such as are demonstrated by practical experience rather than deduced ftom mathematical data. What is said will apply especially to what is termed line-shafting, for conveying and distributing power in machine shops and other manufacturing establishments.

The strength of shafts is governed by their size and the arrangements of their supports.

The capacity of shafts is governed by their strength and the speed at which they run, taken together. The strains to which shafts are subjected are the torsional strain of transmission, transverse strain from belts and wheels, and strains from accidents, such as the winding of belts.

The speed at which shafts should run is to be governed by the nature of the machinery to be driven and the nature of the bearings in which the shafts are supported.

As the strength of the shafts is determined by their size, and the size fixed by the strains to which the shafts are subjected, the strains are to be first considered. There are three kinds of strain mentioned—torsional, deflective, and what was termed accidental strains.

To meet these several strains the same means have to be provided, which is a sufficient size in the shafts to resist them; hence it is useless to consider each of these different strains independently. If we know which of the three is the greatest, and provide for that one, the rest of course may be disregarded. This, in practice, we find to be the accidental strains to which shafts are subjected, and they are always made in point of strength far in excess of any standard that would be fixed by either the torsional or transverse strain due to the regular duty the shafts have to preform.

This brings us back to the old proposition, that for structures that do not involve motion mathemetical data will furnish dimensions, but the same rule will not apply in machinery.

Experience has demonstrated that for ordinary cases, where the power transmitted is applied with tolerable regularity, a shaft 3 in. in diameter, with its bearings four diameters in length, placed 10 ft. apart, and running at a speed of 150 revolutions a minute, is a proper size to transmit 50 horse power.

The apprentice, by assuming this or any well-tried example, and estimating larger or smaller shafts by keeping their diameters as the cube root of the power to be transmitted, the distance between bearings as the diameter, and the speed inversely as the diameter, will find his calculations to agree with the modern practice of our best engineers.

Shafts as a means for transmitting power afford the very important advantage that power can be easily taken off at any point throughout their length by means of pulleys or gearing, also in forming a positive connexion between different machines. Shafts are also the cheapest means of transmitting power within limited distances.

The capacity of shafts in resisting torsional strain is as the cube of their diameter, and the amount of torsional deflection in shafts is as their length. The torsional capacity being based upon the diameter often leads to what may be termed tapering shafts, lines in which the diameters of the several sections are diminished as the distance from the driving power increases, and as the duty to be performed growsless.

This plan of arranging line shafting has been and is yet quite common but certainly was never arrived at by any of the processes of reasoning that have been so continually alluded to in the course of this treatise.

Almost every plan of construction has both its advantages and disadvantages, and the best means of determining the excess of either, in any case, is to first arrive at all the conditions, as near as possible, then form a "trial balance," putting the advantages on one side and the disadvantages on the other, and foot up the sums for comparison.

Dealing with this matter of shafts of uniform diameter and shafts of varying diameter in this way, we find in favour of the later plan a little saving of material and a slight reduction of friction, so advantages; the saving of material relating only to first cost, because the cost of fitting is greater in constructing shafts when the diameters of the pieces are varied; the friction, considering that the same velocity throughout must be assumed, is scarcely worth estimating.

For disadvantages, there is the want of uniformity between fittings that prevents their interchange from one part of the shaft to the other, a matter of great importance; a shaft, when constructed in this way, is special machinery, adapted to some particular place or duty, and not a standard product that can be regularly manufactured as a staple, and thus afforded at a low price. Pulleys, wheels, bearings and couplings have to be all specially prepared, and, in case of change or extension of lines of shafting, this causes annoyance, and frequently no little expense. The bearings, besides being of varied strength, are generally in such cases placed at irregular intervals, and the lengths of the different sections sometimes varied to suit the diameter of the shafts.

Going next to shafts of uniform diameter, everything pertaining to the line is interchangeable; the pulleys, wheels, bearings, or hangers can be placed at pleasure, or changed from one part of the works to another. The first cost of a line of shafting of uniform diameter, strong enough for a particular duty, is generally less than that of one consisting of sections that vary in size, and all the above-named objections of diminishing are avoided.

I have called attention to this case, as one wherein the conditions of operation obviously furnish the true data to govern the construction of machinhry, instead of the strains to which the parts are subjected, and as a good example of the importance of analysing mechanical conditions.

If the general diameter of a shaft was predicated upon the exact amount of power to be transmitted, or if the diameter of a shaft at various parts was based upon the torsional stress that would be sustained at those points, such a shaft would not only fail to meet the conditions of practical use, but would cost more by such an adaptation.

The regular working strain to which shafts are subjected is inversely as the speed at which they run; a strong reason in favour of arranging shafts to run at a maximum speed, if there was nothing more than first cost to consider; but there are other, and more important conditions to be taken into account. Principal among them is the required rate of movement when power is taken off, and the endurance of bearings.

In the case of line-shafting in manufactories, if the speed varied so much from the first movers on the machines as to require one or more intermediate or countershafts, the expense of fitting in this manner would be very greatly increased; on the contrary, if countershafts can be avoided, there is a great saving of belts, bearings, machinery, and obstruction.

The practical limit of speed is in a great measure dependent upon the nature of the bearings, a subject that will be treated of in another place.

IMPROVED WATER WHEEL GOVERNOR.

The apparatus illustrated on page 132 is used in connection with the governor, where there is a variable head of water and when it is desirable to keep up the head though at the sacrifice of speed. Its greatest utility is realized where steam power is employed in connection with water power. The water governor being speeded to run the line a trifle faster than the steam governor, the engine is relieved of its weight so long as there is an available head for the supply of the wheel; but when the water is drawn down to a given point, say from three to twelve inches, the governor automatically closes the gate sufficiently to allow the water to regain the lost head, and, when at the available point, automatically resumes its natural action. All this is accemplished by very simple means, as shown by the engravings. The reservoir is placed so that the high water line in the flume is within three inches of the top of the reservoir.

Our engravings represent opposite sides of the apparatus; and in Fig. 2 is shown the reservoir and float in connection.

The operation is as follows: Water is admitted from the flume through the pipe, I. The float, B, in the reservoir A, rises with the water, and the cord is slackened, which leaves the governor to the natural action. As soon as the water lowers to any given point (regulating according to length of cord), the pawl shifter, C, is drawn down, throwing the closing pawl, F, into action, and the water is closed off. Tho machinery being all in motion, the gate would become closed, with a tendency to go beyond, but for a stop motion which limits the hoisting and closing of the gate, and which is simply a sliding bar inside of the bracket D, and operated by the worm, E.

Another feature of the governor is an adjustable weight connected to an arm of the pawl shifter, C, but not shown in the engraving (other parts of the machine being in front of it). By means of this sliding weight the speed of the governor may be changed from 140 revolutions to 165—a great convenience