(No Model.)

4 Sheets—Sheet 1.

J. P. WETHERILL.

METHOD OF AND APPARATUS FOR MAGNETIC SEPARATION.

No. 555,792. Patented Mar. 3, 1896.

Fig. 1

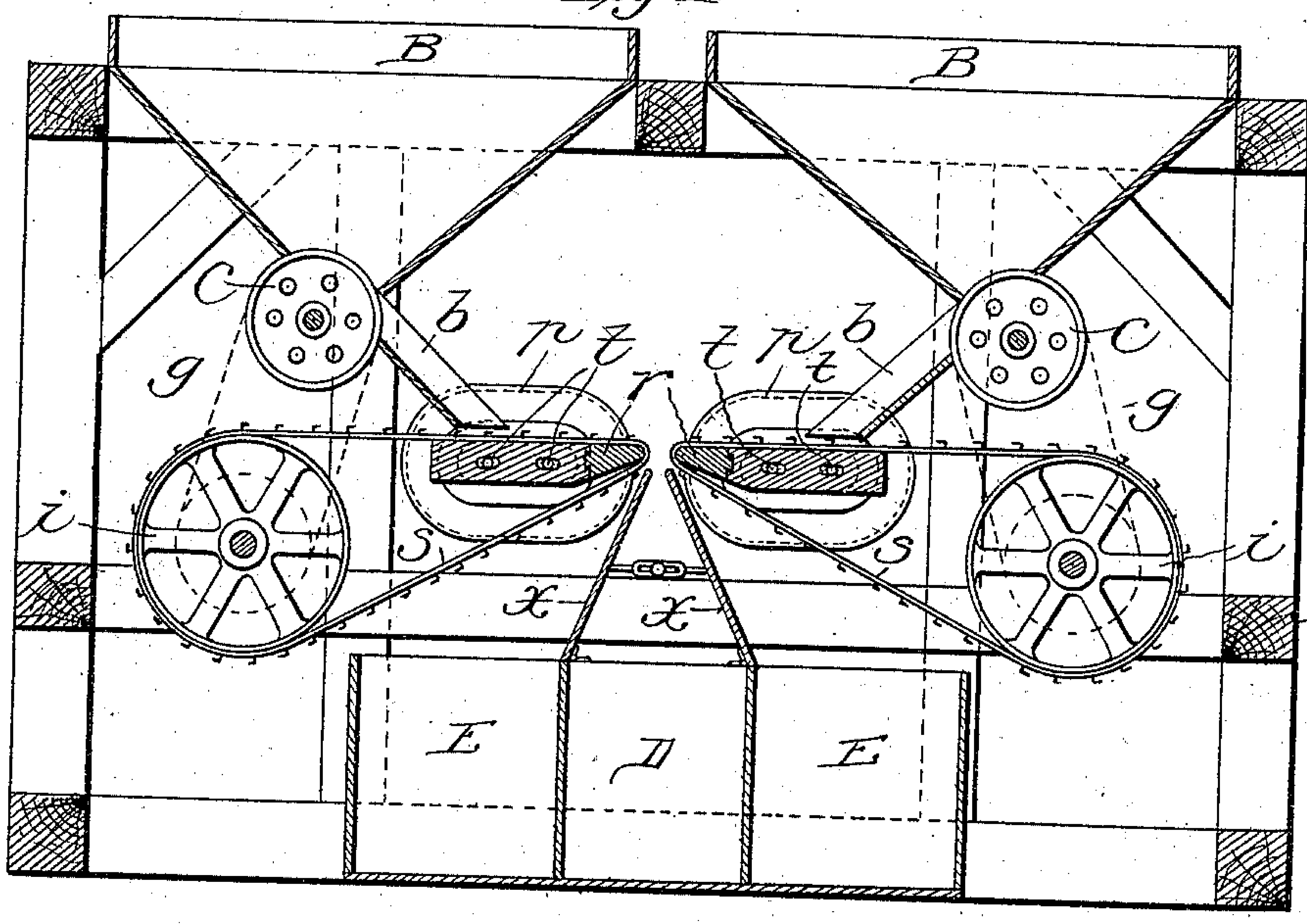
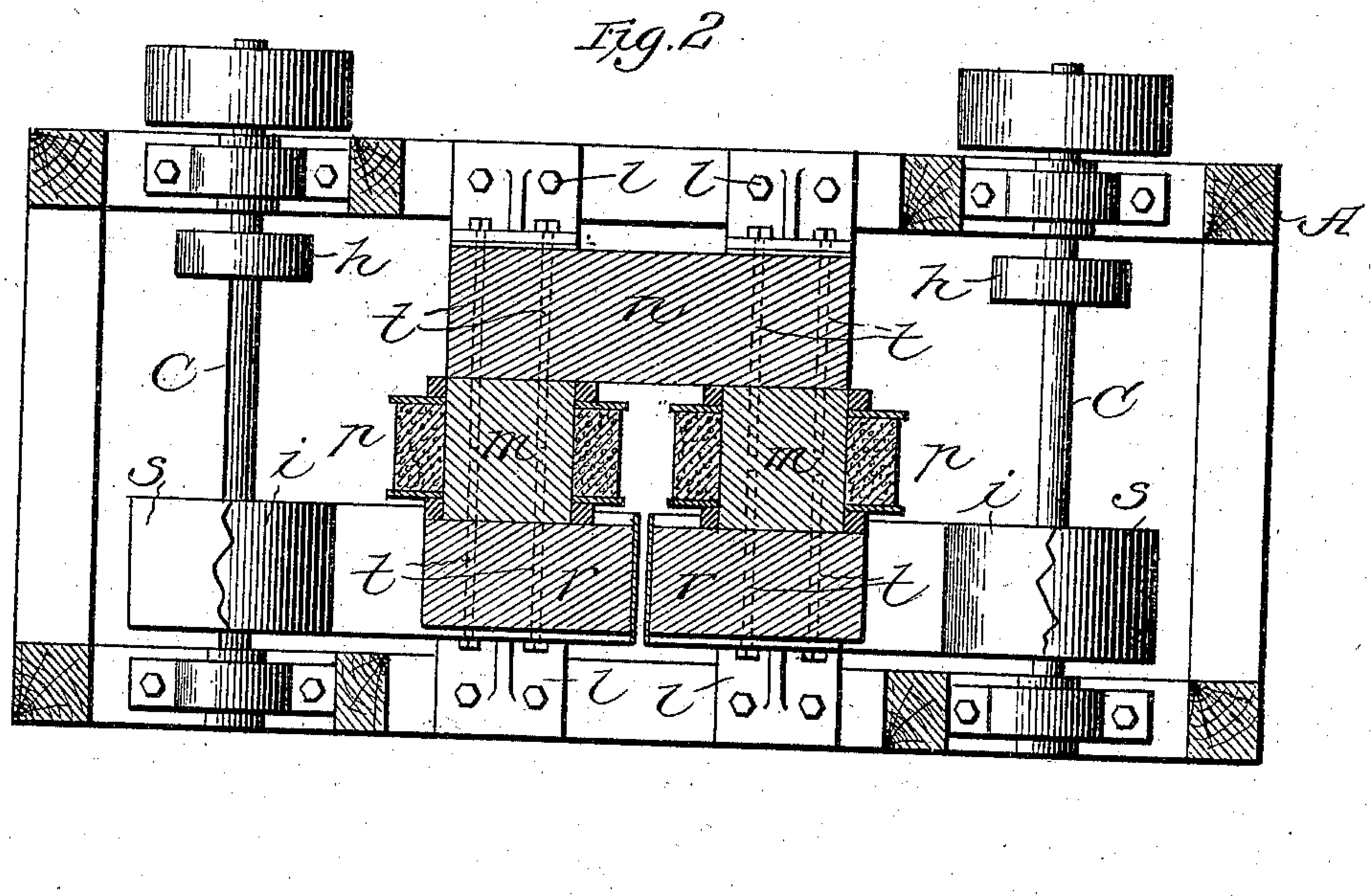


Fig. 2



WITNESSES:

Henry S. Rohner

Harry G. Davis

INVENTOR:

John Price Wetherill,

BY

Kennie & Goldsborough

ATTORNEYS.

(No Model.) 4 Sheets—Sheet 2.

J. P. WETHERILL.

METHOD OF AND APPARATUS FOR MAGNETIC SEPARATION.

No. 555,792. Patented Mar. 3, 1896.

Fig. 3.

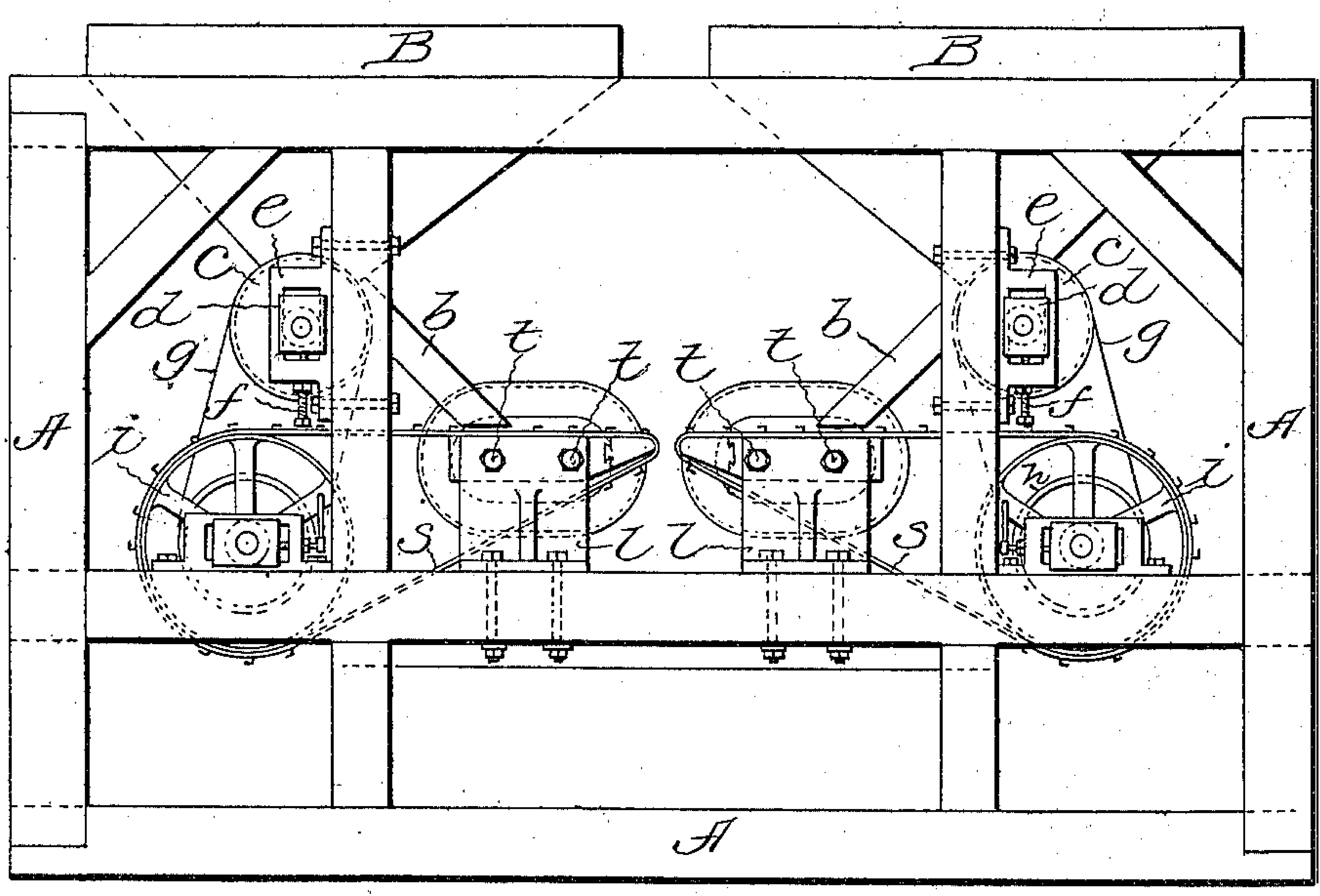


Fig. 4.

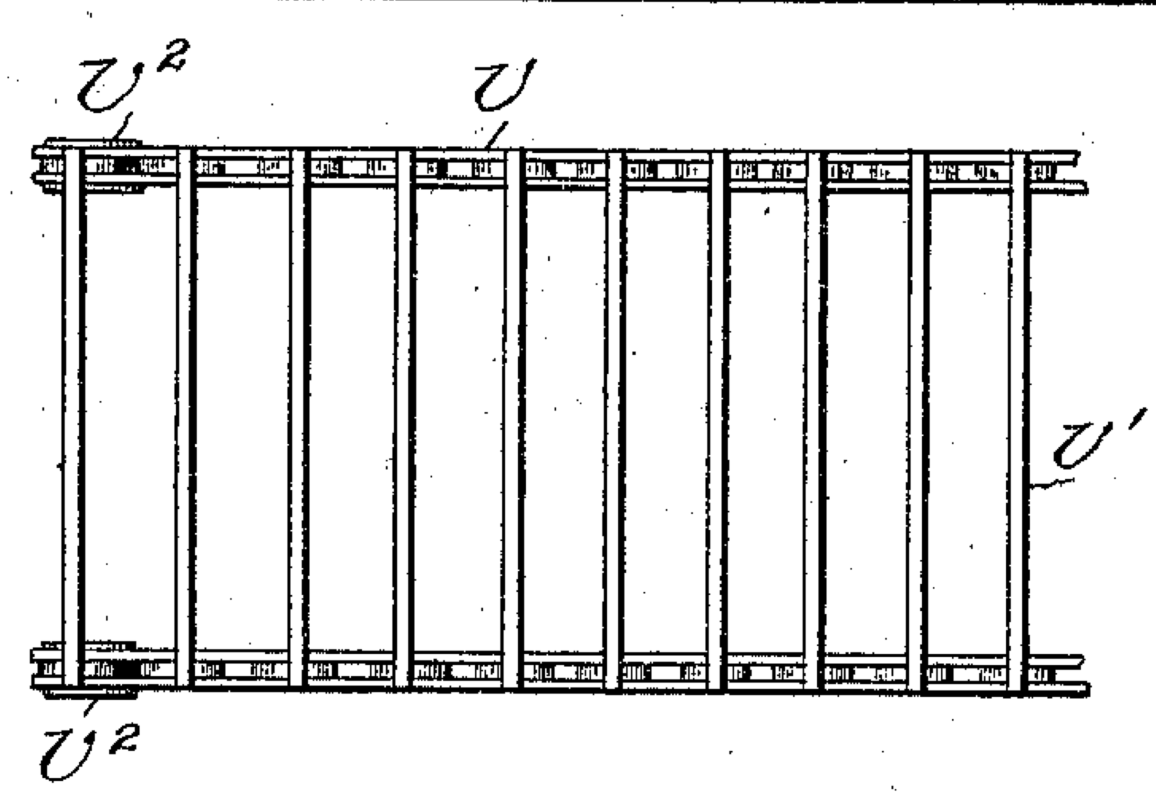


Fig. 5.

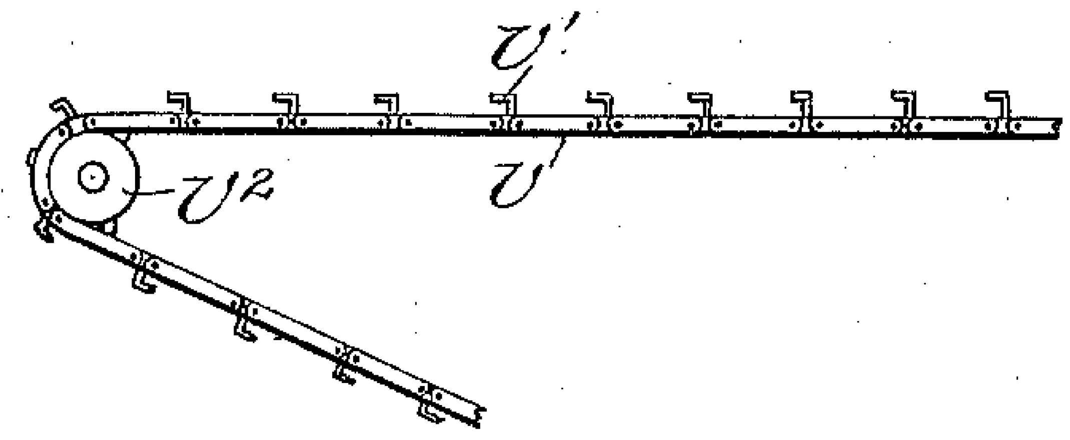
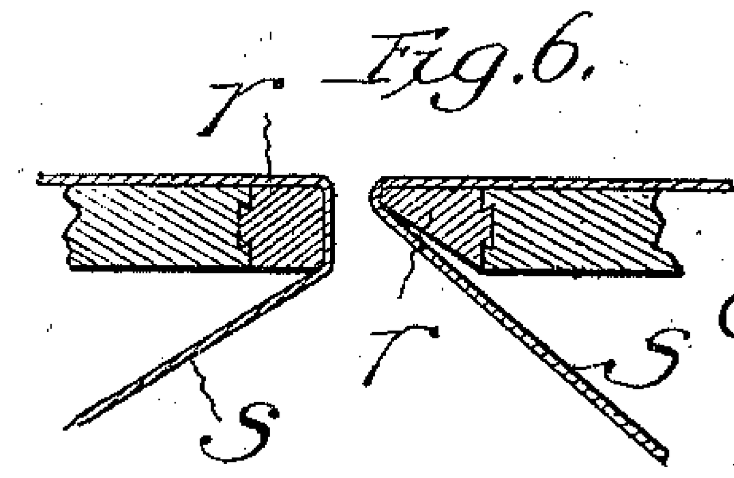


Fig. 6.



WITNESSES:

Harry F. Rohrer

Harry G. Davis

INVENTOR

John Price Wetherill,

BY

Pennie & Goldsborough,

ATTORNEYS.

(No Model.)

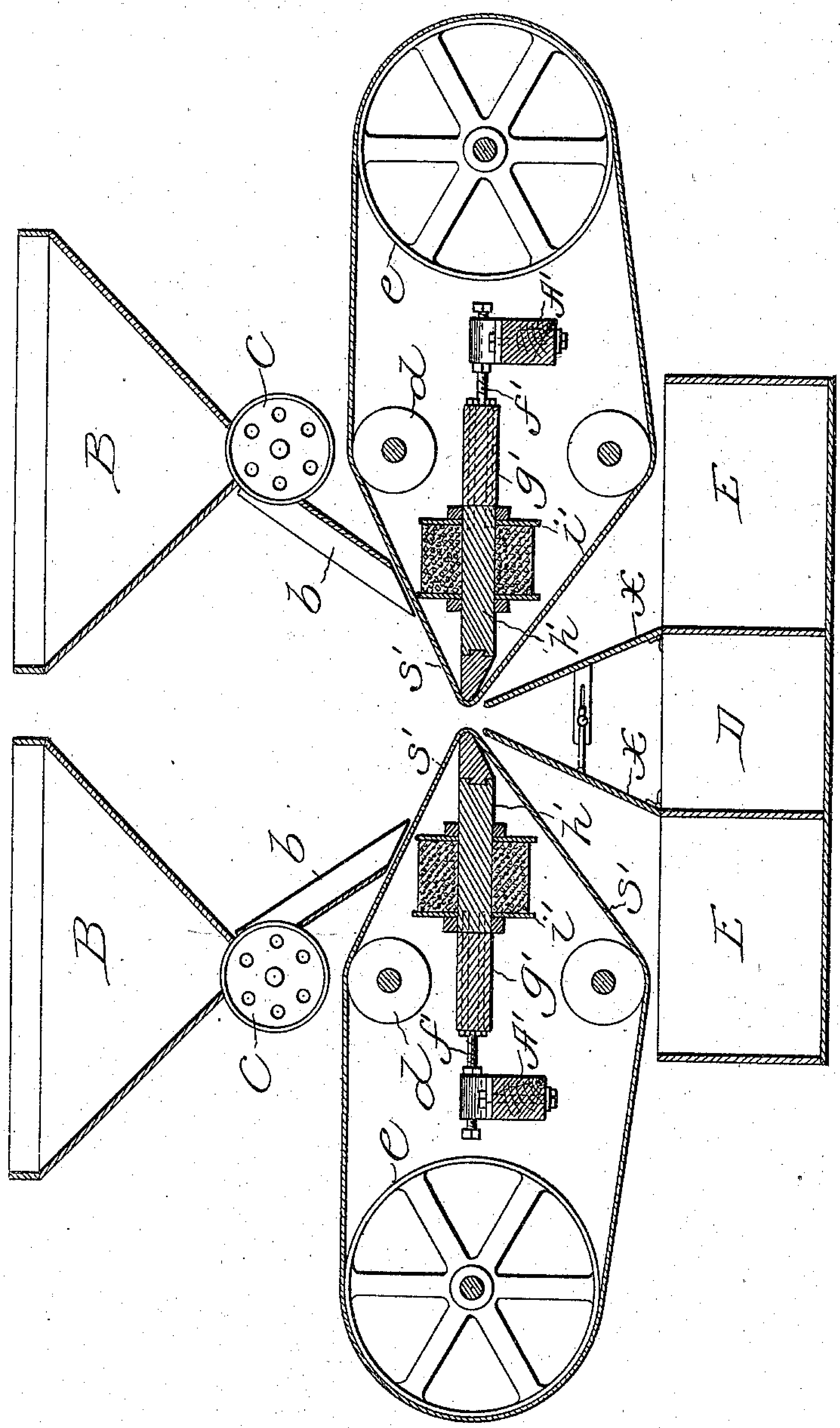
4 Sheets—Sheet 3.

J. P. WETHERILL.

METHOD OF AND APPARATUS FOR MAGNETIC SEPARATION.

No. 555,792. Patented Mar. 3, 1896.

Fig. 7.



WITNESSES:

Harry S. Rohrer,

Harry G. Davis

INVENTOR:

John Price Wetherill,

BY

Rennie & Goldsborough,

ATTORNEYS.

(No Model.) 4 Sheets—Sheet 4.

J. P. WETHERILL.

METHOD OF AND APPARATUS FOR MAGNETIC SEPARATION.

No. 555,792. Patented Mar. 3, 1896.

Fig. 8.

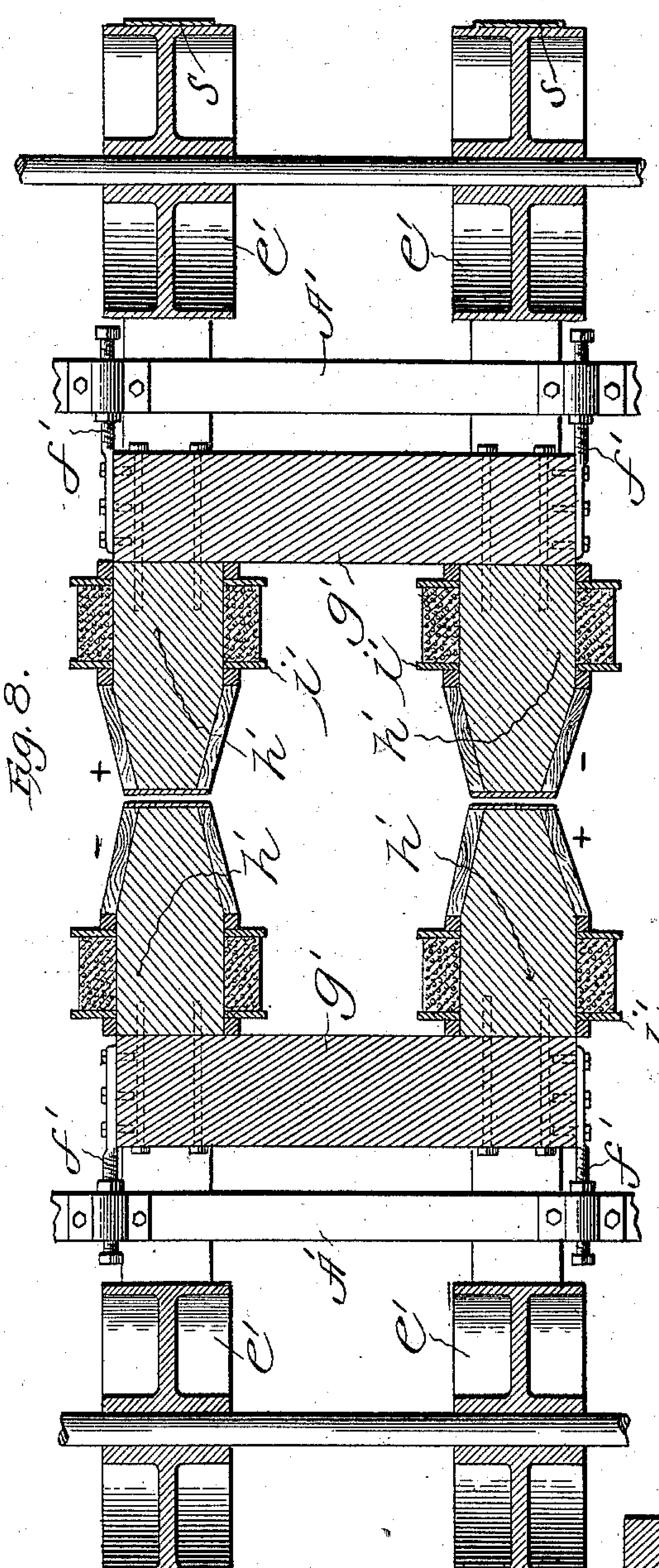


Fig. 9.

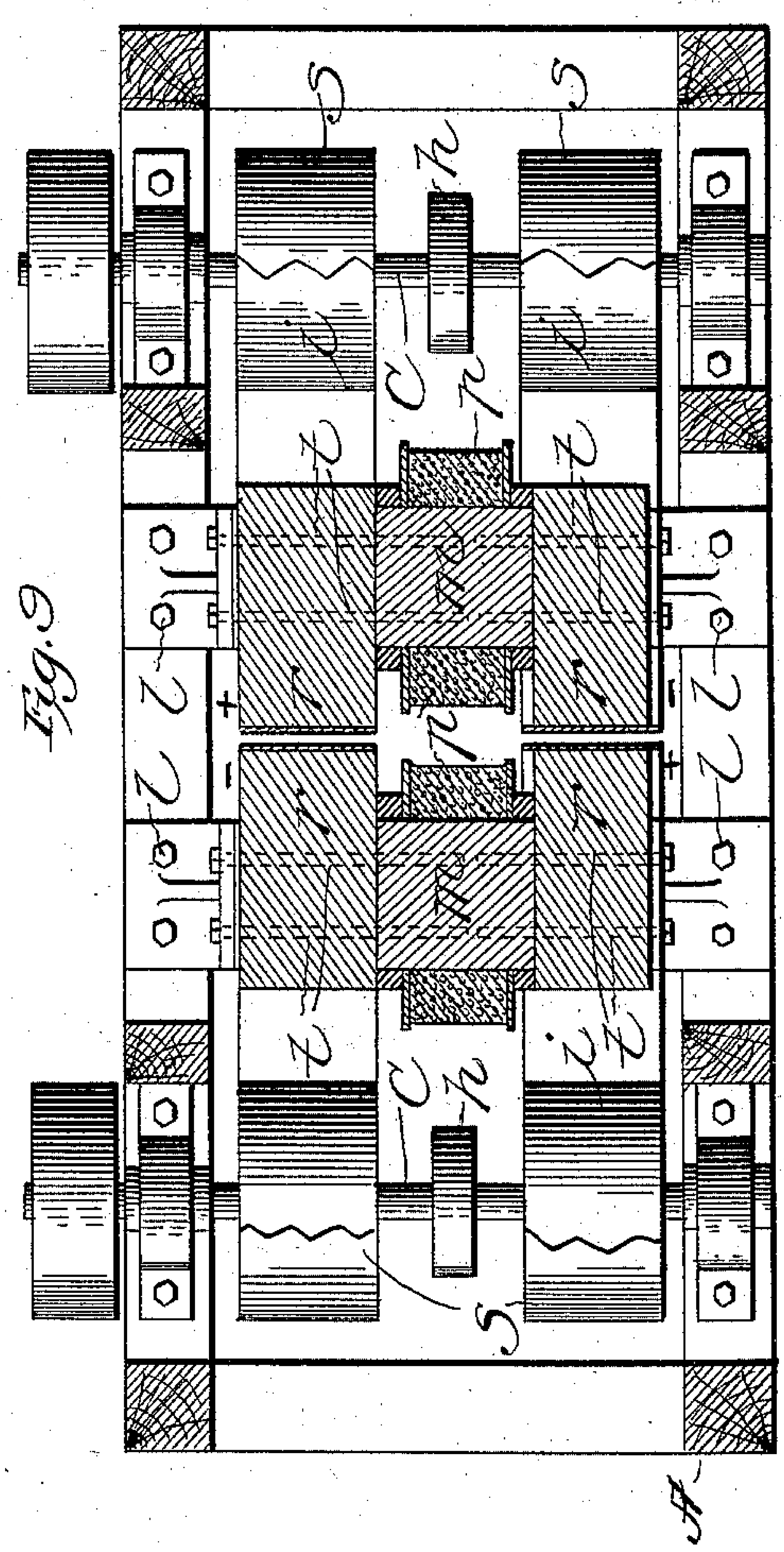
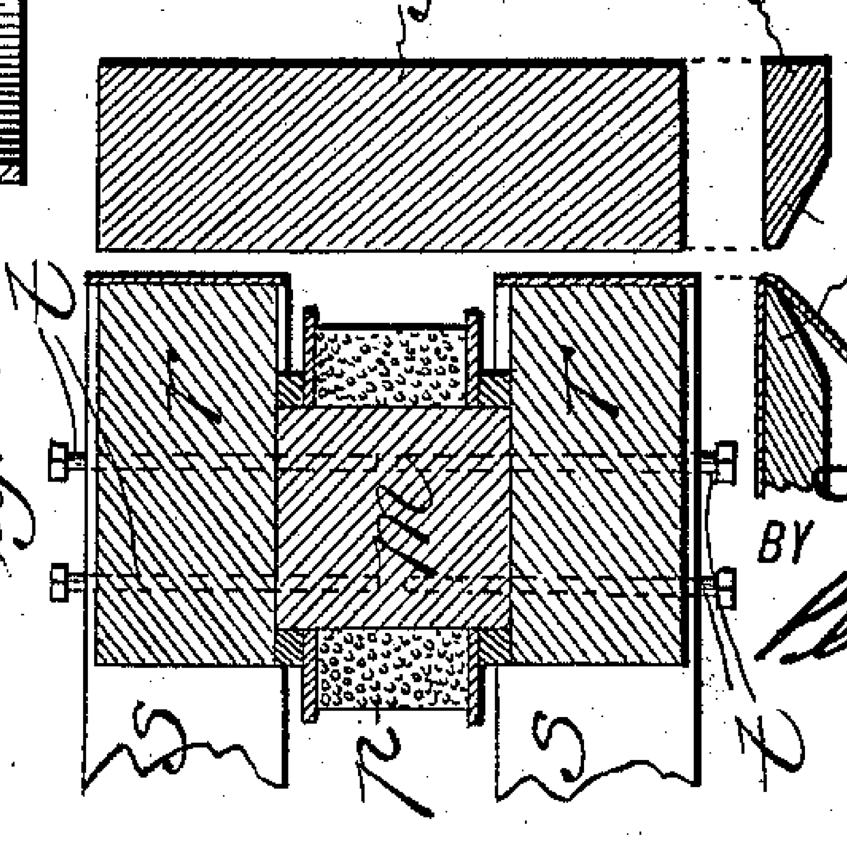


Fig. 10.



WITNESSES:

Harry S. Rohrer

Harry G. Davis

INVENTOR:

John Price Wetherill,

BY

Pennie & Goldsborough,

ATTORNEYS.

UNITED STATES PATENT OFFICE.

JOHN PRICE WETHERILL, OF SOUTH BETHLEHEM, PENNSYLVANIA.

METHOD OF AND APPARATUS FOR MAGNETIC SEPARATION.

SPECIFICATION forming part of Letters Patent No. 555,792, dated March 3, 1896.

Application filed February 10, 1896. Serial No. 578,782. (No model.)

To all whom it may concern:

Be it known that I, JOHN PRICE WETHERILL, a citizen of the United States, residing at South Bethlehem, in the county of Northampton and State of Pennsylvania, have invented certain new and useful Improvements in Methods of and Apparatus for Magnetic Separation; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

My invention contemplates the separation, on a commercial scale, of paramagnetic material of very low magnetic susceptibility from mixtures containing the same, and especially the separation of ferruginous material wherein the iron is present in such small proportion or in such chemical combination that said ferruginous material has been considered incapable of separation and segregation by magnetic separators of the kind heretofore employed in the ore-dressing art.

In the present state of the art, so far as I am aware, the only minerals that are recognized as commercially separable by magnets from ore mixtures containing them are magnetic oxide of iron, (Fe_3O_4,) natural or artificial, and pyrrhotite, both of which have such a high degree of attractability as to adhere to the ordinary seven-inch hand-magnet familiar to the mineralogist, and to be readily removed by familiar forms of separators. Aside from these two classes of minerals, and possibly one or more others closely approximating them in attractability, the knowledge that other ferruginous minerals are susceptible of magnetic attraction has not passed the laboratory or lithologic cabinet stage, and has never been the subject of successful industrial working despite the incentive offered by the recognized high commercial value of the products that would result therefrom.

My present invention realizes broadly the industrial magnetic separation, on a metallurgical scale, of substances of such low magnetic attractability that they are either rated in the art as non-magnetic, or are not recognized as possessing any magnetic attractability whatever. Examples of such substances are afforded by the hematite or limonite present in admixture with sand in ore deposits—as, for instance, the Clinton red fossil ore of Alabama—by the garnet, menaccanite and rutile present in monazite sands, and by spathic iron-ore, (siderite.) These substances, separated through the agency of the intense magneto-motive forces incident to the practice of my invention, are typical of a considerable class, all within a realm of feeble magnetic permeability, extraordinarily remote from that of the so-called "magnetic" minerals, magnetite and pyrrhotite, the abrupt gap between the two classes of substances being unoccupied by substances of intermediate and graduated magnetic susceptibility.

In the practice of my invention for the separation of these and like substances from the non-magnetic gangue accompanying them I first crush the composite ore so that the particles to be separated break apart from each other, unless they are already in that condition, and then pass it through a magnetic field of such extremely-high condensation or concentration that the hematite, or like substance of low attractability to be separated, will be temporarily inductively magnetized and deflected into a line of movement different from that of the gangue.

For the attainment of the best results I feed the material to be separated through the strongest lines of force of the highly concentrated or condensed magnetic field, established across an interval (such as an air or water gap) in a magnetic circuit; and, when the field is formed by the opposing poles of electromagnets, I preferably feed the material into it in such manner that it will enter from opposite sides of the field and pass through the zones of greatest attraction immediately adjacent to the pole-piece edges, avoiding the central zone of substantially equal attraction midway of the poles, as a consequence whereof the particles to be attracted are arrested in the zones of greatest attraction and diverted into receptacles provided for them without coming into the neutral or weaker zones at all. These features are of extraordinary importance for the successful and commercial separation of the class of substances with which my invention deals, as they render it possible to subject the entire mass of the attractable particles to the maximum attractive influencing effect of the magnetic field and secure a corresponding economy in the expenditure of electrical energy for the energizing-coils of the electromagnets, since the full effect of the energy employed is that which is usefully exerted.

In the accompanying drawings I have illustrated several forms of apparatus suitable for the practice of my invention, although it will be apparent that its broad features are capable of embodiment in other forms of construction based upon the same general principles of operation.

In the drawings, Figure 1 represents a vertical section of one form of the apparatus. Fig. 2 represents a horizontal section thereof. Fig. 3 represents a side elevation thereof. Figs. 4 and 5 represent, respectively, and on a somewhat larger scale, a plan view and side elevation of a modified form of conveyer, which may in some instances be substituted for the conveyer shown in the preceding views. Fig. 6 represents, in cross-section, a modification in the relative aspect of the pole-pieces. Fig. 7 represents, in side elevation and partial section, a modified form of the apparatus. Fig. 8 represents a horizontal section thereof. Figs. 9 and 10 represent sectional views of further modifications.

Similar letters of reference indicate similar parts throughout the several views.

Referring to the drawings, A indicates a suitable frame or housing for the convenient mounting and support of the several parts making up the entirety of the apparatus. In the upper part of the frame are supported the feed-hoppers B B for the reception of the material to be treated, which is crushed or comminuted to a degree sufficient to break apart from each other the particles to be separated. At the bottom of each hopper B is located a device for feeding the material in an even layer of graduated thickness to a chute *b*, said device consisting preferably of feed-rollers *c* occupying the bottom of the hopper and mounted in bearings *d* vertically adjustable within brackets *e* by means of a set-screw *f*, or the like, so as to adjust the width of the feed-opening and consequently the thickness of the layer of material fed therefrom, as may be desired.

Each feed-roller *c* receives a constant motion of rotation from a belt *g* driven from a pulley *h* upon a power-shaft C, actuated from any suitable source of power, and upon the same power-shaft C is mounted a pulley *i* for driving the conveyer-belt, as hereinafter described. Transverse to the frame is secured the electromagnetic element of the invention. In the form represented in the drawings this electromagnetic element is supported from suitable brackets *l*, bolted to the machine-frame and is made up of two cores *m*, joined by a connecting-yoke *n*, each core being provided with a bobbin having a wrapping of wire coils *p* in series with each other, the direction of winding of the two coils being such as to produce opposite polarities in their respective pole ends. The pole-pieces *r* are adjustable toward each other preferably through the intermediacy of the screw-bolts *t*, passing through elongated slots made through the body portion of the pole-pieces. The adjustment of the pole-pieces is toward and from each other in a direction transverse to the longitudinal axis of the cores, and the pole-pieces are made of sufficient length that they will, when adjusted as closely together as is contemplated, still entirely cover the proximate ends of the cores. The extreme ends of the pole-pieces are made removable and replaceable, when worn, by means of a dovetail joint, as indicated, and over and about these ends extend conveyers which feed the material forward laterally into the magnetic field. These conveyers may consist of endless belts *s* of thin linen or canvas passed over the actuating-pulleys *i*, and may bear upon their outer surface the conveying-slats or transverse strips shown in Figs. 1 and 3, should these be found desirable in case of excess of magnetic attraction at the pole extremities for the particular material under treatment, although in many cases they may be entirely dispensed with.

Where the material to be separated is of such a character that it is desirable to dispense with any intervening substance between it and the pole-piece over which it is fed, I may feed the material directly upon the upper surface of the pole-piece and move it along said upper surface and over the extremity of the pole-piece by means of the conveyer shown in Figs. 4 and 5 of the drawings, said conveyer consisting of sprocket-chains *v* having cross-slats *v'* moving in contact with the upper surface of the pole-piece so as to convey the material deposited thereon forward, and passing over the sprocket-pulleys v^2.

It will be noted that the cross-sectional area of the cores *m* and of the yoke *n* are indicated in the drawings as substantially equal. They have therefore practically the same magnetic carrying capacity, and the pole-pieces are of corresponding dimensions, not larger in cross-sectional area than that of the cores and yokes, so that the magnetic lines of force may not be dispersed upon entering the pole-pieces. At their ends, on the contrary, the pole-pieces taper toward each other, thereby decreasing in cross-sectional area and causing a corresponding condensation or crowding together of the magnetic lines of force, so as to form a concentrated magnetic field of extraordinary attractive power.

The operation of the invention is as follows: The material to be separated is fed from the hoppers B B and chutes *b* to the conveying device in a layer of the appropriate thickness and is advanced by the conveyer laterally into the condensed magnetic field. As it enters the magnetic field it passes through the zone of greatest attraction thereof immediately adjacent to the pole extremities, whereupon the particles to be attracted are arrested and detained momentarily in contact with the surface of the conveyer as it passes from the polar extremity, while the tailings are carried onward slightly, so as to fall into the central space between the pole extremities and into a receptacle D provided for their reception. The continued movement of the conveyer carries the particles arrested by the attraction of the polar extremities out of the range of such attraction, whereupon they fall from the surface of the conveyer and are deflected by the hinged leaves x into receptacles E. Where the attracted particles have a very low capacity for attractability, they fall from the polar extremities almost immediately after having rounded them, and for this reason the hinged deflecting-plates are carried well up to the pass or interval between the poles, so that the possibility of subsequent commingling of the separated products may be avoided. The degree of separation of the hinged leaves is also capable of accurate adjustment by means of a set-screw and slotted links, as shown. It will be observed that the material to be separated is thus fed laterally into the magnetic field, entirely avoiding the central zone, where the attraction is weaker, and where, as a consequence, material otherwise capable of attraction would fall freely into the receptacle below without being separated. By avoiding the central feed and causing the particles to be attracted to enter initially the strongest zone of attraction they are at once subjected to the full separating power of the magnets, brought to the maximum required for materials of extremely low magnetic capacity by reason of the high condensation of the magnetic circuit at the tapering pole ends. The location of the upper surfaces of the pole-pieces in the same horizontal plane insures the forward feed of the material into the field without gravital impulse, thereby permitting it to receive the full effect of the concentrated lines of force.

It will of course be understood that I do not restrict the employment of my invention to any particular use, but as an example of the conditions under which it may be successfully employed for the magnetic separation of hematite ore from sand or other non-ferruginous material with which it is associated I may state that a mixture of such hematite ore and sand comminuted to a degree sufficient to pass through a sieve of No. 8 mesh and spread out in a moving layer of one-eighth of an inch in thickness has been successfully separated by an apparatus of the kind just described, and wherein the cores were each wrapped with ten hundred and fifty windings of No. 10 copper wire energized by an electric current of eight and one-half ampères and fifty-five volts, the cross-sectional area of the cores and yokes being about 26.87 square inches and the pole-pieces (of the relative size indicated in the drawings) being separated from each other at a distance of seven-eighths of an inch. In this practice, with hematite ore under the conditions named, the speed of travel of the conveyers was about fifty-five feet per minute.

The feature of adjustability of the pole-pieces toward each other is a great desideratum to the successful use of the apparatus, for the reason that the strength of the effective field can be delicately graduated thereby to correspond exactly to the requirements of the particular substance treated, and without it being necessary to alter the ampèrage of the electric current for small variations. It is also important that the material to be separated is fed past the magnet-poles without initial velocity due to gravitation, and at a moderate speed, so that the magnetic attraction may not be neutralized by a preponderating force.

In some cases it will be desirable to pass the tailings from a primary separation a second and even a third time through the apparatus, or, which is equivalent thereto, through a number of them, where the magnetic susceptibility is exceptionally low and a particularly complete separation is desired. Where the material treated contains a plurality of magnetically-separable constituents of different susceptibilities—as, for instance, the menaccanite and garnet present in monozite sands—I find it convenient to primarily remove, as heads, the menaccanite and garnet by an appropriate condensation of the field, and afterward to pass the heads again through the apparatus, or through an adjacent like apparatus, wherein the field is weakened sufficiently to leave the garnet but is still sufficiently strong to remove the menaccanite. The difference in the condensation of the fields can be obtained either by decreasing slightly the ampèrage of the current or by increasing the width of the working interval between the pole-pieces, or by a combination of the two expedients. I have found in practice that a difference of one ampère in the strength of the current is sufficient for such separation of menaccanite and garnet.

It will be observed that the efficiency of the separation hereinbefore described depends upon obtaining a local condensation of the magnetic circuit of such an extraordinary character as to inductively magnetize and remove these minerals of low magnetic attractability, and that fields of such high condensation are remarkably susceptible to varying conditions and are capable of delicate adjustment. Where a still stronger condensation is desired, I leave one of the pole-pieces untapered, as indicated in Fig. 6. In such case I still employ the two belts, as before, but use as an ore-conveyer only the belt that passes around the tapered pole, the increase in the attractive power of the field being obtained at the expense of cutting down the feeding capacity of the machine.

In Figs. 7 and 8 I have illustrated a modified form of apparatus embodying my invention, the main distinguishing feature consisting in doubling the capacity of the machine shown in Figs. 1 to 3, so as to enable it to treat simultaneously two different bodies of material subjected to its action. Moreover, the magnetic fields, instead of being formed between two poles of the same magnet, are formed between poles of separate magnets, with the result that the fields are more rigorously uniform across their entire effective zones of greatest attraction. In this modified form of the apparatus receiving-bins for the separated products are provided, as before, and the feeding devices are of the same general character as in the construction shown in Figs. 1 to 3, save that the conveyer-belts s' may be inclined toward the pole ends, as shown. In this connection it is to be observed that this inclination should not exceed the angle of rest for the material treated and should usually be less than thirty degrees, so that the material may not slide on the belt, and thereby have imparted to it an inertia that would carry it rapidly past the magnet-poles, but so that it may be fed gradually at the predetermined moderate speed required, thereby having opportunity to be fully subjected to the influence of the condensed field before being subjected to the force of gravitation.

The electromagnets, two in number, are secured to a portion A′ of the frame of the apparatus by means of adjusting-stems f', connected to the magnet-yokes g', whereby the magnets as a whole can be moved from and toward each other, so as to vary the interval between the opposing pole ends, as required in practice. Each magnet will be provided with two cores h', surrounded each with a bobbin i', upon which is wound the appropriate number of convolutions of copper wire. The convolutions upon all four cores of the two magnets are conveniently connected in series and energized by a current from the same generator, the direction of winding being such that the poles of each magnet shall be of opposite sign and that the minus pole of one magnet shall be opposite the plus pole of the other, thereby constituting two independent magnetic fields. Care should be taken to separate the cores and pole-pieces of each magnet from each other sufficiently far to prevent leakage across from one pole to the other of the same magnet, as such leakage would have a tendency not only to weaken both magnetic fields, but also to disturb the uniform distribution of the magnetic lines in each, and thereby cause them to act unequally upon the material treated. The pole-pieces (and by this expression I mean the continuation of the cores beyond the energizing-coils) are tapered at their ends in the direction of their thickness, and also preferably in the direction of their width, as shown.

In the construction shown in Fig. 9 the pole-pieces are of like character to those of the apparatus illustrated in Figs. 1 to 3 and are similarly adjustable. The capacity of the apparatus is, however, also doubled, as will be apparent, there being double sets of feed-belts.

In Fig. 10 I have illustrated the employment of one of the electromagnets shown in Fig. 9 placed opposite an inducing-body x, of soft iron, which arrangement I also find acceptable in practice when the cores and pole-pieces are energized to develop at the tapered pole ends the highly condensed or concentrated magnetic fields essential to the practice of the invention.

In an application for Letters Patent for improvements in the separation of Franklinite ore and the metallurgy thereof, filed of even date herewith, I have claimed broadly the method of separating paramagnetic materials of different permeability from mixtures containing them by subjecting the mixture to the action of a magnetic field sufficiently concentrated to remove said paramagnetic material and then separating the removed paramagnetic material into its components by subjecting it to the action of a magnetic field reduced in intensity sufficiently to leave the less permeable component, but sufficient to remove the component of higher permeability. I do not, therefore, claim the same in this application.

Having thus described my invention, what I claim is—

1. The herein-described method of separating ferruginous materials of inferior magnetic susceptibility or permeability from non-ferruginous materials, consisting in bringing the mingled materials into a condensed or concentrated magnetic field, and deflecting the ferruginous material, while under the influence of said condensed field, into a path of movement different from that of the non-ferruginous material.

2. The method of magnetically separating substances of relatively very low magnetic susceptibility from a mixture containing them, which consists in establishing a magnetic circuit, concentrating said magnetic circuit across a working area and developing therefrom intense magneto-motive forces sufficient to inductively magnetize such particles of very low magnetic susceptibility, subjecting the mixture to the action of said intense magneto-motive forces and thereby attracting and withdrawing from the mixture the particles to be removed, and progressively removing the withdrawn particles from the field of action of said intense magneto-motive forces.

3. The method of magnetically separating, from a mixture, substances of such low magnetic attractability as siderite, hematite, garnet, or the like, which consists in establishing a magnetic circuit, passing the mixture through a part of the circuit condensed to form a concentrated field sufficient to inductively magnetize and withdraw the siderite, hematite, garnet, or the like, from the mix-

ture, and progressively removing the withdrawn minerals from the condensed portion of the magnetic circuit.

4. The method of separating from a mixture, substances of such low magnetic permeability as to have been usually regarded as non-magnetic, which consists in establishing a magnetic circuit having an interval across which the magnetic lines of force extend forming a magnetic field substantially uniform along its length, condensing the magnetic lines at said interval, conveying the substances to be separated into the longitudinal edge portions of said condensed magnetic field, and causing said condensed magnetic field to attract and deflect the attractable particles subjected to its action.

5. The method of separating from a mixture substances of such low magnetic permeability as to have been usually regarded as non-magnetic, which consists in establishing a magnetic circuit having an interval across which the magnetic lines of force extend forming a magnetic field substantially uniform along its length, condensing the magnetic lines at said interval, conveying the substances to be separated into the longitudinal edge portions of said condensed magnetic field, and causing said condensed magnetic field to attract and deflect the attractable particles subjected to its action, and continuously removing the particles thus deflected.

6. The method of separating from a mixture substances of such low magnetic permeability as to have been usually regarded as non-magnetic, which consists in establishing a magnetic circuit having an interval across which the magnetic lines of force extend forming a magnetic field substantially uniform along its length, condensing the magnetic lines at said interval, conveying the substances to be separated into the strongest part of said condensed magnetic field transversely to the length of the field and without initial velocity due to gravitation, and causing said condensed magnetic field to attract and deflect the attractable particles subjected to its action.

7. The method of magnetically separating from a mixture substances of such low magnetic permeability as to have been usually regarded as non-magnetic, which consists in establishing a magnetic circuit having an interval across which the magnetic lines of force extend forming a magnetic field, condensing the magnetic lines at said interval, and feeding the mixture at opposite sides of the weaker zone of attraction between the pole-pieces, so that the particles to be attracted will pass through the magnetic field through the zones of greatest attraction and avoiding the central weaker zone; whereby the so-attracted material is deflected into a different path of movement.

8. In a magnetic separator, an electromagnet having a pole-piece tapering toward its free end, said free end being of less sectional area than the magnet-core so as to highly condense the lines of magnetic force, and a conveyer for withdrawing the attracted material from the magnetic field.

9. In a magnetic separator, an electromagnet having a pole-piece tapering toward its free end, said free end being of less sectional area than the magnet-core so as to highly condense the lines of magnetic force, and a conveyer for withdrawing the attracted material from the magnetic field, the tapering end of the pole-piece being arranged transversely to the direction of travel of the conveyer.

10. In a magnetic separator, an electromagnet having a pole-piece tapering toward its free end and having a core substantially equal in breadth to the breadth of the pole-piece, and a conveyer passing around the pole-piece for introducing the ore into the magnetic field and withdrawing the attracted material from said field.

11. In a magnetic separator, an electromagnet having a pole-piece tapering toward its free end, said free end being of less sectional area than the magnet-core so as to highly condense the lines of magnetic force, an inducing-body located opposite the tapering pole end, and a conveyer for withdrawing the attracted material from the magnetic field.

12. In a magnetic separator, an electromagnet having a pole-piece tapering toward its free end, so as to highly condense the lines of magnetic force, an inducing-body located opposite the tapering pole end, said inducing-body being itself the pole end of an electromagnet, and a conveyer for withdrawing the attracted material from the magnetic field.

13. In a magnetic separator, an electromagnet having a pole-piece tapering toward its free end so as to highly condense the lines of magnetic force, an inducing-body located opposite the tapering pole end, and means for increasing or decreasing the interval between the pole end and the inducing-body, and a conveyer for withdrawing the attracted material from the magnetic field.

14. In a magnetic separator, an electromagnet having a pole-piece tapering toward its free end in width and thickness, said free end being of less sectional area than the magnet-core so as to highly condense the lines of magnetic force, and a conveyer for withdrawing the attracted material from the magnetic field.

15. A magnetic separator, provided with opposing pole-pieces of opposite sign, said pole-pieces having tapered ends of less sectional area than their cores and separated from each other by an interval forming a magnetic field, and a lateral conveyer for each pole-piece, said conveyer feeding material to be treated laterally into the magnetic field and directly over the surface of the pole-pieces so that the particles to be magnetized will approach and enter the magnetic field through

the zone of greatest attraction immediately adjacent to each pole-piece and will avoid the weaker zone midway of the pole-pieces.

16. A magnetic separator, provided with opposing pole-pieces of opposite sign, separated from each other by an interval forming a magnetic field, said pole-pieces tapering at their ends, so as to have a sectional area less than that of their cores, and conveyers for the material to be treated, said conveyers passing around the tapering portions of the pole-pieces and in close proximity thereto.

17. A magnetic separator, provided with opposing pole-pieces of opposite sign, separated by an interval forming a magnetic field, said pole-pieces tapering at their ends toward each other, the form of such taper being in longitudinal section substantially that of a right-angled triangle, and conveyers for the material to be treated, said conveyers passing over the surfaces of the pole-pieces and in close proximity thereto.

18. A magnetic separator, provided with opposing pole-pieces of opposite sign, separated by an interval forming a magnetic field, said pole-pieces tapering at their ends toward each other and having their upper surfaces in substantially the same plane, and conveyers for the material to be treated, said conveyers passing around the pole-pieces and in close proximity thereto.

19. A magnetic separator, provided with opposing pole-pieces having tapering ends of less sectional area than the cores and separated by an interval forming a magnetic field, conveyers passing over and around said tapering ends, a central receptacle to receive tailings and outer receptacles to receive the withdrawn magnetized particles.

20. A magnetic separator, provided with opposing pole-pieces having tapering ends of less sectional area than the cores and separated by an interval forming a magnetic field, conveyers passing over and around said tapering ends, a central receptacle to receive tailings and outer receptacles to receive the withdrawn magnetized particles, the entrance to said central receptacle being separated from the outer receptacles by adjustable wings or shutters.

21. A magnetic separator, provided with opposing pole-pieces having tapering ends and separated by an interval forming a magnetic field, said tapering ends being adjustable toward and from each other, and a conveyer for withdrawing the attracted particles from the magnetic field.

22. A magnetic separator, provided with opposing pole-pieces having tapering ends and with their upper surfaces in substantially the same plane, endless conveyers passing over and around said tapering ends, and means for supplying to each conveyer a layer of material to be separated of substantially the width of the tapering ends.

23. A magnetic separator, provided with opposing pole-pieces, movable toward each other and having tapering ends, and conveyers passing over the tapering ends and feeding the material to be separated laterally toward the interval between the pole-pieces.

24. A magnetic separator, comprising a frame having tapering pole-pieces mounted therein and adjustable toward and from each other, endless conveyers passing over and around the tapering ends of the pole-pieces, hoppers having feed-rollers in their outlets for feeding in a layer the material to be separated, and chutes for delivering the material to the conveyers.

25. A magnetic separator, comprising a frame, tapering pole-pieces mounted therein and adjustable toward and from each other, endless conveyers passing over and around the tapering ends of the pole-pieces, hoppers having feed-rollers in their outlets for feeding in a layer the material to be separated, chutes for delivering the material to the conveyers, and separate receptacles for the tailings and separated magnetic particles, the upper portion of the tailings-receptacle being provided with adjustable wings or leaves to deflect the separated magnetic particles into their receptacles.

26. A magnetic separator having two electromagnets presenting two pairs of tapering poles of unlike sign opposite to each other, and conveyers for feeding the material to be separated laterally into the magnetic field from opposite sides of the interval separating them and for withdrawing the attracted particles from the magnetic field.

In testimony whereof I affix my signature in presence of two witnesses.

JOHN PRICE WETHERILL.

Witnesses:
HUGH M. STERLING,
JOHN C. PENNIE.