

AN IMPROVED ABSORPTION DYNAMOMETER

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In testing prime movers, the engineer often laments the dearth of efficient power-absorbing apparatus. Especially is this true in the testing of small high-speed machines, such as automobile engines and steam turbines. In many cases the number of machines to be tested is large, in fact in some instances each machine is given a b.h.p. test before leaving the factory; and in every case where a high degree of reliability is essential from the output, the percentage of machines undergoing test must be large. The attention of the writer was forcibly called to this need several years ago in the testing of a small steam turbine running at 2500 r.p.m., and through this experience the type of apparatus described below was designed and has been used with satisfactory results.

2 In the design of such a piece of apparatus, the following points were to be considered. These are enumerated in the order of their supposed importance.

- a It should be free from binding or "seizing."
- b It should be free from producing changes in the load, due to changes in the apparatus itself, such as change of temperature, wear or friction of parts, etc.
- c It should be capable of absorbing and accurately indicating a wide range of loads, from zero to the full capacity of the machine.
- d The regulation of the load should be positive and instantaneous.
- e The apparatus should require a minimum amount of attention and be capable of continuous service.
- f It should be self-contained, occupy a small amount of floor space, and be free from noise and the splashing of oil and water.

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g It should be capable of being quickly changed from one prime mover to another.

h It should require a small amount of cooling water.

3 In considering the above items, it will be noted that Items *a* and *b* practically eliminate mechanical-friction apparatus from the field, while Items *b*, *c* and *d* practically eliminate machines depending upon the friction or resistance of liquids for their operation. With these two classes of apparatus removed, there remained only the principle of magnetic induction for the construction of an efficient absorption dynamometer.

THEORY

4 From this principle we know that a conductor revolving in a field of variable magnetic intensity has an electric current induced

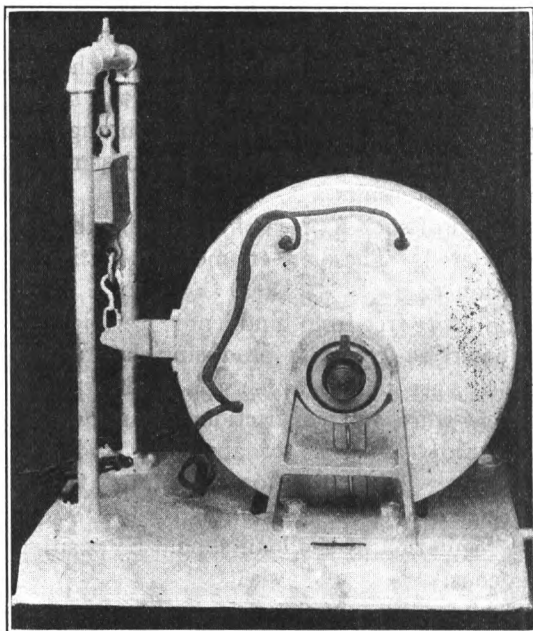


FIG. 1 MAGNETIC ABSORPTION DYNAMOMETER

in it. The reaction of this current upon the field that produces it causes a torque between the conductor and the field. There are two ways of dealing with the current induced in the conductor. In

one, the current may be collected by a commutator or slip rings and carried off from the machine; in the other, the current, or rather currents, generated in the conductor may be allowed to remain, and, circulating in the paths of least resistance, they will ultimately short-circuit among themselves and produce heat.

5 In the first case, we have simply a dynamo mounted in a cradle. This serves as a very efficient and satisfactory type of dynamometer. There are, however, objections to its use. The currents generated must be taken care of either by water rheostats or lamp banks or utilized in the performance of work. Water rheostats and lamp banks require considerable attention and occupy space. Owing to the irregu-

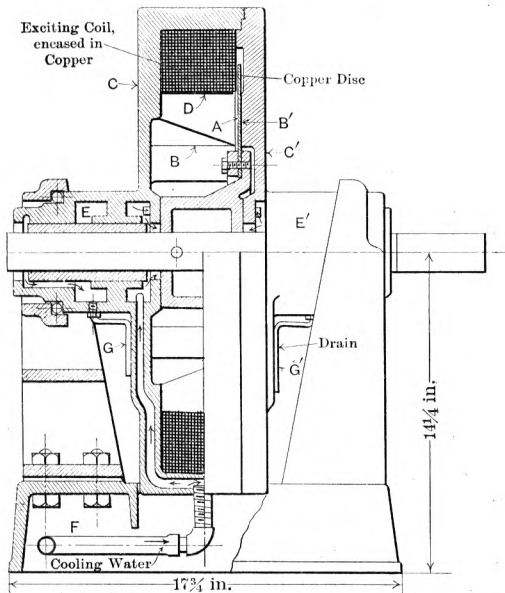


FIG. 2 END ELEVATION AND PART SECTION

larities in the testing, the utilization of the current for the performance of work is in most cases impracticable. The initial cost of a testing unit of this type is necessarily large.

6 If the currents in the conductor are permitted to short-circuit themselves, the conductor is heated; the amount of heat produced is equivalent to the work absorbed by the dynamometer; and the heat thus generated may then be carried off by cooling water. [This is the principle utilized in the design illustrated, a description of which follows.

DESCRIPTION

7 In brief, the dynamometer consists of a metallic disc revolving between a set of pole pieces so constructed as to produce a magnetic field of variable intensity. Fig. 1 shows the front view of a machine designed to absorb 45 h. p. at from 1200 to 1500 r.p.m. Fig. 2 is an end elevation and part section showing the construction of the dynamometer. It will be seen from this figure that it consists of a copper disc *A*, mounted on a bronze hub and revolving in front of pole pieces *BB'*. The magnetic circuit is made up of the casting *C*, the air gap and the cover plate *C'*. The castings *C* and *C'* are bolted together and carry

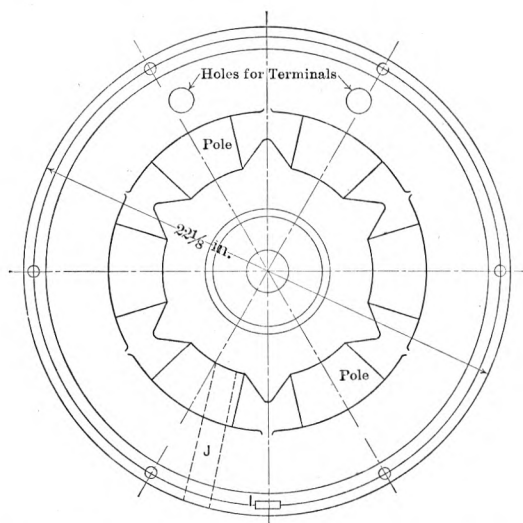


FIG. 3 LEFT HALF OF FIELD CASTING SHOWN IN SECTION IN FIG. 2

the exciting coil *D* and the bearings *E* and *E'*. The magnetic yoke, made up of castings *C* and *C'* carrying the field coil and disc, is supported in ball bearings, and is prevented from rotating with the disc by the spring balance shown in Fig. 1. This latter measures the pull or torque between the rotating disc and the stationary yoke.

8 The magnetizing coil is encased in copper, the terminals being carried out through holes in the casting *C*, which are carefully sealed after the coil is in place.

9 The heat generated by the short circuiting of the eddy currents generated in the copper disc, is carried off by the cooling water which

enters through the base connection at *F* (Fig. 2) and passes up through the bearings into the field casting. It then passes out through openings which are not shown in the illustration. This water not only carries off the heat generated, but serves as a lubricant for the bearings. That which passes through accumulates in the central chamber *E*, and is discharged at the base of the machine through the drains *G G'*.

10 Fig. 3 is a detail drawing of the left half of the field casting *C*, shown in section in Fig. 2. It will be seen that there are six poles in the machine. The circulating water enters at *I* and leaves through the port at *J*. Similar ports are provided in the cover plate *C'*, Fig. 2.

OPERATION

11 In operating, the engine under test is directly connected to the dynamometer shaft by means of some form of flexible coupling, the cooling water is turned on and the engine is started. After normal speed is reached, the load may be thrown on by energizing the field coil. The amount of current, and consequently the torque or pull on the spring balance is regulated by a rheostat connected in series with the coil. After running a few minutes, the quantity of cooling water is adjusted so that the temperature of the machine does not exceed 150 deg. fahr. In larger machines the coil may be wound with asbestos-covered wire and the temperature permitted to reach 212 deg., so that the cooling water is evaporated within the dynamometer. This reduces the quantity of cooling water required about 75 or 80 per cent.

12 The normal working temperature having been reached, the load on the machine remains absolutely constant, provided the line voltage is constant; for the mechanical friction, which is the bearing friction of the revolving disc, is small and practically constant and changes in temperature due to changes in the supply of cooling water also affect the load on the dynamometer very little. The regulation by the rheostat is instantaneous and positive. When the dynamometer is driven by a smooth-running engine, the torque as indicated by the spring balance will not show a variation of $\frac{1}{8}$ lb., while the balance is sensitive to less than $\frac{1}{16}$ lb. This indicates an accuracy that is not necessary even in the most refined testing work.

RELATION BETWEEN SPEED AND TORQUE

13 In the case of the present machine the torque is almost pro-

portional to the speed and is maximum at about 600 r.p.m. From this point the torque drops off about 15 per cent at 1200 r.p.m., and remains almost constant from 1200 to 1500 r.p.m.

14 The torque depends upon the speed, number of poles, thickness of air gap, thickness of the copper disc, shape of the copper disc, and shape and spacing of the pole pieces. By varying the number of pole pieces, and the thickness of the copper disc, the point of maximum torque on the speed-torque curve may be shifted anywhere from 25 r.p.m. to 2500 r.p.m.

CONCLUSION

15 This type of dynamometer is well adapted either for the testing of high-speed motors with a wide variation in speed, such as the automobile engine, or for the testing of slow-speed apparatus having a small variation in the speed. It can be built in practically any size from 10 h.p. up. The principal disadvantage is the high initial cost, although this is not an item where serious and continuous testing work is going on, as in factories or in the laboratories of technical schools, for the labor saved and the increase in capacity resulting through the use of the machine will in a short time more than pay for the initial outlay.

16 The efficiency, which may be expressed as the ratio of the energy absorbed by the dynamometer, minus the energy supplied to the exciting coil, divided by the energy absorbed by the dynamometer, may be made anything up to 99.9 per cent and depends upon the weight of copper placed in the coil. Ordinarily the efficiency is made about 96 per cent, or 4 per cent of the power absorbed by the dynamometer is required in the form of electrical power for excitation.

DISCUSSION

C. M. ALLEN. This paper describes a unique and interesting form of absorption dynamometer, but practically all of the claims brought out in the paper are applicable to and descriptive of the Alden absorption dynamometer. The Alden absorption dynamometer never binds or seizes if it is properly set and operated, and with the automatic valve attached, the internal friction, temperature, wear, etc., have no effect on its keeping balanced steadily, holding the load constant for an indefinite period of time. It accurately indicates the load from full capacity practically to zero, merely the friction of its bearings is

indicated, and I do not see why the dynamometer described in this paper would not have the same amount of initial load. The regulation of the load on the Alden brake is positive, and although not instantaneous in its true sense, the full load can be put on or off as quickly as the valve can be opened or closed. The Alden brake also requires very little attention if properly set up and operated. The automatic valve entirely does away with any hand manipulation, keeping the load constant for hours without any attention. For a given amount of horse power, the Alden brake probably takes up as little room as the one described in this paper, because the brakes can be made with multiple discs. They run as quietly as any ordinary oil bearing and are as free from splash of oil and water. They are also readily changed from one prime mover to another. They can either be mounted on a portable stand, as the one described in this paper, or they can be put on the overhanging end of the engine shaft. The amount of cooling water ordinarily used would be a little greater with the Alden brake than in the electrical dynamometer described in order to keep the temperature of the machine lower for the best operation; but for small machines running at high speeds, it is perfectly feasible to run the cooling water hot enough to make steam.

We have used Alden dynamometers in the laboratory of the Worcester Polytechnic Institute for a good many years, ranging in size from discs 6 in. in diameter up to 34 in., in horse power from $\frac{1}{10}$ up to 150, and in speed from 0 up to 3000 r.p.m., and we are convinced that they are reliable, accurate and comfortable machines to work with. These brakes have always done the work demanded so exceptionally well that the writer has taken up the testing of large water-wheel units after installation. Further particulars concerning the action of these large dynamometers are given in the paper on *The Testing of Water Wheels after Installation*.¹

The Alden dynamometers are used extensively in a large number of engineering schools of this country and abroad. They are also used by a great many of the largest automobile manufacturers in this country for testing their engines before installation in the cars, and in some cases after installation by connecting a dynamometer to each end of the rear axle.

These remarks concerning the Alden dynamometer are entirely unnecessary for those who are familiar with it, but were written for the benefit of those who are still looking for a reliable and accurate prony brake.

¹Trans., vol. 32, p. 275.

THE AUTHOR. I am very glad that Professor Allen has brought out the advantages of the Alden brake as compared with those claimed for the dynamometer described in my paper. The Alden dynamometer fulfils very nearly the specifications outlined for the magnetic dynamometer. However, I believe that the latter has the advantage of requiring less attention and about one-tenth of the weight of water, or in some cases much less; also of the elimination of mechanical friction which renders seizure of the rotating with the stationary parts a very remote possibility. While this is well taken care of in the Alden brake, yet if the temperature of the water rises so that the lubricating oil becomes less viscous between the discs there is always present this danger. I further believe that the regulation or the changing of the load requires a greater amount of attention. The magnetic dynamometer, if properly constructed, operates as steadily as an electric motor and is, without doubt, the ideal machine in so far as operation is concerned.