as single acting cams, the follower being returned to position by some outside force.

In Fig. 25 is shown a follower, F, whose line of motion does not intersect the axis of the cam, but is placed at some distance to one side thereof. To produce the same motion as before the contour must, of course, be modified to suit the position of this line. In Fig. 26 is shown a cam which is circular in contour, but whose center is not coincident with its axis of rotation, a—that is, it is an ordinary eccentric. Such a cam as this will of course, move the follower exactly the same as if it were driven by a crank with a pitman of infinite length—that is provided the end of the follower is made flat at right angles to its line of motion and of a width exceeding its stroke, all as shown in the diagram. In Fig. 27 is shown the ordinary heart-shaped cam, which gives a motion somewhat similar to the last named, but with more sudden changes at the times of reversal.

In Fig. 28 is shown a follower which is in the form of a lever instead of being a slide, as in the other diagram. In this case too, the contour of the cam must be modified to suit the arc f, which replaces the straight line incident to a sliding follower. Although the term "follower" may not be in very general use I have here adopted it as a convenient and suggestive name for any member of a machine which is driven directly by a cam, whether it slide, as in Fig. 22, or oscillate about a center, as in Fig. 28, or whether it move in any other line than here given, as it might be, were it guided by irregular sufaces or by swinging levers at its different ends. The two forms here shown are, however, almost universally used in practical work.

In Fig. 29 is shown a cam which, starting at the zero point o, will move its follower out for a short time, then hold it at rest during the passage of s', then out again at o', then at rest again at s'', then in at i, then at rest again at s''', then in at i', then at rest during the passage of s to the starting point at o. Owing to the lack of words of a definite meaning, describing the teeth, inclines, corrugations, jams, lugs, horns, spuds, or whatever they may be called, upon the surface of the cam, I have sometimes in my own practice used the system of marking shown in Fig. 29, where o stands for the first time going out, o' for the second time, etc. The various i's stand in the same manner for "in," and the s's for "stay." The general term for the irregular surface of the cam would, according to this method, be the "ins and outs." This is not offered as an ideal system, but as a makeshift which, upon further trial, may prove useful enough to adopt as a standard in any drafting-room where it is well enough liked. It is applicable to the various forms of cams already mentioned, but in the case of double-action cams the direction of the follower, whether in or out, would have to be indicated upon the drawings.

So far we have with one exception been considering followers whose bearing surfaces upon their cams were theoretically knife edges. Of course this will not work in practice, and said edges must be somewhat rounded to an approximately cylindrical or flat form. This change of shape modifies the form of the cam in the same way as does the insertion of a roller in the end of a follower, the action of which will be presently described. In the practical laying out of cams it is usually not necessary to go very far into the mathematics of the subject, as the "mechanico-graphical" method referred to in a former paper is generally the easiest, and the shape of the cam can readily be made to accommodate itself to any kind of a follower surface which may rest upon it.

Wherever practicable (unless, indeed, the pressure is very light and the speed moderate) the follower should be furnished with a roller, preferably of as large diameter as convenient, and not too heavy, which roller is almost as necessary to reduce friction and wear as are the wheels of a carriage in substitution for a sleigh upon snowless ground. In Fig. 30 is shown a roller, R, resting upon a cam, C, with a dotted line, C′, representing the path of the axis a' of the roller relatively to the cam. It is evident that this dotted line is the real cam—that is, it is the shape which directly determines the motion of a', just as does the contour of C, Fig. 22, determine the motion of F by means of its sharp edge at its lower end. A little reflection will show that C is not a reduced duplicate of C′, but that all points in its surface are thrown in radially from like points upon C′ by the amount of the radius of R—that is, in the case of a' sliding in a straight radial line. In Fig. 31 is shown an effect that may be produced by using too large a roller, where the reduction in size of C′ to suit the radius of the roller has made the cam impracticably sharp. Even if the point at P could be perfectly sharp, the sharpest possible shape that could be obtained at P′ would be an arc of a circle with the radius of R. Thus it will be seen that there is a practical limit to the suddenness of reversing the motion of a follower, dependent upon the relative size of the cam and roller, and upon the sharpness of edge which will be durable upon the cam. The remedy for such trouble as is shown in Fig. 31 is found in making the cam of larger diameter, and perhaps the roller smaller.

With a given diameter of cam, rotating a given speed, there is, of course, a limit to the velocity at which the follower can be driven, based upon the fact that if the inclined plane is too steep the side stress and the consequent friction upon a follower driven upward by it becomes so great as to preclude its practical use. This angle (marked 45° in F. 18) should, in the writer's opinion, never exceed that figure where it is upon the "driving" side of a cam tooth, and a greater angle, say 60° or more, is still better. Of course upon the "following" side it can be much more acute, providing the follower is pushed down fast enough to stay in contact with the cam, and not possess the fault, which many followers have in real life, of moving sluggishly on account of being pushed by springs which are too weak, or, of an attempt to make gravity work faster than nature designed it should. Such followers are apt to strike very unpleasant blows upon the cam at a point where they were intended to glide smoothly. With a curved incline upon a cam, as shown in Fig. 22, the contour should not be at any point less than 45° with a radial line which may be struck from the axis through such point—that is, upon the driving side, as before said. Whenever it is found that the desired speed of motion necessitates a less angle than this, the only remedies are either to make the cam rotate faster or to enlarge its diameter, so that it may have a greater suface speed.

Note.—In the article preceding this, in June *Mechanics*, on page 164, second column, 2½ inches from the top, immediately after the word "Philosophy," the following was unfortunately omitted: "Of course a much more complete and scientific analysis of this whole matter may be found in the works of Reuleaux upon Kinematics, and many new ideas may be obtained by an inspection of his cabinet of models at the Gewerbe Akademie, in Berlin." This awkward mistake made the writer appear to say that models of the "507 mechanical movements" referred to had been brought to Cornell University, instead of the Reuleaux models, as intended.—*Mech.*

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14 x 20 Ft BORING AND TURNING MILL.

We illustrate herewith a new boring and turning mill recently brought out by the Niles Tool Work: of Hamilton Ohio.s

This machine has been designed to meet the wants of shop whose occasional needs require a machine to turn work of 20′ diameter or more. For the ordinary requirements of these shops a mill to swing 14′ is ample, put at the same time it is important when the need arises, they can operate on much larger work. The purchase of a mill 20′ swings involves a very large outly, too large an investment in one machine for the amount of work there is to do. Constructed as this mill is the additional investment to enable it to operate on large work is but little greater than the necessary investment in a 14′ mill and hence does not tie up a large amount of money for machinery to meet an occasional want.

This mill is a 14′ boring and turning mill, provided with extention bed-plate and power apparatus for moving the housings and entire upper works back so as to take in work over 14.′ diameter. The mill is exceedingly well arranged for this purpose. All the movements required are made by power and the changes from 14′ to 20′ can be made very quickly.

The mill is made very strong and substantial and has ample power to carry two good cuts at the extreme swing 20′ The extension bed-plate can be made for any required swing 20′ however is as large as is usually required.

The machine as illustrated, is built to take in work 5′ high, but this can be increased if desired, mills having been built to take in work 10′ high. Table is 10′ diameter. The driving cone has nine steps and is strongly back geared, affording 18 changes of speed. The boring bars have 48″ traverse.

They are counterweighted and have quick return. The bars are counterweighted by a single weight, arranged so that the strain is always directly through the axis of the bar. This device is patented and is an important feature of the Niles mills.

The bars are easily and quickly handled and undue wear in the bearing prevented. Each head has quick hand traverse by rack and pinion. The bars may be set over to operate at any angle. They are brought exactly to the center of the mill, so