By using the "S" scale up to 4° only and obtaining other values by direct proportion, A_0 values may be obtained.

From the relation vers A = sin A × tan $A/2$, the versine of any angle from 11° 26′ to 90° can be obtained. When A is between 0° and 4° the corresponding sine of $A/2$ may be substituted. From 4° to 11° 26′ the corresponding sine $A/2$ may be used and the result increased by $\frac{A/2 - 1}{10}$ percent.

Accuracy to be Expected in Slide Rule Results.—Assuming that for the ordinary operation of multiplication the final reading can be made within 1/250 of an inch, it can be shown that the result read off can be relied on for equations 1, 2, 3 and 8 on the "A" scale to within 2 in 1,000, and for equation 4 on the "D" scale to within 1 in 1,000. When the versine is obtained from both the sine and tan scale the result might vary in the extreme by about 3 in 1,000 but would probably be less than this amount in error.

x_1 and y_1 values obtained from x and y values might vary up to 1/250th and are consequently not very reliable for large angles and radii.

The usefulness of the slide rule for computing properties of curves can be determined by a consideration of the accuracy desired in each particular case.

Actual Tests of Graph and Slide Rule.—Fig. 4 shows a portion of Block 39, St. Julien addition to Banff. It was desired to find offsets from line AB to points 2, 1 and C, DC a parallel to AB being tangent to curve at point C. The offsets were found by plotting and scaling to a scale of 20 feet to an inch.

In order to calculate offsets from AB it is necessary to first find offsets from CD. Then, by simple subtraction the desired offsets can be found.

Table I. shows results obtained by direct calculation, slide rule and graph. For comparison, values found by subtraction from the results as the draftsman obtained them by plotting and scaling are also given. The slide rule is sufficiently accurate for the case given and much more accurate than the scaling in this case. In any event, it is obvious that the slide rule or graph provides a comparatively quick and useful check on plotting or calculation from mathematical tables.

LEAKAGE FROM PIPE JOINTS.*

By F. A. Barbour.

THE fact stands out that in entirely metered systems, or in systems where the meters exceed 85 per cent. of the services, at least 20 per cent. of the water furnished is, on the average, unaccounted for, and the question arises as to whether we should be content with such a condition. It is to be noted that this 20 per cent. loss is not based on a comparison of pump records with the water sold, but on the figures furnished by superintendents as to the water unaccounted for in their systems, these figures presumably making corrections for such items as pump slippage. It would seem that a loss of 20 per cent., due to leakage from mains and services or to under-registration of meters, which undoubtedly represents the best conditions, is sufficiently sizable to justify careful consideration of possible remedies.

We all know that the total unaccounted-for water in unmetered systems is enormous; presumably we all agree that metering is the great remedy; and yet, as reported by the United States Department of Commerce, only 40 per cent. of the services are metered in 201 cities, containing 26,000,000 people and having an average per capita consumption of 139 gallons per day. This total loss is not the subject of our immediate discussion, but as a means of calling attention to present standards of management a few figures may not be amiss.

The total population in the United States supplied with water from public works may be taken, for present purposes, at 50,000,000 people, and the average amount of water furnished per day at 100 gallons per capita. The total water supplied daily by public works is, therefore, in round figures, 5,000,000,000 gallons. It is probably a safe statement that 50 per cent. of this quantity is wasted. Assuming the actual cost of furnishing the useless 2,500,000,000 gallons to be $25 per million gallons—and this is an extremely low figure—the cost per day of the water wasted is equal to $62,500, or $22,800,000 per year, which is equal to the interest on an investment of $500,000,000. Figured in this rough way, the results do not speak well for our present-day standard of management of water systems. If it should be answered that it is not practicable to prevent this loss, a reasonable reply would be that at least we should know more about its causes than apparently is known at the present time.

As already stated, metering is the great means of reducing the total waste on which the previous figures are based. There remains, however, the fact that in the fully metered systems, on the average, at least 20 per cent. of the water furnished is unaccounted for, and probably if more accurate data were available this percentage would be shown to be materially greater.

Emil Kuichling estimated 2,500 to 3,000 gallons per mile per day as the leakage from well-laid mains; Dexter Brackett estimated a leakage of from 10,000 to 15,000 gallons per day in the Metropolitan District; and John R. Freeman stated that his best guess of the underground leakage in New York was from 25 to 35 gallons per day per capita, equal to from 20,000 to 30,000 gallons per day per mile of pipe. In six cities, with 95 per cent. of the services metered, reported by Brackett in 1904, 36 per cent. of the water was unaccounted for, equal to an average loss of 11,300 gallons per mile of pipe. James H. Fuertes, in the 1906 report to the Merchants' Association of New York, presented statistics from thirteen cities in which on the average 82 per cent. of the services were metered, which showed that 31 per cent. of the supply was unaccounted for, equivalent to approximately 18,000 gallons per mile of pipe. What part of these losses are chargeable to the mains is unknown, but from the results of such leakage surveys as have been made, and from the reported actual losses discovered in some cities, it is probable that 7,500 gallons per mile of pipe per day is a conservative estimate of the water lost by leakage from the 60,000 miles of mains now in use in the public supplies of the United States, or 450,000,000 gallons daily. At $25 per million gallons, this is equal to a daily loss of $11,250 or $4,110,000 per year, or the interest on $100,000,000. In the light of this economic waste it would, therefore, appear that the subject of leakage from mains is worthy of careful consideration.

The Committee on Water Consumption of the New England Waterworks Association reported in 1913 that "in general it may be said that if in a well-metered system the water unaccounted for does not exceed 25 per cent. of the total pumpage, the practice is good." Doubtless this should be interpreted to mean that a 25 per cent. loss

*From paper read before the November meeting of the New England Waterworks Association.