Manning's formula, in its original form, is practically as good as Kutter's for channels of small or ordinary dimensions. Although his roughness coefficient is slightly more variable than Kutter's $n$ in cases where the roughness conditions are constant, this disadvantage is more than offset by the greater simplicity of the equation. However, for unusual conditions such as the Mississippi River, Kutter's formula possesses the advantage. The average error of the results calculated by the Manning formula for the gaugings of Humphreys and Abbot was 19.8 per cent., while the average error of those calculated by the Kutter formula for the same gaugings was only 4 per cent. For general applicability the Kutter equation undoubtedly possesses an advantage. The form of Manning's equation given by Parker probably would prove satisfactory for a limited range of conditions. For general use, however, it could hardly be recommended.

### Kutter Includes Slope Correction

The only essential difference between the Bazin and Kutter formulas is that the latter includes a slope correction, while the former does not. Both investigators started with the same fundamental form. In fact, for certain values of $m$ (coefficient of roughness in Bazin's formula), $n$ and $S$ (friction slope; or, if the velocity is constant, the surface slope), the two formulas are identical. For each value of $m$ greater than 0.36 there is a set of values of $n$ and $S$ for which the Kutter formula will give results identical with those given by the Bazin formula, for all values of $R$. For values of $m$ less than 0.36, $S$ would have to be negative in order for the two formulas to be the same.

Kutter complicated his equation by introducing the slope in such a way as to cause $C$ to increase with an increase in $S$ when $R$ is less than one meter, to be independent of $S$ when $R$ equals one meter, and to increase as $S$ decreases when $R$ is greater than one meter. In all cases, the effect of a change in $S$ is greatest for flat slopes, decreases as $S$ increases, and becomes negligible when $S$ is about 0.001. Kutter's determination to introduce the slope in this manner was based primarily on a study of Humphreys' and Abbot's gaugings on the Mississippi River and on the measurements made by Bazin in a small experimental channel.

Bazin concluded that the slope effect shown by the Mississippi River gaugings was due to errors in measurement rather than to any general law applying to the flow of water. Although he recognized the effect of $S$ on $C$ in certain series of his own experiments, he did not consider it to be of sufficient importance to warrant its introduction into a general formula.

Many engineers have criticized the Kutter formula on account of its containing the slope term. Some have expressed the opinion that $C$ always increases as $S$ increases, while others have claimed that $C$ is entirely independent of $S$. Practically all of them have admitted the accuracy of Bazin's work and have questioned the accuracy of the Mississippi River gaugings. Bazin's experiments were made in an artificial channel about 6 feet wide and about 3 feet deep, while Humphreys' and Abbot's gaugings were made in a river channel about a mile wide and sometimes as much as 135 feet deep. Such inaccuracies as do occur in the latter are due to the unfavorable circumstances under which the measurements were made, rather than to any lack of care on the part of the observers.

### Velocities Too Large

A careful study of the gaugings made by Humphreys and Abbot, which were used by Kutter in determining his slope term, has been made. This study included a comparison of their results with the later and more accurate work of the Mississippi River Commission, as well as a comparison of vertical velocity curves obtained by double floats with those obtained by current meters. It was found that the velocities as given by Humphreys and Abbot are probably from 6 to 10 per cent. too large; that the cross sectional dimensions are probably accurate within allowable limits; and that the values of $S$ may possibly be in error as much as 55 per cent. at Columbus, from 7 to 21 per cent. at Vicksburg, about 27 per cent. in the case of the two gaugings at Carrollton having the steeper slopes, and over 100 per cent. in the case of the other two gaugings at Carrollton.

### Should Not be Rejected

On first thought it might seem that the magnitude of these possible errors is great enough to discredit Humphreys' and Abbot's work. However, if consideration is given to the unfavorable conditions under which the measurements were made, as well as to the amount of knowledge and experience available at that time regarding the gauging of such streams, it seems remarkable that the results are as good as they are. The results obtained from the measurements at Columbus, and those obtained from the two gaugings at Carrollton where the slopes were least, are the only ones that should be rejected. Although the other gaugings offer but a poor basis for a general formula, they do merit consideration, especially since errors of a given amount in $S$ cause errors of only about half as much in $C$. Of course, none of the measurements should be rejected on account of the errors in velocity, since allowance can readily be made for such inaccuracies.

While the various engineers who have criticized the Kutter formula on account of its containing a slope correction, have differed somewhat in their opinions as to the effect of $S$ on $C$ in small channels, they have unanimously claimed that $C$ does not decrease as $S$ increases under any conditions. However, no one of them has ever submitted data in support of his statements. A study of the question seems to show that in the case of large channels having flat slopes, $C$ does decrease as $S$ increases.

For small channels the evidence is not so consistent. Practically the only data at hand suitable for investigating this effect in small channels is that taken by Bazin. Studies based on such of his data as might properly be used for this purpose, did not show any definite effect. Out of five comparisons only one indicated an increase in $C$ with an increase in $S$. The other four did not show any appreciable effect of $S$ on $C$. Bazin's conclusion was apparently justified in the case of small channels.

It is not unlikely that for open channels $C$ always decreases with an increase in $S$, but that this effect becomes appreciable only in instances where the slopes are unusually flat. It is not possible to say at present whether or not the magnitude of the effect is dependent on the size of the stream, since no data is available for small channels with flat slopes.

### No Detailed Comparison

Although a great many engineers have discussed the relative merits of the Kutter and Bazin formulas, no one of them has ever made a detailed comparison of the two equations. The nearest approach to a satisfactory comparison that has ever been published is the one given by Bazin when he proposed his new formula. A cursory examination of this might lead to the conclusion that Bazin's formula is the better of the two. However, a careful study of Bazin's work shows that he was somewhat partial to his own equation. In certain instances his classification of experiments seems questionable. In others, as for instance, the Irrawaddy measurements, he hid the agreement of the Kutter formula by platting only average values. While he did not fail to point out the advantages of his own equation, he neglected to call attention to those of the Kutter formula.

Several engineers have said that in series of experiments where the roughness conditions were plainly constant, Bazin's $m$ is less variable than Kutter's $n$. However, as in the case of the criticisms of the slope effect, no one of them submitted evidence to prove his statements. Studies made on the basis of 24 series of experiments, covering a wide range in conditions, showed that the average variation of $m$ exceeded that of $n$ in 23 instances out of the total of 24, and that in the 24th series the variation in $m$ was as great as the variation in $n$. The mean of the average variations of $m$ for all of the series was 9.67 per cent., while the corresponding value for $n$ was only 3.58, about one-third as great. Out of the total of 24 comparisons, 16 were based on Bazin's own measurements.

There is no question but that Kutter's formula is the best equation for open channels at the present time. Although