amples in the designing of machines that have been in actual use in various workshops, giving one or more illustrations of each.

Taking the general, if not universal, type of all our factories; it must first be understood that we may divide their works into a series of machines. The required power to move them is obtained from the pressure of steam in a closed boiler, or from the flow of water acting on the paddles of a wheel. This wheel, or in the case of steam power the engine, constitues the first machine; and in many cases the next step is to apply it to turn a heavy fly-wheel, whose use is to render the motion as uniform as possible through its own momentum. The motion so obtained is then carried on, by means of belting and lengths of shafting, through all the different floors of the building; and then applied to the last series of machines, those that do the actual useful work.

To proceed now more into details, it may be noticed that there is placed on the main shafting over each machine, or more accurately speaking, directly useful machine, a rather plain and small wheel; which is connected by means of a belt or strap with another, very similar to it, but forming a part of the machine itself. Thus all the intricate motions of the various parts of the latter are merely a resolution or transference of the first simple uniform circular motion, through the aid of a large number of devices.

The first inconvenience that might appear to a novice to be caused by this arrangement, is that while all would be very well as long as every machine in the factory was at work at the same time; supposing it happened as must often be the case, that several were not required to be in use, would it not then be very undesirable to have such continue in motion, wearing themselves out on nothing; not to mention the loss of power, the increased space required, or the danger of the workmen? This difficulty, however, it is almost needless to mention, has long been got rid of by a very simple device, so common that it must surely be familar to every one that takes any interest in machinery; as it leads to a further part of the subject though, we will take it for our first example.

The upper wheel on the main shaft is made of increased width (sometimes continuous between the points of support) so as to allow of the strap moving sideways along it for a short distance. Below are placed two wheels, side by side, almost touching similar in form to the upper one, but of a width only a very little greater than that of the strap itself. The inner of these wheels is keyed firmly to its axle, which turns with it and drives the whole machine; the outer one turns round loose on its axle, and does not transmit its motion to anything. It will thus be seen that any machine provided with this device may be stopped or set in motion without affecting the others, by simply shifting the driving strap from one to the other.

We now come to what appears to be a second objection; the means of avoiding which are I think not so generally known. What is then to prevent the strap from slipping sideways on the smooth surface of the wheels, moving from one to the other, or falling off altogether; and might not such an occurrence do injury to a workman standing by, or cause great inconvenience through the accidental stopping or starting of the machinery at improper times? appear to be very natural questions. A round band running in a groove on the surface of the wheels is sometimes used to avoid these objections, but it cannot be shifted sideways without difficulty, and were a very strong and thick band required, too deep a groove would have to be made. The method that answers best, and is at the same time found just as safe as any other, is readily explained in the following way.

Any portion of a driving strap coming in contact with a wheel is held tight in whatever position it may happen to be in when the contact commences, and retained in that position during the whole time it is being carried round, and until it leaves the wheel on the opposite side. Thus if the strap happens to be deflected a little to the right on the advancing side, it will be so carried round the wheel, and work its way along it in that direction as long as the deflection lasts. This fact is taken advantage of when the strap is to be shifted; but its more important use is just what we are seeking.

Suppose the wheel become conical in shape, as shewn in the figure. The part of the strap at A would accommodate itself to the slanting surface under it; and the stiffness of the material itself would in consequence throw the lower portion into the curved form shewn, the part at B on the advancing side being nearer to the larger end or base of the cone than that at A. Now the rotation of every point being parallel to the base, the path of B would be along the dotted line; and the strap would continue working its way along the cone till it either became too tightly stitched, and was torn in too, or fell off the larger end. Suppose again though, that a second cone of the same size were placed on the same axle, sloping in the other direction, with the two bases touching each other; what must then follow is that the strap would take up a fixed position immediately over the junction of the two cones. This is what is actually done in practice, the slop of the cones being very slight, and the obviously objectionable ridge given to the wheel is shewn in the figure considerably exaggerated to make it more clear.

To take a further example in the application of this principle it may be observed from the above, that while it is necessary to keep the advancing side of a driving belt in the same plane as the wheel, it is of little consequence whether the retreating side be deflected off to the right or left, or not. The device shewn in the following figure will in consequence be found perfectly practicable so long as the motion is in one direction only, that shewn by the arrows, and a considerable distance be left between the wheels.

The wheels are placed on axles not parallel to one another, so that the motion is, as it were, carried round a corner. They need not be at right angles; but must in any case be so arranged that the part E of the upper one is in the same plane as the lower one and also that the part C of the lower, which has a slight projection to the front owing to the size of the wheel itself, is in the same plane as the upper wheel. It is quite evident that if the motion was reversed the strap would be at once cast off, in spite of any slightly rounded form the faces of the wheels might have received.

Before leaving this portion of our subject, a few words on the strength required in the belt or strap which is to work a wheel, seem needful.

It can be proved mathematically, an investigation into which it is not necessary for us to enter, that the pull in lbs. on the strap, that is on each return of it, when it is moving at the unit rate of speed of one foot per minute, is equal to the number of foot-pounds of force transferred by it in the same time. And further, that the pull decreases directly as the velocity increases. Thus, if we have to convey by a strap, from one wheel to another, a power of 162,000 foot-pounds per minute, and the strap is required to move at the rate of one foot per minute, it would have to be made capable of withstanding a pull of 162,000 lbs. But supposing we increase this impractically slow velocity to one of 600 feet per minute, or 10 feet per second, then the strap will have to withstand a pull of only $\frac{162000}{600}$, or 270 lbs.

Therefore, calling P the pull, V the velocity, and W the work done, we may state the formula:

$$P \times V = W$$

Care being taken in working with it to employ the same set of units throughout.

Thus to take another example, suppose a force of five horse power is to be carried over a strap moving at the rate of 6000 feet per minute:

5 H. P. = 5 x 33,000 = 165,000 foot pounds per minute, therefore $P = \frac{165000}{6000}$ $27\frac{1}{2}$ lbs.

It is interesting to note, that following this principle, through the aid of high velocities the old heavy leather bands have in some workshops been replaced by slender wire ropes; and that in one instance, the power to work a crane, capable of lifting a weight of 25 tons, has been carried over a cotton rope but $\frac{5}{8}$ of an inch in diameter, and weighing only $1\frac{1}{2}$ oz. to the foot.

CAMS.

About the simplest form of cam in use is the eccentric circle. An analysis of the motion produced by it, which is not uniform, would not be uninteresting; but as this form is so frequently met with in connection with the slide valves of steam engines, it will be well to omit examining it further, and proceed at once to the more complicated kinds of cams.

The one we shall first consider is merely a modified form of the eccentric circle, giving an intermittent motion, and used sometimes in connection with the slide valves of steam engines in which the expansion system has been adopted.

Bereft of all connecting gear, which, though of course a necessity, we may leave out of sight in considering the motion produced by the machine itself, it takes the form shewn in the accompanying figure. The tie-angular piece P, turning about C as a centre, and working within the rectangular opening, is the altered form of the eccentric circle. P is described by drawing a circular arc about each side of an equilateral triangle, with the opposite angle as centre. Thus C B is part of a circle having A as its centre, and A B and A C the same with C and B as centres.