Comments on the Proposal to Classify Paving Grades of Asphalt Cement by Viscosity at 140°F

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INTRODUCTION

For many years, paving grades of asphalt cement have been classified in terms of penetration at 77°F. Thus we have 60/70, 85/100, 150/200, and other penetration grades. The penetration test is made at 77°F, because this approximated room temperature in the early laboratories where the test originated more than fifty years ago.

Recently, consideration has been given by some agencies in the United States to abandoning the penetration test completely and to classifying paving grades of asphalt cement on the basis of their viscosities in stokes or poises at an elevated temperature. Some of the reasons advanced for this suggested change are:

(a) it would express the consistencies of asphalt cements in fundamental units of viscosity (stokes or poises), instead of the so-called empirical units of the penetration test.

(b) it would provide grades of asphalt cements having more uniform consistencies at high temperatures, which some claim would assist mixing, laying, and rolling operations.

(c) it would eliminate the wide differences in viscosity at high temperature that can exist for asphalt cements having the same penetration at 77°F.

In the past, when viscosity information was obtained for asphalt cements, the test temperature employed was usually 275°F. Figure I illustrates typical viscosity temperature curves for asphalt cements. Regardless of the source or consistency of paving grades of asphalt cements, their viscosity-temperature curves tend to be approximately parallel, and the slopes of their viscosity temperature curves are more or less the same, although exceptions sometimes occur. In general, therefore, at any test temperature over the range from 140°F to 270°F selected for grading asphalt cements by viscosity, individual asphalts would fall into the same grades. For example, if a group of asphalt cements were in the lowest viscosity grade on the basis of their viscosities at 140°F, they would also tend to be in the lowest viscosity grade if they were grouped by their viscosities at 275°F, or at any temperature between 140°F and 275°F.

Recently, new specifications for S.C., M.C., and R.C. liquid asphalts have been adopted by The Asphalt Institute, A.A.S.H.O., and A.S.T.M., in which the viscosities of all grades are specified in centistokes at 140°F. This is intended to give producer and consumer alike a clearer understanding of how the various liquid asphalt grades compare in viscosity.

Those who favour classifying asphalt cements by high temperature viscosity, feel that it would be helpful if asphalt cements for hot-mix

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pavement construction were also graded by viscosity at 140°F, and this test temperature has been proposed, at least for the time being.

The four grades of asphalt cement being currently considered on the basis of their viscosities in poises at 140°F are listed in Table 1, and their suggested viscosity limits are illustrated in Figure 2.

Table I

Proposed Paving grades of asphalt cement based on viscosity in poises at 140°F.

Paving Grade of Asphalt Cement	Range of Viscosity in Poises at 140°F
A.C. 5	500 to 750
A.C. 10	1,000 to 1,500
A.C. 20	2,000 to 3,000
A.C. 40	4,000 to 6,000

EFFECT ON ASPHALT CEMENTS

Figure 2 is a graph of viscosity in poises at 140°F versus penetration at 77°F for a considerable number of representative asphalt cements in current use in the United States and Canada. The area between lines A and B represents the range of asphalt cements presently employed for pavement construction in our own country. However, asphalt cements from about ninety per cent of Canada's own very substantial crude oil production, lie btween lines A and C. From Figure 2, it is easy to read off the range in penetration at 77°F for asphalt cements now used or available in Canada, that would be associated with each of the proposed four viscosity grades. This comparison is summarized on Table 2.

Table 2

Range of penetration at 77°F associated with each of the proposed new grades of asphalt cement which are based on viscosity in poises at 140°F.

Viscosity Grade at 140°F	Corresponding Range of Penetration at 77°F
A.C. 5	80 to 250
A.C. 10	45 to 170
A.C. 20	25 to 120
A.C. 40	15 to 80

It is of particular interest that one of the proposed new grades, A.C. 10, would include all of the three most commonly used current grades of paving asphalts, 60/70, 85/100, and 150/200 penetration.

For at least fifty years, one of the basic teachings of the asphalt industry has been that a marked difference in pavement performance can be expected if 60/70 penetration asphalt is used in place of 150/200 penetration, and vice versa. In addition, even a casual study of the history of the wide-spread use of asphalt binders in North America since 1925 provides clear evidence that the softer grades of asphalt have been selected for asphalt pavements placed over weaker foundations and carrying lighter traffic, and that the use of harder grades like 60/70 penetration has been restricted to pavements on strong foundations that are to carry heavy traffic. There are experienced engineers in Western

Canada and the Maritime Provinces for example, where traffic volumes are smaller, who believe that in some cases at least, pavement performance has been less satisfactory when they changed from S.C. 6 to the not much harder 150/200 penetration grade.

In spite of this vast accumulation of experience, particularly over the past two or three decades, those who would now have us completely abandon the penetration test and adopt in its place the grading of asphalt cements by viscosity at 140°F, are implying in effect that the wide differences in penetration at 77°F associated with each of the proposed new viscosity grades shown in Table 2 and illustrated in Figure 2, will have no noticeable effect on pavement performance. This is an astonishing reversal of attitude. Almost overnight, we are being advised (indirectly of course), that the penetration of an asphalt cement at 77°F, which has been the principal guidepost to the selection of grades of asphalt cement for many years, is no longer important for this purpose. What is even more astonishing, those who are urging the grading of asphalt cements by viscosity at 140°F and the total discard of the penetration test at 77°F, are asking us to accept this change **without offering any substantial evidence from the field,** that the penetration of an asphalt cement at 77°F has suddenly become of little or no significance insofar as asphalt pavement performance is concerned.

The penetration test at 77°F is sometimes referred to as a meaningless empirical test, but this criticism is not justified. A number of technical papers, (for example, S. L. Neppe, (1952), "Classification of Bitumens by Certain Rheological Properties, Part I", Journal of the Institute of Petroleum, Volume 38, p.p. 127-136; and G. Carre and D. Laurent, (1962), "Relationship Between Penetration and Viscosity of Bitumens", Prix Charles Bihoreau, Association Francaise des Techniciens du Petrole), testify to the technical respectability of the penetration test as an indirect measure of viscosity at 77°F, and a number of formulae are available for converting penetration at 77°F to viscosity in poises at 77°F.

For those who are particularly interested in the rheological properties of asphalt, it might be added that test data obtained by Mr. J. A. A. Lefebvre of our Research Department have shown that in general, for paving asphalts currently used in Canada, the viscosity of an asphalt cement at 77°F for zero rate of shear is normally less than twice its viscosity at infinite rate of shear. Although the rate of shear inherent in the penetration test is variable, both its range and its average value lie somewhere between zero and infinite shear rates. Consequently, in general, for asphalt cements presently used for paving operations in Canada, the measure of viscosity provided by the penetration test, probably does not differ greatly from the viscosities actually developed by an asphalt cement for the rates of shear to which it is subjected in a pavement in the field.

EFFECT ON CUTBACK ASPHALTS AND ASPHALT EMULSIONS

The road performance of cutback asphalts and asphalt emulsions will also be influenced by the proposal to eliminate the penetration test at 77°F entirely, and to grade asphalt cements by viscosity at 140°F. If the grading of asphalt cements by viscosity at 140°F were adopted, these asphalt grades would immediately become the asphalt bases for cutback asphalts and asphalt emulsions. It is impractical to expect that if asphalt cements for hot-mix paving were graded by viscosity at 140°F, that the present series of asphalt cements, which are graded by penetration at 77°F, would be continued as the bases for cutback asphalts and emulsions.

It should also be clearly recognized that if the penetration test at 77°F for asphalt cements were discarded completely, the consistencies

of the residues from the distillation of cutback asphalts to 680°F, and of asphalt emulsions to 500°F, would also be specified in poises at 140°F, instead of penetration at 77°F. For M.C. cutbacks for example, for practical reasons which include the poor reproductibility of the consistency of distillation residues, it seems unlikely that the specified range of viscosity at 140°F for the distillation residue would be less than that of A.C. 5. Table 2 and Figure 2 demonstrate that this would correspond to a range of penetration at 77°F of 80 to 250, which is much wider than the currently specified penetration range of 120 to 250.

Similarly, the range of viscosity at 140°F specified for the distillation residues for R.C. cutbacks is not likely to be less than that of A.C. 10. From Table 2 and Figure 2 it is clear that this would correspond to a range of penetration at 77°F of 45 to 170. This is a very much broader range of penetration at 77°F than the presently specified penetration limits of 80 to 120.

Practical field experience over the years has shown that the values of the penetration test on the distillation residues of M.C. and R.C. cutback asphalts and of asphalt emulsions, do have a marked effect on the service performance of asphalt road surfaces made with these binders; For example, in recognition of this, in some regions of North America in the past M.C. cutback asphalts with particularly soft asphalt bases have been specified. Even for the relatively warm climate of Victoria, Australia, 80/100 penetration is the hardest grade of asphalt cement permitted for the manufacture of cutback asphalts for surface treatments.

EFFECT ON LONG TERM PAVEMENT PERFORMANCE

There are two principal stages in the life of a hot-mix asphalt pavement. These are:

1. The construction stage, that seldom exceeds from two to four hours, during which the paving mixture is at an elevated temperature, and
2. The service stage, that should last for from fifteen to twenty years or more if the pavement is properly designed and carefully constructed, during which the pavement is at normal temperature.

With respect to the **relative importance** of these two stages, it would appear reasonable to focus the greatest attention on those factors that contribute to a longer and more satisfactory service life, and to place much less emphasis on factors that merely facilitate construction operations.

One of the arguments employed to support the grading of asphalt cements by viscosity at 140°F in poises, is that 140°F is the lower limit of the range of temperature for construction, and the top limit of the temperature range experienced by a pavement during its service life. However, it can be shown that while the grading of asphalt cements by viscosity at 140°F might facilitate construction operations it could be detrimental to long term pavement performance.

It has already been pointed out, that in general, for any test temperature over the range from 140°F to 275°F that might be specified for grading asphalt cements by viscosity, an asphalt cement from any given source would fall into the same grade. For example, as illustrated by Figure 1, any group of asphalt cements that belonged to the lowest viscosity grade, on the basis of their viscosities at 140°F, for instance A.C.5 from Table 1, would also tend to belong to the lowest viscosity grade if they were classified by their viscosities at 275°F, or at any specified temperature between 140°F and 275°F. Consequently, the grading of asphalt cements by viscosity at 140°F would tend to provide paving

mixtures of relatively uniform characteristics at the elevated temperatures employed for construction, regardless of the source of the asphalt cement. It is believed by some, that this uniformity of characteristics of paving mixtures at high temperatures regardless of the source of the asphalt cement, would be highly advantageous for pavement construction operations. (However, the problem of facilitating construction operations can be approached from a quite different and more realistic basis, and this will be the subject of another paper).

On the other hand, during the 15 to 20 years or more of satisfactory service life expected from a good asphalt pavement, it is at the road surface temperature. A temperature of 77°F is much closer to the average of the road surface temperature range, than is 140°F, which is the upper limit of the service temperature. Consequently, the characteristics of asphalt pavements at 77°F can be expected to have a much greater influence on the actual performance of these pavements throughout their service lives, than the characteristics of the same paving mixtures at the higher temperatures of the construction stage. It was mentioned earlier, that for A.C. 10, one of the grades of asphalt cement proposed on the basis of viscosity at 140°F, the corresponding penetration at 77°F would range from 45 to 170 for asphalt cements in current use in Canada. It has also been pointed out, that the experience of the past 30 to 40 years has demonstrated that there could be a very disturbing difference in the performance of an asphalt pavement in any given location, depending upon whether the penetration of the asphalt binder at 77°F was 45 or 170.

Consequently, while the grading of asphalt cements by viscosity at 140°F might facilitate construction operations, it could have a very detrimental effect on long range asphalt pavement performance, particularly in regions where the climate includes extreme ranges of temperature. For this reason, before the grading of asphalt cements by viscosity at 140°F is seriously contemplated, a comprehensive investigation should be undertaken to determine precisely what effect this would have on long term pavement behaviour.

SUMMARY

1. The proposal to grade asphalt cements on the basis of viscosity in poises at 140°F, and to completely discard the penetration test at 77°F, has been reviewed.
2. It has been shown that each of the proposed four grades of asphalt cement based on viscosity at 140°F, would have a very wide range of penetration at 77°F. For the A.C. 10 grade for example, the corresponding range of penetration at 77°F would be from 45 to 170 for asphalt cements currently employed for pavement construction in Canada.
3. Because of their effect on distillation residues, the proposed new grades of asphalt cement could have a deleterious influence on the road surface performance of cutback asphalts and asphalt emulsions.
4. While the grading of asphalt cements by viscosity at 140°F might facilitate hot-mix pavement construction operations, evidence from several decades of experience indicates that it could have a very detrimental effect on the long term service behaviour of asphalt pavements, particularly in regions subject to extremes of temperature.
5. It is recommended that before the proposal to grade asphalt cements by viscosity at 140°F, and to eliminate the penetration test at 77°F, is seriously considered, a comprehensive investigation should be undertaken to determine the influence this would have on long range pavement service performance.

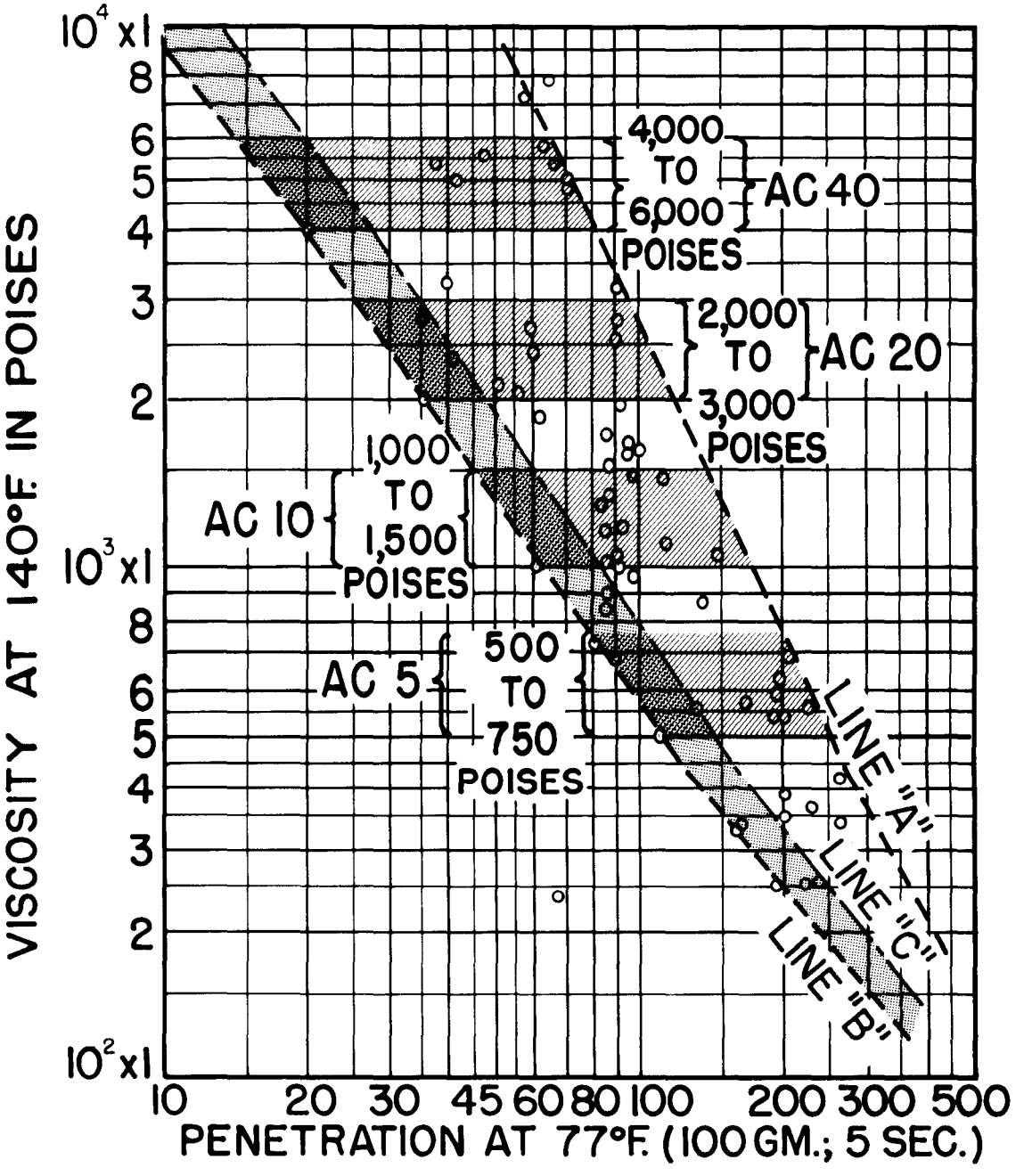

FIG. 2 CORRELATION BETWEEN VISCOSITY AT 140°F. AND PENETRATION AT 77°F. FOR CURRENTLY USED ASPHALT CEMENTS.

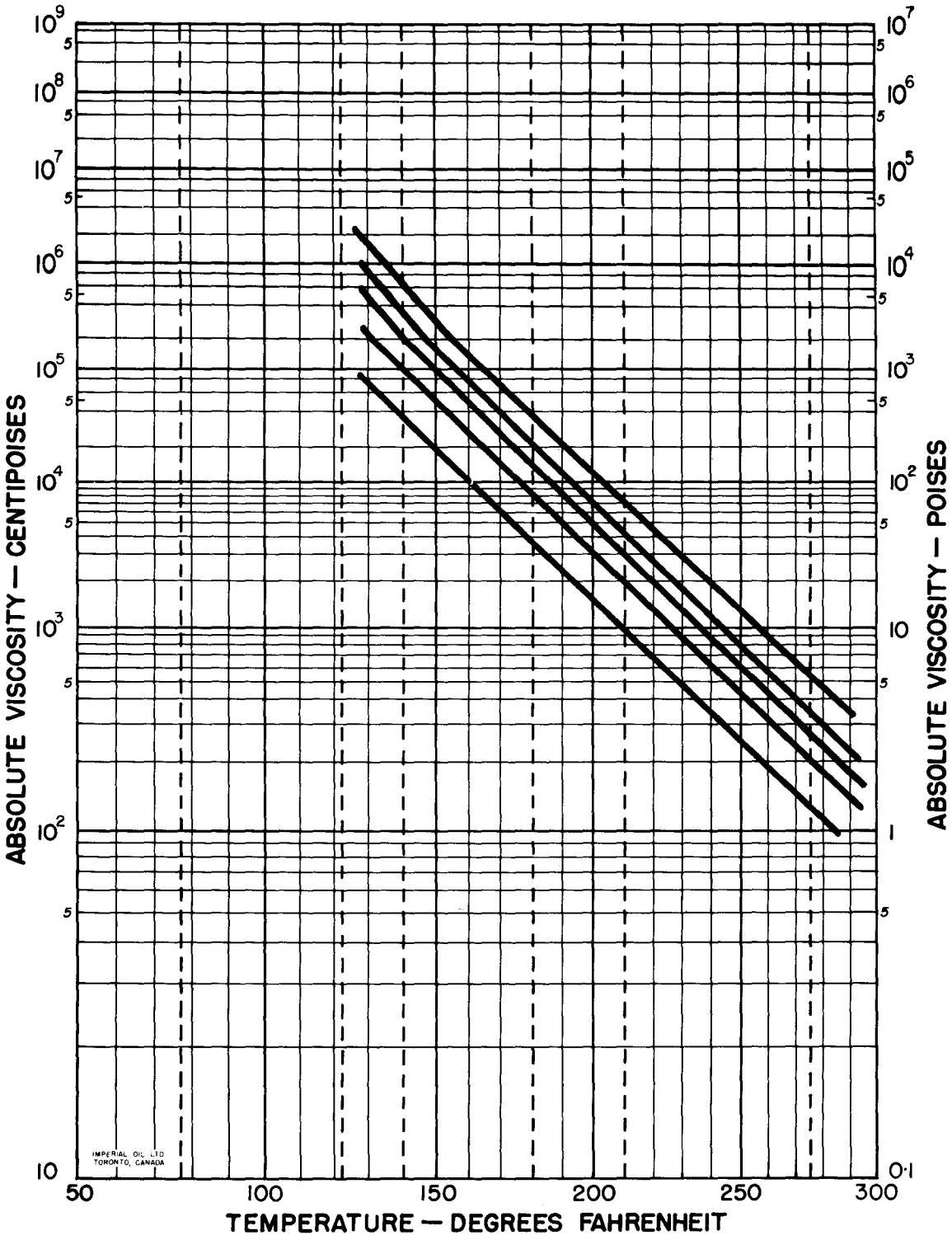

FIG. 1 TYPICAL VISCOSITY–TEMPERATURE CURVES FOR ASPHALT CEMENTS.