which the pin on the crank enters. To get 1-76th of a division, the pin must evidently move over 10 spaces in the 19-hole circle. By continuing to move over 10 spaces you finally divide the circle. The sectors shown are adjustable, and form a guide to the space moved over, obviating the necessity of counting at every division. Although the calculations required are not very intricate, the tables supplied are, I may safely say, always used.

This method, when the worm and wheel are accurately cut, furnishes excellent results, far excelling in speed and accuracy the ordinary stepping off process. But if it is wished to graduate circles for astronomical purposes, as near accuracy as possible is required. The divisions are made by a worm wheel and worm, as before, but in this case, in the most approved form, the worm wheel is nearly 4 ft. in diameter, and has 4,320 teeth around the circumference, each tooth, therefore, representing a division of five minutes of arc. This wheel is in the first place divided by hand and requires the most extreme care, delicacy of touch, and microscopical exactness.

One method of dividing it, due to John Troughton, is a method of bisection. The wheel is very carefully turned and polished (no scratches) on its edge and face, and along a fine circle drawn on the face near the periphery the divisions are laid out. The radius laid out from zero gives 60°. This arc bisected and the half laid off from 60° gives 90°. The arc between 60° and

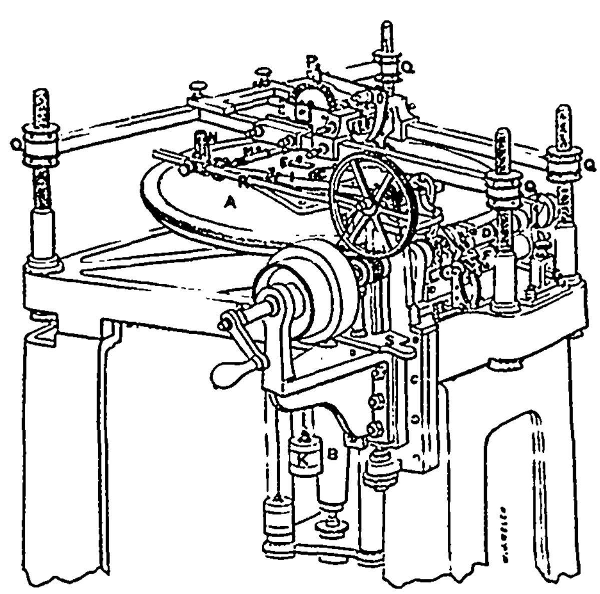

Fig 8
Dividing Engine.

90° bisected, gives 75°, and between 75° and 90° gives 82° 30', while the arc between 82° 30' and 90° bisected, gives 86° 15'. Further, the arc between 82° 30' and 86° 15', trisected, gives 85°, while the arc between 85° and 86° 15', trisected, gives 85° 25'. Lastly, the arc between 85° and 85° 25', quinquisected, gives 85° 20', and this equals 5' x 2", and so can be finally divided by continual bisection. A very fine dot, visible only to the microscope, is made at each point of division, and the errors of these dots are determined and tabulated by the aid of reading microscopes, mounted on radial arms. Finally, the teeth are cut exactly opposite the corrected positions of the dots by a cutter. Fig. 8 shows the completed machine. The plate A. is 46 inches in diameter, and has two sets of divisions, one faint on a silver inlaid ring, and the other stronger on the gun-metal. The rest of the machinery is for making the scratch and turning the plate automatically.

Another and very appropriate example of the use of mathematics arises from the cutting of the teeth on such worm wheels. Given a wheel of given diameter, with a given number of teeth, find the pitch of the worm, and the converse, given the pitch of the worm, find the diameter of the wheel for any given number of teeth. Again, given the pitch and the diameter of the worm, find the angle at which the cutter must be set in order that the teeth and worm may exactly fit. Finally, given the shape of the worm thread, determine the form of the cutter, that the wheel and worm may work smoothly and uniformly together. To solve these problems will require, besides arithmetic, a fairly thorough knowledge of geometry and elementary trigonometry, and also a knowledge of the properties of, and an ability to trace two plane curves, the involute and the epicycloid.

Such problems are continually arising in machine work, and although rules and tables can be obtained for the guidance of workmen in standard cases, other cases are very likely to arise in which original calculations will have to be made. When such is the case, how much better it is that the workman should be able to undertake the calculations himself. He then has the satisfaction that always follows a problem solved, and moreover stands a much better chance of advancement than if he were a mere machine, able only to follow rules, and depending on the guidance of tables.

It follows, from the examples that have been given, that the mathematics required in the actual performance of ordinary operations, if the calculation is to be done by the mechanic, are a thorough knowledge of, and capability of applying the principles of arithmetic, a knowledge of geometry, including descriptive geometry and mechanical drawing, and a knowledge of the elements of plane trigonometry, particularly the solution of triangles. These seem to me to be necessary to the comprehension and intelligent performance of many common operations.

I can only, in conclusion, state my belief that, although mechanics manage to perform their work tolerably satisfactorily with their present very deficient mathematical training, if even such a course of mathematics as I have outlined could be imparted to every artisan, both the quality and quantity of the work produced would be considerably enhanced, and also there would result to the workman himself a very decided advantage.

—The Engineers' Club of Toronto, at its meeting Dec. 5th, heard a very interesting paper on the Trigonometrical Survey of the Dominion, by O. J. Klotz, Astronomer to the Department of the Interior, Ottawa. The club then discussed the sewage disposal report of C. H. Rust, city engineer, Toronto, and at the close of the discussion Prof. J. Galbraith moved and E. B. Temple seconded a resolution which calls for the disposal of Toronto's sewage otherwise than in the harbor, by building intercepting sewers and by "treating the sewage by the most approved modern methods." This seems easy enough in a resolution and the Engineers' Club doubtless felt that the sanitary condition of the city was being vastly improved, but it