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PREFACE

THE Electrical Engineer is now confronted with a variety of new problems for whose solution he must look to a full development of the science of electro-dynamics. This in the near future will stand in the same relation to the electric-motor that the science of thermo-dynamics stands in now to the steam engine. And since no branch of dynamics has a better claim to be called an exact science than electro-dynamics, it will be able to offer not only convincing but final solutions of these problems. To apply the principles of electro-dynamics to the direct-current motor is the aim of this book.

Writing for Electrical Engineers particularly, I take for granted a certain acquaintance with the use and design of motors, but, as the book is intended to be of service to engineers generally, unexplained technicalities have been avoided as far as possible.

There are now so many excellent text books on electricity and magnetism, that I offer no apology for omitting discussion of elementary principles here.

I have not considered it necessary to allude to the subject of self-induction, except in connection with the question of sparking. The advanced student will perceive the analogy between the law of acceleration given in Chapter VII. and that for the rise of current in an inductive circuit, and may be tempted to pursue the subject for himself.

The numerical accuracy attempted has been limited to that attainable with an ordinary ten-inch slide rule, on which all the examples have been worked out. Importance is attached to the graphic method of solution, and the diagrams are intended to serve as exercises for the student, who should work out similar problems with different data by the same methods.

I have to thank many friends for assistance, particularly Mr. H. S. Hering, for allowing me to use the results of his tests on electric cars; Mr. L. H. Parker, for providing me with particulars of the construction and performance of the electric locomotives on the Baltimore and Ohio Railroad; Mr. H. P. Curtiss, for placing at my disposal the outcome of his experiments on the Buffalo and Niagara Falls Electric Railway; and the Railway Department of the General Electric Company, for furnishing me with valuable information and data.

C. A. CARUS-WILSON.

McGILL UNIVERSITY, MONTREAL:
February 1898.

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CHAPTER V

SERIES-WOUND MOTORS

When the **magnets** of a dynamo are **connected in series with the armature,** the induction factor will vary with the current. In Fig. 20 distances measured along *ob* represent current in the armature, and also in the magnets. We will take 500 volts as the tension of the line, 5 ohms as the resistance of the motor, the maximum current being thus smaller than 100 amperes. Let the distance 01 represent 100 volts, 10 amperes, 100 r.p.m., 1,500 inch-pounds of torque, and an induction factor of 15. Let *oa* represent the tension of the line, *ob* the maximum possible current. Join *ba*, and produce it. We shall call *ba* the loss line, since the intercept *kc* of any ordinate between it and a horizontal line through *a* gives the volts lost in heat. On *ob* construct the induction curve. Thus, if for a current of 70 amperes, the induction factor is 67·5, we must set up on the point representing 70 amperes in the armature, a vertical distance equal to 4·5 inches, and this will be a point on the induction curve.

If there is no residual magnetism the induction factor is nothing when the current is nothing. When the current is reversed the induction factor will also be

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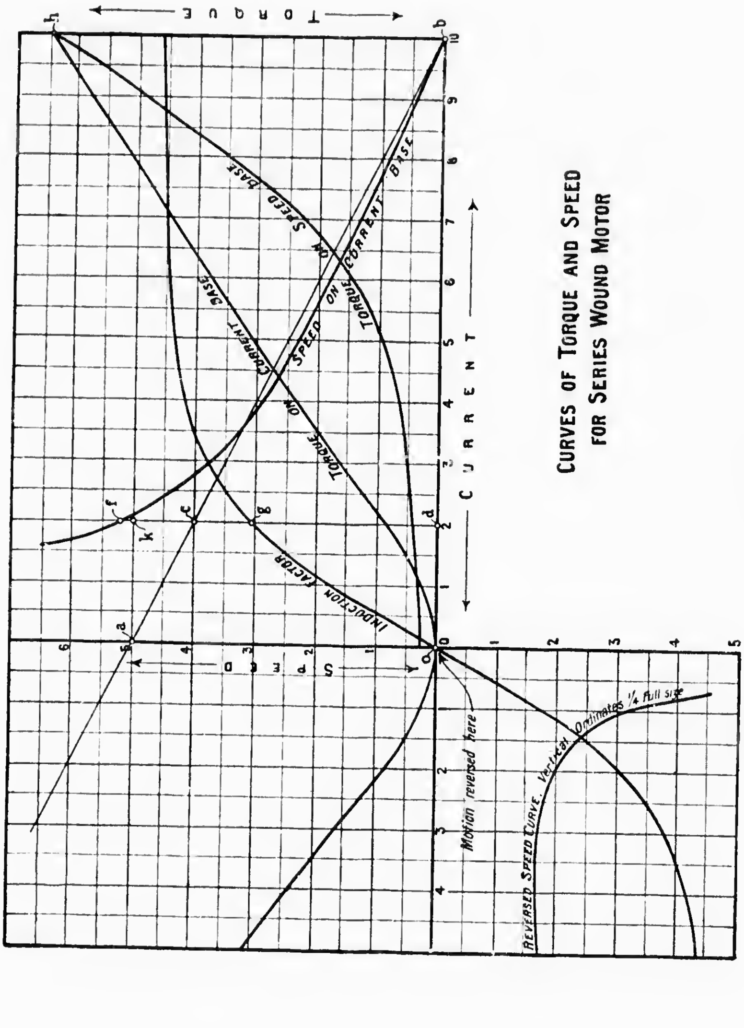

CURVES OF TORQUE AND SPEED FOR SERIES WOUND MOTOR

FIG. 20

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Fig. 20

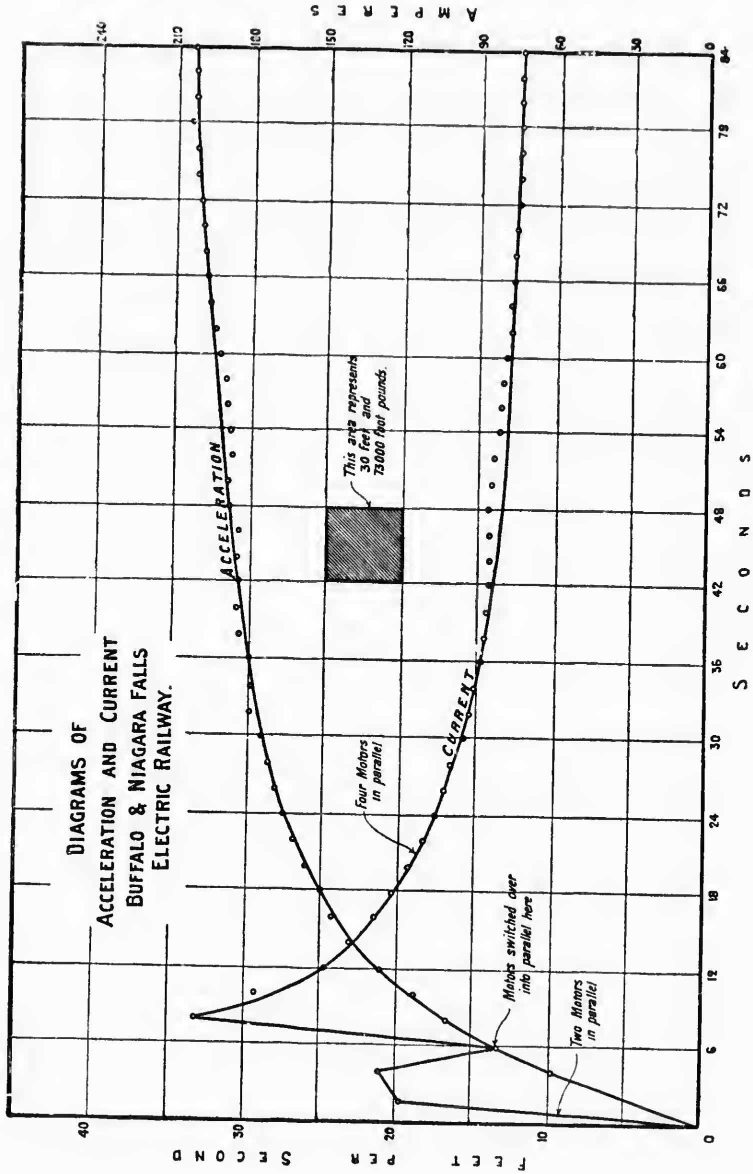

Fig. 51

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speed up is well shown. The final current is 18 amperes per motor.

The mean current for the first four seconds from the moment when the circuit is made appears to be 75 amperes. This would give us a total torque per motor (see Fig. 21) of 2,430 inch-pounds. Deducting the frictional torque corresponding to a current of 18 amperes per motor —namely, 755 inch-pounds—we have 1,675 inch-pounds available for acceleration. Since the weight to be accelerated is 3·4 tons per motor, the acceleration is 2·05 f.p.s. per second. The acceleration curve has been drawn as if the acceleration were constant from the moment of making the current; this is not strictly correct. The curve should cut the time base about one second from the origin, but it gives a fairly accurate measure of the mean initial acceleration, which by measurement appears to be about 2·1 f.p.s. per second.

Fig. 52 is the record of a test in which the motors were allowed to speed up in series. The current taken does not appear to have been quite so much as in the case represented in Fig. 51. The form of the current curve is well shown, both with the series and with the parallel connection, and indicates the jerk experienced when the motors are thrown into parallel, the acceleration at this point being greater than at the moment of starting. The energy required to attain a speed of 35 f.p.s. is less than that required by the method illustrated in Fig. 51.

The diagrams show a considerable increase in the current taken from the line at the moment when the motors are thrown into parallel connection. It is instructive to inquire if this increase is necessary, and to

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Let us take the case of a tramcar weighing 10 tons, driven by two motors working on a line having a tension of 500 volts. Suppose that we have to design an arrangement by which the car will start up from rest and travel 500 feet in 30 seconds. The motors are to be series wound.

First find the least possible accelerating current per motor by Equation 107, remembering that $W=5$ tons. We get $c_a=29 \cdot 5$ amperes. Take 30 amperes to allow for the resistance of the motor. From Equation 103 we find that the best value of $\frac{Mv}{d}$ is $5 \cdot 15$. For the present we may take $v=4 \cdot 78$ and $d=33$ inches, giving $M=35 \cdot 5$.

The maximum speed is 25 feet per second or 17 miles an hour. If the frictional and other resistances retarding the motion amount to 3,580 inch-pounds of torque on the car axle, the corresponding current will be 15 amperes, and the resistance of each motor must therefore be 0·6 ohm.

The initial acceleration will be 1·25 f.p s. per second, and the current of 45 amperes will be constant until the starting rheostat is all out, at which point the speed of the motor will be given by $n=\frac{500-45\times 0 \cdot 6}{35 \cdot 5}=800$ r.p.m. The speed of the car will therefore be 24·2 feet per second. Thus we see that if the induction factor is constant, the acceleration can be maintained constant up to a speed of 97 per cent. of final speed; after this point the motor will speed up according to the law already given in Chapter VII.; the error involved in assuming that the acceleration is constant up to full speed will be small, and

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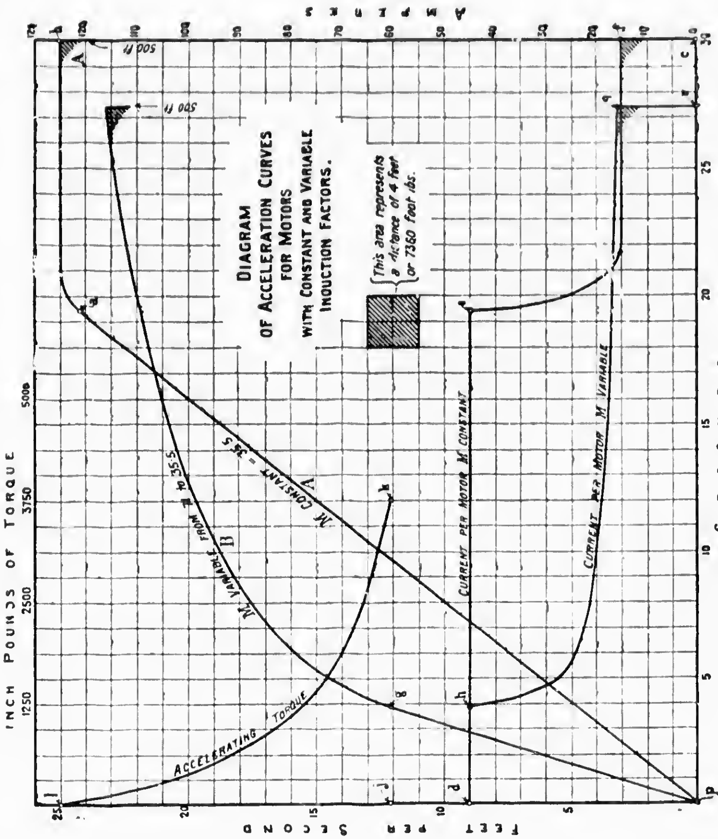

FIG. 56