H. POTH.

FIELD POLE FOR DYNAMO ELECTRIC MACHINES.

APPLICATION FILED MAR. 9, 1906.

919,458. Patented Apr. 27, 1909.

3 SHEETS—SHEET 1.

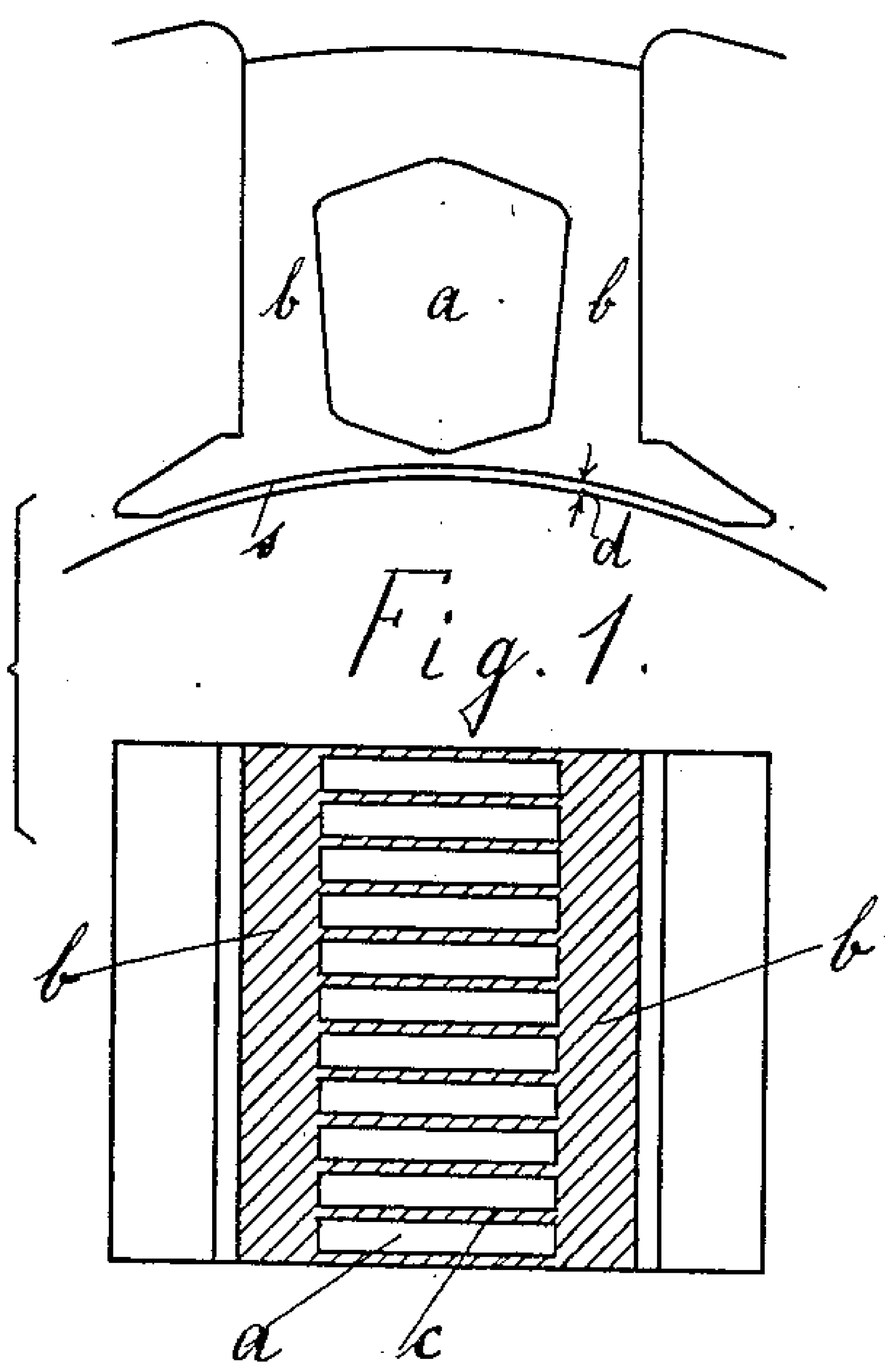

Fig. 1.

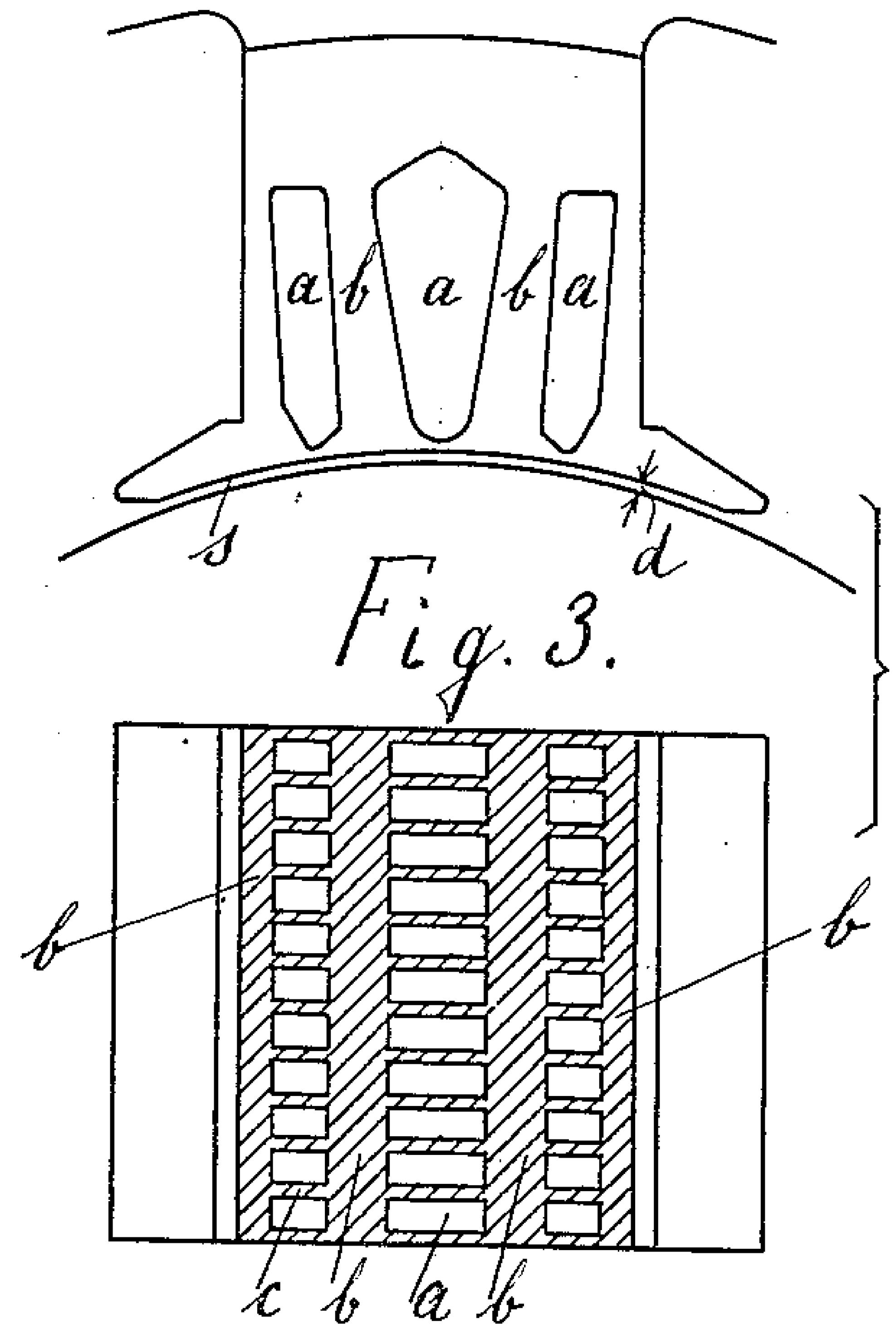

Fig. 3.

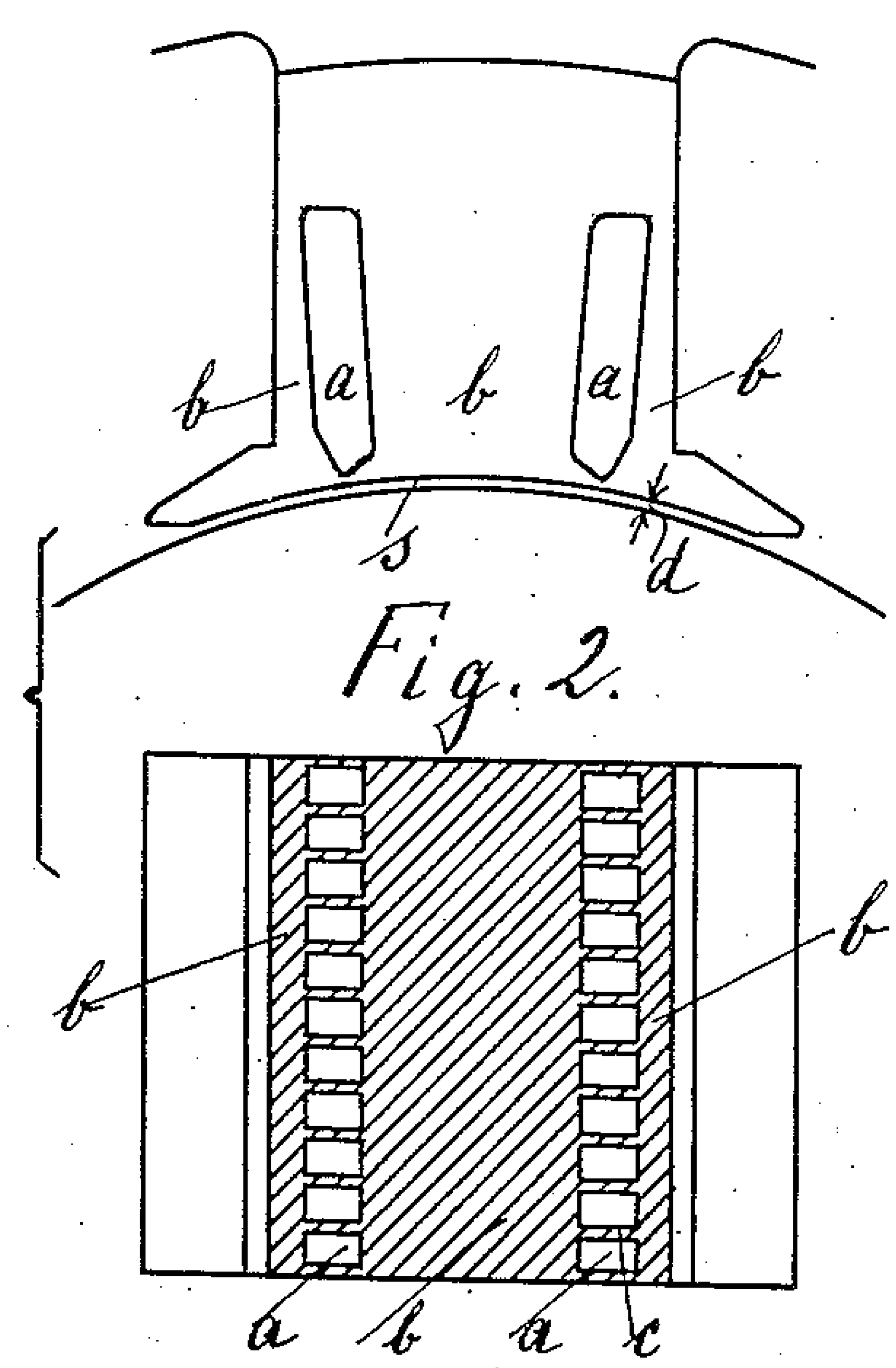

Fig. 2.

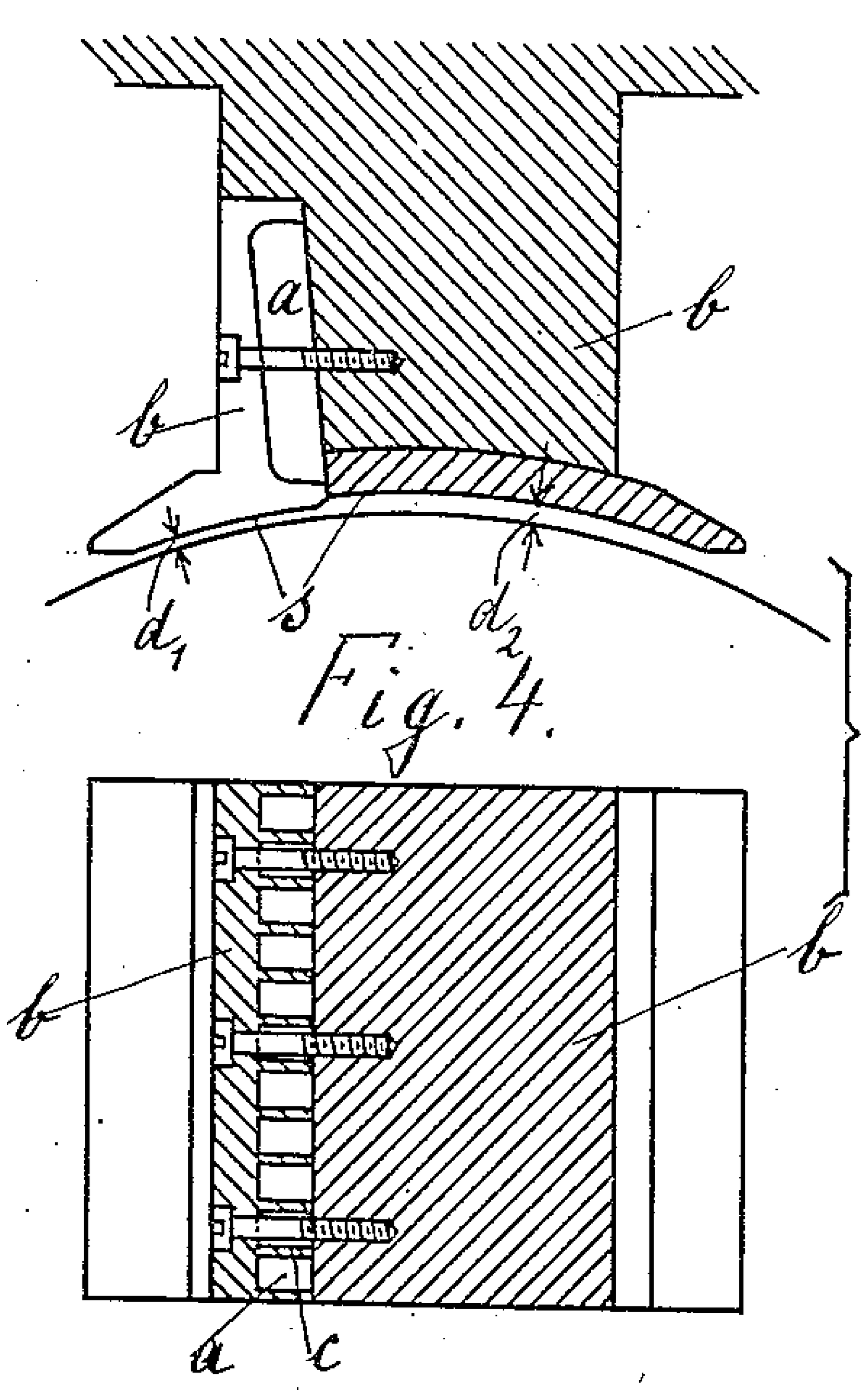

Fig. 4.

Witnesses

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3 SHEETS—SHEET 2.

Fig. 5.

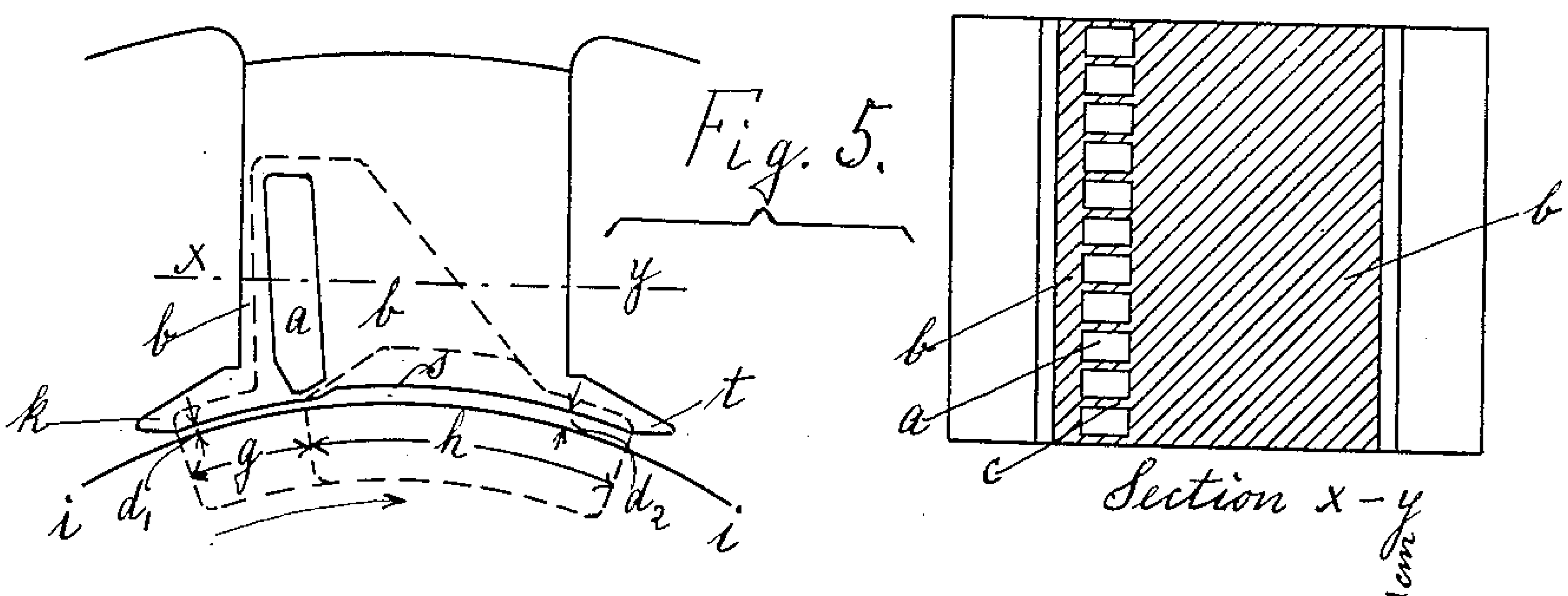


Fig. 6.

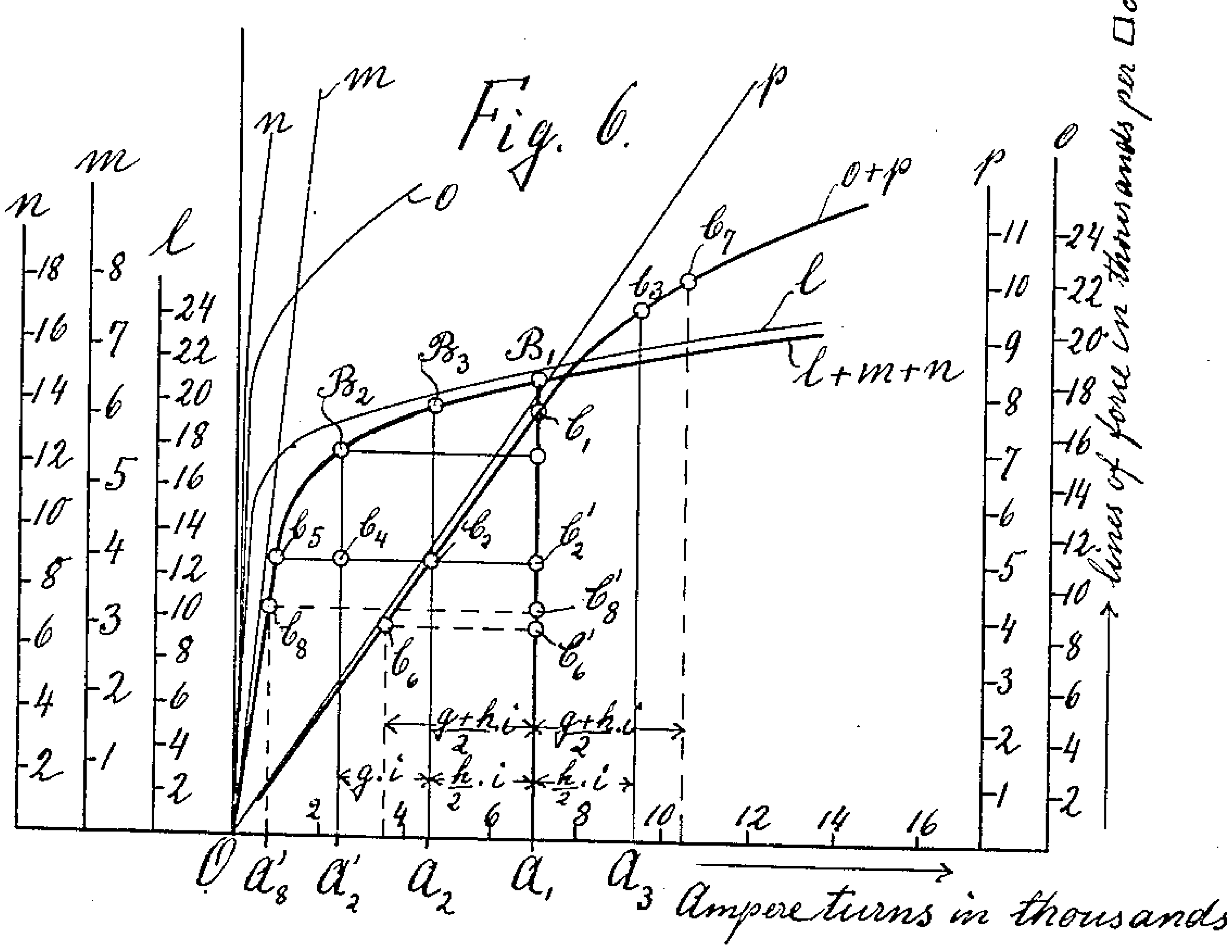
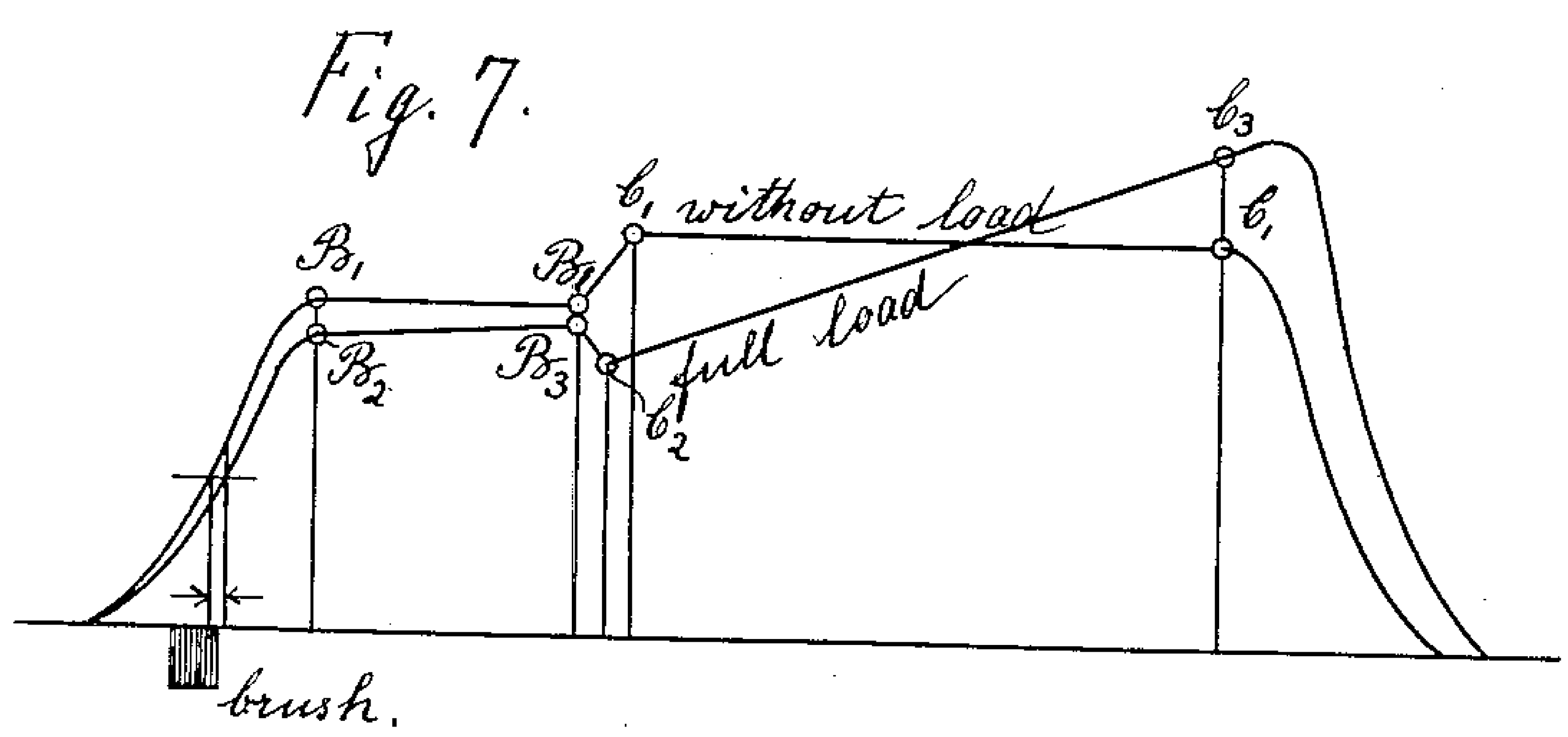


Fig. 7.



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3 SHEETS—SHEET 3.

Fig. 8.

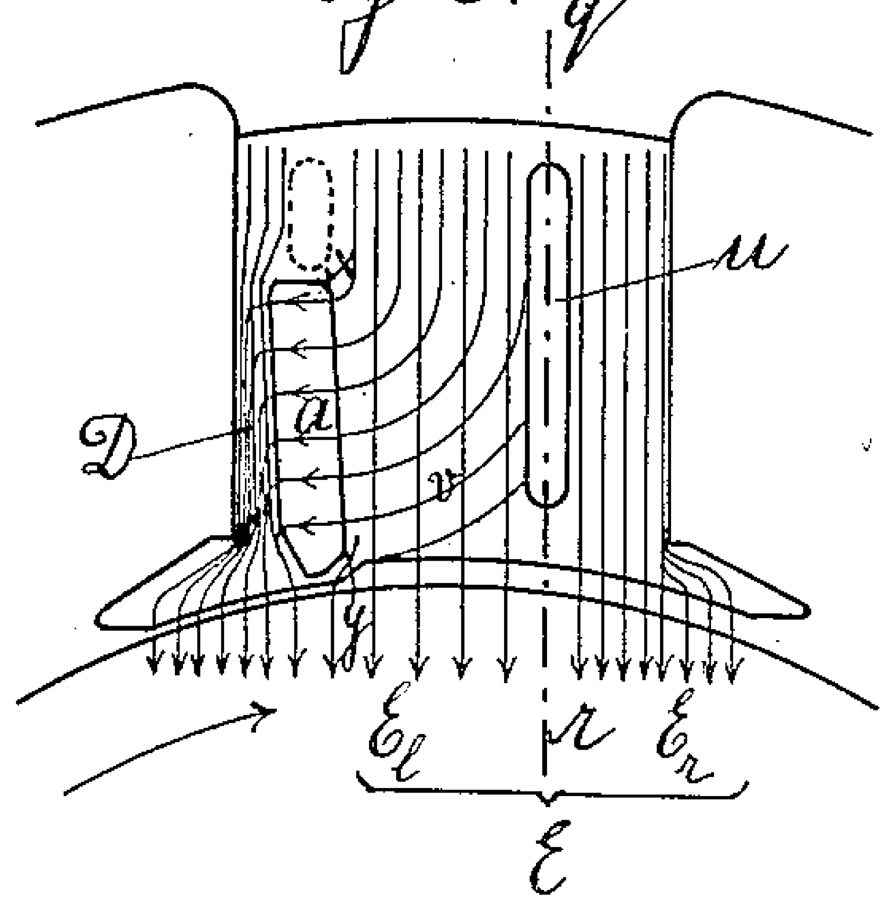


Fig. 9.

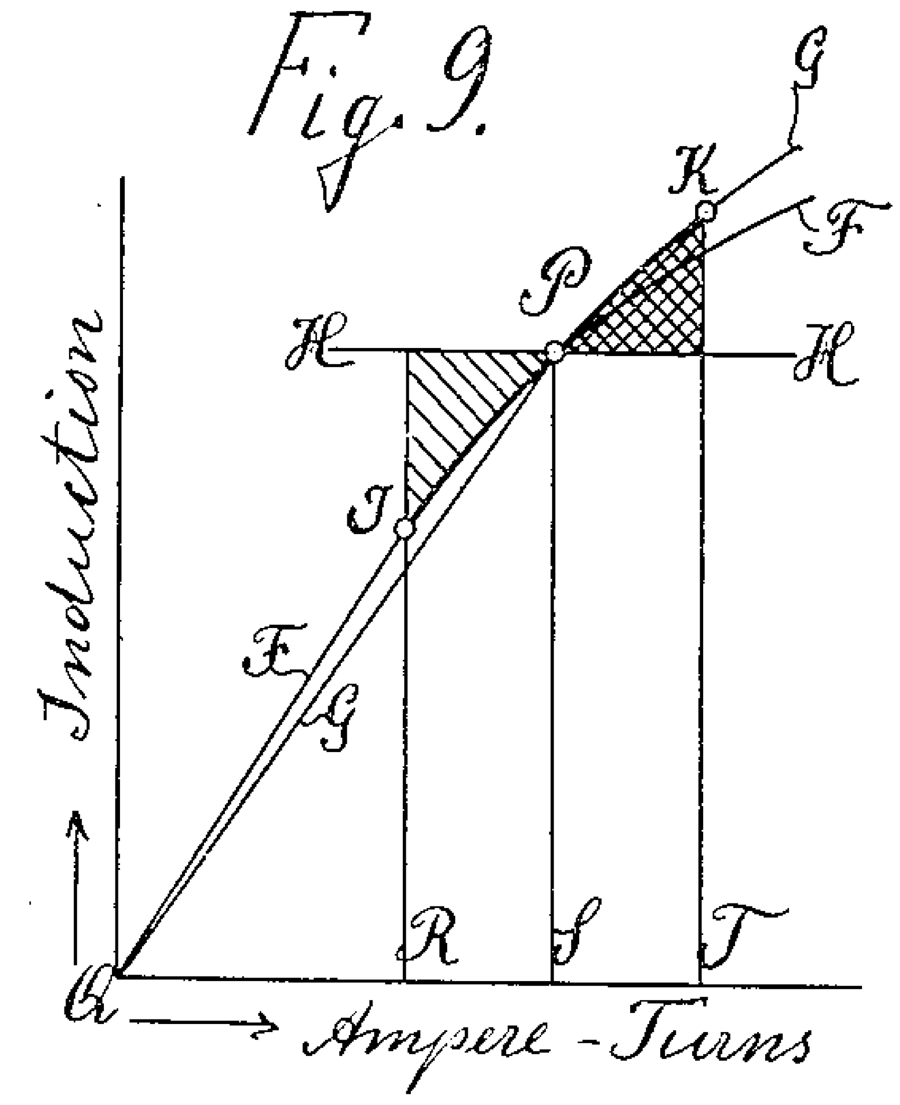


Fig. 10.

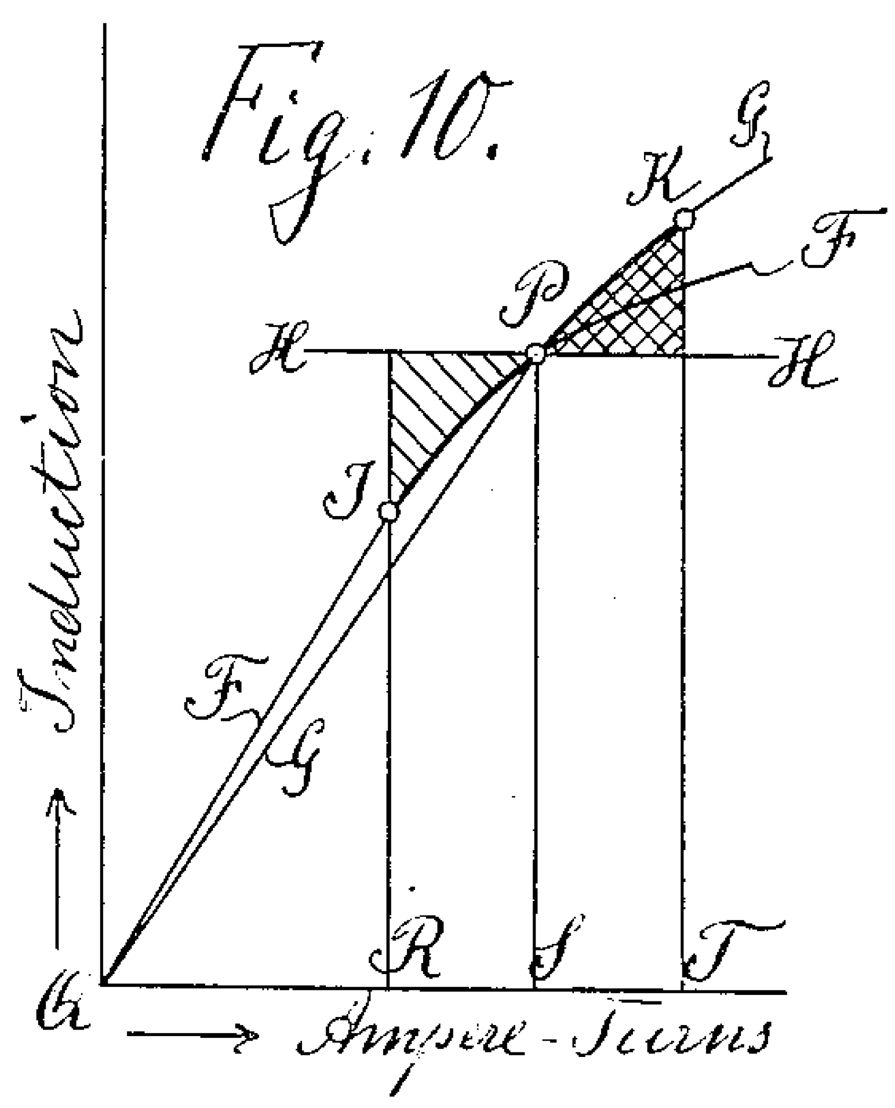


Fig. 11.

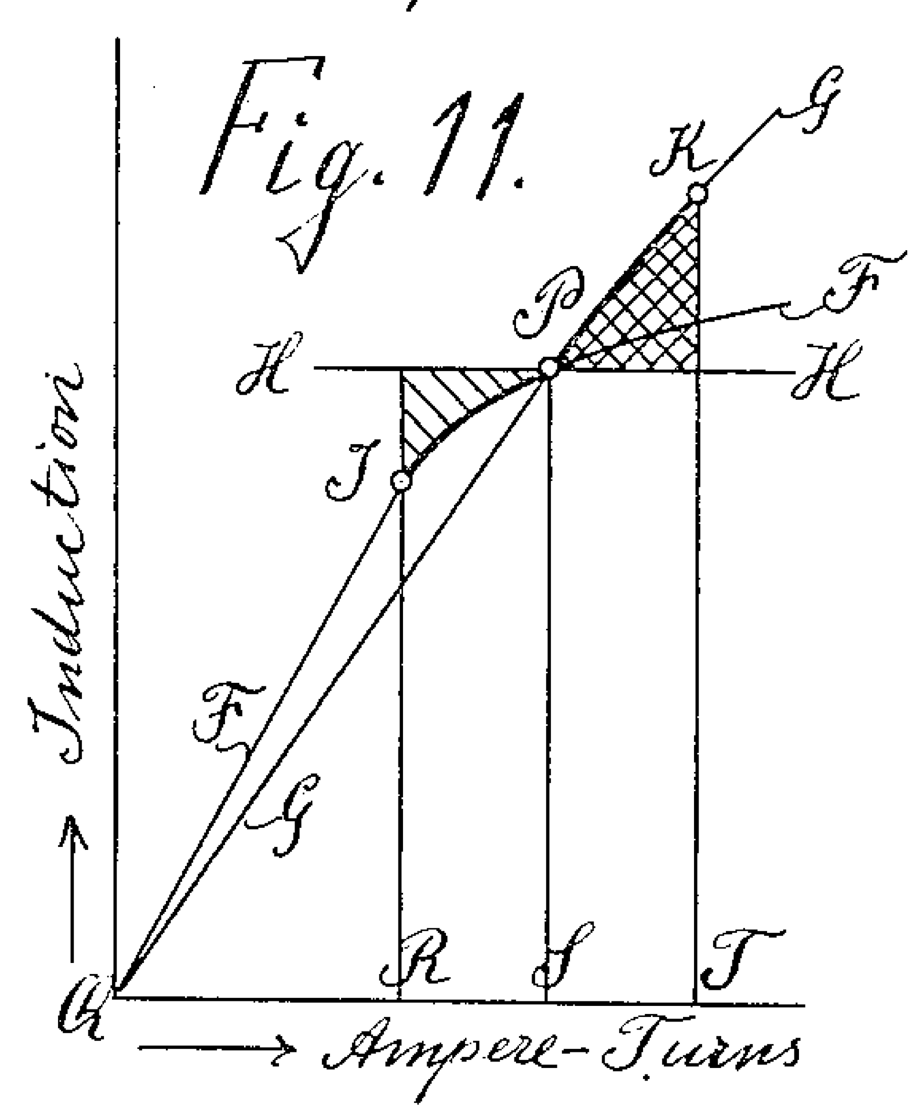
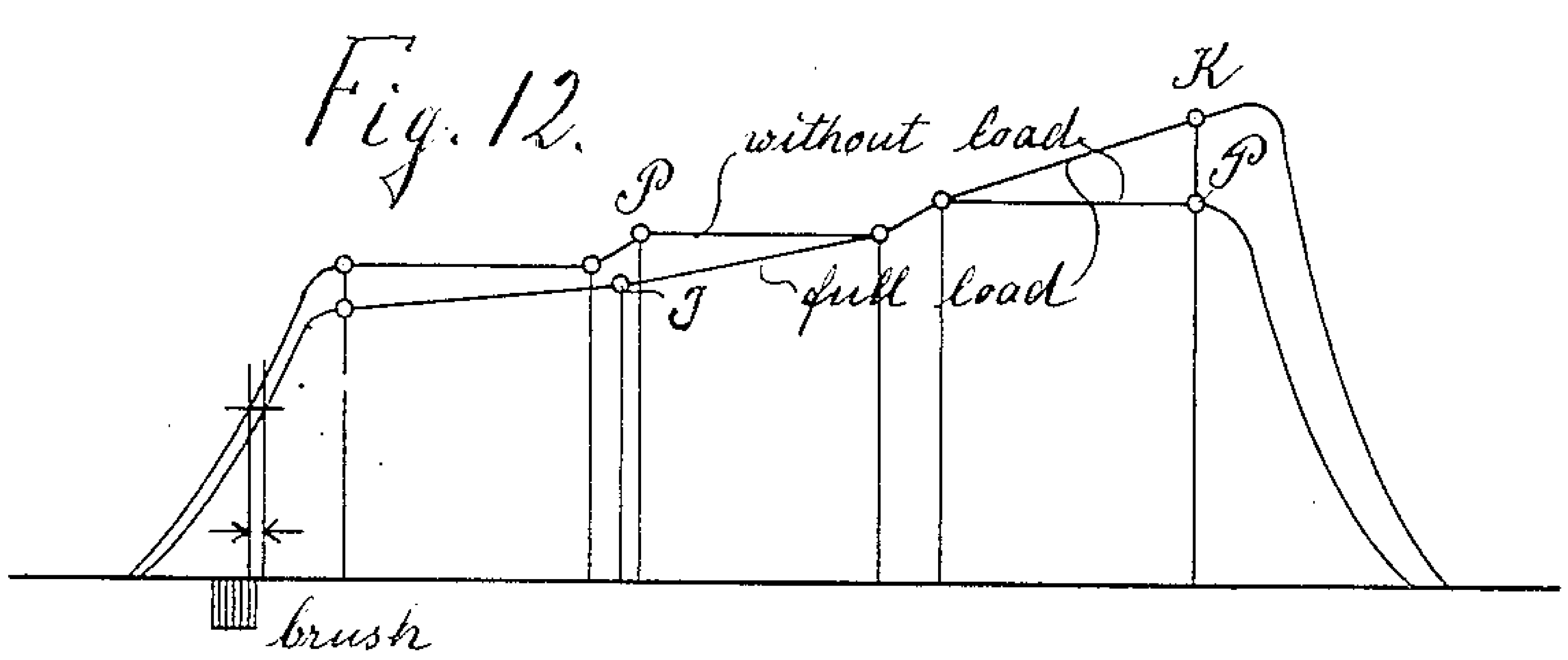


Fig. 12.



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UNITED STATES PATENT OFFICE.

HEINRICH POTH, OF BROOKLYN, NEW YORK.

FIELD-POLE FOR DYNAMO-ELECTRIC MACHINES.

No. 919,458. Specification of Letters Patent. Patented April 27, 1909.

Application filed March 9, 1906. Serial No. 305,091.

To all whom it may concern:

Be it known that I, HEINRICH POTH, a subject of the German Emperor, and a resident of Brooklyn, in the county of Kings and State of New York, have invented certain new and useful Improvements in Field-Poles for Dynamo-Electric Machines, of which the following is a specification.

My invention relates to the construction of pole pieces for decreasing or entirely doing away with the cross magnetizing effect of the armature, and is designed as an improvement upon field poles having recessed pole pieces for this purpose.

The load limitations of a dynamo electric machine are fixed either by excessive spark formation or by the heating. If a direct current dynamo or motor is to run at all loads between no load and full load without sparking and without shifting the brushes, then there must be only a small distortion of the magnetic field, the cause of which is the cross-magnetizing effect of the armature current. The smaller this distortion or the smaller also the weakening of the commutating field, the easier will it be to obtain the conditions of sparkless operation for high loads.

The heretofore known and used means for preventing or decreasing the cross-magnetizing consist either in highly saturating the armature teeth and the pole horns or in attempting to increase the resistance to the passage of the cross magnetizing lines of force by inserting air gaps. Under high loads, however, a satisfactory operation cannot be obtained by this means alone.

The object of the present invention is a pole construction in which the cross-magnetizing is reduced to the smallest amount in one or several parts of the pole in accordance with circumstances and a greatest possible stability of the ordinary field as well as a considerable saving in copper is thereby obtained.

Figure 1 is a diagram showing the construction of the pole with a central air space bridged by magnetic paths. Fig. 2 is a similar view showing an air space near each side of the pole bridged by magnetic paths. Fig. 3 is a similar view with central and side air spaces bridged by magnetic paths. Fig. 4 is a diagram showing a pole having a single air space at one side formed by attaching an independent part to the side of the main pole to which are attached the magnetic paths crossing the air spaces thus formed. Fig. 5 is a diagram of the pole with one air space bridged by magnetic paths showing the course of the cross flux. Fig. 6 is a diagram showing the curves of the magnetism of the pole. Fig. 7 is a diagram showing the field curves of the machine running with and without load when the magnetic paths are not inserted. Fig. 8 is a diagram showing the normal flux of the pole resulting from the magnetic paths bridging the air spaces. Figs. 9, 10 and 11 are diagrams showing various degrees of saturation in the parts E_1 and E_r of the pole in Fig. 8, and Fig. 12 is a diagram showing the field curves with and without load, with the magnetic paths inserted.

Referring to Figs. 1 to 3 the magnet core is divided into one or several parts *b* by one or several groups of air spaces *a* or non-magnetic portions inserted in the same in such manner that the intermediate walls *c* separating the air spaces *a* from each other form a magnetic bridge of small cross section between the parts *b*, and these alternate with each other in a series with the groups of air spaces in the direction of the armature circumference. A decrease in the cross section of the magnet pole arises from this which results in a concentration of the flux of the principal lines of force in the part *b*. One or more portions of this part *b* may now be so highly saturated that the cross-magnetizing windings of the armature are able to change the magnetic flux of this part but a very little. One way to obtain this is to make the air gap *d* between this part and the armature as small as possible, so that for the crossing over of the air resistance only a small part of the entire magnetizing force is necessary in order that the remaining part can thus be used merely for saturating. This can be further obtained by making the air spaces *a* which extend nearly to the pole face *s* lying opposite to the armature or even possibly extending through this so great that the paths *c* remaining between them have very small cross sections and in consequence of this are already saturated by a small total flux of the lines of force of the pole. The saturated part *b* of the pole as well as the air spaces *a* next to the paths *c*, offer, therefore, a very great magnetic resistance to the cross magnetizing flux of the lines of force. By a suitable selection of the number, size and position of the air spaces a, as well as by proper selection of the air gap d of the part b which is to be saturated one can obtain any desired slight change in the flux of the lines of force in this saturated part of the pole.

The proportions may be so selected that in running without load the saturated parts b are completely saturated far beyond the knee of the magnetizing curve upon their entire length drawn in the direction of the principal lines of force in the pole core, so that the saturation of these parts under the influence of the cross-magnetizing of the armature even under load remains always still beyond the knee of the magnetizing curve, no matter whether the cross windings of the armature have a magnetizing or demagnetizing effect upon these parts.

The pole core is best constructed laminated. For increasing the saturation of the part b which is to be saturated, some of its plates may be substituted by nonmagnetic material, or corresponding air spaces may be inserted.

If one wishes to strongly saturate the pole horns in solid pole cores for avoiding the formation of sparks, then these parts which are provided with corresponding ribs and which may best be laminated for this purpose, may be screwed upon the solid core. The separating joints for this case are seen in Fig. 4. In any case it is of advantage in grooved armatures to subdivide the strongly saturated part for avoiding the all too great eddy current losses, while in smooth armatures it can be solid.

In dynamos and motors which are to be run in both directions, both pole horns of course must be in accordance with the above described highly saturated parts, so that no matter in which direction the armature revolves, the leading side of the pole will be always provided with the means embodied in my invention, to reduce the effect of the cross-flux. Though I am mentioning in the claims only a non-magnetic space or an air space, I consider thereby also covered the modifications, showing several air spaces, as being a mere duplication of my construction.

For explaining the magnetic courses in a direct current generator, the case represented in Fig. 5 may be chosen, in which the pole core is divided into two parts b by a group of air spaces of which one part that lies at the leading horns and has the air gap d_1 is highly saturated, while the other part with the air gap d_2 corresponds with the ordinary pole construction. For the sake of simple investigation and representation it may be further assumed that the paths c are exceedingly thin and the air spaces a very broad, so that the influence of the small number of lines of force passing through the paths is negligible and may be left out of consideration.

i designates the linear load of the armature, expressed in amperes per centimeter of the armature circumference.

g, h designate the corresponding lengths of the pole arc of the two parts b—b of the pole core in centimeters. Then it is evident from the figure that the leading horn k is influenced by the cross-magnetizing windings

$$\frac{i.h}{2}+i.g,$$

the trailing horn t is influenced by $\frac{1}{2}\,i.h$, while at the same time at the beginning of the arc h, the cross magnetizing windings $\frac{1}{2}\,i.h$ operate altogether so that the cross windings work demagnetizing at the leading horn k and at the beginning of the arch h, and work magnetizing at the trailing horn t. It may be assumed hereby that the magnetizing effect of $i.g$ upon the trailing horn t may be neglected on account of the great saturation of the part of the pole core lying over the arc g. Also the magnetic resistances in the armature core and upon the cross path through the magnet core may be neglected.

In Fig. 6 the magnetizing curves are plotted for the parts of the passage of the lines of force which correspond at the same time to the cross magnetizing flux of force of which the abscissæ of the curves represent the ampere windings, and the ordinates the induction of the single parts of the joint path of the lines of force. Curve l stands for the part b of the pole at the leading side. Curve m for the air gap d_1 under the arc g of .2 cm. length; curve n for the teeth of 2.8 cm. length under the arc g; curve o for the armature teeth under the arc h; curve p for the air gap d_2 of 1.1 cm. length under arc h. From these values we obtain the abscissæ of the magnetizing curve for the leading horn k as the sum of the abscissæ of the curves $l+m+n$, the abscissæ of the magnetizing curve for the trailing horn as the sum of the abscissæ of the curves $o+p$. If we take for example for the machine running without load the number of ampere turns of the field at $OA_1=7000$, then the ordinates of the points B_1C_1 represent the induction in the machine running without load in the corresponding scale. By the loading of the armature the field will thereupon be distorted. The corresponding values of the induction under load are obtained if one takes the distance $\frac{1}{2}\,i.h$ to right and left from A_1 and further $i.g$ to the left of A_2. The ordinates A_3 and B_2 give us then the induction in the leading horn k, the ordinates A_3C_3 the same in the trailing horn t, while A_2C_2 represents the induction at the beginning of the arc h. In the example chosen, the air induction at the beginning of the arc h sinks from 7800 to 5150, or about 34%, and would sink even to 3820 or about 51% in the ordinary form of pole with equal air gap d_2 between the pole iron and armature iron at all points. Under the arc g on the other hand the air induction falls only from 6500 to 5730 or only about 12%. The greatest weakening of the field for the ordinary pole construction is obtained when one takes the distance

$$\frac{g+h}{2}.i$$

to right and left from A_1, since for this case of the entire cross magnetizing windings $(g+h).i$, one half works at the beginning while the other works at the end of the pole arc. The ordinates of the point $C_6=3820$, and of the point $C_7=10100$ represent then the induction in the leading horn k and in the trailing horn t respectively of the ordinary pole form. If now one would permit for the new construction of the pole an equal percentage weakening of the field as in the ordinary construction, then the point B_2 could change to C_8, whereupon the proportion must arise

$$A_1C_1:A_1C_6=A_1B_1:A_1C_8.$$

From this there would be necessary either $A'_2\,A'_8$ or in our example 1740 ampere turns, that is 25% less, or one could correspondingly increase the load of the armature. Thus by the new pole construction a considerable saving of copper or a raising of the load which may be carried in the machine is obtained. One obtains the smallest weakening of the field if the magnetizing curve $l+m+n$ rises quickly and bends quickly in the knee which may be easily obtained by choosing a small arc g by slight air induction under the same, as well as by a smallest possible air gap d_1 which is best made as small as mechanical considerations will permit, further by suitable selection of the cross section of the part b and of the dimensions and position of the air spaces a, as well as by using iron of the highest magnetic conductivity.

Fig. 7 shows the field curves of the machine running with full load and without load, in which the air induction under the pole arcs is represented as the ordinates depending upon the armature circumference wherein like numbers correspond to the same points of the pole arc in Figs. 6 and 7. One may see that the commutating field and thus the commutating E. M. F. under the brush corners changes only insignificantly.

Thus far, the discussion relates only to the case in which the magnetic paths are extremely thin and thus the effect of the same is to be neglected.

In the following may now be explained the principal difference which characterizes the arrangement of the magnetic paths in ordinary form. It consists in that a special division of lines of force is caused by the same, in such manner that a considerable diminishing or prevention of the total cross-magnetizing is obtained, which latter makes possible a still further considerable saving of copper.

For the following explanation the already treated consideration of Fig. 5 may be selected, which in order not to overload the drawings is represented again in Fig. 8.

For the sake of simplicity let here the already characterized highly saturated part at the left of the recess a be indicated by D, the part to the right of the recess a as a whole be designated by E while its parts with E_l E_r (E left and E right). A group of air spaces may be called in the following merely recesses. Besides the discussion deals only with a constant magnetic excitation.

If one considers first that the paths are omitted, then in running without load the same induction will influence the part E throughout. By inserting the paths it is now brought about that a certain number of lines of force pass over to D by the paths from E in consequence of the difference in magnetic potential prevailing at different points of the entire length of D, because of the high saturation of the portion D produced by the small air gap which the lines of force passing through D have to cross in order to get to the armature, compared with the large gap separating pole portion E from the armature. Owing to the considerable length of the pole arc of this part D, a small air induction is produced at the same time. Hence only a comparatively small number of ampere turns is used for driving the lines of force through this air gap, while by far the largest part of ampere turns is used for saturating the part D.

The flux of lines of force through the air spaces may be disregarded since it is slight. Consequently in the part E a greater number of lines of force will flow than formerly since now besides those lines of force which were present also in the first case and which pass from the magnet iron through the air space into the armature, still others arise which pass over from E to D. By this, however, a greater saturation arises in E, and will be the highest in the vicinity of the recess a. The lines of force are somewhat crowded together and made more dense toward the recess a. An increase of the saturation, however, involves a decrease in the cross-magnetizing as is well known, and thus also a diminution in the drop in voltage of the machine. Considered exactly the relations which now arise are as follows: If one designates with N the entire number of lines of force which pass out of one pole into the armature, further the number of lines of force of the part D with N_1, those of E with N_2, then in the case without an arrangement of paths we get $N=N_1+N_2$. If now one has the same outer dimensions of the pole as well as the air gap of the pole arc also in the case with paths, then after the insertion of the same N_1 increases because of the now lower magnetic resistance, while at the same time N_2 lowers because of the now arising somewhat higher magnetic resistance. The sum N of the two will, however, remain about the same or be even greater than before. The principal point of difference and at the same time advantage is, however, the fact that in E an unequal saturation occurs, whose highest value is considerably greater than in the case without paths, and what is most important of all, as will be shown hereafter, that the greater saturation occurs at the part of the pole upon which the armature wires affect the greatest weakening; that is, in the selected example in the vicinity of the recess *a*. Besides it is evident from this that this higher saturation will be obtained without any extra expense for magnet copper, but takes place automatically at the same time with the inserting of the paths.

The lines of force crossing over from E to D will enter horizontally or almost horizontally into the paths in Fig. 8, while they are directed downwardly at a slight distance from the recess *a*. The course of the lines of force can be represented somewhat as arcs of a circle (Fig. 8), so that the territory of the higher saturation can be bounded on the right by the line *qr*, and below by the arc *v*. The lines of force will really spread out somewhat at this point, but one can obtain a sharp boundary at the right for instance by inserting a recess *u*, in which the paths would naturally be omitted for this purpose. One can obtain the same effect also at the place over the recess *a* in the same manner as shown for example by the dotted lines. For the purpose of a graphic representation the position of the recess *u* may be so chosen that its middle line which is in this case the line *qr* coincides with the middle of the pole arc E. In this place the effect of the armature wires lying under E equals O, while the magnetic pressure of the same increases to left and right so that the total magnetic pressure upon the side E_l gets less and is increased upon the side E_r. While thus in the case in which no paths are used, the magnetizing curve because of the slight and at all places equal saturation of the iron has an almost straight line course and holds for the entire arc E, this form somewhat as that of the curves $o+p$ of Fig. 6 of the drawings are used will hold only for the right half, while it is very much more curved for the left half E_l, and strives to follow more the course of the curves $l+m+n$. The condition that the air induction under E_l because of the now somewhat higher saturation of the part E_l becomes a little bit smaller, works favorably for this. A glance at Fig. 6, as well as Figs. 9, 10 and 11 of the drawings, which latter will hereafter be explained, shows, however, at once that the entire weakening of the field of E must become less. By proper selection of the relations the strengthening of E_r cannot only be made to entirely compensate for the weakening of E_l but even surpass it and therewith increase the total number of lines of force as well from E as also those of the entire pole which gives a considerable saving of copper in the magnet winding. By this one thus has in hand a new means to compound in a simple and exceedingly cheap manner shunt wound machines. Naturally the smaller the loss of tension is in the armature, the easier will it be to obtain this.

In Figs. 9, 10 and 11, these various relations are graphically represented and set forth, wherein the curves F represent the magnetizing curves for the part E_l for the various degrees of saturation, the curves G represent those for the part E_r for a considerably lower but in all three cases about equal degree of saturation. The point P corresponds to the middle of the pole arc of E. While thus the distribution of the lines of force under the pole arc E in running without load takes place along the horizontal line H—H, measured upon the scale for each half (that is, it would be constant for each half of the arc) it would result in running under load along the strongly drawn out portions of the curves I—P, P—K, whose ordinates now represent the air induction along the arc E. In this Q—S indicates the number of ampere turns of the field, R—S and S—T represent the cross magnetizing windings of the armature under E for E_l and E_r. The three figures show that with increasing saturation of E_l the weakening of that part which is represented by the simple hatched portions become smaller and smaller, so that finally the strengthening of E_r which is represented by the double hatched portions preponderates as Fig. 11 shows. In this case thus the above mentioned increase in the number of lines of force in the pole would take place. Considering now further (which is not shown in the drawings) that the air induction under E_l is somewhat less than under E_r, and that thus the scale for the former must be correspondingly greater, then the operation just described will only be further aided, which follows without further discussion.

A few figures will explain somewhat more exactly the relations. It may be for example that the proportion of the cross section of the iron paths to the intermediate air spaces is taken as 1:4 and for the sake of simplicity the thickness of the paths may be 2 *m—m*, and the width of the air spaces 8 *m—m*. Then the working out of an example when the induction in the above part D amounts to about 20000 per square centimeter, gives a flux through the paths above 3650 and below 4900 lines of force for one centimeter length of passage in the direction $x—y$, that is, for a cross section of .2 square cm. The flux through the air may be neglected. If one selects now as the normal saturation of E_r an induction of 12000 per square cm., then the induction in the left part E_l will accordingly rise to about 17000. The permeability of the iron is, however, at 17000, only about ⅓ as great as it is at 12000. The influence is thus at once evident. In a suitable selection of the construction these numbers may be easily modified so that they correspond to the proportions represented in the Figs. 9, 10 and 11. It may be further observed that the loss of potential occurring in E_l is of little influence upon the number of lines of force passing through the paths on account of the almost straight line course of the magnetizing curve at very high saturation.

In order to keep the induction in D constant upon the entire length and to thereby obtain the most favorable form of the magnetizing curve for this part, one need only place the recess *a* somewhat obliquely, that is, so that the cross section of the material of the part D decreases toward the top as the figure shows.

The corresponding field curves in running without load and an under load with reference to the influence of the paths are shown in Fig. 12 wherein here also as in the former Figs. 6 and 7 equal proportions of the Figs. 9 to 12 correspond to like points of the pole arc.

From the above it is accordingly evident that the more highly saturated parts there are present the smaller will be the total cross magnetizing or distortion of the magnet field. It is not necessary that all parts of the pole be saturated with equal strength. Since the effect of the cross windings decrease toward the middle of the pole, the parts lying near the middle may also receive a smaller degree of saturation than for example the pole horns. This case is represented in Figs. 2 and 3, which also show at the same time the construction with several groups of air spaces. Here the most highly saturated parts are shown at the pole horns, while the parts lying toward the inner portion of the magnet core can receive the desired degree of saturation by means of the paths.

By a suitable selection of the proportions the same or almost the same saturation may be obtained in all parts of the pole in running under load. Likewise under certain conditions the induction in the air under the entire arc of the pole can be brought to the same or substantially the same value.

The above considered construction in Figs. 5 and 8 is the most suitable with relation to the prevention of the weakening of the flux of lines of force, however, the number of constructions may be considerably increased; because the effect of the paths is always present as soon as there is a difference in magnetic potential. The latter is ever the same in the present invention, or at least can be made so in all cases by proper dimensioning. Further it is neither necessary that the axis of an entire group of air spaces extend in the direction of the armature axis, nor that the principal plane of an air space stands perpendicularly to the armature axis. These forms are only shown in the drawings for the sake of simplicity and economy in construction, still the desired purpose or the effect suitable to the particular purpose of the machine may always be obtained also for constructions differing from those by a proper dimensioning. For example, instead of placing the recess obliquely as above mentioned in order to produce a magnetic difference of potential upon the entire length of D of Fig. 8, one may also place the recess parallel to the boundary surface of the core and obtain the desired division of the material for obtaining a difference in the potential by cutting out some of the plates corresponding thereto in the part D. Finally the paths in general have at the same time the further mechanical advantage that they contribute to the solidity of the entire magnet body. Especially in such cases in which for example the part lying at the pole horns is very long and narrow and besides the recesses are open below, there is the danger that a vibration of this part occurs by the magnetic pull which under certain conditions may result in grinding of the magnet iron against the armature. Besides, this disadvantage can also be increased by the weight of the magnet coils which in assembling are forced generally against the frame with a certain pressure in order to prevent a movement of the coils. In poles which are laminated the assembling of the magnet pole itself is made thus considerably easier. The advantages of the new pole construction are accordingly principally as follows: (1) The spark formation is prevented by reason of the high saturation of the pole horns. (2) A higher load figure of the machine or a corresponding saving in the magnet copper is obtained by the high saturation of the pole horns. (3) The present pole construction has over other known constructions the principal advantage, that on account of the favorable division of lines of force brought by the magnetic intermediate walls the total cross magnetizing (that is at the same time the distortion of the magnet field as also principally the weakening of the same by the distortion) is at the same time not only reduced to the smallest possible amount but the weakening of the field is even entirely done away with and in a favorable case even in running under load gives rise to an increase of the entire flux at the same magnetic excitation, whereby a considerable saving in magnet copper is obtained. (4) In the same model one can change from the usual construction to the new construction while maintaining the normal magnetism and the total cross sectional form of the magnet core without a change of the dimensions of the frame being necessary, since the proportions can always be so chosen that for every machine for any particular purpose the same exciting force will be necessary as for the ordinary construction. Also the alternating current machines and rotary converters may have the new pole construction applied to them. In these machines in phase shifted currents a reactance is effected in the regular magnet field which principally relates to the pole horns and operates in a magnetizing or demagnetizing manner upon the same. In single phase converters the armature reactance, even when the current has no phase shifting, is of an oscillating nature and in the maximum equal to the full value of the direct current armature reactance besides constantly alternating its direction. An oscillation of the intensity of the field upon the armature circumference is caused by this, which can make a sparkless working of the direct current side impossible.

Having thus described my invention, the following is what I claim as new therein, and desire to secure by Letters Patent:

1. A pole piece formed with a non-magnetic space or part producing a tapering away from the pole face of part of the leading horn side of the pole, and having magnetic bridges adapted to lead part of the main flux of the pole across and into said tapering portion of the leading horn side thereof.

2. A pole piece formed with a non-magnetic space or part producing a tapering, away from the pole face, of part of the leading horn side of the pole, and having magnetic bridges in the non-magnetic space or part connecting the main interior portion of the pole with said tapering portion of the leading horn side thereof.

3. A pole piece formed with a non-magnetic space or part disposed eccentrically to the pole axis and dividing the pole into a plurality of portions and magnetic material extending from one of said portions through said non-magnetic space or part and leading to the other of said portions of the pole.

4. A pole piece formed with a non-magnetic space or part disposed eccentrically to the pole axis and approaching the pole axis toward the pole face and dividing said pole into a plurality of portions, and bridges of magnetic material extending from one of said portions through said non-magnetic space or part and leading to the other of said portions of the pole.

5. A pole piece formed with an air space disposed eccentrically to the pole axis and dividing said pole into a plurality of portions, and transverse bridges of iron extending through said air space and connecting the portions of the pole together.

6. A pole piece formed with an air space disposed eccentrically to the pole axis and approaching the pole axis toward the pole face and dividing said pole into a plurality of portions and transverse bridges of iron extending through said air space and connecting the portions of the pole together.

7. A pole piece having an independent member of magnetic material secured to the leading horn side of the pole with a non-magnetic space or part between itself and the pole and magnetic paths extending across said non-magnetic space or part and connecting said independent member with the main portion of the pole.

8. A pole piece having an independent member secured to the leading horn side of the pole with an air space between itself and the pole and iron paths bridging said air space.

9. A pole-piece having an independent member of magnetic material secured to the leading horn side of the pole with a non-magnetic space or part between itself and the pole at a suitable distance from the pole axis and approaching the pole axis toward the pole-face, and magnetic paths extending across the said non-magnetic space or part and connecting said independent member with the main portion of the pole.

10. A pole-piece having an independent member secured to the leading horn side of the pole with an air space between itself and the pole at a suitable distance from the pole axis and approaching the pole axis toward the pole-face, and iron paths bridging said air space.

11. A pole piece formed with a non-magnetic space or part producing a tapering, away from the pole face, of part of the leading horn side of the pole throughout the entire length of said space or part, and having magnetic bridges in said non-magnetic space or part connecting the main interior portion of the pole with said tapering portion of the leading horn side thereof.

HEINRICH POTH.

Witnesses:
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