A SIMPLE CIRCULAR COMPUTING SCALE.*

By JAMES ALEX. SMITH.

IT is not necessary to emphasize the utility of mechanical aids to computation in modern engineering practice. Although for some purposes calculating machines are almost indispensable, yet much routine work can be more expeditiously dealt with by applications of the slide-rule methods, provided a sufficient approximation to accuracy is attainable, a result not always following the use of the less complex commercial scales reading to one part in one hundred only.

The writer some years ago constructed a very satisfactory instrument of the circular scale type, requiring for its production, chiefly, a comparatively moderate acquaintance with the use of the dividers and drawing-pen. Three figures are significant, that is, the results as read, are correct to one part in one thousand, but, by estimating the fourth figure, possible error may be confined within still smaller limits. Operations in multiplication, division, reciprocals and logarithms may be effected; a number may also be raised to the square, cube, or other power, or any root may be found.

Of course, a well-constructed slide-rule, if of sufficient length, would have an equal scope, but to read

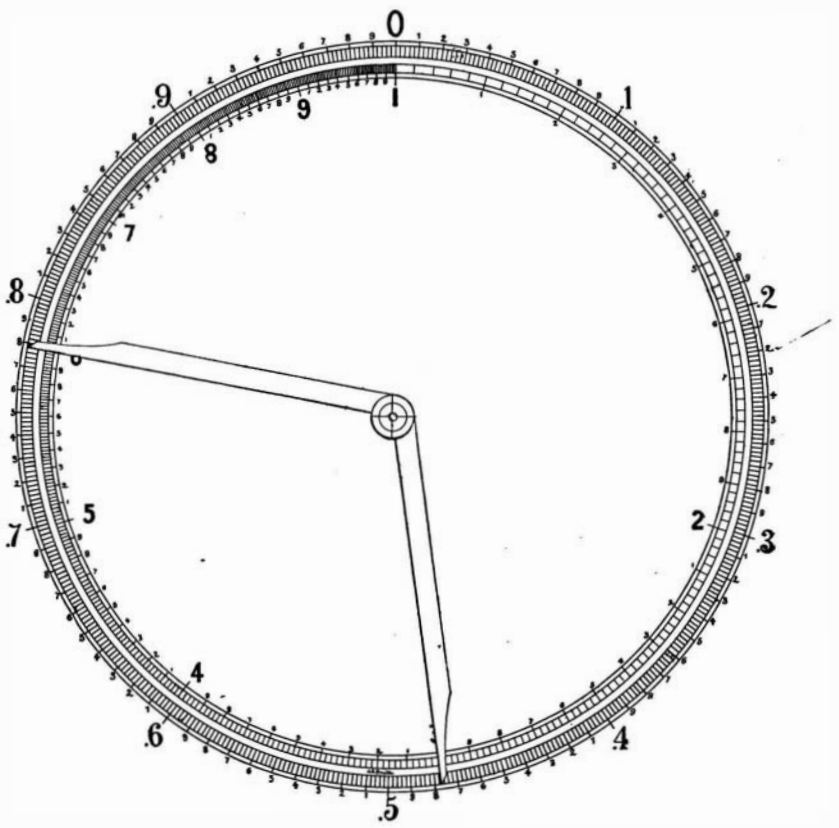


FIG. 1.—SIMPLE CIRCULAR COMPUTING SCALE.

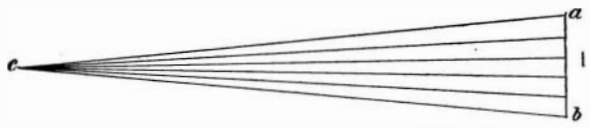


FIG. 2.—HOW DIVISIONS ARE SUBDIVIDED.

to three figures there must be at least 1,000 graduations, the smallest less than 1-2,000 of the aggregate. Since the minimum space readily recognizable is about 1-50 inch, it follows that such a scale must have a length of at least 40 inches, and in the straight rule the necessity of carrying forward the results requires the duplication of the series, which would then become 80 inches long, or when the adjacent scales are fully extended, 160 inches, a prohibitive length.

Continuity and compactness are both secured by the use of a circular instead of a rectilinear form; a single series of divisions then constitutes an endless scale, and a circle of about 13 inches diameter replaces the pair of 80-inch slides.

Fig. 1 shows the method of graduating the instrument, but owing to the reduced scale on which it is reproduced the divisions are not as small as possible. The relation between numbers and their logarithms, as represented by commensurate spaces, will be observed. The logarithms (outer circle) are equally spaced; the successive correlated numbers (inner concentric circle) are, reckoning clockwise, in a series of gradually reducing intervals, diminishing in a ratio which it is not necessary to consider here; it suffices to state that it is identical with that of the usual logarithmic tables.

It is a property of a logarithmic series that numbers (or lengths, measured always from an initial point or base line, 1 in the inner circle of the diagram) if *added* will give a number equivalent to the product of the numbers taken. Conversely, if *subtraction* be substituted for addition, the resultant number is equal to the quotient obtained by the division of the given numbers, one by the other. To assist in the calculations a pair of pointers are employed which are hinged together and are also pivoted to the center of the scale disk. As an example of the method of multiplying, place the inner edge of one of the pointers in coincidence with 1, or the fiducial mark on the circle of numbers, extend the other limb to, say, 2; bring the first edge to, say, 3; then the second edge will fall upon 6, as shown in the diagram. Thus a part of a logarithmic scale extending to 2 has been added to a part extending to 3, and the sum is a part extending to 6, equal to their product; that is, by a process of addition 2 has been multiplied by 3. Conversely, assume that with, say, the same setting (2), from 6 the part 2 is taken, then the indicator falls upon 3, and division of rotation, it virtually enters upon a second revolution or extension of the scale, and the value so found must in consequence be increased or decreased tenfold, according as to whether multiplication or division is in progress. For instance—still with the setting of 2—if the part 2 be added to the part 9, the indicator crosses the base 1 and marks 1.8 in a second revolution, hence the result must be read $1.8 \times 10 = 18$.

To raise a number to any power, either whole, decimal or mixed, or to extract the corresponding root, advantage is taken of another property of a logarithmic series, viz.: if a log. of a number be simply multiplied or divided by the numerical value of the given power or root, the result will be the logarithm of the respective power or root required.

To illustrate: Assume that the cube of 2 is required, then radially adjacent to 2 in the inner circles of numbers will be found .301 in the outer circle of logarithms; this is the logarithm of 2, hence if the logarithm .301 be multiplied by the number of the power given, in this case 3, the result will be the logarithm of the number sought. Adjacent to .903 in the circle of logarithms will be found 8 in the circle of numbers, therefore 8 is the value of 2 raised to the third power or cubed.

Conversely, to find the cube root of 2. Logarithm of $2 = .301$ as before, $.301 \div 3 = .100$ (nearly) or the logarithm of the number sought; adjacent to .100 the number is 126; allowing for the decimal point this is read 1.26, and is—within the limits of accuracy of the instrument—the result.

In making an instrument of this sort the primary essential is the logarithmic, or outer circle, decimally divided, preferably into 1,000 equal parts. In the absence of a lathe or gem cutting machine the graduations may be effected as follows: Step the circle into five equal parts and bisect each of these to obtain the ten primary divisions; do not trust wholly to the dividers, or to a preliminary bisection by a line drawn through the center, but check the result by transferring the points to a segment of thin card, and applying it to each division before final ruling. Divide the paper arc into ten secondary parts, first bisecting, then stepping by 5. Check these and when found correct, transfer to the ten segments of the circle. Similarly divide one of the secondary spaces into ten spaces, and carry the tertiary marking round the circle. The whole of the divisions in the circle of numbers may be set out by the use of the table of logarithms in conjunction with the graduations of the outer circle, but the method would be extremely tedious. The writer found that after a certain number of points have been determined by such comparison, a few simple devices serve to apply the rate of variation so obtained to the other segments, and to carry the work on quite expeditiously.

The logarithms of the primary points 1, 2, 3, 4, 5, 6, 7, 8, 9, are respectively .000, .301, .477, .602, .699, .778, .845, .903, .954.

If the figures in the second line be located in the outer circle, then the points on the same radius in the inner circle adjacent are the positions of the primary numbers, 1—9.

The places of the secondary, or decimal divisions, of segment 1 to 2 are similarly found by the following tables:

Number....	1.1,	1.2,	1.3,	1.4,	1.5,	1.6.	1.7,	1.8,	1.9,
Log.....	.041,	.079,	.114,	.146,	.176,	.204,	.230,	.255,	.278.

For closer reading each of these secondary segments is further divided into two—not bisected—by the use of the following:

Numbers...	1.05,	1.15,	1.25,	1.35,	1.45,	1.55,	1.65,	1.75,	1.85,	1.95.
Log.....	.021,	.061,	.097,	.130,	.161,	.190,	.217,	.243,	.267,	.290.

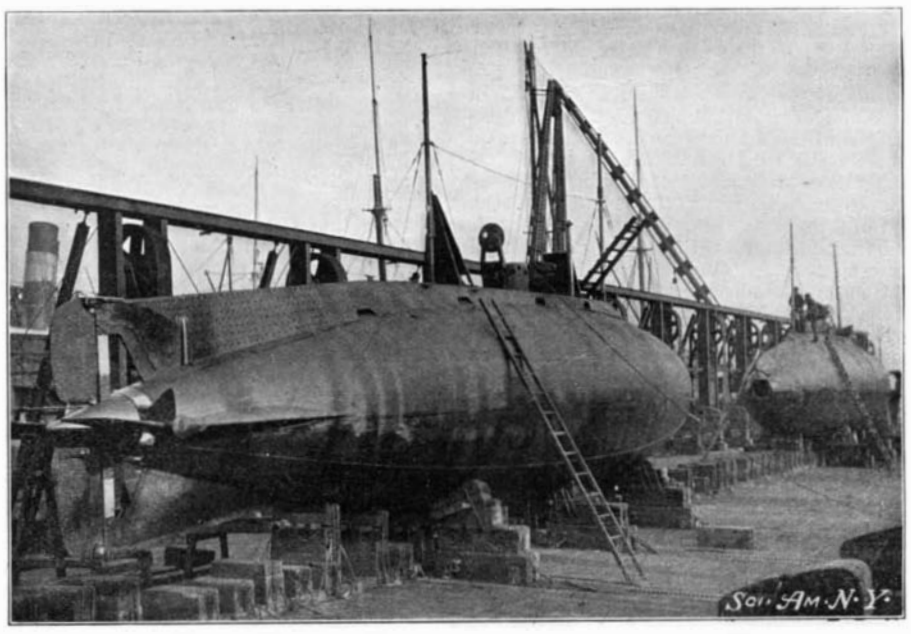
The divisions may now be carried fully round the circle and be subdivided into the smaller spaces by a form of diagonal scale, thus: Lay off on a piece of thin, hard paper, a line *ab* Fig. 2, slightly longer than the chord 1 to 1.1, or 1 to 1.05 if the division has been carried to twenty parts. Divide this line into five equal segments. To a point *c*. distant about 12 inches perpendicularly from the center of *ab*, draw from the end of each segment an accurately straight line. Snip across the lines until a straight section of the paper shows an overall measurement across the lines equal to the chord to be divided, then prick or dot off on the arc, continuing to cut back toward *c* as the divisions to be dealt with decrease in magnitude.

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

THE SUBMARINE BOATS "PIKE" AND "GRAMPUS."*

THE "Grampus" and "Pike," two submarine boats of the Holland class, built at the Union Iron Works, San Francisco, Cal., have just passed all the tests to which they were subjected by the Navy Department.

On June 7, 1900, the government authorized the construction of six submarine boats, of which the craft recently finished at San Francisco formed a part. The "Grampus" and "Pike" are each 63 feet 4 inches in length, 11 feet 9 inches in diameter, and have a displacement, submerged, of 120 tons. When on the surface they are driven by a single-screw, four-cylinder, Otto gasoline engine of 160 horse power. They are provided with a generator of 70 horse power, which may either be driven by the gasoline engine for charging the batteries, or be thrown on to the batteries when the boat is submerged and used as a motor for driving the propeller. Like the rest of the class, the "Grampus" and "Pike" are built with a double bottom, and with three watertight compartments. In the forward compartment are the gasoline tank and the torpedo tubes. The amidship compartment contains the main ballast tanks, which are located in the double-bottom. Above them are the storage batteries, the torpedoes, and the air flasks, in which fresh air for the crew is stored at 2,000 pounds pressure. In the third compartment at the stern are the gasoline engine, motor, the clutches, and the steering gear.



THE "GRAMPUS" AND "PIKE" IN DRYDOCK.

Submersion is effected by trimming tanks assisted by a pair of horizontal driving rudders at the stern. The vessel is controlled from a conning tower protected with four inches of armor.

ELECTRIC SODIUM MANUFACTURE IN GERMANY.

H. DANNEEL gives some interesting information concerning the electric sodium industry in Germany. Four establishments are engaged in the manufacture. At Bitterfeld, the Elektrochemischen Werke use no less than 3,000 horse power in the process, but information concerning the output of the metal is not given. Another establishment, at Rheinfelden, uses 1,600 horse power, the resulting sodium being consumed in the

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