(No Model.) 3 Sheets—Sheet 1.

C. Q. PAYNE.

DEVICE FOR AND METHOD OF ADJUSTING AND EQUALIZING THE MAGNETIC DENSITY IN THE POLE PIECES OF MAGNETIC SEPARATORS.

No. 500,606. Patented July 4, 1893.

Fig. 1,

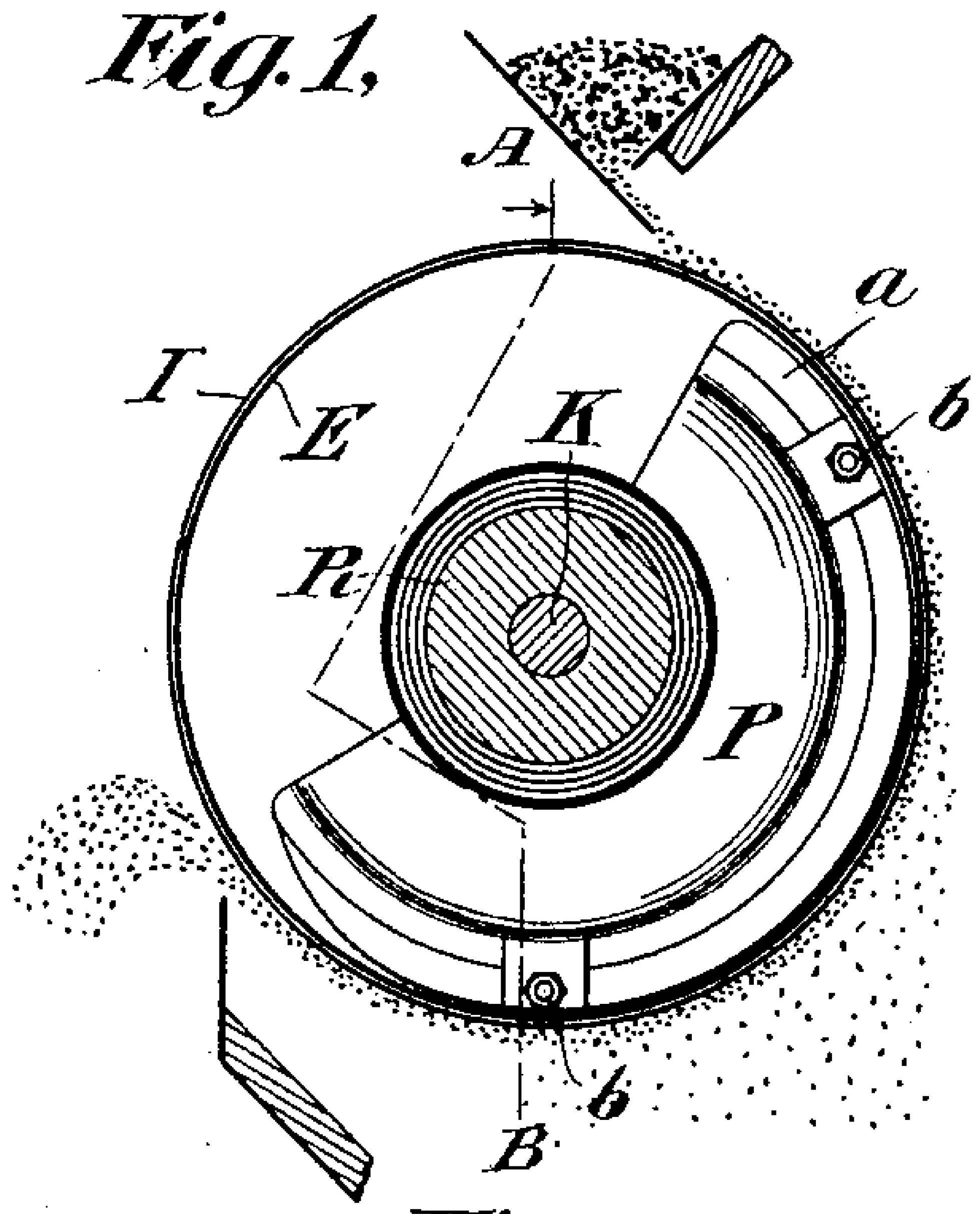


Fig. 2,

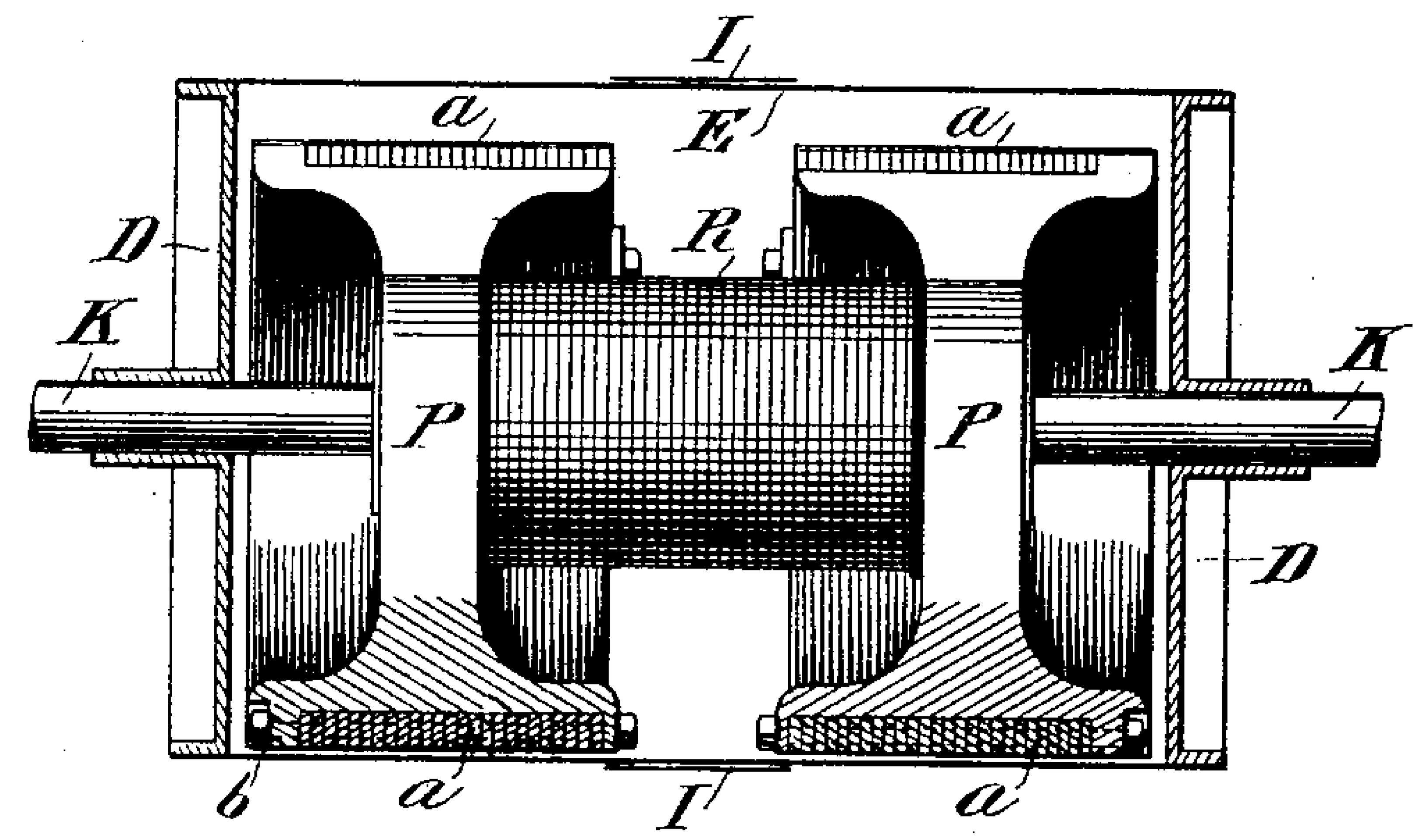


Fig. 3,

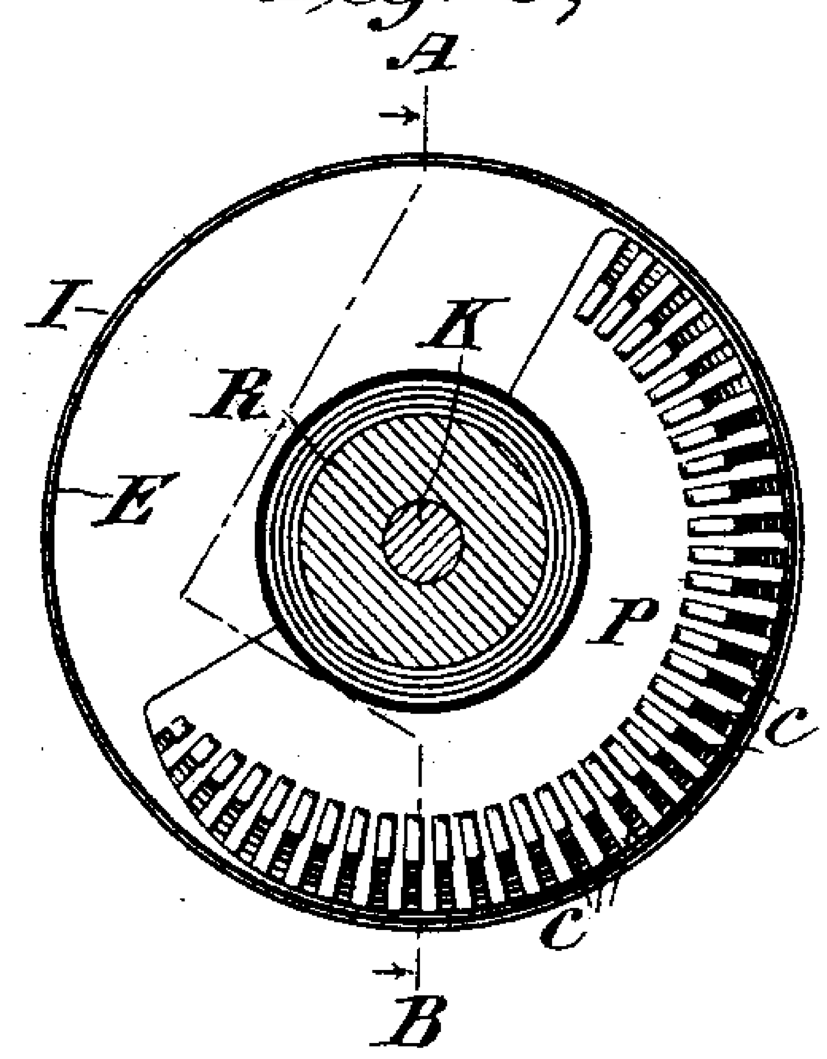


Fig. 4,

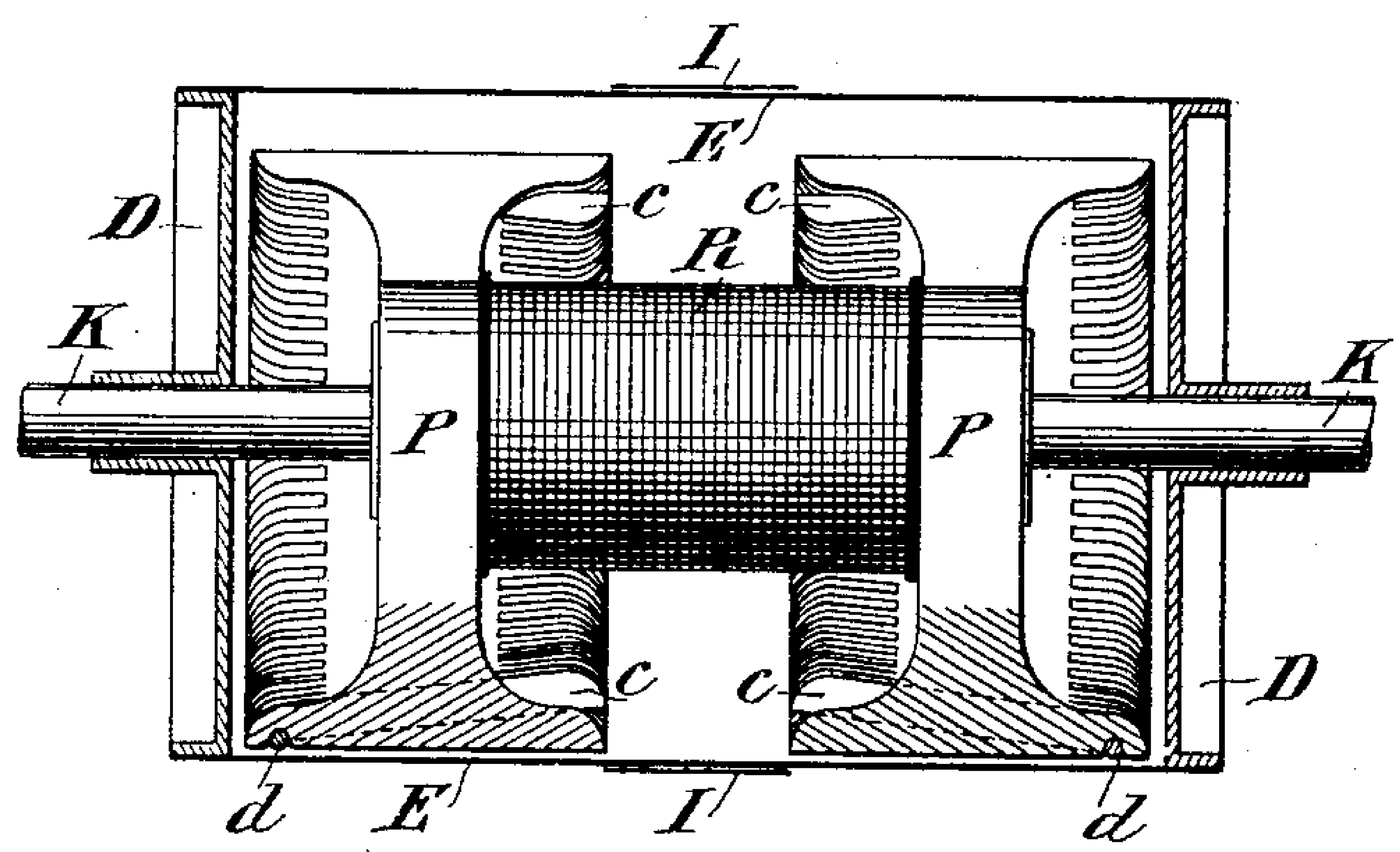


Fig. 9,

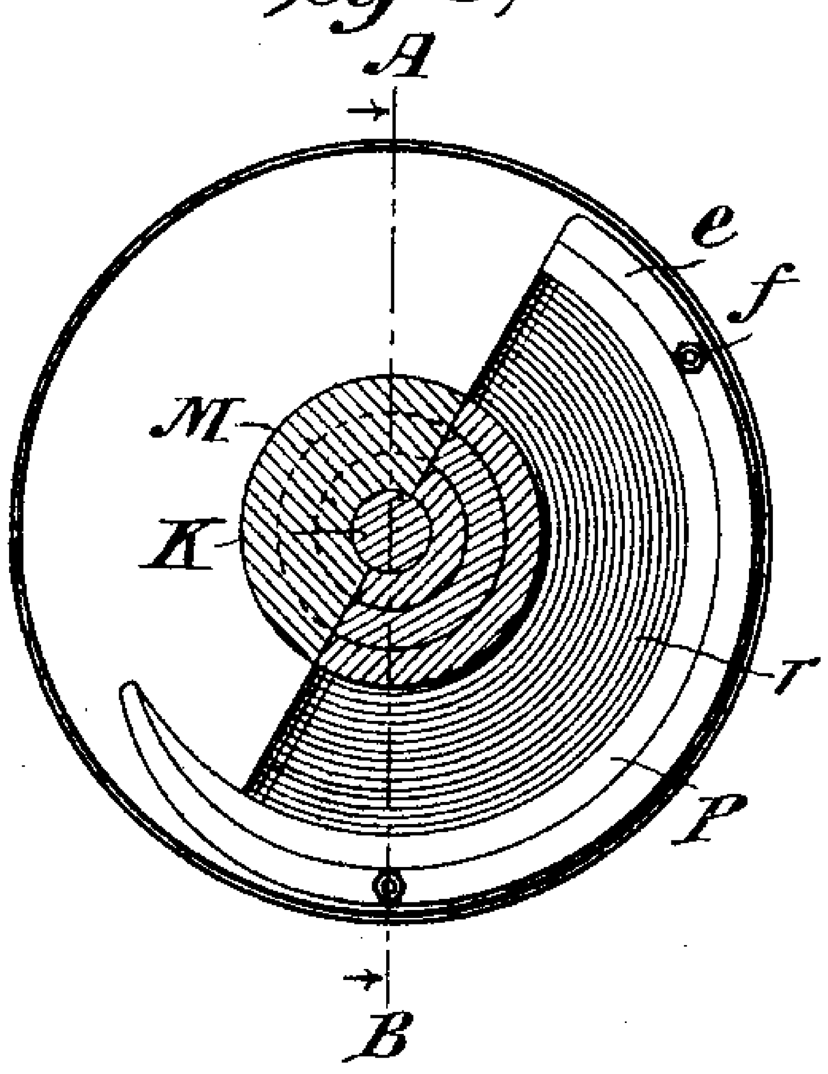
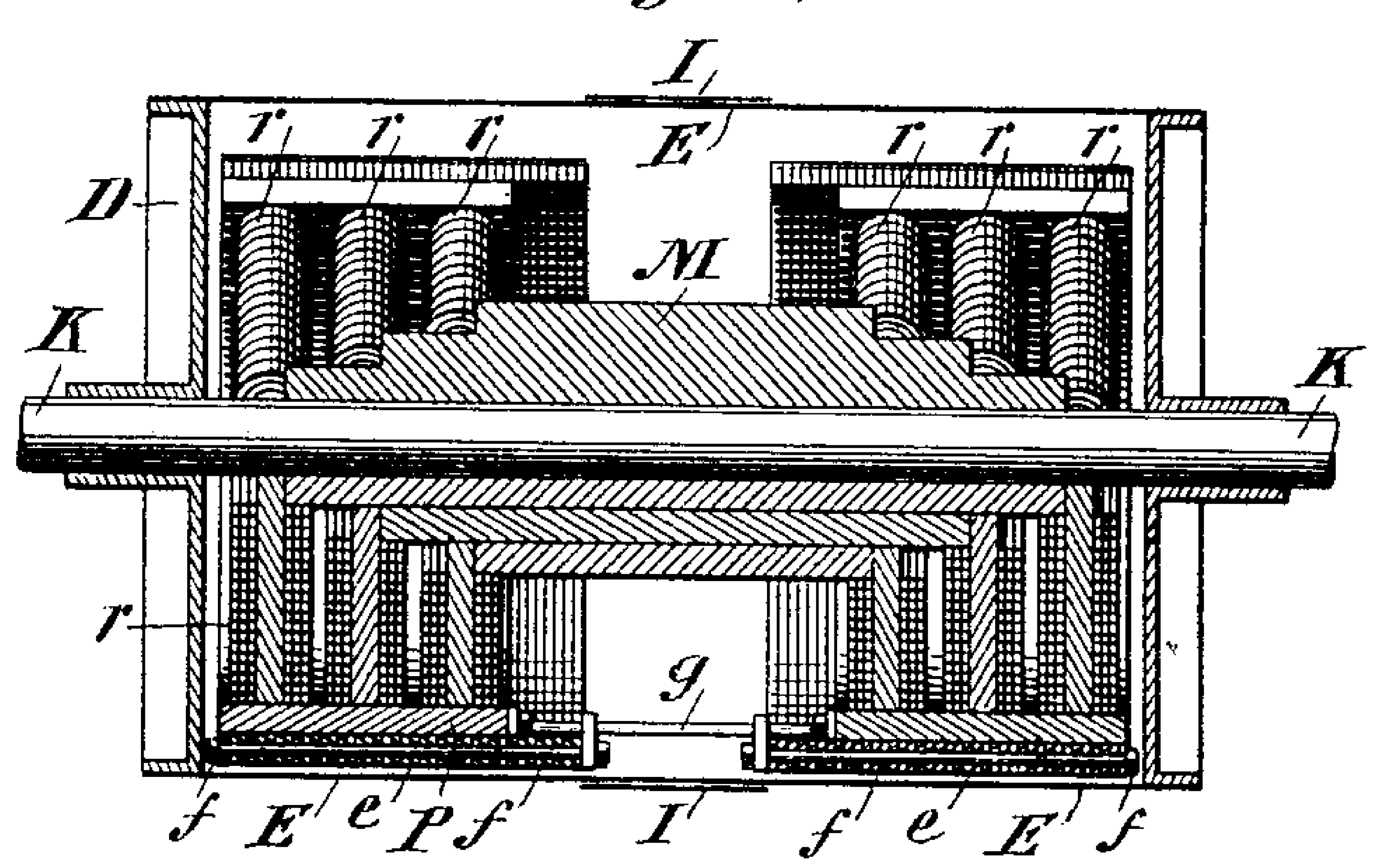


Fig. 10,



Witnesses

C. E. Ashley

H. W. Lloyd.

Inventor

Clarence Quintard Payne

By his Attorney

Millard Parker Butler

(No Model.)

3 Sheets—Sheet 2.

C. Q. PAYNE.

DEVICE FOR AND METHOD OF ADJUSTING AND EQUALIZING THE MAGNETIC DENSITY IN THE POLE PIECES OF MAGNETIC SEPARATORS.

No. 500,606. Patented July 4, 1893.

Fig. 5,

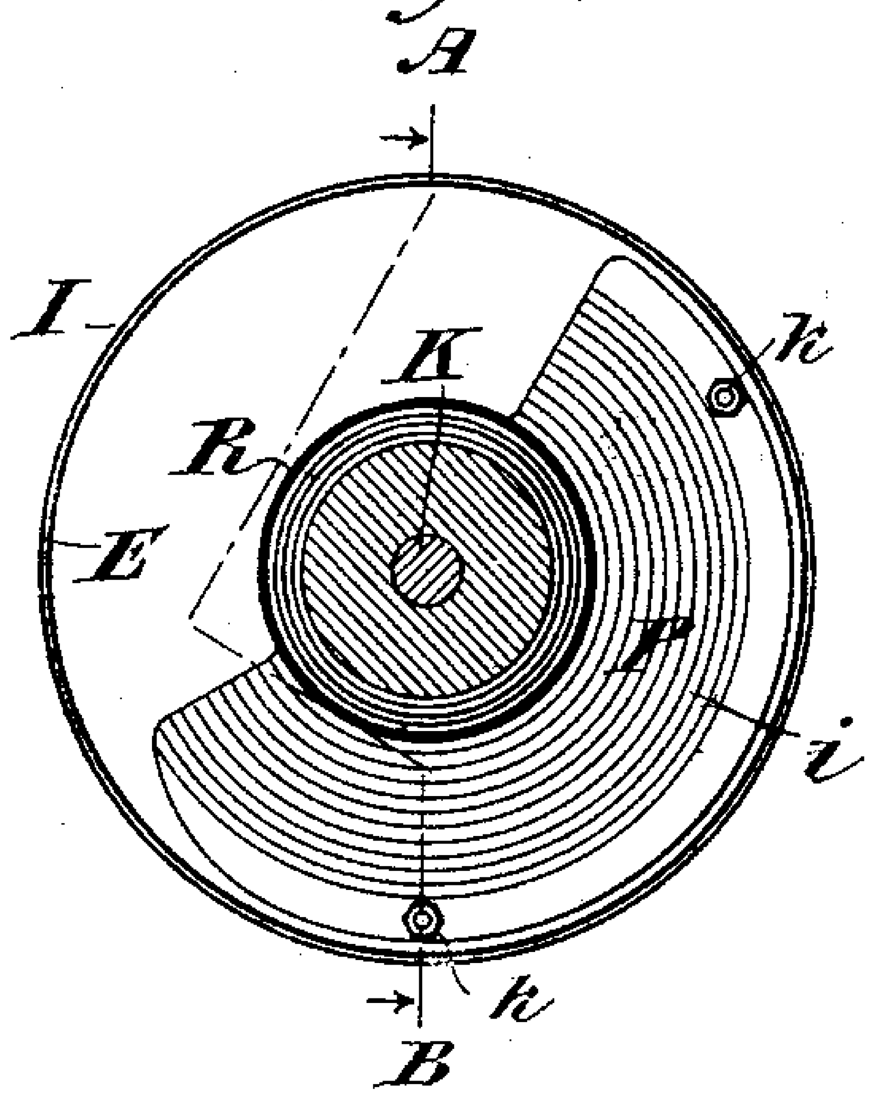


Fig. 6,

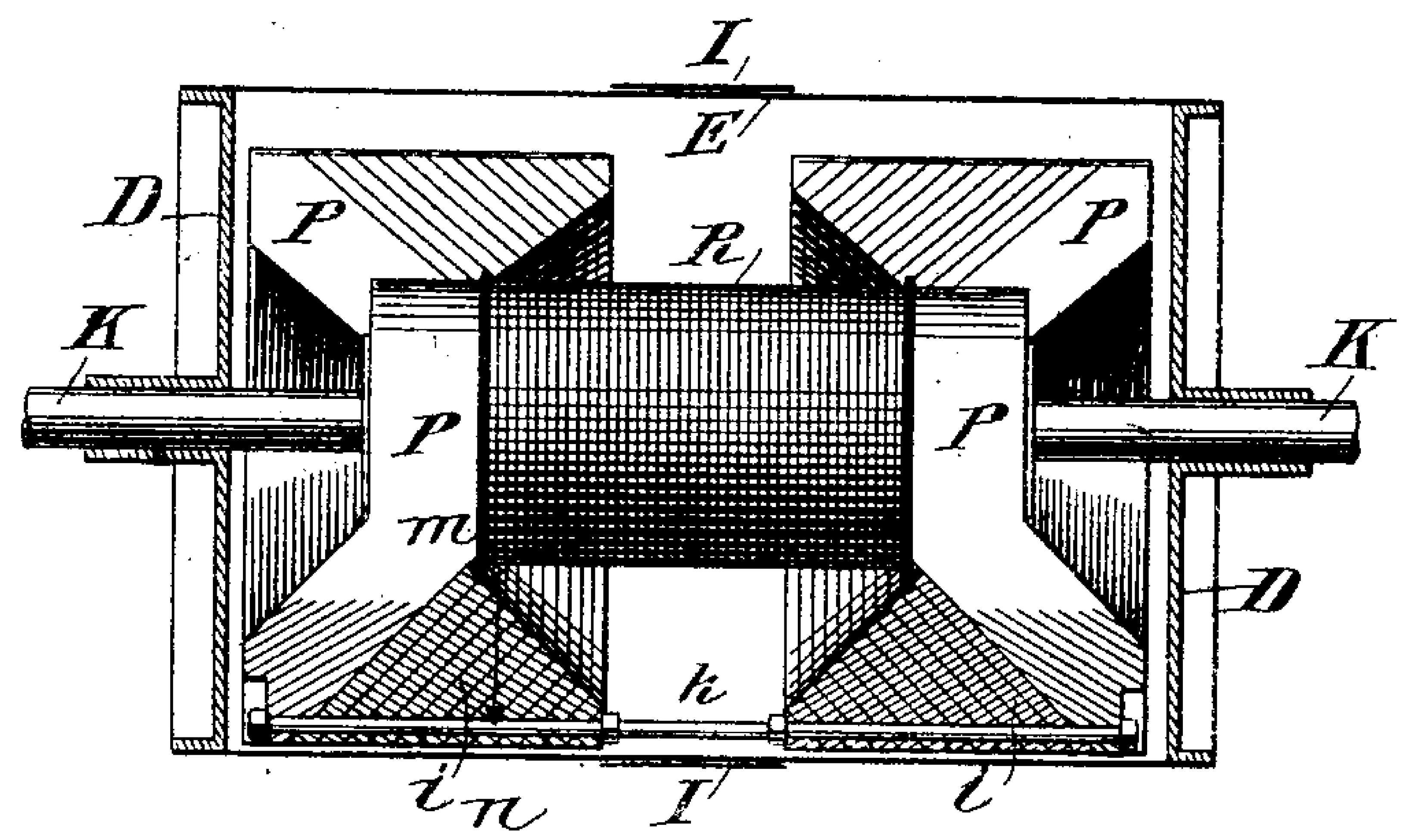


Fig. 7,

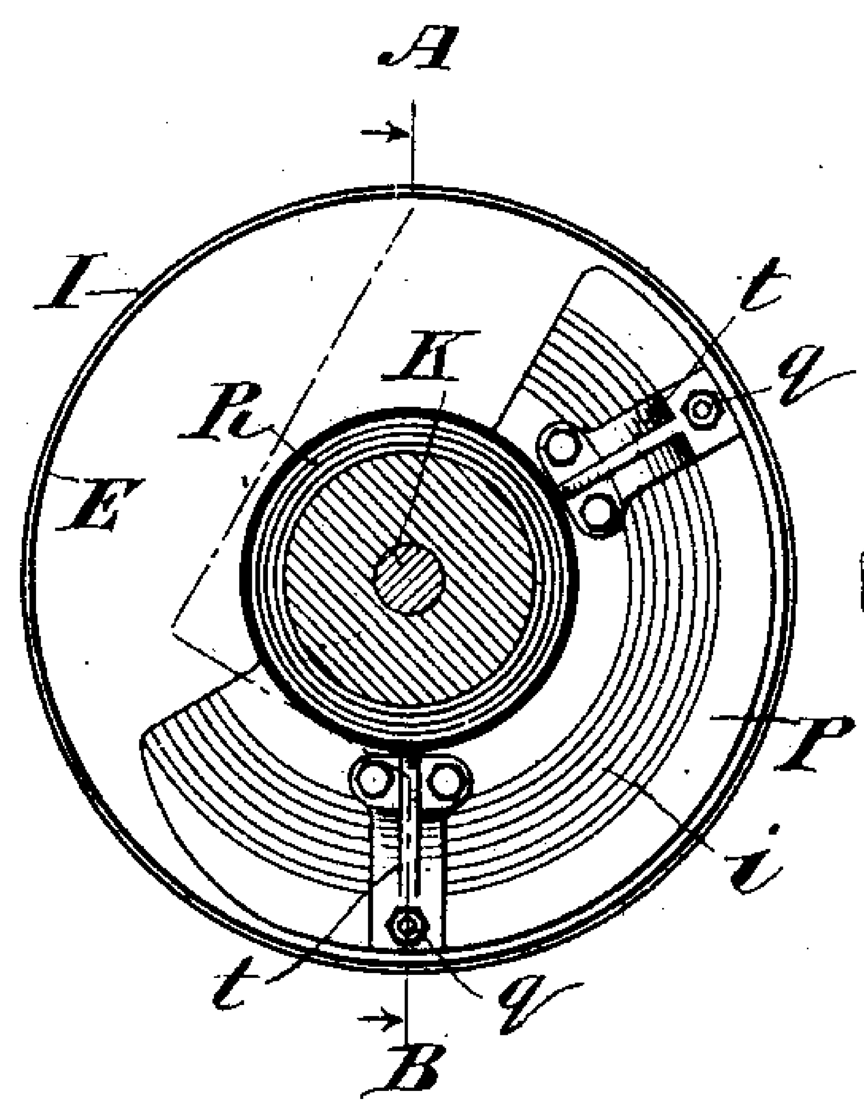
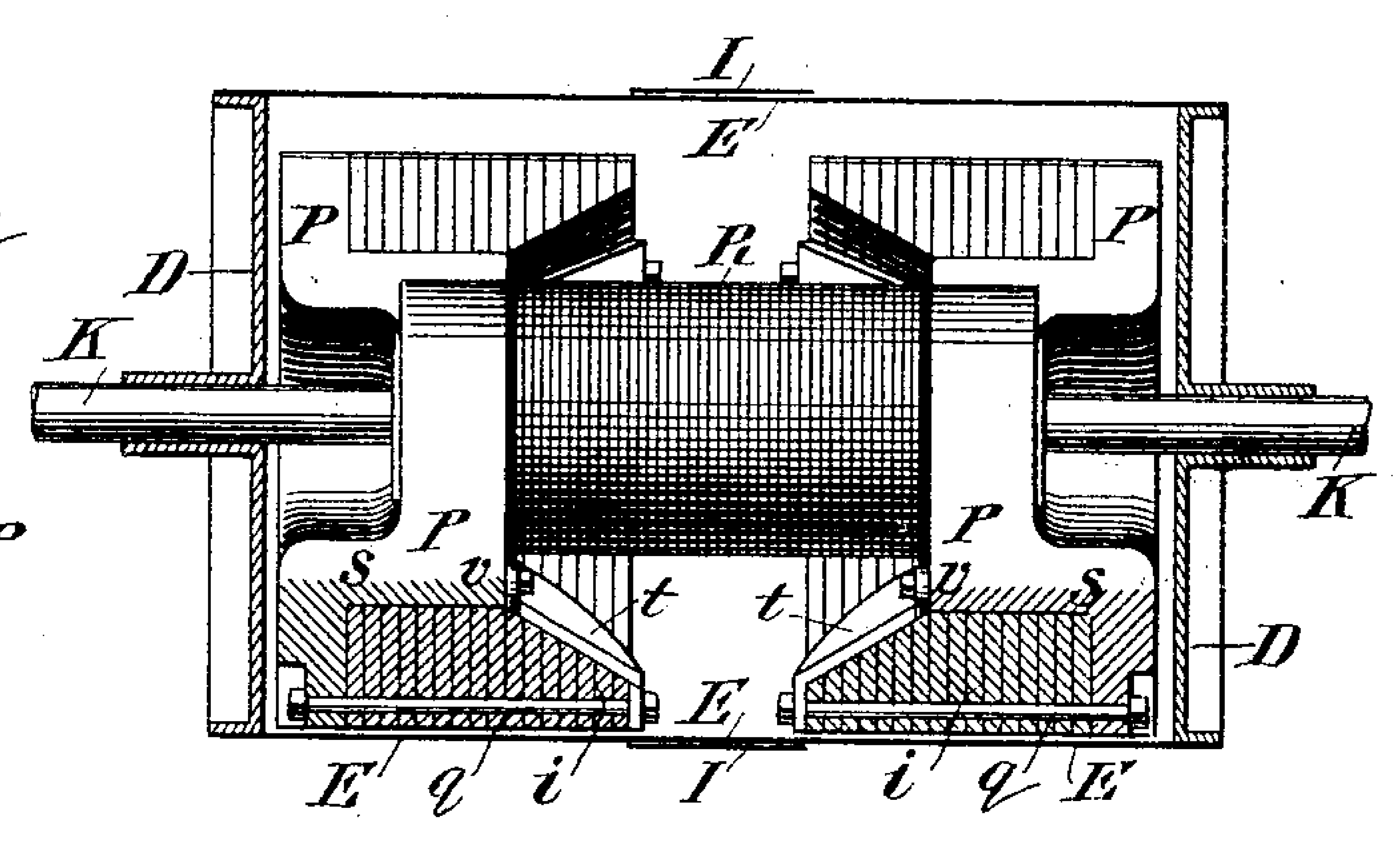


Fig. 8,



Witnesses

C. E. Ashley

H. W. Lloyd

Inventor

Clarence Quintard Payne

By his Attorney

Willard Parker Butler

(No Model.)

3 Sheets—Sheet 3.

C. Q. PAYNE.

DEVICE FOR AND METHOD OF ADJUSTING AND EQUALIZING THE MAGNETIC DENSITY IN THE POLE PIECES OF MAGNETIC SEPARATORS.

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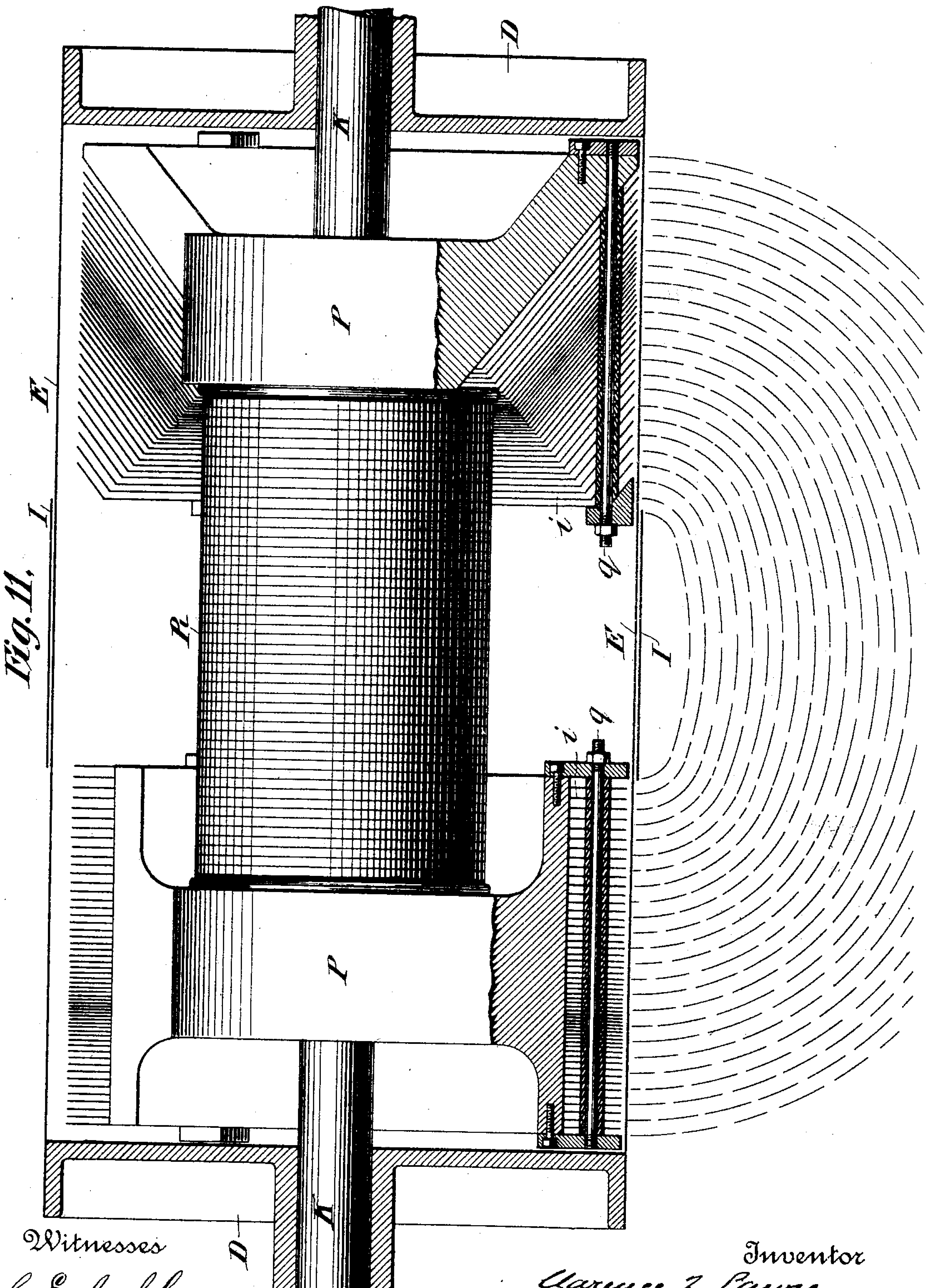

Witnesses
C. E. Ashley
H. W. Lloyd.

Inventor
Clarence Q. Payne
By his Attorney
by Willard Parker Butler

UNITED STATES PATENT OFFICE.

CLARENCE Q. PAYNE, OF STAMFORD, CONNECTICUT.

DEVICE FOR AND METHOD OF ADJUSTING AND EQUALIZING THE MAGNETIC DENSITY IN THE POLE-PIECES OF MAGNETIC SEPARATORS.

SPECIFICATION forming part of Letters Patent No. 500,606, dated July 4, 1893.

Application filed May 26, 1892. Serial No. 434,438. (No model.)

To all whom it may concern:

Be it known that I, CLARENCE QUINTARD PAYNE, a citizen of the United States, and a resident of Stamford, Fairfield county, State of Connecticut, have invented certain new and useful Improvements in Devices for and Methods of Adjusting and Equalizing the Magnetic Density in the Pole-Pieces of Magnetic Separators, of which the following is a specification.

My invention relates to devices for adjusting and equalizing or distributing uniformly the magnetic density of the lines of force across the polar faces of the pole-pieces of an electromagnet.

While the invention is applicable to any form of electromagnetic machine in which such a distribution is desirable, it is primarily designed for use in magnetic separators for the purpose of separating particles of iron in a magnetic form from any non-magnetic materials with which they may be mixed, and more especially for use in that class of separators which are adapted to the separation of crushed iron ore into the different grades or classes known in ore dressing as heads, middlings and tailings.

It is a well known fact that with a uniform magneto-motive force, the distribution of magnetic density at the polar faces of an electromagnet depends upon the size and relative position of the polar faces. If the polar surfaces form parallel areas of equal size which face one another, the distribution of magnetic density at the two surfaces will be approximately uniform, for the reason that the lengths of the air-paths of the lines of force between the two areas, and hence the magnetic resistance, are equal for all parts of the polar faces. If, however, the two equal polar areas do not face one another, but form an angle with one another, or lie adjacent in the same plane or surface, the distribution of magnetic density along their surfaces will not be uniform. In this case, the shortest distance of the lines of force, in completing their circuit through the air, is just across from the inner edge of one polar surface to the inner edge of the other, and as the lines of force tend to pursue paths of least resistance, they will be most dense in the region where they arch over in as short an arch as possible, and they will be less dense along the longer paths which arch over more widely. The lines of force, in completing their paths through the air, occupy positions at the two faces of the pole-pieces which are normal to said polar faces, while above the polar faces they pursue curved air paths in joining the polar faces. As the lines of force choose the shortest path in completing their circuit through the air, it is evident that a plane passed through the air-path of a line of force will be perpendicular to the polar faces and will intersect them in a direction at right angles to their length.

To distinguish the direction in which the magnetic density becomes equalized by the present invention—as being across and not along the polar faces,—the direction is defined as "coinciding with the planes of the air-paths of the lines of force joining the polar faces."

In a previous companion application, Serial No. 429,753, filed April 18, 1892, I have shown and described a form of separator in which the magnetic field (of which two are formed on the same magnetic circuit), is situated between parallel polar surfaces which face one another. This arrangement insures a uniform distribution of magnetic density across the width of the polar surfaces, while at the same time the distribution of magnetic density may, by varying the distance between the polar surfaces, be so altered in the direction of their length as to accomplish important results in the work of magnetic separation.

In the invention for which companion application Serial No. 434,079 was made, a form of field entirely different from that just mentioned is employed. Here the polar faces of the electromagnet are adjacent and either lie in the same surface or in surfaces which make an angle with one another. The magnetic density is greatest at the inner edges of the two polar faces, and decreases gradually toward the outer edges.

The object of this invention is to obtain upon those portions of an operating screen which are opposite the polar faces of the electromagnet and in the direction of their widths, a uniform attracting force. This is done by so inclining the screen surface and the polar faces with respect to each other, that wedge-shaped air-gaps are introduced between them, or, in other words, by making, in a field of normal inequality of magnetic distribution, a selective use of certain positions of the field opposite the polar faces, which form surfaces inclined to said polar faces.

In the invention which forms the subject of the present application, use is made of those portions only of a magnetic field which are opposite the polar faces of an electro-magnet, as in the last mentioned application, but entirely different means are employed to accomplish the same result. The object is here to secure a uniform distribution of magnetic density across the widths of the polar faces which lie adjacent and in the same surface. A uniform attracting force across those portions of the screen surface which are in front of and parallel to the polar faces then follows as a necessary result.

By this invention not only am I able to accomplish all the important results in the work of magnetic separation described in the two previous applications, but a more perfect control and adjustment of the magnetic attracting force in the work of separation is, by these means, secured.

The invention will be best understood by reference to the accompanying three sheets of drawings forming a part of this specification, in which—

Figures 1 and 2 show in transverse and longitudinal section respectively a type of electromagnet in which the pole-pieces are partly composed of a series of movable plates. Figs. 3 and 4 show respectively similar views of an electromagnet in which the pole-pieces are partly composed of a series of plates which can be given a slight rotary motion. Figs. 5 and 6 show respectively similar views of an electromagnet in which the pole-pieces are partly constructed of oblique conical segmental plates. Figs. 7 and 8 show respectively similar views of an electromagnet in which the pole-pieces are partly composed of a series of vertical segmental plates, and Figs. 9 and 10 show respectively similar views of an electromagnet in which the same results are sought by a subdivision of the electro-magnet core in such a manner as to vary the magneto-motive force in different parts of the magnetic circuit. Fig. 11 illustrates the method of spacing the movable plates across the polar faces of pole-pieces both of the form shown in Figs. 1 and 2, and also of that in Figs. 5 and 6.

Similar letters refer to similar parts throughout the several views.

These electro-magnets are all designed to secure in directions coinciding with the planes of the air paths of the lines of force that join the pole-pieces, a uniform distribution of magnetic density, and hence a uniform magnetic attraction along those portions of an operating screen placed opposite said polar faces of the electro-magnets. They represent therefore, equivalent devices for accomplishing the same result.

In the views other than Figs. 9 and 10, P R P is an electro-magnet, in which R represents the electro-magnetic spool or bobbin, composed of a soft iron core wound with copper wire, and P P represent the two pole-pieces, one of which is charged with magnetism of a positive polarity while the other is charged with magnetism of a negative polarity.

E is the operating screen or drum of the separator, rotating on the shaft K.

In the construction of the electro-magnet shown in Figs. 1 and 2, the pole-pieces P P are composed partly of thin iron segmental plates *a a* in sufficient number that their edges form the faces of the pole-pieces. These plates are all of the same shape and size and are held together and supported by means of the bronze bolts *b b*.

By use of washers of different thickness, and preferably of non-magnetic material, placed over the bolts and between the plates, it is possible to obtain any desired variation in the spaces between the latter.

To obtain a uniform distribution of the lines of force in those portions of the magnetic field opposite the two polar faces, the plates *a a* are placed spaced at distances increasingly farther apart in the direction of the inner edges of the polar faces, so that at those parts of the polar surfaces where the lines of force are most thinly distributed, the plates will be set most closely together, and where the lines of force are more dense, they will be set at greater distances apart.

Owing to the fact that magnetism tends to accumulate along the edges of polar surfaces, the lines of force while most dense at the inner edges of the polar faces, will nevertheless show a slight accumulation at the outer edges as well. To secure a uniform distribution of the magnetic density across the polar faces it becomes therefore necessary to place the plates most closely together at a short distance from the outer edges of the polar faces, increasing the distance between the plates rapidly in the direction of the inner edges as shown in Fig. 11. Here for the purpose of illustration a pole-piece of the form shown in Figs. 1 and 2 and also one of the form shown in Figs. 5 and 6 are placed upon the same electromagnet. The exact distances apart at which the plates must be set in order to accomplish a uniform distribution of the lines of force at their outer faces, will vary with the difference in the distribution of the magnetic density in the spaces between the inner and outer edges of the polar faces, and must be determined experimentally.

The effect of the above described distribution of the movable plates whose edges form the faces of the pole pieces, is to introduce air spaces at the polar faces which run lengthwise of said polar faces, and occupy positions numerically across the widths of the polar faces in a direct proportion to the normal distribution of magnetic density across polar faces which lie in the same surface. In other words, the air spaces are more frequent in the direction of the inner edges of the polar faces. From the above it also follows that the movable plates occupy positions numerically across the widths of the polar faces in an inverse proportion to the normal distribution of magnetic density across polar faces lying in the same surface, that is, they are less frequent in the direction of the inner edges of the polar faces.

In the construction shown in Figs. 3 and 4 a series of movable plates *c c* is employed, placed in longitudinal slots across the faces of the pole-pieces P P. One end of every plate is supported at the outer edge of its respective pole piece in the manner indicated in Fig. 4, where thin rods are recessed into the faces of the pole-pieces at the points *d d* to hold the plates. By slightly rotating the plates *c c* inwardly about the points *d d*, they can be given a varying angular inclination with reference to the faces of the pole-pieces. A series of wedge shaped air-gaps may in this way be introduced along the faces of the pole-pieces, and these air-gaps can be varied in size by the motion of the plates *c c*. In this way an increasing amount of metal is removed from the pole-pieces in the directions of their inner edges, where the magnetic density would otherwise be greatest, and by varying the position of the plates *c c*, the magnetic density along an operating screen placed in front of the polar faces can be adjusted and made uniform across the magnetic field in directions coinciding with the planes of the air-paths joining the pole.

In the construction shown in Figs. 5 and 6, although the pole-pieces P P are here likewise partly composed of movable iron plates, they are so shaped and arranged that the lines of force encounter increasing magnetic reluctances in the direction of the greater normal distribution of magnetic density that is to say in the direction in which the magnetic density would increase if the greater magnetic reluctances were not interposed, and for any given longitudinal plane, coincident with the lines of force this direction in either pole-piece would extend in a line across its polar face, toward the face of the adjacent pole-piece.

The inner sides of the pole-pieces P P are shaped to conform to the surfaces of cones and to these sides a series of plates *i i* of decreasing size are fitted, whose surfaces also form segments of cones. These plates are held in place by the bronze bolts *k k* and along which they can be moved in adjusting the spaces between them. It will be obvious that lines of force passing from *m* to *n* in the direction of the arrow encounter an increasing number of air spaces and hence an increasing magnetic reluctance, as the arrow is moved to the right, while by the inclination of the plates they are afforded unbroken iron paths, and hence less reluctance in directions which lead toward the outer edges of the pole pieces. By adjusting the position of the plates in the manner already explained in connection with Figs. 1 and 2 the magnetic density may be made uniform, across the faces of the pole pieces.

From the construction described above it will be evident that in securing a uniform magnetic density across the polar faces, the usual distribution of magnetic density across polar faces of the same size and lying in the same plane, is prevented or counteracted, whereas in the construction shown in Figs. 1 and 2 a redistribution of the magnetic density is obtained by means of the plates *a a* to secure the desired result.

In the construction shown in Figs. 7 and 8 the pole-pieces P P are again partly composed of movable iron plates *o o*. These are placed vertically and are held together and supported by means of the bronze bolts *q q* and brackets F F. The magnetic density is made uniform across the faces of the pole-pieces of this electro-magnet by adjustment of the plates *o o* in the manner already explained. In this case however the desired uniform distribution of magnetic density is effected partly by the method shown in Figs. 1 and 2 and partly by that shown in Figs. 5 and 6. Here along the surfaces *v* S *v* S of the pole-pieces P P a redistribution of the magnetic density is effected through the spacing of the plates *o o* along said surfaces, while beyond the points *v v* an increasing magnetic reluctance is introduced by the successive air spaces, between the plates, which the lines of force have to travel in their paths toward the inner edges of the polar faces.

In the construction shown in Figs. 9 and 10 instead of employing a single core in the electro-magnet the core is subdivided, so that the parts *r r r* form circular segments around which copper wire is wound as shown. These are then placed directly upon the two pole-plates P P to which the several cores are attached. The back piece M completes the construction of the electro-magnet. By the use of cores increasing in size and winding in the direction of the outer edges of the pole-plates P P it is possible to secure a uniform distribution of magnetic density across the polar faces with the same strength of magnetizing current for all the cores, and without the use of distributing or adjusting plates at the polar faces. The same result may also be accomplished by using several cores and copper winding of the same size and amount, but varying the magnetizing force of the different cores, by increasing in the necessary proportion the strength of the energizing current of those cores which are nearer the outer edges of the pole-plates P. P. Again the same result may be effected by adopting either of the two preceding methods as a partial means of equalizing the magnetic density across the polar faces, combined with the use of the plates *e e* as a means of completing the desired magnetic equalization. This is the precise arrangement shown in Figs. 9 and 10. An increasing magnetizing force is consequently exerted in the direction of the outer edges of the polar faces by the use of cores of increasing size and increased winding in that direction, and at the same time thin distributing plates *e e*, similar to those shown in Figs. 1 and 2 are used as a further means of precise adjustment. These plates *e e* are held together by the bolts *f f* and attached to the pole-plates by the bronze connecting bars *g g*. The distributing plates may, if desired, also be extended somewhat beyond the inner edges of the pole pieces as shown.

It will be obvious from the foregoing description that the desired result may be attained in one of three ways; viz: first, by subdividing the pole pieces of an electro-magnet in such a way as either to redistribute or to counteract the usual distribution of the magnetic density such as occurs along adjacent polar faces of equal size lying in the same plane; second, by subdividing the core of an electro magnet so as to vary and adjust the magnetizing force in different portions of the pole-pieces; and third, by combinations of the two preceding methods.

It will also be obvious that the desired result is obtained in any of the constructions described above, by maintaining in all parts of the magnetic circuit a constant ratio between the magneto motive force and the sum of the external and internal magnetic reluctances of the circuit.

Any one of the devices explained above may be applied to a working apparatus for the purpose of treating a crushed iron ore, as described in certain previously filed applications for Letters Patent for magnetic ore separators, Serial Nos. 429,573 and 434,079 and the method of operation of the same will be in all respects similar.

Although Figs. 1 to 10 show cylindrical drum screens in connection with pole-pieces whose faces lie in the same surface, and form segments of cylinders, the present invention is not limited to a particular form of screen or position of the polar faces, while it is desirable in those cases where centrifugal force is employed to aid the separation, to use an operating screen of cylindrical form, in order to secure thereby a more uniform separating action. In other cases, as for example, where water is used to aid the separation, a belt, apron or chute, may be preferably employed in connection with an electromagnet the shape of whose polepieces, and the position of the polar faces, will then depend upon the form of the screen which is adopted.

While a number of different arrangements or constructions of the electro-magnet are illustrated and described in the present specification whereby the desired equalization or uniform distribution of magnetic density is secured across the polar faces, it will be evident that still other arrangements or constructions of the electro-magnet are possible which will accomplish the same result, and I do not therefore limit my present invention to the precise constructions shown in the accompanying illustrations. Nor is the invention necessarily limited to the use of a magnetic separator, for it may be used in any other form of electro-magnetic machine in which a uniform distribution of the magnetic density across the polar faces of the pole-pieces of the magnet is desirable.

I claim as my invention—

1. An electro-magnet provided with pole-pieces, the component parts of which electro-magnet are so subdivided and energized, that a uniform distribution of magnetic density is secured across the widths of the polar faces.

2. An electro-magnet provided with pole-pieces, across whose faces the lines of force pursue air-paths of unequal length, having its component parts so subdivided and energized, that the effect of said inequality is compensated and a uniform distribution of the magnetic density is secured across the widths of the polar faces.

3. An electro-magnet, provided with pole-pieces composed partly of movable and adjustable plates, substantially as described, for adjusting and equalizing the magnetic density across the polar faces in directions coincident with the planes of the air-paths of the lines of force between the polar faces.

4. In a magnetic separator, the combination, substantially as hereinbefore set forth, of an electro-magnet provided with pole-pieces whose faces lie in the same surface, the component parts of which electro-magnet are so subdivided and energized that the magnetic density at the polar faces is adjusted and equalized across their widths, and an operating screen passing through the magnetic field in front of the faces of the pole-pieces.

5. In a magnetic separator, the combination, substantially as hereinbefore set forth, of an electro-magnet provided with suitable pole-pieces, a series of movable and adjustable plates forming part of said pole-pieces, for adjusting and equalizing the magnetic density across the polar faces, and an operating screen passing through the magnetic field in front of the pole-pieces.

6. In a magnetic separator, the combination substantially as hereinbefore set forth, of a rotary iron screen, and an electro-magnet, provided with pole-pieces whose faces lie in the same surface, the component parts of which electro-magnet are so subdivided and energized that the magnetic density is equalized in directions coincident with the planes of the air-paths of the lines of force between the pole-pieces.

7. An electro-magnet for use in magnetic separators, provided with pole-pieces, whose

faces lie in the same surface, the component parts of which electro-magnet are so subdivided and energized that a constant ratio of the magneto-motive force to the sum of the internal and external magnetic resistances of the magnetic circuit, is maintained.

8. An electro-magnet, for use in a magnetic separator, provided with pole-pieces, whose faces lie in the same surface and are partially subdivided by air spaces.

9. An electro-magnet, for use in a magnetic separator, provided with pole-pieces, whose faces lie substantially in the same surface, and which are partially subdivided by air spaces, extending in planes throughout the lengths of said polar faces and occupying positions across the same numerically in direct proportion to the normal distribution of the magnetic density across the same.

10. An electro-magnet for use in a magnetic separator, provided with pole-pieces, whose faces lie in substantially the same surfaces, and which are partially subdivided by air spaces extending across the polar faces, the depth of said air spaces being varied in direct proportion to the normal distribution of the magnetic density across the polar faces.

11. An electro-magnet for use in a magnetic separator, provided with pole-pieces, whose faces are approximately in the same surface, and which are composed of movable plates occupying positions numerically in an inverse proportion to the normal distribution of the magnetic density across the polar faces.

12. In a magnetic separator, the combination substantially as described, of an electro-magnet, provided with pole-pieces, the component parts of which electro-magnet are so subdivided and energized that a constant ratio is maintained of the magneto-motive force to the sum of the internal and external resistances of the magnetic circuit, for all parts of the circuit, and an operating screen passing through the magnetic field in front of the pole-pieces of the magnet.

13. The method, substantially as hereinbefore described, of adjusting and equalizing the magnetic density across the polar faces of the pole-pieces of an electro-magnet in directions coincident with the planes of the air-paths of the lines of force by varying the resistance in the path of the lines of force within the electro-magnet.

14. The method substantially as described, of adjusting and equalizing the magnetic density across the polar faces of the pole-pieces, of an electro-magnet in directions coincident with the planes of the air-paths of the lines of force joining the polar faces, by making the ratio of the sum of the internal and external magnetic resistances of the magnetic circuit to the magneto-motive force, a constant for all parts of said circuit.

In testimony that I claim the foregoing as my invention I have signed my name, in presence of two witnesses, this 24th day of May, 1892.

CLARENCE Q. PAYNE.

Witnesses:
WILLARD PARKER BUTLER,
C. H. LUDINGTON, Jr.