no question but that the quality of the results has been in direct proportion to the amount of compaction or interlocking secured by proper rolling, and it is his opinion that results generally show that the proper rolling of the stone before the application of the pitch is of the greatest importance.

Relative Advantages and Use of Tar, Tarry Compounds, Asphalt, Bitumen and Other Materials.—The proper selection of the bituminous material or pitch for use under the penetration or under any method is a most serious one and is influenced by many conditions other than method of use. Such, like price, soil, weather and traffic conditions, desires of users of, and abuttors on the road, the conditions likely to prevail regarding after-maintenance and cleaning, etc., etc., are largely local, and are probably not germane to the discussion in this paper.

Confining the statements to the above subjects and considering only the penetration method of use, it may be said:

The use of unrefined tars has been found unsatisfactory and has been practically abandoned. The extent and character of the refining seems to depend largely on the peculiar conditions to be expected in any case of the use of the material, but some points in this connection are still unsettled. It seems generally agreed that the presence in the tar of more than a minimum of water or ammoniacal liquor renders it undesirable for this method of use; that certain amounts of "light oils" are necessary for giving to the pitch the desired fluidity in handling; that a generous proportion of "middle" and "heavy" oils —especially the latter—is demanded in order that the tar may retain the longest possible "life" or elasticity after use and under the ageing or weathering effects of weather and traffic as well as for giving the "body" to the pitch demanded by this method; and that a limited amount of "free carbon" may be advisable in order to help to give body to the tar and to assist in reducing its susceptibility to changes in temperature. This "free carbon" (matter insoluble in carbon bisulphide) may be either the natural fraction of the tar or it may be added foreign material such as Portland cement or finely powdered limestone. Some crusts built by the penetration method with a low carbon tar have seemed to improve as fine material was supplied by traffic.

At first an opinion existed widely that the value of a tar for road work was in inverse proportion to its percentage of "free carbon" content, but the writer was loath to accept this view because of his knowledge of the proved great value of certain tars in which this fraction was unusually high. Results of practice with the penetration method to date seem to indicate that it is not the simple proportion of the "free carbon" fraction to the whole tar which was of use as a criterion in passing on the value of the tar for the penetration method but rather the ratio between the "free carbon" fraction and one or more other fractions (the heavier oils) on which depends the worth of the whole tar.

The use by the penetration method of tars with a "free carbon" content of less than 2 per cent. has resulted in an objectionable susceptibility of the road surface to summer heats, while the use of tars whose "free carbon" fraction was greater than the percentage of the heavier oils in the same tar has shown a too great hardness or friability under extreme cold.

In the use under the penetration method of the native asphaltic materials and of the oil residuums, a certain amount of "light oil" seems desirable for the sake of fluidity, and a limited amount of "middle" and "heavy" oil fractions for the sake of "life" and elasticity. The "pitch" fraction, being the base in those cases, must possess the desired characteristics of adhesiveness, cohesiveness, lack of brittleness and resilience. The proper proportions of the lighter fractions depend on the characteristics, in those particulars at least, of the "pitch" as well as upon the conditions of traffic, etc.

Early practice under the penetration method condemned the use of "cut back" products,—i.e., those artificially prepared by the addition of oils to previously reduced pitches—probably because in many cases such pitches had not been carefully prepared with this end in view but were by-products or wastes from processes arranged for the production from the raw material of the portions other than the pitch.

The writer believed that not only was it possible to make satisfactory road compounds for use under this method from a pitch by cutting it back with lighter materials, but also that it was quite possible that, in many cases, a far more satisfactory product could thus be obtained than by simple reduction, to the desired consistency, from the raw material.

Subsequent experience has seemed to confirm this theory and some of the most satisfactory results under the penetration method have been secured by the use of pitches compounded by adding the necessary oils to a previously and purposely prepared, fairly hard, asphaltic pitch.

In such cases, the harder pitch possessed all the usual qualities of a good asphaltic paving pitch and the flux, those of a proper flux for making asphaltic cement, except that perhaps more volatile oils were included to permit of easier and better use under the peculiarities of the penetration method. Experience seems to have proved that there is a limit to the amount of "greatness" that can safely be permitted in the flux so—as above—used and that an excess of this characteristic may ruin the results under this method by permitting, if not encouraging, the internal motion between the coarse particles of the crust, especially in the usual case of a deficiency of the smaller sizes.

In the use of the materials referred to, so much depends on the peculiarities of the local demands that brief general statements are again somewhat difficult. A few such may, however, be justified. For instance, experience has seemed to prove that in the use of tars or tar-compounds under the penetration method, better results have been secured where the softer materials have been used provided such softness was not secured by an excessive proportion of volatile or light oils. This seems especially true when considering the tendency of certain pitches to produce surfaces slippery in wet or cold weather.

As regards asphaltic materials (including oil residuum) it seems that in many cases where softness has been given by a generous amount of the middle oils (non-volatile) the resulting surfaces under this method have shifted under traffic in warm weather and evidenced "lubricating" rather than the necessary "binding" characteristics of the pitch compound.

Regarding the quantity of pitch to be used under the penetration method while the character of the wearing course (as to sizes, kind, etc., of the material) will affect the decision, it may be stated that ordinarily the successful amount of bituminous material per square yard of surface seems to have been between 1½ and 2 gals. The writer has built entirely satisfactory work with as low as 1¼ gals. per square yard, but under exceptional condi-