis for purchasing asphalts for construction.

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Little or no controversy developed with respect to fundamental viscosity, or more specifically kinematic viscosity, requirements for liquid asphalts. The application of the concepts to paving-grade asphalt cements, however, has proved to be extremely controversial, and valid differences of opinion, each of which is scientifically and technologically sound, have arisen.

For liquid asphalts, essentially a constant conversion factor was determined for converting the empirical Saybolt-Furol viscosity requirements to kinematic viscosity equivalents. The ability to determine kinematic viscosity at 140 F for all grades of liquid asphalts quickly and accurately led to early acceptance of the new system and units in specifications for these materials. As the authors (1) of this paper predicted in 1962, the problem with respect to asphalt cements has been more difficult. At that time we stated the following:

> However, the adoption of fundamental units to asphalt cements, with the complete elimination of the penetration test, presents very complex problems. These problems are: (a) Asphalt cements differ widely in viscosity-temperature susceptibility so that materials of equal viscosity at one temperature may have widely different viscosities at other temperatures. (b) Asphalt cements at atmospheric temperatures exhibit complex flow properties. The degree of complex flow differs for asphalts produced from different crude sources and by different methods of refining. (c) The degree of complex flow changes with temperature changes for individual asphalts; it also changes during hardening in service.

In reviewing the activities of the past 8 years, we find that these predictions of complications have proved to be only too true. Nevertheless, the knowledge gained by studying the flow properties of asphalts produced and used in the United States and Canada over a wide range in temperature has given the researcher and engineer a far better understanding of the complex rheology of asphalt and its effect on mixture design, pavement construction, and performance during service under varying environmental conditions. Thus, despite the differences of opinion that still exist, a number of the objectives of the initial program have been attained.

In our opinion, the original objectives have sometime been overlooked in some of the discussions surrounding the various proposals for specifications of asphalt cements based on viscosity grading. The purpose of this discussion is to attempt to place the various viewpoints in proper focus by relating how the AASHO Committee on Materials undertook the development of specifications for asphalt cements based on grading by viscosity at 140 F. Some of the considerations on which its decisions were based are also included.

REQUIREMENTS BASED ON FUNDAMENTAL FLOW PROPERTIES PROPOSED

For implementing the results of many of the studies, a number of different approaches have been suggested with respect to the adoption of fundamental viscosity requirements in specifications for asphalt cements. The following are some of these:

1. Grade by penetration at 77 F and use viscosity requirements at 140 or 275 F or both to control limiting flow properties;
2. Grade by viscosity at 140 F on asphalt as supplied with limiting requirements on viscosity at 275 F;
3. Grade by viscosity at 140 F on the residue from a thin-film oven test (TFOT) with limiting requirements on viscosity at 275 F; and
4. Grade by viscosity at 140 F with limiting requirements on viscosity at 275 F and additional requirements on consistency at low temperatures such as viscosity at 60 or 77 F or penetration at 60 or 77 F.

The AASHO committee made the decision to use the fourth alternative listed. Because a number of minor differences existed in the viscosity limits of the different grades in proposed specifications, the committee then made a judgment decision that the needs of the highway departments could best be met by 4 grades, AC-5, AC-10, AC-20, and AC-40. The designated number of the grade is the target value in poises at 140 F divided by 100. The tolerance established for each grade limit was then set at ±20 percent of the basic value. Thus, the limits at 140 F for the various grades are as follows:

Grade	Limits (poises)
AC-5	500 ± 100
AC-10	1,000 ± 200
AC-20	2,000 ± 400
AC-40	4,000 ± 800

A task force was charged with developing other requirements for the specification. Because of the wide diversification of flow properties of asphalts produced from petroleum crude sources and refining methods used in the United States, the development of a specification that could be directed toward national use was not easy and some compromises were required.

TEST DATA ANALYZED

In accomplishing its work, the task force made extensive use of test data for a representative group of asphalts produced in the United States. These asphalt cements, graded by viscosity to meet the study specification of The Asphalt Institute, were obtained from 15 sources in 1965. They were selected to provide the maximum range in low-temperature flow properties that could be predicted from test data on penetration grades. The asphalt samples were thoroughly analyzed by The Asphalt Institute, by some state highway departments, and by the Federal Highway Administration. Most of the data used by the task force are those developed by the Materials Research Division of the Federal Highway Administration and reported in 1966 (2).

Because the AASHO specification was for national use, limits were sought that would to the extent possible take into account the wide range in flow properties before and after laboratory aging for all asphalts supplied in the United States. At the same time such limits should be sufficiently selective to rule out unusual or extreme materials.

Initially a specification was drafted with a number of alternate requirements based on available test data on typical viscosity-graded asphalts. The tests and test requirements suggested were considered suitable for use in a transition type of specification, incorporating viscosity with conventional penetration, ductility, and thin-film oven tests. The alternate requirements are given in Table 1.

TABLE 1

ALTERNATE SPECIFICATION REQUIREMENTS FOR VISCOSITY-GRADED ASPHALT CEMENTS

Test	Test Method	Viscosity Grade			
		AC-5	AC-10	AC-20	AC-40
Viscosity at 140 F, poise	T202	500 + 100	1,000 + 200	2,000 + 400	4,000 + 800
Viscosity at 275 F, centistoke	T201	110+	150+	210+	300+
Viscosity at 60 F, Mp		-16	-30	-68	-140
Penetration at 77 F	T49	120+	70+	40+	20+
Penetration at 60 F	T49	40+	24+	14+	8+
Ductility at 77 F, cm	T51	100+[a]	100+	100+	50+
Solubility in trichloroethylene, percent	T44	99.0+	99.0+	99.0+	99.0+
Flash point, COC, F	T48	350+	425+	450+	450+
Flash point, PMCC, F	T73	350+	375+	400+	400+
Thin-film oven test	T179				
Viscosity of residue at 140 F, poise	T202	1,500 ± 500	3,000 ± 1,000	6,000 ± 2,000	12,000 ± 4,000
Viscosity of residue at 140 F, poise	T202	-2,000	-4,000	-8,000	-16,000
Penetration of residue at 77 F	T49	60+	38+	24+	15+
Penetration of residue at 60 F	T49	20+	10+	6+	3+
Ductility of residue at 77 F, cm	T51	100+	50+	20+	10+
Ductility of residue at 60 F, cm	T51	40+	15+	6+	3+

[a]If the penetration is more than 200 and the ductility at 77 F is less than 100 cm, the material will be acceptable if its ductility at 60 F is more than 100 cm.

SPECIFICATION REQUIREMENTS SELECTED

The methods used for selecting the tests and test requirements and the possibility of using alternate requirements are included in the following discussion.

Figure 1 shows the relation of viscosity at 140 F to the viscosity at 275 F for asphalt cements from different sources. Essentially linear relationships result when the viscosities of the different grades from each producer source are plotted on log scales.

Asphalts J and O represent the extreme range for each viscosity grade and K represents one of the intermediate sources. Of particular interest is the narrow range in viscosity at 275 F for each grade demonstrating the uniformity in consistency in the temperature range of 140 to 275 F.

The horizontal line for each grade represents the minimum requirement for viscosity at 275 F. The limits are approximately the same as those proposed in the Research Specification of The Asphalt Institute. As shown in Figure 1, none of the asphalts in the series of study asphalts would fail these limits.

The need for some type of low-temperature consistency requirement has been stressed by the Federal Highway Administration and other groups from the time viscosity grading was first proposed. This was discussed earlier by the authors (1). Probably the most adverse criticism to using a viscosity-graded system at 140 F is the wide range in apparent penetration or apparent viscosity at low temperatures that would be permitted. The obvious objective is to measure the apparent viscosity directly, and much work has been done to develop low-temperature viscosity tests suitable for control of this property. However, they are complicated and are not developed to the state that they can readily be implemented for specification purposes. The most logical alternative for the present, therefore, appeared to be the use of the penetration test for the lower temperature control point. Two possible temperatures for penetration requirements were considered, penetration at 60 F and penetration at 77 F.

The range in penetration at 60 F for asphalt cements produced in the United States for each viscosity grade is shown in Figure 2. Asphalt sources E and J represent the approximate maximum range of asphalts supplied in the United States; I, K, and O are typical intermediate sources. The mean values for about 150 asphalts fall between the curves for asphalt sources I and J. Obviously the range in penetration for each viscosity grade is extremely wide when considered on a national basis. Also, the range

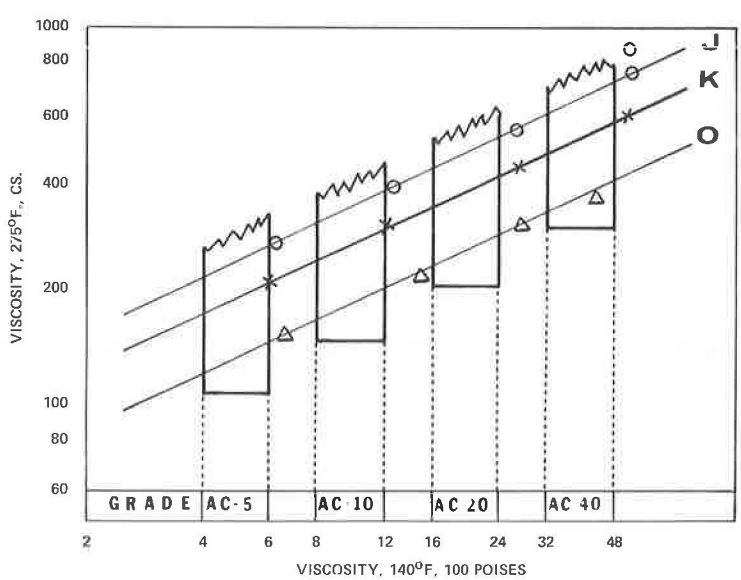

Figure 1. Relation between viscosity at 140 F and viscosity at 275 F.

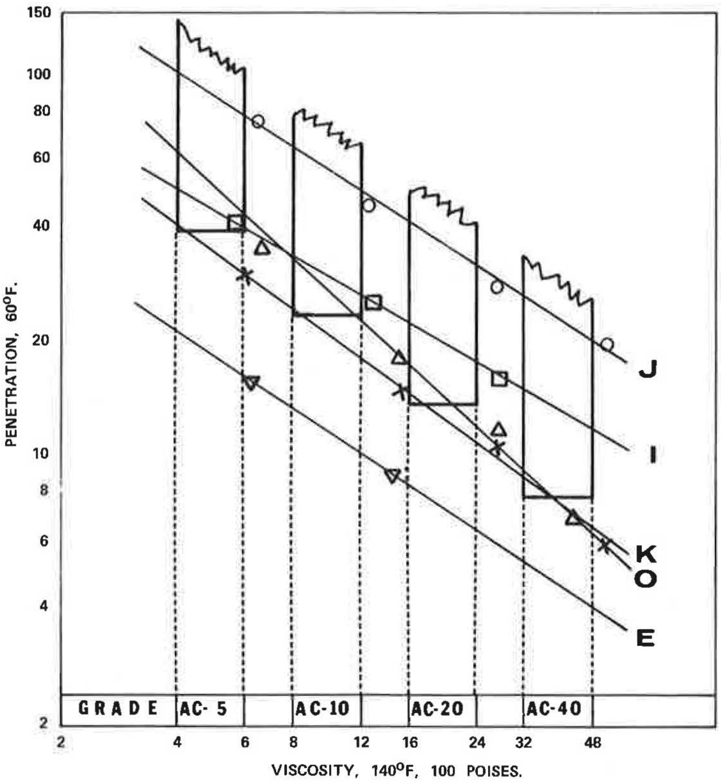

Figure 2. Relation between viscosity at 140 F and penetration at 60 F.

would vary depending on the specific marketing area. Because asphalts from source E are known to be extremely shear susceptible, are subject to brittleness at low temperatures, and would require special design considerations when used, it was considered reasonable to set limits in the guideline specification that would not be met by such materials. Consequently, as shown by the horizontal lines for each grade in Figure 2, the following limits for penetration at 60 F were considered:

Grade	Penetration at 60 F
AC-5	40+
AC-10	24+
AC-20	14+
AC-40	8+

Figure 3 shows a similar consideration for penetration values at 77 F. Essentially the same pattern emerges. Because penetration at 77 F has the advantages of providing a familiar "tie-in" with well-established values under the older system and is also in a range of more easily controlled temperatures with higher numerical results subject to less experimental error, penetration limits at 77 F were chosen as the basis for the specification control. The limits were set as follows:

Grade	Penetration at 77 F
AC-5	120+
AC-10	70+
AC-20	40+
AC-40	20+

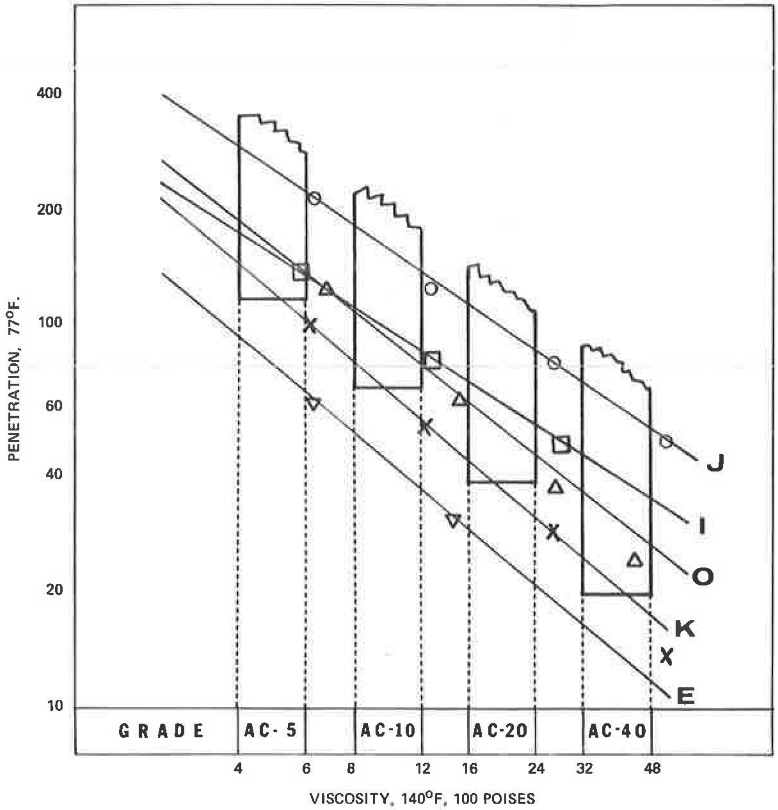

Figure 3. Relation between viscosity at 140 F and penetration at 77 F.

Even though this decision to use penetration at 77 F in the viscosity-graded specification is not consistent with the objective to eliminate empirical tests, it provides the desired degree of control of viscosity and has practical advantages in acceptance testing.

Consideration was given to The Asphalt Institute's proposal to use viscosity at 60 F as a specification requirement; but, because of the complex nature of the test and the lack of testing apparatus in many states and producer laboratories, it was not thought suitable for routine use at the present time. Figure 4 shows the range in viscosity at 60 F at a shear rate of 0.05 sec^{-1} for the asphalts studied. As previously shown for 60 F in Figure 2, asphalts E and J are the extremes, and asphalts I, K, and O are intermediate materials. The maximum requirement considered for each viscosity grade is shown by the horizontal line for each grade. The limits were set to give approximately the same level of control as the requirements for penetration at 60 and 77 F. The Asphalt Institute proposed an equation and a chart for approximately converting penetration at 60 F to viscosity at 60 F. However, the use of conversion of penetration to viscosity for specification purposes probably would create acceptance problems.

In summary, the consistency control selected for the AASHO specification included viscosities at 140 and 275 F and a penetration at 77 F.

The need for specification requirements to control hardening of asphalt during construction and service in pavements is well recognized. The TFOT has been established to be adequate to measure and control hardening characteristics of asphalts during hot plant mixing. Studies by the California Division of Highways and others have shown that the rolling TFOT can be used as an alternate to the standard TFOT.

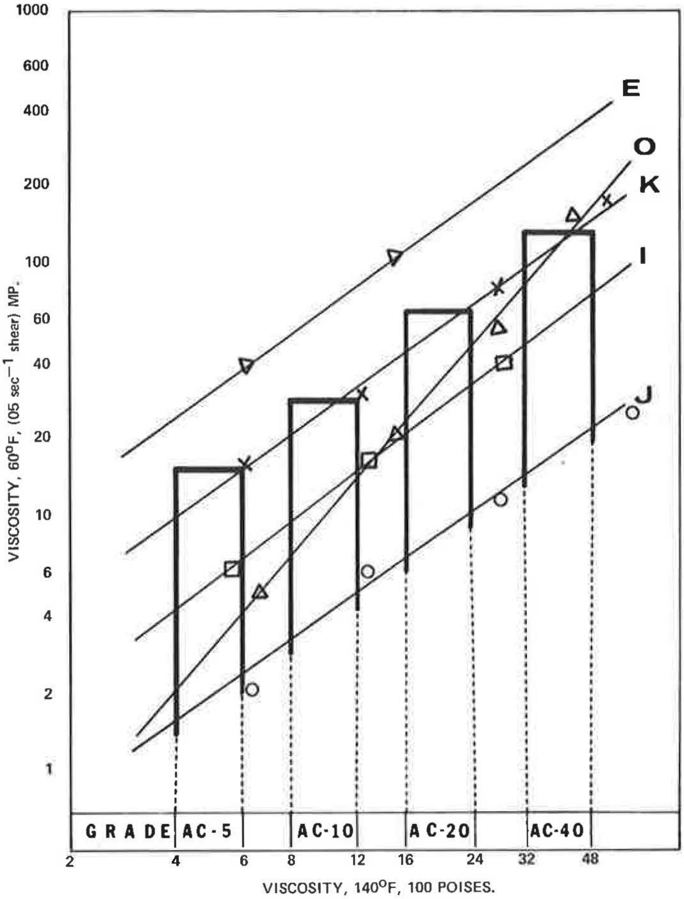

Figure 4. Relation between viscosity at 140 F and viscosity at 60 F.

The following alternative requirements to control hardening were considered for the AASHO specification:

1. Viscosity ratio at 140 F after and before TFOT,
2. Viscosity ratio at 60 or 77 F after and before TFOT,
3. Maximum viscosity at 140 F after TFOT, and
4. Range in viscosity at 140 F after TFOT.

To ensure more uniformity in consistency during construction, the hardening preferably should be controlled by a range in viscosity at 140 F on the thin-film residue. The principle is similar to the California proposal to grade asphalts after a thin-film test. Figure 5 shows the relation between viscosity at 140 F before and after the TFOT and the approximate maximum range for asphalts produced in the United States. Asphalts A and J had the highest viscosity after the TFOT, and asphalt O had the lowest viscosity. As shown by the blocks for each grade, the following maximum and minimum requirements for viscosity of residues after the TFOT were considered:

Grade	Maximum and Minimum
AC-5	1,500 ± 500
AC-10	3,000 ± 1,000

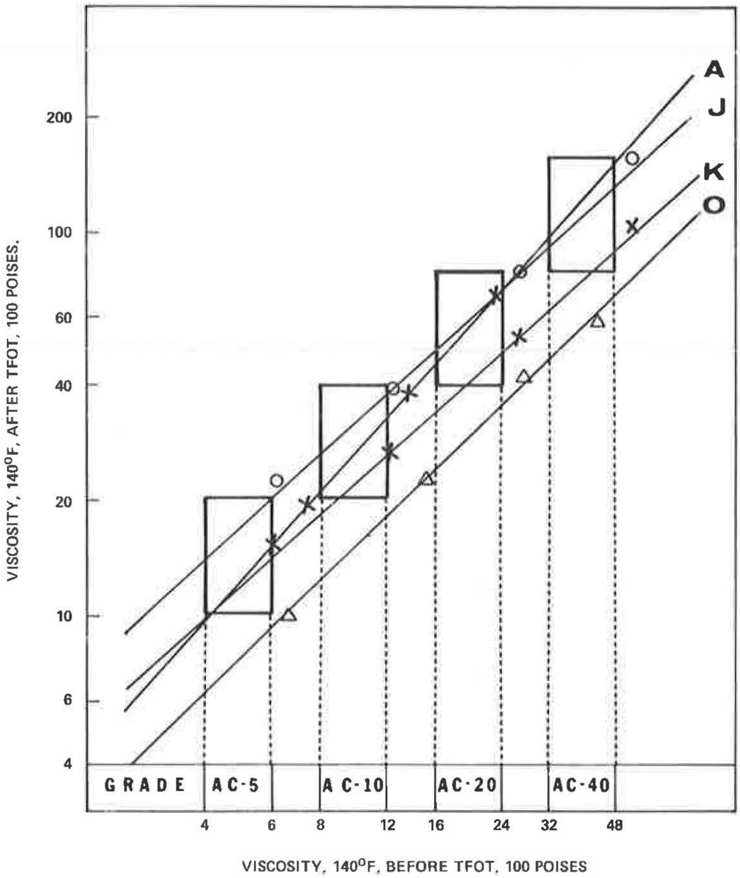

Figure 5. Relation between viscosity before and after thin-film oven test.

Grade	Maximum and Minimum
AC-20	6,000 ± 2,000
AC-40	12,000 ± 4,000

The use of these ranges in viscosity, together with viscosity requirements before the TFOT, was found to be somewhat restrictive when applied to a national specification. Therefore, the alternative of using only a maximum viscosity at 140 F on the residue was considered. The maximum limiting value shown in Figure 5 is 4 times the target grade viscosity before the TFOT. The requirements should provide for the proper protection against undue hardening and are not unduly restrictive for a national specification. The maximum limits shown in Figure 5 were, therefore, adopted for the AASHO specifications.

Considerable opposition has been expressed by some of the asphalt producers to the use of a ductility requirement on thin-film residue on the premise that, although some asphalts have ductilities below the national average and in some cases do not meet the present requirement in AASHO specification M 20 for penetration-graded asphalts, they still provide good service. However, there is enough evidence from previous studies (3, 4) to show that a minimum ductility is necessary to provide some assurance of better performance. Studies by the Federal Highway Administration (5, 6) also have shown that some asphalts have a high loss in ductility when heated to temperatures encountered in construction. Therefore, the AASHO task force decided that a requirement for ductility on the thin-film residue serves a useful purpose and should be included in the viscosity-graded asphalt specifications.

By using ductility data on the TFOT residues of viscosity-graded asphalts and 88 other asphalt samples, the following limits at 77 F and 60 F were considered for the AASHO specification:

Grade	Ductility at 77 F	Ductility at 60 F
AC-5	100+	40+
AC-10	50+	15+
AC-20	20+	6+
AC-40	10+	3+

A ductility at 60 F offers some advantage because most asphalts have ductility values within the limit of the usual testing machine and may provide a better means for evaluating the asphalts. However, because experience and most of the field performance information is related to ductility at 77 F, the task force adopted the requirements at 77 F.

Requirements also were adopted for flash point (Cleveland open cup, COC), the spot test, and solubility in trichloroethylene. The limits set are comparable to those in AASHO M specifications for penetration-grade asphalts. Thus, an AASHO specification based on viscosity grading at 140 F containing the following requirements has been written and adopted: viscosity at 275 F; penetration at 77 F; flash point, COC; solubility in trichloroethylene; spot test with alternate solvents; and thin-film oven test, viscosity of residue at 140 F, and ductility of residue at 77 F.

The specification was published in July 1970 as an interim specification and assigned number M 226-70I. It will be published in the new tenth edition of AASHO standards to be released in 1971 as a full standard. The new specification can be used as an alternate to the penetration-graded specification M 20 that remains in effect. A copy of the complete specification is shown in Figure 6.

The AASHO specification as adopted will be quite lenient in some states but in others will eliminate some asphalt as now manufactured. We recognized that the supply situation or past practices may make it necessary and justifiable for individual states or groups of states to modify requirements based on their needs. The development of current information on the characteristics of asphalts being furnished the states should provide a basis for future revision of the AASHO specification. Consideration might be given to the California approach to place more control on the properties of the residue from a TFOT. With the approved capabilities of states to determine viscosities at low temperatures, requirements based on viscosity should be considered as a replacement for the present penetration limits at 77 F. For any adjustments in the proposed limits, we strongly recommend that use be made of the relationships shown in Figures 1 through 5. Arbitrary shifting of limits without regard to the interrelationships among test characteristics within grades and among the different grades of asphalt from the same source could lead to unjustified inequities.

PROS AND CONS OF VISCOSITY GRADING

After the specification was prepared by the AASHO task force, it was circulated to the major asphalt producers for comment. Comments varied all the way from the "limits are too restrictive" to "limits are not restrictive enough." Perhaps the greatest concern expressed related to multiple tanks needed by producers selling to some states using the old system and to other states using the new specification. This is a matter of legitimate economic concern, and it is hoped that neighboring states or groups of states will cooperate to the extent possible in changing over to new specifications.

Some of the comments received indicated a lack of understanding of the basis of the specifications. It was also indicated that the problem of chosing the proper grade of asphalt or the proper mix design was being confused with the asphalt specification re-

SPECIFICATION FOR VISCOSITY GRADED ASPHALT CEMENT

AASHO Designation: M 226-70 I

SCOPE

1.1 This specification covers four grades of asphalt cement graded by viscosity at 140F (60C) for use in pavement construction. For asphalt cements graded by penetration at 25C (77F) see AASHO Specification M 20, for Asphalt Cement.

MANUFACTURE

2.1 The asphalt cement shall be prepared from crude petroleum by suitable methods.

REQUIREMENTS

3.1 The asphalt cement shall be homogeneous, free from water, and shall not foam when heated to 175C (347F).

3.2 The grades of asphalt cement shall conform to the requirements given in Table I.

SAMPLING

4.1 Samples of asphalt cement shall be obtained in accordance with AASHO Method T 40, for Sampling Bituminous Materials.

METHODS OF TEST

5.1 The properties of the asphalt cements shall be determined in accordance with the following standard methods of the American Association of State Highway Officials:

Viscosity at 140F (60C)	T 202
Viscosity at 275F (135C)	T 201
Penetration	T 49
Flash Point	T 48
Solubility in Trichlorethylene	T 44
Thin-film Oven Test	T 179
Ductility	T 51
Spot Test	T 102

TABLE I

REQUIREMENTS FOR A SPECIFICATION FOR ASPHALT CEMENT – VISCOSITY GRADED AT 140F (60C)

AASHO Designation: M 226

Test	Viscosity Grade							
	AC-5		AC-10		AC-20		AC-40	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Viscosity, 140F (60C), poises	500±100		1000±200		2000±400		4000±800	
Viscosity, 275F (135C), Cs	110	–	150	–	210	–	300	–
Penetration, 77F (25C), 100g, 5 sec.	120	–	70	–	40	–	20	–
Flash Point, COC, F	350	–	425	–	450	–	450	–
Solubility in trichloroethylene, percent	99.0	–	99.0	–	99.0	–	99.0	–
Tests on residue from Thinfilm oven test:								
Viscosity, 140F (60C), poises	–	2000	–	4000	–	8000	–	16000
Ductility, 77F (25C), 5 cm per min., cm	100	–	50	–	20	–	10	–
Spot test (When and as specified. See Note 1) with:								
Standard naphtha solvent	Negative for all grades							
Naphtha-Xylene-solvent, ___ percent xylene	Negative for all grades							
Heptane-Xylene solvent, ___ percent Xylene	Negative for all grades							

Note 1. – The use of the spot test is optional. When it is specified, the Engineer shall indicate whether the standard naphtha solvent, the naphtha-xylene solvent, or the heptane-xylene solvent will be used in determining compliance with the requirement, and also, in the case of xylene solvents, the percentage of xylene to be used.

Figure 6. New AASHO specification.

quirements. For this reason, the following general summary of the problem appears to be in order.

One of the opposing views of viscosity grading at 140 F centered on the problems arising from differences in viscosity-temperature susceptibility of asphalts and the problems of pavement cracking often attributed to the asphalt being too hard. A possibility of brittle pavements due to excessive stiffness from too hard asphalts was shown. However, the illustrations given were based on no controls on consistency of the asphalts at lower temperatures. The minimum limit on penetration at 77 F in the proposed AASHO specification tends to eliminate the extreme conditions. Admittedly, large differences in low-temperature rheology would still exist, but the problem could be further guarded against by specifying a different grade asphalt and by modification of mix design to provide optimum conditions. If necessary, further low-temperature restrictions could be used. The need for these actions under viscosity grading should not be much greater than that which now exists for penetration grading.

The philosophy behind proper mix design using the viscosity-grading system is often overlooked. The basis for designing the mixture, in part, is to provide adequate stability (or stiffness) at the highest summer temperature and at the same time to avoid extreme brittleness that might lead to pavement cracking during the winter. By viscosity grading at 140 F, the differences in binder consistencies for the same grade are reduced to a minimum if the design temperature is 140 F (7). If binder consistency is correct at this temperature, research as well as experience has shown that the temperature ranges for mixing and compaction for a given grade are for all practical purposes the same regardless of the source of the asphalt. At low temperatures, we are concerned with a critical consistency that, if exceeded, could result in extreme brittleness and consequent cracking or other deterioration in the pavement. Although this critical consistency is not necessarily viscosity per se, it most likely is directly related to viscosity or apparent viscosity. We must admit that at present we do not have clear-cut answers to this problem. However, the range between the maximum and minimum stiffness modulus for a given grade that was emphasized in some of the comments as being too great for some asphalts is not the primary concern and is not necessarily related to the performance of the mixture. We are concerned only that critical values at either the soft or hard end of the scale are not exceeded. A range of satisfactory values exists in which the asphalt viscosity has relatively little effect on performance for given conditions.

We know also that the critical mixture consistency (or stiffness) is not a function of the binder viscosity alone. This depends on a number of additional factors such as type and gradation of aggregate, type and amount of mineral filler, asphalt content of the mixture, temperature during service, traffic conditions, and type of base. Additional complications arise from the different degrees of shear susceptibility present in different asphalts at low service temperatures. Thus, the problems created by low and high temperature during service cannot be solved by viscosity grading of asphalts but with the application of proper mix design techniques; it is improbable that such problems will be aggravated. In addition, the use of the proposed AASHO specification containing consistency measurements at 3 points should serve as an automatic indicator of the characteristics of the asphalt being used, and considerations can be given to unusual materials during the mixture design. Any significant change in asphalt viscosity-temperature susceptibility during the progress of a job would automatically show up through acceptance testing. Under the present penetration specifications, such information is not automatically revealed by acceptance testing. It is important to point out that the AASHO use of a third consistency point is a departure from the research specifications of The Asphalt Institute that were the basis of some of the fear of extreme differences resulting from different asphalt viscosity-temperature susceptibilities.

As previously pointed out, the proposed AASHO specification retains a link with past experience by requiring a measurement of the penetration at 77 F. However, the point needs to be made that a serious mistake can be made if one attempts to equate our knowledge of performance of penetration grades to a predicted performance of viscosity grades on the basis of substituting a single viscosity grade for a single penetration in all instances, for example, AC-10 for 85 to 100. One of the problems is the variation of performance of the same penetration grade from different producers. Such variation is also likely to occur under the new grading, but the more complete knowledge of the binder characteristics should make such behavior more predictable than less so and provide information to the contractor and buyer of any substantial change in asphalt supply that might affect construction operations and pavement performance.

Comments have been made in reference to the work of Lefebvre (8) showing differences in Marshall stabilities for materials of equal viscosity. However, this finding is in variance with findings in the Materials Division's laboratory for strength tests made by the Marshall and direct compression methods. Our studies show excellent correlation between viscosity of the binder and strength of the mixture for aggregates of the same type and gradation (7). Asphalts from several sources having widely different viscosity-temperature characteristics were used in these studies. The correlation was later confirmed by using viscosity-graded asphalts.

In summary, it can be said that the proponents of viscosity-graded specifications generally agree that such specifications will not automatically solve all the problems of asphalt construction or magically improve the quality of asphalt cements. However, in our opinion the advantages of such specifications outweigh the disadvantages, provided (a) that viscosity grading is supplemented by suitable controls on maximum consistency at low temperatures (indicated in the AASHO specification by penetration at 77 F) and (b) that proper attention is given to selecting the best grade for the environment and traffic. The specification proposed by AASHO is a national specification developed to include nearly all asphalts produced in the United States. Further study and experience might well show that some adjustment of limits or test requirements is necessary either on a national or on a regional basis. We strongly believe that the proposed AASHO specification represents the best balance that is now possible between conflicting needs and that its adoption by other specification agencies and universal use in construction specifications will mark a step forward for the asphalt industry.

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Discussion

L. C. KRCHMA, Mobil Oil Corporation—To a degree philosophical, there is no question that good asphalt pavement is a game of optimums. Pavement success and progress rest in doing the best we can with what we have at hand. A simple, thicker lift revolutionized compaction without demanding anything special in materials or equipment. Thus, good paving technology and full-depth design pavements give us unusual performance on the same basis. We should not take for granted the tremendous returns always gained with optimum asphalt contents. It is inescapable that pavement results and progress demand more of the same. This is the occasion for examining not the work reported here by Woody and York but whether grading asphalt cements at 140 F also represents an optimum such as the examples given.

For homework on a grading optimum, we offer the following as the controlling factors:

1. The nature of the crude from which asphalts are recovered primarily determines the character of asphalt. Processing methods are only secondary.

2. At the present state of paving technology, we are concerned with uniformity in application and in service. We are not at the point of any marked change in quality irrespective of whether we grade at 140 F.

3. Application temperature but not service temperature is subject to engineering control once a grade of asphalt is selected for a project.

4. Grading as practiced with asphalt is solely a tool to designate an asphalt of a given consistency. Its function is legal and commercial. Hence, safety, purity, and

durability (except as influenced by temperature susceptibility) are the same irrespective of grading system. It follows that additional selectivity among asphalts, where required, can only be obtained by tests and limits in addition to those used to grade the asphalt.

5. Service provided by today's asphalt pavements, with respect to both mileage and quality, was obtained with asphalts meeting 77 F graded specifications.

From these, grading issues are (a) uniform asphalt cement consistency at application and service temperatures and (b) asphalt cement economy, convenience, and availability. These are mutually incompatible but need consideration.

To obtain the uniformity referred to earlier, we have the following tools: (a) specification limits, (b) paving operation controls, and (c) choice of asphalt grade. These are mutually compatible and, hence, can help cope with the grading issues.

Concerning uniformity, from first principles, increasing differences between grading temperature and either service or application temperature results in increased variability.

This is shown in Figure 7, grading at 77 F, and Figure 8, grading at 140 F, for the same family of asphalts with identical differences in their temperature susceptibilities. Therefore, concerning asphalt service temperature consistency, on the average, uniformity is better at 32 F, for example, when graded at 77 F (distance AC, Fig. 7) than when graded at 140 F (distance AC, Fig. 8). Because the service temperature is below 140 F the majority of the time, 77 F is more representative of service conditions than 140 F. To get the same uniformity at such service temperatures with 140 F grading requires a more restrictive specification limit at temperatures other than 140 F. This would make it necessary to shrink the asphalt family by the shaded portion shown in Figure 9. (This is grading at 140 F, shown in Figure 8, drawn to make distance

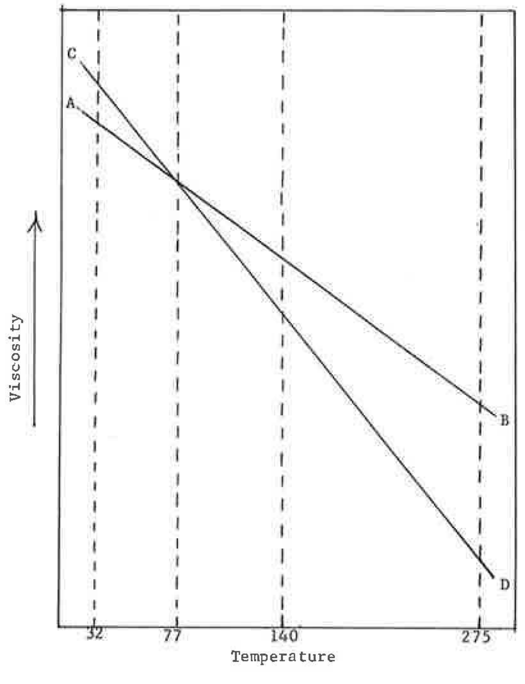

Figure 7. Service and application temperatures with 77 F grading; viscosity variabilities imposed by inherent temperature susceptibility differences among asphalts.

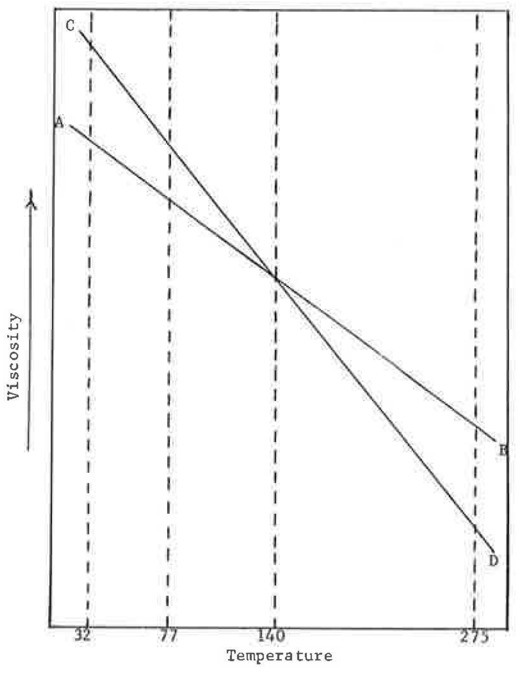

Figure 8. Service and application temperatures with 140 F grading; viscosity variabilities imposed by inherent temperature susceptibility differences among asphalts.

AC′ at 32 F equal to distance AC shown in Figure 7.) Hence, the alternatives open to grading at 140 F are more variable at service temperatures or more restrictive specifications. These do not represent the best use of materials at hand.

We can avoid these undesirable alternatives and associated complications when asphalts are graded at 77 F. With 77 F grading, it is possible to obtain more uniformity at service temperature. This feature is evident from a comparison of Figures 7 and 8. Then, uniformity at application temperature is gained by rational process controls by using available technology. So, we can get the best of both worlds: uniformity in both service temperature and application temperature areas.

Then, too, as McLeod shows, more attention to the selection of the asphalt grade promises even further performance uniformity where consistency at service temperature is critical. We may have been at fault in stressing the universal use of one grade such as the 85 to 100. It appears there are advantages to using both harder and softer grades, if we use them at their optimums.

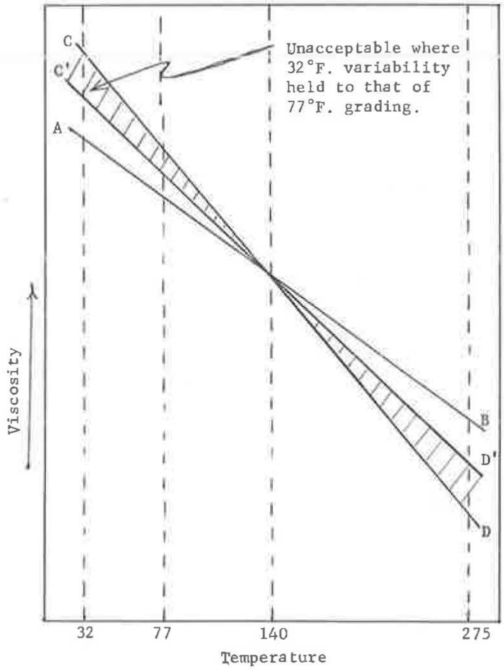

Figure 9. Reduction in acceptable 140 F graded asphalt temperature susceptibilities equaling 77 F grading service temperature-viscosity variabilities.

Further, the proper grading approach needs to be resolved. There are those who favor grading based on oven residues. Among other possibilities would be to grade by the temperature at which the asphalt is at some important service condition. Such grading might be more significant.

On the basis of this discussion, grading at 77 F plus good application information and its use in control plus some additional attention to grades best faces up to the significant issues. Further, it provides the best grading system, immediately available and recognized, to which other tests and limits can be added to increase the control of temperature susceptibility and durability as may be required in the future. These facts and possibilities bring 77 F grading closest to the optimum needed for good asphalt paving technology.