Feb. 14, 1933. C. E. NICOLET 1,897,763

MAGNETIC SEPARATOR

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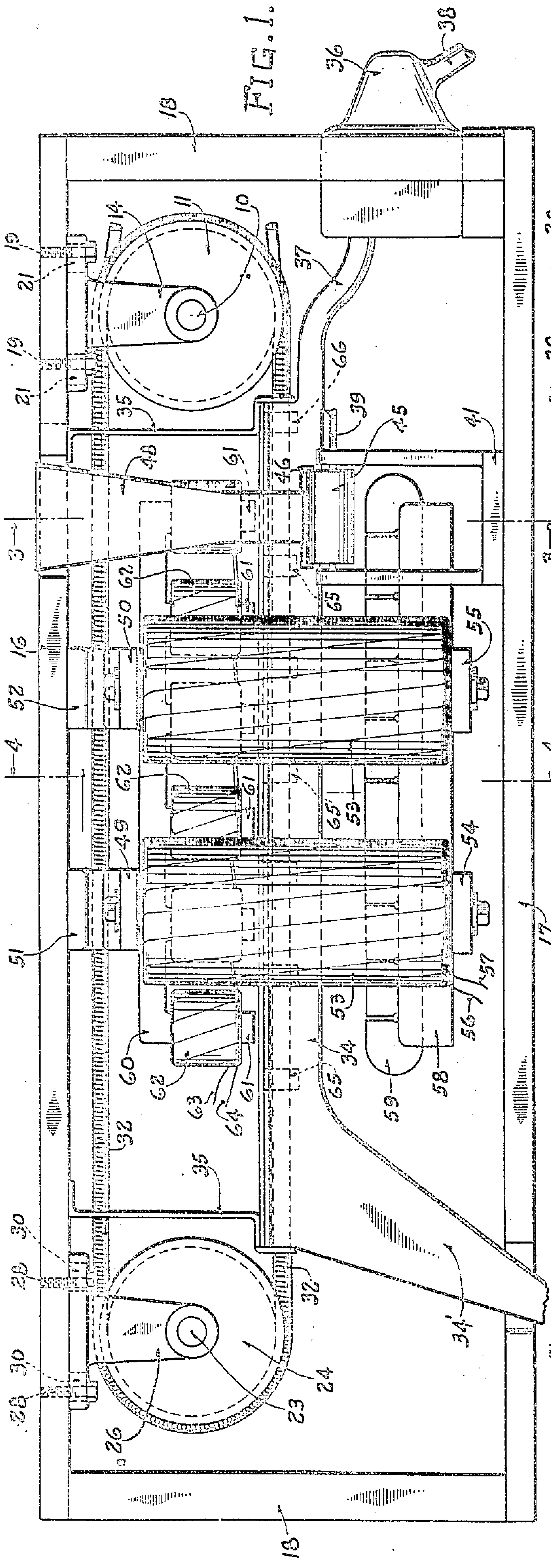

FIG. 1.

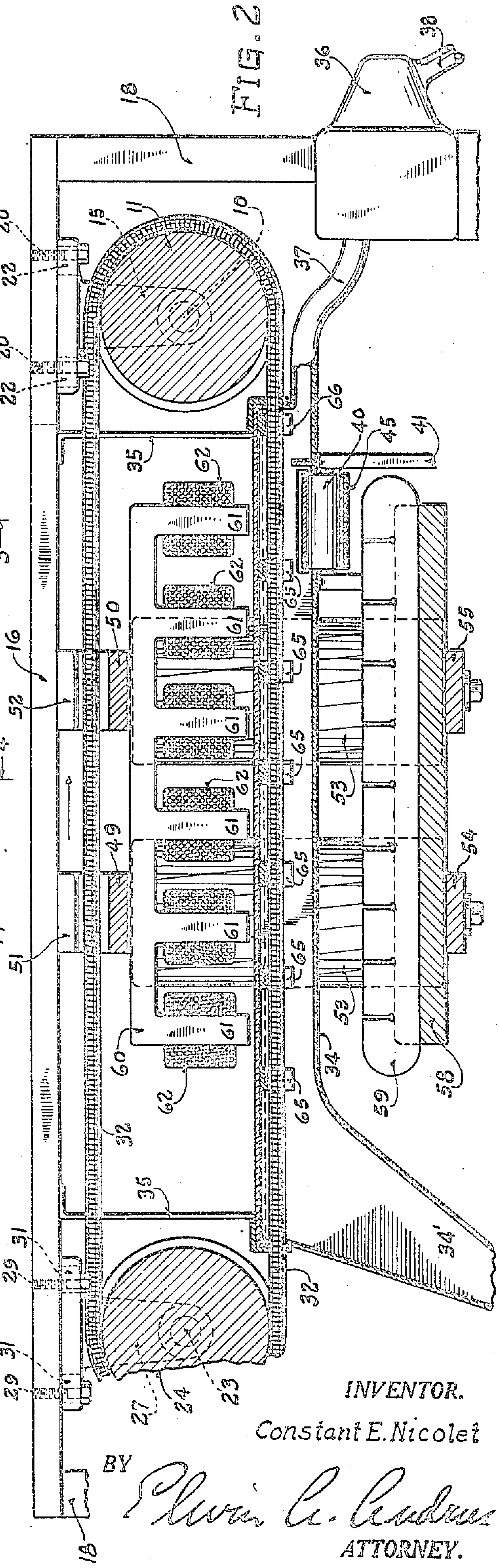

FIG. 2.

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FIG. 3.

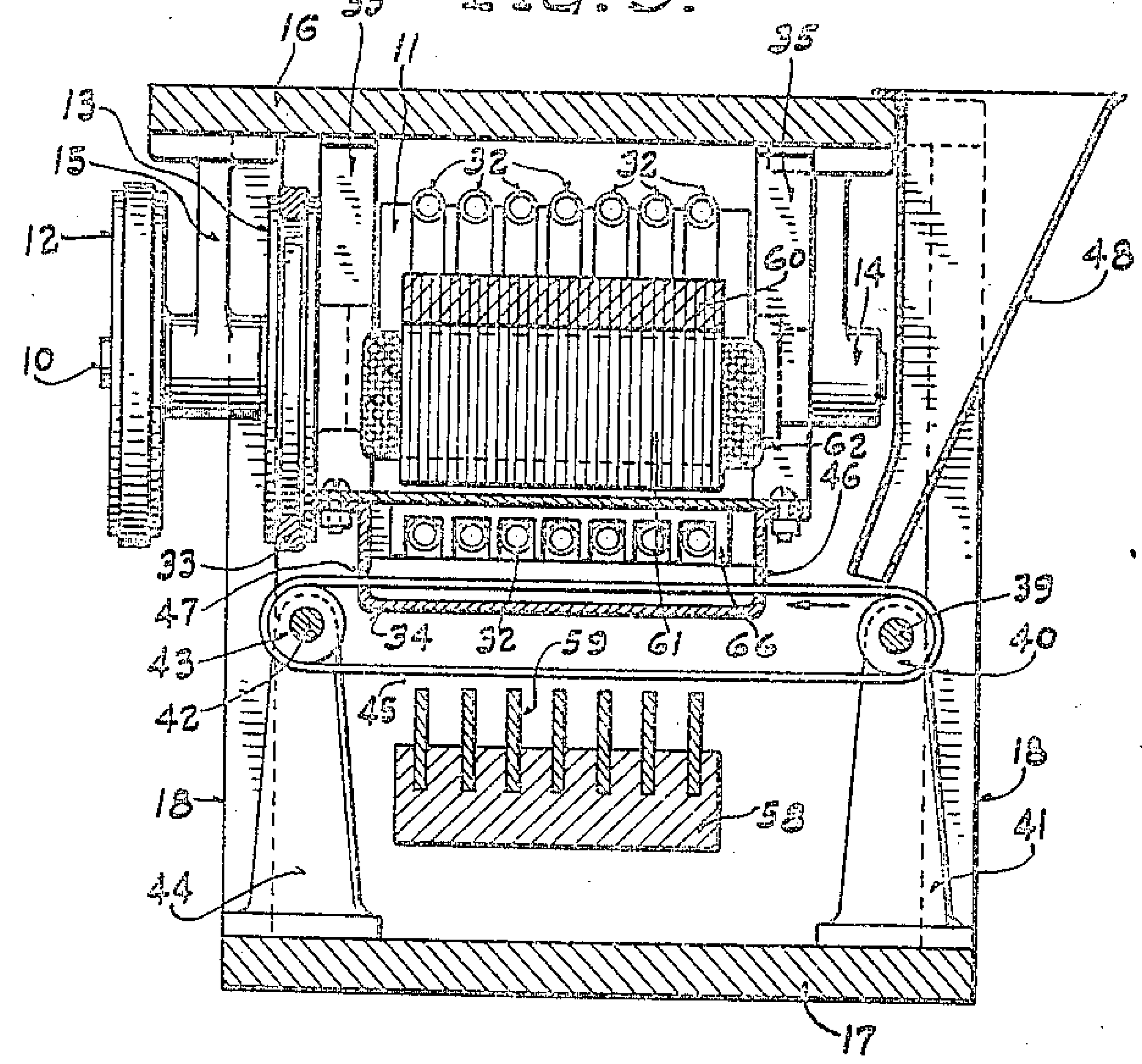
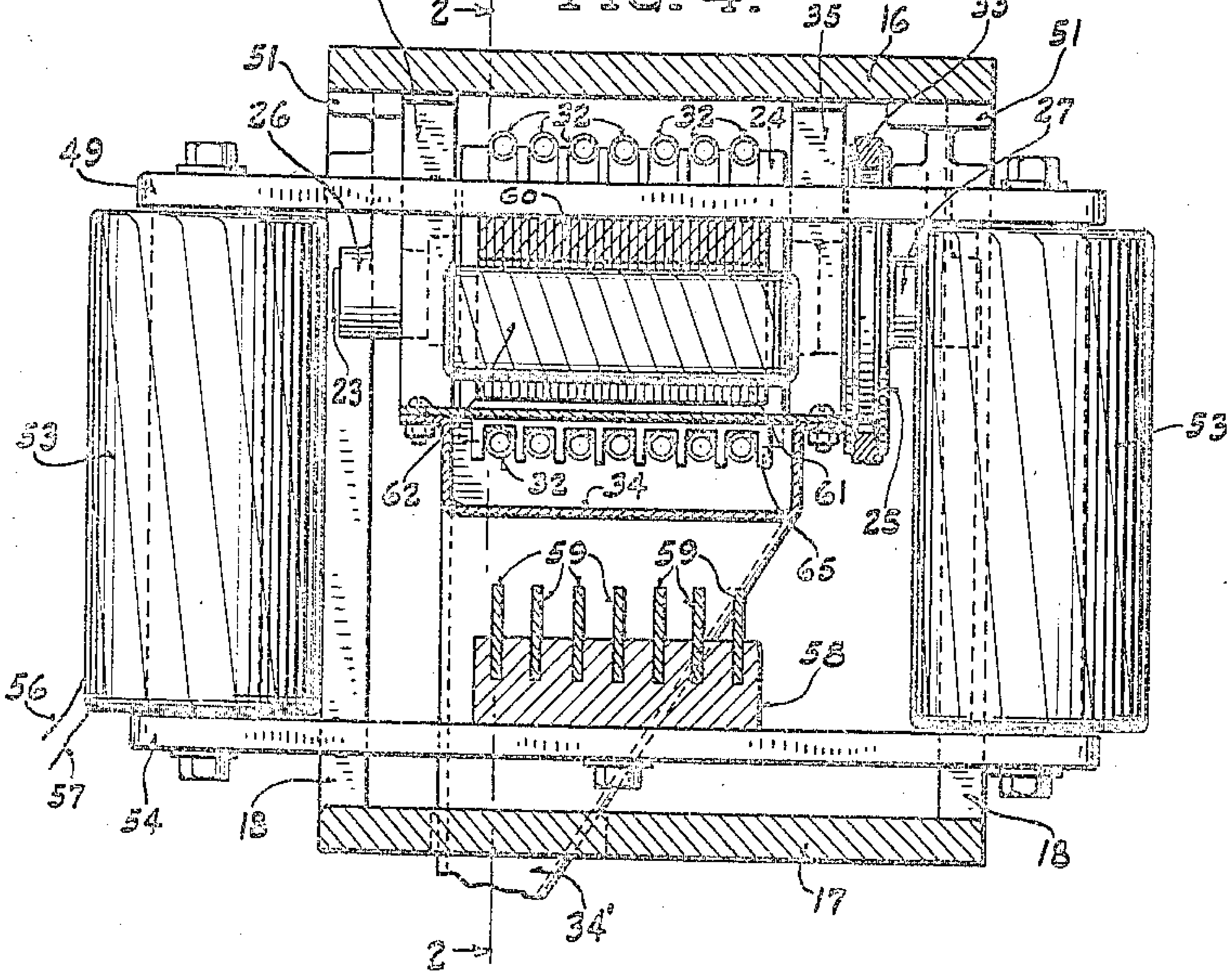


FIG. 4.



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1,897,763

UNITED STATES PATENT OFFICE

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MAGNETIC SEPARATOR

Application filed January 18, 1932. Serial No. 587,317.

This invention relates to magnetic separators and especially to magnetic separators in which the magnetic field is periodically varied in intensity.

An object of the invention is to provide a magnetic separator which is capable of efficient operation with wide variations in production.

Another object is to provide a magnetic separator in which the material under treatment is agitated to produce a more effective separation.

In accordance with the present invention, these and other objects are attained by associating the material to be treated with a magnetizable member which is rendered magnetic by induction and which is capable of being vibrated in response to variations in intensity in a magnetic field. This member is passed through a magnetic field, the intensity of which is periodically varied, preferably by superimposing an alternating current magnetic field on a direct current field. As the member passes through the periodically varying magnetic field, it is adapted and arranged to vibrate in accordance with the variations in the field and the non-magnetic particles are thrown off. The magnetic particles are carried by the vibratory member through and beyond the influence of the field where they are removed.

For a further understanding of this invention, reference may be had to the accompanying drawings in which:

Figure 1 is a side elevational view of the apparatus employed in the present invention;

Fig. 2 is a partially elevational and partially sectional view, the section being taken along line 2—2 of Fig. 4;

Fig. 3 is a transverse sectional view taken along line 3—3 of Figure 1; and

Fig. 4 is another transverse sectional view taken along line 4—4 of Figure 1.

Referring to the drawings, a shaft 10 carrying a roller or drum 11 and pulleys 12 and 13 is journaled in stanchions 14 and 15 which are secured to either side of one end of a top supporting member or plate 16 which in turn is supported from base 17 by a plurality of upright supports 18. The stanchions 14 and 15 may be secured to the supporting plate 16 by means of studs 19 and 20 which pass through elongated slots 21 and 22 in the base of the stanchions and which are in threaded engagement with the supporting plate 16 so that the position of the stanchions may be adjusted longitudinally along the face of the plate.

A shaft 23 carrying a roller or drum 24 and pulley 25 is journaled in stanchions 26 and 27 which are secured to either side of the opposite end of the top supporting member or plate 16. The stanchions 26 and 27 may be secured to the supporting plate 16 by means of studs 28 and 29 which pass through elongated slots 30 and 31 in the base of the stanchions and which are in threaded engagement with the supporting plate 16 so that the position of these stanchions may also be adjusted longitudinally along the face of the plate.

A plurality of endless vibratile carrier members 32 which are composed of or comprise paramagnetic material, for example elastic paramagnetic members such as steel springs, pass around rollers 11 and 24 and are held in spaced relation by suitable grooves in the rollers. These carrier members are desirably mounted as closely as possible but they should not be mounted so close together that the springs come in contact with one another during vibration.

The shaft 10 is driven by power which is supplied from a suitable source to the pulley 12, and the pulleys 13 and 25 on shafts 10 and 23 with the rollers 11 and 24 are driven at the same rate of speed from shaft 10 by the belt 33 which spans pulleys 13 and 25.

A relatively shallow non-magnetic tubular trough 34 which is rectangular in cross section is suspended on a plurality of brackets 35 from the top supporting member or plate 16. The trough is disposed intermediate the rollers 11 and 24 so that the lower travel of the carrier members 32 will pass longitudinally therethrough. A downwardly curved end portion of tubular trough 34 and the end and side portions of the trough form a tapered discharge hopper 34′ through which magnetic material is removed and air is drawn into the tubular trough. At the opposite end of tubular trough 34 and exhaust fan 36 for removing non-magnetic material is connected to the lower portion of the trough through duct 37 and is discharged through the discharge pipe 38. The openings in the ends of the tubular trough 34 through which the carrier members 32 travel are of substantially the same diameter as the carrier members to prevent excessive quantities of air from being drawn into the trough through these openings.

A shaft 39, carrying a roller 40, is journaled in stanchions 41 which are secured to one side of base 17. A similar shaft 42 carrying a similar roller 43 is journaled in stanchions 44 which are secured to the opposite side of the base. A conveyor belt 45 is mounted on rollers 40 and 43 to travel across the trough 34 transversely of the carrier members 32. The upper loop of the belt 45 is arranged to enter and leave the trough through openings 46 and 47 in the sides thereof and is spaced a short distance below the carrier members 32. Power from any suitable source is applied to the shaft 39 to turn the belt 45 in the direction indicated by the arrow. As the belt is turned the untreated ore is continuously fed onto the belt from the hopper 48. By raising and lowering the hopper 48 the depth of the bed of ore on the belt may be regulated and by varying the speed of the belt, the rate of feed may be changed.

A megnetic circuit is provided to produce a periodically varying magnetic field to vibrate the carrier members 32 as they advance through the tubular non-magnetic trough 34. This magnetic circuit comprises metal plates 49 and 50 which are mounted transversely between the top and bottom rows of the carrier members 32. These metal plates 49 and 50 are secured to the top supporting member 16 by means of brackets 51 and 52 respectively. Direct current coils or windings 53 are wound on suitable iron cores and are suspended from the ends of plates 49 and 50 so that the cores will be in contact with the plates. The lower end of the cores, which are secured to plate 49, are connected together by a metal plate 54. The lower end of the cores, which are in contact with plate 50, are likewise connected together by a metal plate 55. The plates 54 and 55 extend transversely below the tubular trough 34 through which the carrier members 32 pass. The coils 53 are electrically connected together either in series or in parallel and are connected to a source of direct current by means of leads 56 and 57.

A lower unidirectional field armature 58 disposed below and extending longitudinally along the central portion of the tubular trough 34 is secured to the top surfaces of plates 54 and 55. The top surface of the armature 58 is provided with a plurality of parallel longitudinal grooves in which pole pieces 59 are inserted. The pole pieces 59 may be built up of laminated sections to prevent the presence of eddy currents when the pole pieces are energized.

An upper fluctuating field armature 60, which has substantially the same length and width as the lower armature 58, is secured to the bottom surfaces of plates 49 and 50, directly above and spaced from the lower armature 58. The bottom surface of armature 60 is provided with a plurality of pole pieces 61 which extend transversely across the armature, above the tubular trough 34 and between the top and bottom rows of carrier members 32. Alternating current coils or windings 62 are wound on pole pieces 61. The coils or windings 62 are electrically connected together either in series or in parallel and are connected to a suitable source of alternating current by leads 63 and 64 to energize pole pieces 61. Armature 60 and pole pieces 61 may be built up of laminated sections to prevent eddy currents when the pole pieces are energized.

Since the cores, upon which coils 53 are wound, are in contact with the plates 49 and 50 to which armature 60 and associated pole pieces 61 are secured and also in contact with the plates 54 and 55 to which armature 58 and associated pole pieces 59 are secured, a unidirectional magnetic field is established between the spaced pole pieces 59 and 61 when the coils 53 are energized by direct current.

When the coils 62 are energized by alternating current, the flux produced by pole pieces 61 is superimposed on the unidirectional magnetic field which exists between the spaced pole pieces 59 and 61. With each reversal of current through coils 62, the alternating current flux either supplements or opposes the direct current flux, thereby creating a resultant unidirectional field between the spaced pole pieces 59 and 61 which periodically varies in intensity. As the unidirectional field between pole pieces 59 and 61 is varied in intensity, a corresponding vibration is produced in the carrier members 32. One cause for vibration is that the paramagnetic carrier members 32 or the paramagnetic portions thereof are magnetized by induction and they are attracted by and moved toward pole pieces 61 which are nearer the carrier members than pole pieces 59.

The carrier members 32 are spaced from the top of the trough 34 by means of grooved supports 65 and 66 which act as stops to define the nodes when the carrier members

32 are vibrated. These supports also act to restrain lateral movement of the carrier members, thus permitting a greater number of carrier members to be mounted on rollers 11 and 24.

The supports are desirably disposed so that the lengths of the carrier members between adjacent supports 65 are equal to permit the amplitude of vibration of these segments to be increased. To increase the amplitude of vibration, the tension in the carrier members is adjusted by varying the position of the stanchions 14 and 15 and stanchions 26 and 27 until the natural period of vibration of the segments is in resonance with the frequency of the alternating current.

The amplitude of vibration of the carrier members 32 between the equally spaced supports 65 may also be increased by maintaining a given tension in the carrier members 32 and varying the equal spacing between the supporting members 65 and/or by increasing the intensity of the alternating current magnetic field.

The end support 66 is desirably disposed so that the lengths of the carrier members between this support and the adjacent support 65 is greater than the lengths of the carrier members between the equally spaced supports 65 so that the springs between the end support 66 and the adjacent support 65 do not vibrate in resonance with the carrier members between the equally spaced supports and with the frequency of the alternating current. The spacing between the end support 66 and the adjacent support 65 may be more or less than the length of the springs between the equally spaced supports.

As illustrative of the method of operation, rollers 11 and 24 are rotated in a clockwise direction, thereby causing the carrier members 32 to continuously advance through trough 34. Rollers 40 and 43 are rotated in the direction of the arrow, thereby causing the conveyor belt 45 to continuously advance through trough 34 at right angles to and underneath the carrier members 32.

Coils 53 are connected to a suitable source of direct current to create a direct current magnetic field between the spaced pole pieces 59 and 61. Coils 62 are then connected to a suitable source of alternating current to periodically vary the intensity of the field by superimposing an alternating current field thereon.

The tension in the carrier members 32 is adjusted so that the natural period of vibration of the segments between the equally spaced grooved supports 65 will be in resonance with the frequency of the alternating current traversing coils 62 in order to obtain the maximum amplitude of vibration of the carrier members. The exhaust fan 36 is started to create a suction through the discharge hopper 34′, trough 34 and duct 37.

The material to be treated, for example finely ground magnetic iron ore, is fed into the charging hopper 48 from whence it is fed by gravity onto the moving conveyor belt 45. The conveyor belt carries the material into trough 34 underneath the advancing carrier members 32. The magnetic particles in the material are attracted and carried forward by the carrier members. The free non-magnetic particles are removed from the trough through duct 37 by the current of air which is produced by the exhaust fan. Some of the non-magnetic particles remain associated with the magnetic particles and are carried along by the carrier members 32. This is due in part to the mechanical bond which exists between the magnetic and the non-magnetic particles and to the fact that the magnetic particles are drawn to the carrier members with such speed that the adjacent magnetic particles are bound into masses or bundles within which non-magnetic particles are entrapped.

As the magnetic carrier members advance through the varying magnetic field and are vibrated, the masses or bundles of material are broken up and the non-magnetic particles are thrown off. The non-magnetic particles are then removed from the trough by the exhaust fan 36. When the carrier members have traveled beyond the pole pieces 59 and 61 they become demagnetized. The fan 36 having been regulated so that the action of the air entering through the discharge hopper 34′ is less than the force of gravity, the magnetic particles will descend into the discharge hopper from whence they may be removed into a suitable container.

Inasmuch as the natural period of vibration of the segments of the carrier members between the end support 66 and the adjacent support 65 is not in resonance with the alternating current, they vibrate with less amplitude than the other segments and large amounts of material will adhere to these slowly vibrating or non-vibrating segments.

While vibratile members composed of coiled steel springs are specifically described, it is to be understool that other kinds of vibratile members may be employed. For example, strips of rubber or leather to which strips or fins composed of or comprising paramagnetic material may be employed. Other changes may be made in the described embodiment without departing from the invention.

I claim:

1. A magnetic separator which comprises spaced opposed pole pieces adapted and arranged to create a unidirectional magnetic field which periodically varies in intensity,

a tubular non-magnetic trough disposed in the space between said pole pieces, a plurality of vibratile carrier members comprising paramagnetic material adapted and arranged to be moved through said trough, means for introducing material to be treated into said trough adjacent said carrier members, and means for producing a current of air in said trough.

2. A magnetic separator which comprises spaced opposed pole pieces adapted and arranged to create a unidirectional magnetic field which periodically varies in intensity, a tubular non-magnetic trough disposed in the space between said pole pieces, a plurality of vibratile carrier members comprising paramagetic material adapted and arranged to be moved longitudinally through said trough, a conveyor belt adapted and arranged to be moved transversely through said trough across said carrier members, a charging hopper for associating material to be treated with the conveyor belt, and means for creating a current of air in the trough.

3. A magnetic separator which comprises spaced opposed pole pieces adapted and arranged to create a unidirectional magnetic field which periodically varies in intensity, a tubular non-magnetic trough disposed in the space between the pole pieces and having a discharge hopper at one end, a plurality of vibratile carrier members comprising paramagnetic material adapted and arranged to be moved longitudinally through said trough and across said hopper, a conveyor belt adapted and arranged to be moved transversely through said trough across said carrier members intermediate the ends of said trough, a charging hopper for associating material to be treated with the conveyor belt, and means for creating a current of air in the trough.

4. A magnetic separator which comprises a tubular non-magnetic trough having a discharge hopper at one end thereof, a conveyor belt adapted and arranged to be moved transversely through the other end of the trough, a plurality of vibratile carrier members comprising paramagnetic material adapted and arranged to be moved longitudinally through said trough over said conveyor belt and said hopper, pole pieces disposed on opposite sides of the central portion of said trough and adapted and arranged to create a unidirectional magnetic field which periodically varies in intensity, and means for creating a current of air through said trough.

5. A magnetic separator which comprises a tubular non-magnetic trough having a discharge hopper at one end and an exhaust fan for creating a current of air connected to the opposite end thereof, pole pieces disposed on opposite sides of the central portion of said trough and adapted and arranged to create a unidirectional magnetic field which periodically varies in intensity, a plurality of endless vibratile carrier members comprising paramagnetic material adapted and arranged to be moved longitudinally through said trough and over said discharge hopper, and a conveyor belt adapted and arranged to be moved transversely through the central portion of said trough below said carrier members.

6. A magnetic separator which comprises a tubular non-magnetic trough having a discharge hopper at one end and an exhaust fan for creating a current of air connected to the opposite end thereof, pole pieces disposed on opposite sides of the central portion of said trough and adapted and arranged to create a unidirectional magnetic field which periodically varies in intensity, a plurality of equally spaced supports disposed along said trough and an end support disposed adjacent one of said equally spaced supports and spaced a different distance therefrom, a plurality of vibratile carrier members comprising paramagnetic material adapted and arranged to be moved longitudinally through said trough over said supports and over said hopper, and a conveyor belt adapted and arranged to be moved transversely through the trough below those sections of the carrier members between the end support and the adjacent support.

7. A magnetic separator which comprises spaced rollers adapted and arranged to be rotated at a uniform rate of speed, a tubular non-magnetic trough having a discharge hopper at one end disposed intermediate said rollers, a plurality of vibratile carrier members comprising paramagnetic material mounted on said rollers and adapted and arranged to be moved longitudinally through said trough and over said discharge hopper, pole pieces disposed on opposite sides of said trough adapted and arranged to create a unidirectional magnetic field which periodically varies in intensity, a conveyor belt adapted and arranged to be moved transversely through said trough across said carrier members, a charging hopper for associating material to be treated with said conveyor belt, and means for creating a current of air in said trough.

8. A magnetic separator which comprises spaced rollers adapted and arranged to be rotated at the same speed, a tubular trough having a relatively shallow elongated portion which is rectangular in cross section disposed intermediate the rollers, elastic paramagnetic carrier members adapted and arranged to be moved through the trough by the rollers, guide members disposed along said trough to space the carrier members out of contact with each other, pole pieces disposed along the shallow portion of the trough adapted and arranged to give a peri-

odically varied unidirectional magnetic field, a discharge hopper for removing magnetic material from the trough, and means for creating a current of air through the trough to remove non-magnetic material therefrom.

9. A magnetic separator which comprises spaced rollers adapted and arranged to be rotated at the same speed, a tubular trough having a relatively shallow elongated portion which is rectangular in cross section disposed intermediate the rollers, vibratile magnetic carrier members adapted and arranged to be moved through the trough by the rollers, guide members spaced along the trough to space the carrier members out of contact with each other, opposing pole pieces disposed above and below along the shallow portion of the trough and arranged to give a periodically varied unidirectional magnetic field, said carrier members being disposed nearer one terminal of the field, means to regulate the vibration of the carrier members, means to remove magnetic material from the trough, and means to create a current of air through the trough to remove non-magnetic material therefrom.

In witness whereof I have hereunto subscribed my name at Milwaukee, Wisconsin, this 14th day of January, 1932.

CONSTANT E. NICOLET.