DISCUSSION ON "DEVELOPMENT OF A SUCCESSFUL DIRECT-CURRENT 2000-KW. UNIPOLAR GENERATOR" (LAMME), BOSTON, MASS., JUNE 28, 1912.

J. E. Noeggerath: It is a great pleasure indeed to congratulate Mr. Lamme upon his frank and exceedingly important paper on acyclic machines, and to comment on it, as, naturally, having been in a position to overcome similar difficulties in the development of the unipolar machines I am connected with, I appreciate the extraordinary problems that have to be met.

A few of the troubles mentioned by the author did not materialize, as those connected with the slots for the conductors, since the machines were built differently from the start; also the rings never came loose, but, as fair exchange, experiences were bought dearly in other ways. Of the problems in common some were solved in the same manner, some entirely differently, by which statement I do not lay claim to a better solution.

Mr. Lamme's design of the collector rings is ingenious. He states that one of the reasons for building them up out of two

FIG. 1

FIG. 2

concentric rings was to facilitate their exchange. A different way of solving this difficulty is not to mount the collector rings on the armature directly, but rather *on a separate shell* which, magnetically, forms part of the armature. (Fig. 1.) This eliminates the necessity of handling the heavy bulk of the armature, reducing the weights that have to be taken care of in shipping and dismounting, to considerably less than 10 per cent.

The collectors are so designed that one-half of the rings can be taken off from one end and the other half from the other end. In case of a large number of rings two or more collector shells are used for each set.

Due to the length of the conductors, it is necessary to provide in some way against the stresses produced by heat expansion. For the purpose of eliminating them, Mr. Lamme inserted a *flexible element*.

The corresponding solution which avoids the necessity of taking away space from the magnetic section, consists in *dividing the conductor lengthwise*, the end of one-half protruding into the

end of the other half (Fig. 2), or in providing a sliding connection, the conductor fitting loosely into a hole in the ring. Since the peripheral speeds are very high, this connection forms a perfect contact which has proved successful in years of operation.

Bearing troubles were solved in identically the same way by Mr. Lamme and myself, both of us using coils in the bearings to counteract the stray fields.

Part of the collector ring troubles, too, was taken care of in the same way, as in both cases soft insulated graphite brushes of a specific kind are used; if I am not mistaken, even the same make is used.

Mr. Lamme's investigation relating to the other brush troubles and supplementing my investigations of the theory of the electric contact are ingenious and I gladly acknowledge that where I have

FIG. 3.

FIG. 4.

taken the first step, Mr. Lamme at the present stage has obtained superior results as to the voltage drop in the contacts. He succeeds in permanently keeping it down to an average of 0.4 volt; he even mentions 0.1 volt; these are excellent results.

I am glad to have Mr. Lamme a commiserator as to the mileage that has to be traveled over by the brushes. If such requirements had been fulfilled by single-phase commutator motors, the maintenance expense would have become reasonable long ago.

As to running the generator, *i.e.*, the rings against the brushes, it has been my experience for a long time that this is feasible; an additional advantage not mentioned but probably known to Mr. Lamme, is that in running against the brushes, a compounding action takes place.

If any criticism can be made outside of those mentioned by the author of the paper himself, it would refer to the great bulk

of the machine; this can probably be explained to a considerable extent by the comparatively low speeds employed.

As Mr. Lamme has brought up again the question of the magnetic fields of unipolar machines, I put now before the Institute the results of an investigation which originally I intended to elaborate into a paper.

I have found that, in contradistinction to the accepted ideas—this ought to be of fundamental importance with regard to the theory of the magnetic field—*magnetic fields set at right angles to each other do not affect each other in the least* (Fig. 3 and 4).

In other words, if a field is set up in a magnetic material which is permeated by a second field at right angles to it, the relation of the first field to its electromagnetic force is not in the slightest degree affected by the second field, although the second field may be so strong as to have completely saturated the iron at right angles to the first field.

If for instance in Fig. 3, *M*-1 and *F*-1 represent respectively a strong magnetomotive force and a strong magnetic field, it is natural that it will be little or not at all affected by a small second magnetomotive force and magnetic field, etc., *M*-2 and *F*-2, set at right angles to 1.

However, it should be expected, according to the usual conception, that if *F*-2 and *M*-2 reach saturation (Fig. 4), then with the same *M*-1, *F*-1 should be considerably reduced, because one should assume that if the iron is saturated in one direction of the field *F*-2 there will be no possibility for any magnetic flux to pass through it, even though directed at right angles.

However, *F*-1 is not at all affected by *F*-2. This is not in contradiction to the phenomena observed with fields which are said to be and are in some respects at right angles to each other in alternating-current machinery, in commutating direct-current machinery and even in many types of unipolar machines. (However, unipolar machines can be so designed that the fields are in such relation to each other so as to be actually at right angles. This is of course not usually the case when conductors are placed in slots or holes as in Mr. Lamme's machine). This is, as I stated, not a contradiction, as a close scrutiny will show that the fluxes in the cases usually considered are affected in their mutual relationship not because they are at right angles but for any of a number of other reasons.

These conditions seem to find a parallel in the modern theory of light.

In concluding, I take pleasure in stating that I have observed the successful operation of Mr. Lamme's 2000-kw. machine. It ran very well indeed; there was no sparking; it ran cool, noiselessly and without vibration.

It is almost needless to say that I hope the paper will give a new impetus to this development, which though apparently stagnant in the United States, I had the pleasure of reviving in Europe.

Elihu Thomson: I listened to Mr. Lamme's account of his experiences with the unipolar machine with much interest. It is an example of how bold an engineer must be at times even to undertake the problems of which so little is known. He enters the field and tries to do the work and then finds so many difficulties that it is a wonder he ever gets through or does not lose his enthusiasm before he has gone as far as Mr. Lamme has gone. I congratulate him on the final result in having a machine that will do the work. Now, in regard to unipolar construction, it will be recalled that in 1884 in the old electrical exhibition in Philadelphia George Forbes showed two or three examples of unipolar dynamos. They had great blocks of carbon for brushes, but it is about the worst material to be used in the case of a unipolar machine where the contact resistance is high. The loss involved would be very great. About 1885 or '86 we were studying the problem of the possibility of large power stations for continuous work, from the point of unipolar design, thinking possibly we might construct a number of machines in series for a very large output such as 25,000, or 30,000 kilowatts, large in those days. I was led to look into the unipolar design. I built two machines of moderate size to test out the conditions; the armature conductor was single without series connection. This single conductor was used much as in Fig. 2 of Mr. Lamme's paper, only the compounding which I obtained in that machine was by making the current-collecting ring connect with the inner conductor by a spiral band going around two or three times, as if a huge ribbon had been wound around, which carried the current to the outside ring. That is simply doing the same thing as carrying the leads from the brushes around in order to get compounding. The machine, however, developed difficulties and it was evident that we did not have enough knowledge in those days for proper construction. The iron losses were evidently, however, quite low. I would say that the rotor itself was composed of a plain cylindrical bar which was evenly plated with copper on the outside so as to confine the conduction to the outside, and in the air gap. I was led to suspect in those days that possibly there was a lessened loss to be expected in iron, where we did not have a reversal of flux, and in building some inductor dynamos later we found the iron losses so low that they were hardly measurable because the flux merely changed direction from one point to another, so that the amount of iron subject to magnetic changes was very small. That, I think, would apply in the case of unipolar machines and account for the low iron losses.

I was interested to note the remarks that Mr. Lamme makes as to the brushes. This problem in a way reminds me very strongly of the early days of railway motors. We had a hard fight to get railway motors to work in the street, where they were exposed to the dust and dirt of the street, and the commutators likewise. We attempted to run them open, without any boxes or casing, and encountered many difficulties. I was on the point of telling

our company to hold up on railway motor business because the commutator repair bills would swamp them. We then introduced the carbon brush. The box type of motor kept the dust off, and our hard work was over. For a time it was a very serious outlook. I recall that in 1889 Mr. C. E. L. Brown, known to us all as one of the most competent engineers, whose work has stood as the very highest, was engaged at that time in unipolar design, and the Oerlikon works had a contract to build a machine for 10 volts for electrolytic work. It was of large output, something like 12,000 or 15,000 amperes. I saw the parts of the machine in the shop. The rotor was a large copper pulley with rims turned up at each side for the traverse of the brushes. I said to Mr. Brown, "That is all right; but how about collection of current from that ring? The wear will be terrific on those surfaces and your ring will soon have the flanges worn off." He said "Do you really think so?" I said "I know so. I don't believe it is possible for you to run at those high speeds without wearing them off." In about a year's time a letter came from Mr. Brown saying he had found exactly what I told him about the brush wear was true, and he said "Now I am going to try carbon." I wrote back that I thought he would be in worse trouble with carbon than with leaf brushes, because the leaf brush will accommodate itself to the surface, while the block of carbon will dance and jump, and cannot possibly follow the vibration of the machine unless the pressure be so high as to cause a mechanical friction that will be absolutely prohibitive. Later on I heard from Brown that these things were true. I have been interested very much to see the chemical methods of keeping contacts clean as applied in the way that Mr. Lamme says has been done. When I was analytical chemist, to keep our metal surfaces clean we washed them with a little hydrochloric acid. If applied to cases of the kind in such a way that the acid would not do any damage around, it would often solve difficulties.

W. L. Waters (by letter): Mr. Lamme, at the end of his paper, states—"As an example of engineering pertinacity, this machine is possibly without a rival." I would change the word "possibly" to "probably." The writer had the pleasure of assisting Mr. Lamme in some of the work described, and I think that engineers that have been through similar difficulties will realize that his bare narrative covers a long period of strenuous work—work that would never have been brought to a successful conclusion, but for the extraordinary resourcefulness and perseverance of the man who was directing it. As stated in the paper—"It might be said.....that many of the troubles encountered with this machine could have been foreseen," but when it is considered that this is merely one of a thousand machines that were being handled in the routine work by the engineers responsible for this unipolar machine, it is easily seen that the only way to decide the numerous points which arose was by the direct experiments described in the paper.