Discussion on Acyclic (Homopolar) Dynamos.

F. B. Crocker: At the Philadelphia meeting of the Institute in May, 1894, the speaker read a paper entitled "Unipolar Dynamos for Electric Light and Power." It received little encouragement then and there has been very little since that time. The present paper is therefore welcome, as it is the first ray of hope in 11 years for the successful development of a machine of this type. This paper gives evidence of real progress; the machine is not experimental—not a one-kilowatt machine generating one volt, but one that gives 300 kilowatts at 500 volts.

As a matter of fact it is the original Faraday type. Faraday also proposed to multiply the pressure by connecting discs in series; he suggested the revolving of discs in opposite directions in the same field and connecting their peripheries by brushes or mercury, thus causing the current to flow outward in one disc and inward in the other, the current being taken from the two shafts. There are still other methods of multiplying the pressure besides the one which the author uses. One way is to have concentric cylinders revolving in the same field, the current entering one end of the first cylinder, passing out at the other end, then passing through the second cylinder in the same direction, and so on—a series connection threading through the field repeatedly in the same general way as in the machine described by the author, the inductors however being concentric cylinders instead of elements of a cylinder.

The author has adopted a plan of splitting the cylinders longitudinally into strips, like the staves of a barrel, and then connecting these strips in series. The speaker understands that there are 12 of these strips and 24 brushes, one brush at each end of each of these elements of the cylinder. This type of machine is one in which the inductor, whether an element or the whole cylinder, revolves in an annular space, in which the field is always in one direction and, as nearly as possible, of uniform strength throughout. Therefore, the electromotive force is simply the number of lines of force cut per second divided by 10^8. A conductor one foot long moving 12 000 feet per minute or 200 feet per second in a field of 90 000 lines per square inch, would generate 26 volts.

The fact that the armature reaction *in the air-gap* does not materially affect the flux is interesting, but is what we might expect from the fact that cross ampere-turns do not materially reduce the flux in ordinary dynamos. It is the back ampere-turns that have that effect. In the present case there are cross ampere-turns but no back ampere-turns. On the other hand *in the iron*, as shown in Figs. 10 and 11, because it becomes partly saturated, the resultant flux due to two magnetomotive forces acting at right angles, is not equal to the square root of the sum of the squares, because that implies that the reluctivity is constant, whereas we know it increases with the density, consequently in that case the flux is not so great. Nevertheless

Mr. Noeggerath says at the bottom of page 9, that the regulation is good, and that the difference between full-load and no-load pressure is only slightly higher than the drop; in other words, armature reaction is not excessive, only slightly greater than the resistance drop. He said, during the presentation of his paper, that it was only 6 or 8%. It is very interesting to see, in one of the diagrams given, that by merely moving the brushes forward or backward, the conductors connecting these brushes with the circuit had the effect of compound winding or differential winding; and that you might even have a series machine, without any field winding, because the current going into the armature, and out again, as it were, had the effect of a field coil.

The limitation of this machine is of course the speed at which the current can be taken off. At the speeds adopted by the author, one element which might be a plain cylinder of the old-fashioned unipolar type generates 1/12 of 500 volts, a commendable pressure for a unipolar machine. Though he uses the term, the speaker thinks that "unipolar" is not a happy expression. There are, in fact, two poles, the flux passing across the air-gap from one pole to the other. The term "unipolar" is therefore not appropriate, though it has been in use for a very long time. Acyclic or non-cyclic is much more appropriate.

Regarding eddy currents in the armature: if there is a blow-hole in the casting there is practically no electromotive force generated in the area covered by the blow-hole; the current therefore tends to flow backward in that area, being supplied from the adjoining portions of the inductor. It is evident that a casting which is not uniform or a mechanical construction which is not uniform will involve eddy currents, because the current can flow back whenever the electromotive force is less in one part than in other parts of the armature.

A. E. Kennelly: An interesting point brought out by this paper is that the direct-current machine shows distinct advantages over the alternating-current machine. The ordinary direct-current machine is in reality an alternating-current machine with the alternating current rectified for external use by a commutator. A telephone will sing when connected to the terminals of the ordinary direct-current generator, whereas we may expect it to remain mute when connected to the terminals of a true direct-current generator, the homopolar generator.

Electrical engineers have always regretted not being able to get a magnetic material that could be cast, a material that would conduct magnetically but not electrically. Heretofore it has usually been necessary to laminate the iron in order to destroy eddy currents in the body of the revolving armature of a high-pressure direct-current generator; this laminating is quite expensive. But in an arrangement of this kind we can obtain a revolving solid mass, in which there will be no sensible production of eddy currents or hysteresis.

The secret of the success arrived at in a machine of the type described by the author is the relatively enormous speed obtainable in comparison with machinery that existed before the introduction of steam-turbine; and it is by reason of this enormous speed that the high electromotive forces of 30 volts per foot can be obtained. The result ought to be a great reduction in the weight of the active parts, after the weight of the material which is purely structural has been deducted. Owing to this electromotive force produced per foot of active conductor, accounting of course for the small ohmic drop in the active conductors themselves, we arrive at a type of machine in which the surface of the collector, which takes the part of the commutator, is nearly double the surface of the armature core. This is shown clearly on the diagram on page 16.

It is worthy of note that the designer has been able to reduce the brush frictions as low as they appear to be. Even though the main losses in the machine seem to be frictional losses, hysteresis losses, and eddy-current losses, still one would suppose that the friction losses of the brushes would have been the limiting losses which might have interfered with the success of the machine. The fact that they are reduced to so low a quantity is surely a matter for congratulation.

C. Cartwright: The advantage of this type of machine over the ordinary direct-current commutator type should, it seems to the speaker, be emphasized; this advantage is most apparent in comparing machines designed for railway purposes. The insulation of this machine is of a mechanical rather than of an electrical nature, and there is an absence of commutator troubles due to overloading—these conditions, it would seem, combine to make this type of machine especially desirable. Other most desirable features are its simplicity of design and cheapness of construction. It is constructed so that only the simplest machining is required such as can be done on a lathe or boring-mill. Also, there are no complicated parts, and the machine can be easily assembled.

F. V. Henshaw: Any designer who has tried to solve the problem of building a direct-current generator for connection to a steam-turbine is greatly interested in the development of this unipolar type of machine. It seems to the speaker that the reduction of the surface speed of contact rings is of much importance. Of course, in a machine of this kind, there being no commutation, the bad effects of this high speed are chiefly due to mechanical causes. The large size of the collector rings impresses one, and Fig. 20 shows clearly the effect of high speed on the contact drop.

Another feature is the location of the brushes. If the brushes could be placed outside of the frame it would be most desirable. The speaker presumes that these details have been carefully considered; possibly inherent conditions have caused the designers not to attempt to place the contact rings outside of the frame.

J. E. NOEGGERATH: A few words explaining why the speaker used the terms "axial" and "radial" types. Classification into cylinder type and disk type relates solely to the mechanical construction; it does not give an idea of the condition prevailing in the machine itself. The speaker knows of a low-pressure machine, now in operation in a New England town, in which the electromotive forces are induced in a radial direction, but from a mechanical point of view it is a cylinder machine. To avoid possible confusion, then, the speaker adopted the terms "axial" and "radial."

Regarding armature reaction, it is true that a comparison with the effect of the cross ampere-turns of multipolar machines

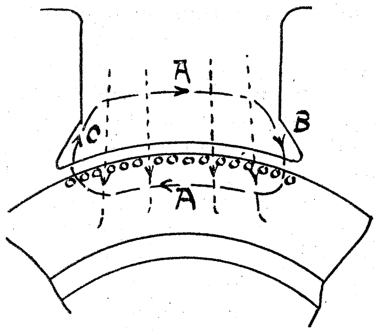

FIG. 1.

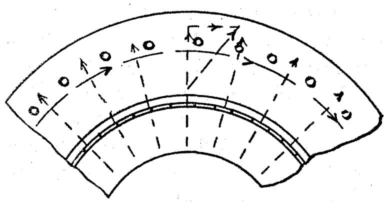

FIG. 2.

apparently justifies the conclusion that the difference in pressure between no load and full load should be greater than is indicated in the paper; but there is a considerable difference in the action of the cross ampere-turns in multipolar and acyclic dynamos. In the former type the effect of the secondary flux produced by the cross ampere-turns is threefold: first, there is a rectangular intersection of primary and secondary fluxes at *A*; secondly, there is an action in the direction of the primary flux at *B*; thirdly, an action in direction opposite to the primary flux at *C*. The first one is of the least influence and corresponds to the armature reaction in acyclic dynamos. As far as total primary flux is concerned, actions *B* and *C* would neutralize each other if there were no saturation. But since there is saturation, the loss in density at C overbalances the gain in B and thus affects the regulation. In acyclic machines where the pole encloses the armature in a complete cylinder there is no such crowding of lines but a plain rectangular intersection of fluxes as discussed in the paper. Its influence on regulation can, by the way, become very strong if the densities are not properly chosen.

As far as core losses are concerned, blow-holes in the armature are not really a very serious matter. The speaker has bored holes in both the armature and fields for purposes of ventilation and still the core loss is not high. The openings in the frame produce core loss chiefly in the armature and the openings in the armature produce core loss chiefly in the field. If these openings are sufficiently removed from the air-gap, the influence is not very strong; more serious is the unevneness of the air-gap.

For theoretical reasons it is impossible to put collector rings inside of the frame. As far as the relation of ring speeds to losses is concerned, the curve in Fig. 19 indicates that while the $I R$ drop rises with increasing speed, yet the friction losses decrease so that the total losses remain practically constant above certain high speeds.

The collector rings are of cast-steel, although for mechanical reasons it would be better to have them of nickel-steel. There is, of course, wear on the brushes but not more wear than on the carbon brushes generally used with turbine machines.