of the indicator and the regulation by means of an accurate tachometer. The bearings are all carefully adjusted and the engines operated for at least a whole day under loads varying from zero to one hundred per cent. overload.

The McEwen engine is a high-speed engine designed especially for extremely close governing under the severest and most rapid fluctuations of load—such as are met with in the driving of electric generators for electric lighting, electric railway service, mine haulage, electric crane work, etc. The accompanying illustration shows a compound McEwen engine, built by the Waterous Engine Works Co., Brantford, Ont.

ROLLER AND BALL BEARINGS.*

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The subject is a very extensive one and is the cause of a great deal of correspondence in our leading mechanical and scientific journals. No department of mechanical design or construction has received more careful consideration than that of roller and ball bearings. Very rapid strides have been made recently in the perfecting of roller bearings, making their employment more common. We read of roller bearings having been used 25 years ago, but with little success, owing chiefly to the way they were constructed, and it is only within the last few years that they have been so constructed as to make them practicable. For many years the only successful application of rolling motion to bearings was the ball bearing so universally adopted in bicycles, and although these bearings have been found most satisfactory when subjected to light loads, all attempts to apply them to heavy loads have so far resulted in failure, arising chiefly from the balls indenting the races upon which they run. As soon as this takes place, the balls begin to lose their friction reducing properties. If a semi-circular trough be constructed which accurately fits a ball and one end of the trough be raised, it will be found that the ball will move by sliding and not by rolling; this is indentation carried to the extreme. Another defect in the ball bearing is that the balls are allowed to touch each other, and as the touching point of any two balls are revolving in opposite directions, there must be a certain amount of friction. The same error in the construction of roller bearings was made until cages were introduced. These cages serve the double purpose of keeping the rolls in alignment with the axis of the shaft and of keeping them separated from each other, doing away with the friction caused by the touching points of the rolls running in the opposite directions as is the case of ball bearings. Judging from the various size of balls used in bearings, one might be led to suppose that ball bearings knew no law.

A few years ago very small balls were used, but they proved very unsatisfactory, for cones and cups were soon destroyed and had to be renewed. The same error was made in roller bearings, and when the cages were introduced, and less rolls used in the same size bearing, larger rolls had to be used to bear the same load. Those who advocate the use of small balls, and the same argument holds good with rolls, argue that as the balls bear on a point, and as more small balls can be placed in a bearing of a given size than large ones, there are more points of contact, and the result, a more durable bearing. The error in this argument is, in assuming that a ball or a roller bears on a point, which is not the case, excepting when working under a very light load, but when the bearing is loaded, the rollers or balls are slightly compressed and the very slightest compression causes the point of contact to enlarge. If a large roller or ball is compressed, to the same extent, the point of contact will be greater than in the case of the small roller or ball, because the larger the sphere the flatter the curve. Tests have been made to prove beyond doubt that the carrying capacity of rollers and balls is as the squares of their diameters, in other words one ½-inch ball or roller will carry as heavy a load as four ¼-inch ones. The writer has made tests with loading ¼-inch rollers in bearings until the weight was sufficient to elongate the rolls by rolling them out, and thus reducing the size, and in a very short time rendering the bearing useless.

The question is very often asked, how much do roller bearings reduce friction, or how much less power does it require to run a shaft fitted with roller bearings than one fitted with ordinary bearings. While there is very little reliable information on this point, experiments have shown that friction increased little if any, with the increase of pressure, and that the friction increased considerably less than the proportion of the square root of the speed. In tests made by Geo. F. Symons it was shown with bearings 2½-inch in diameter that the friction developed was from .0025 to .005; these figures were obtained under comparatively light loads. In comparing ball bearings with babbitt bearings, it was found that under 200 lbs. pressure to the square inch, and 800 revolutions per minute, babbitt bearings 2½-inch in diameter lubricated with 20 drops of oil per minute, and having a ½-inch lateral play, heated badly. Under the same pressure ball bearings were running at 2,600 revolutions per minute, or more than three times as fast, without signs of heating. The American Machinist of October 17th, 1895, gives the following: "The first was in the shop of Brown & Sharp, where a set of rolls used for rolling sheet steel, cold, were first operated for some time with ordinary bearings, previous to the change, a 6-inch belt running over a 24-inch pulley on a machine had been found inadequate to drive it, and a 4-inch belt had been placed over it. The two belts arranged in this way had driven the machine, but it had been found impossible to run more than a few hours at a time on account of the heated bearings. After putting in the roller bearings it was found that a 1-inch belt would drive the machine when doing the same work, and we recently saw a 2-inch belt driving the machine, and were informed that it was regularly used, running on the same pulley. It had been found unnecessary to stop on account of hot bearings, and the speed had been increased 25 per cent." There is here shown such an enormous advantage in the use of rollers, as to make the plain statement of the facts seem like a fairy tale, but we can vouch for its accuracy in every particular. It shows that a very great advantage may be gained by roller bearings in some cases, and also shows that a very large proportion of the total driving power applied to rolls when used on such work is consumed in overcoming frictional resistance in the machine. The pressure required to slightly reduce the thickness of a strip of hard tool steel 6 in. or 8 in. wide is, of course, very great, and the actual foot pounds of energy required to do it, must be small. The consequence is that the great pressure upon the bearing causes corresponding frictional resistance in them which consumes practically about all the power applied to the machine, and this gives to the roller bearings a chance to make perhaps the very best possible showing. In a machine where the actual work to be done required more power, and the frictional resistance less, proportionately, the showing might be expected to be very different. Such a case, and one more nearly representing the average condition under which comparisons will be made, is to be seen at the establishment of the Gilbert Clock Co., at Winstead, Conn., where there are 600 feet of line shafting, having 104 bearings of the usual type, lined with babbitt metal, and these bearings were replaced by roller bearings. The shafting is driven by a 40 h.p. water wheel and, according to the brake or dynamometer tests made 25.02 h.p. of this was absorbed by the frictional resistance of the line shaft when using the old bearings as against 18 h.p. with the roller bearings, thus saving 7.02 h.p. or 17.55 per cent. of the whole power developed by the wheel, and 28 per cent. of the original friction of the shaft. Fourteen Mossburg roller bearings were on June 29th, 1897, applied to a 3-inch shaft, 80 feet long, running 200 revolutions per minute, and subjected to careful and repeated tests which showed a saving of more than 50 per cent. in power required to overcome the friction of the shaft running in babbited bearings. The shaft had been thoroughly tested when running in the ordinary babbited boxes, and found to consume by friction, when running at full speed, 6.21 h.p., and to come to a standstill in two minutes after being disconnected from the source of power. Similar tests were made after the shaft had been fitted with roller bearings; the power required to overcome the friction being found to be only 3.01 h.p. and the shaft revolved ten minutes after being disconnected from the source of power. The bearings have been in use six months, running 22 hours every day, and are in first-class condition, showing little wear, and giving very little trouble. From an article taken from The Canadian Engineer, on roller bearings, by W. Bayley Marshall, C.E., we learn the result of the following test A passenger train of six carriages fitted with roller bearings throughout, has been running for

*A paper read before the Mechanical Superintendents' Association.