United States Patent

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[54] **METHOD AND APPARATUS UTILIZING A ROTATING ELECTROMAGNETIC FIELD FOR SEPARATING PARTICULATE MATERIAL HAVING DIFFERENT MAGNETIC SUSCEPTIBILITIES**

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[52] **U.S. Cl.** **209/214,** 209/223, 209/227

[51] **Int. Cl.** **B03c 1/14,** B03c 1/24

[58] **Field of Search**......209/218, 219, 223, 227, 214, 209/212, 220; 55/3; 210/222, 223

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[57] **ABSTRACT**

Crushed iron ore is introduced into a rotating electromagnetic field. The tailings, which possess little or no magnetic susceptibility, drop downwardly and are gravitationally removed. The concentrate, having a high degree of magnetic susceptibility, is carried by the field for almost a complete revolution. The middlings, on the other hand, have a degree of susceptibility less than the concentrate, and are accelerated with the concentrate only until a sufficient amount of centrifugal force is developed to throw the middlings outwardly to thus separate them from the concentrate.

24 Claims, 7 Drawing Figures

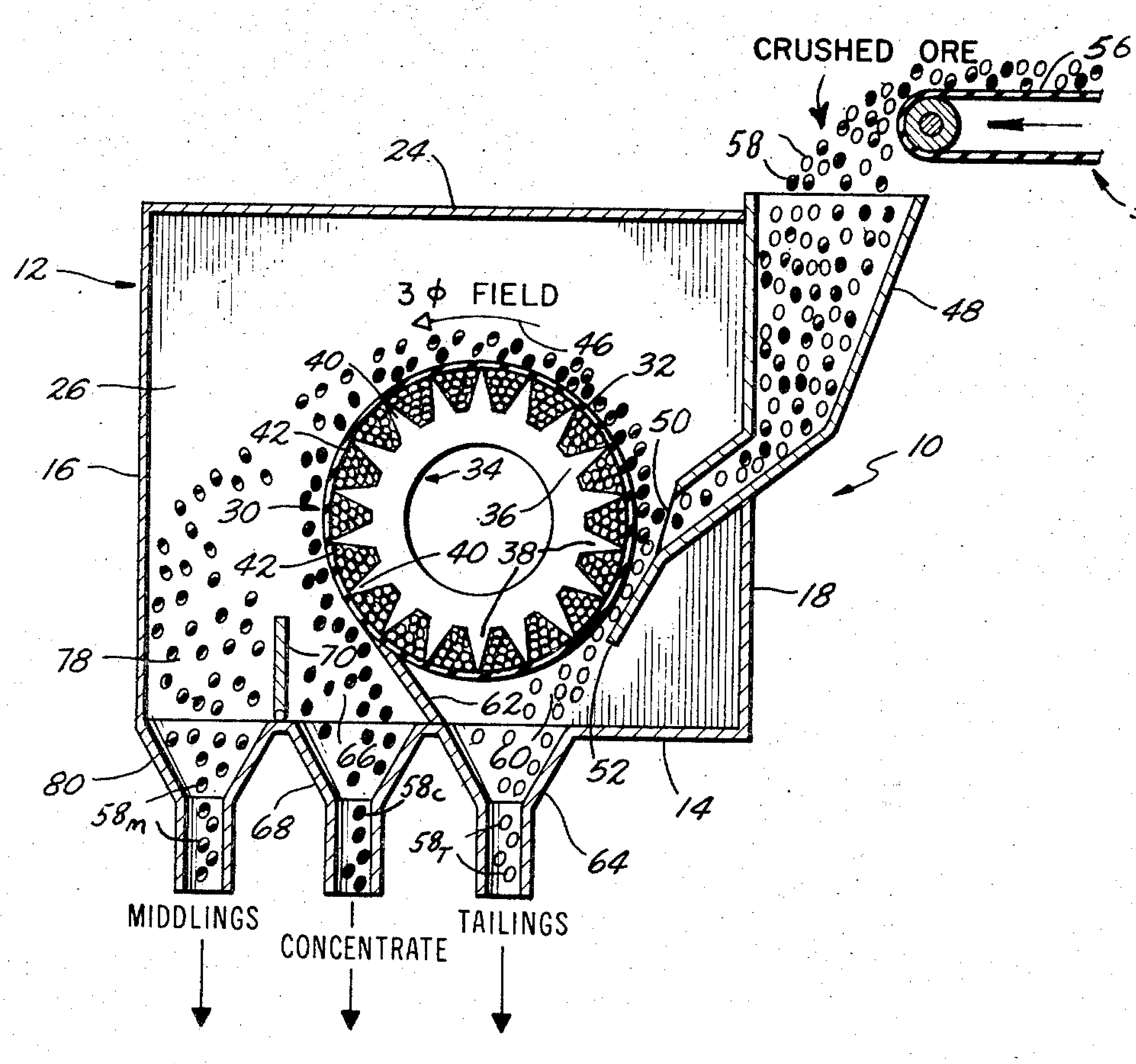

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FIG 1.

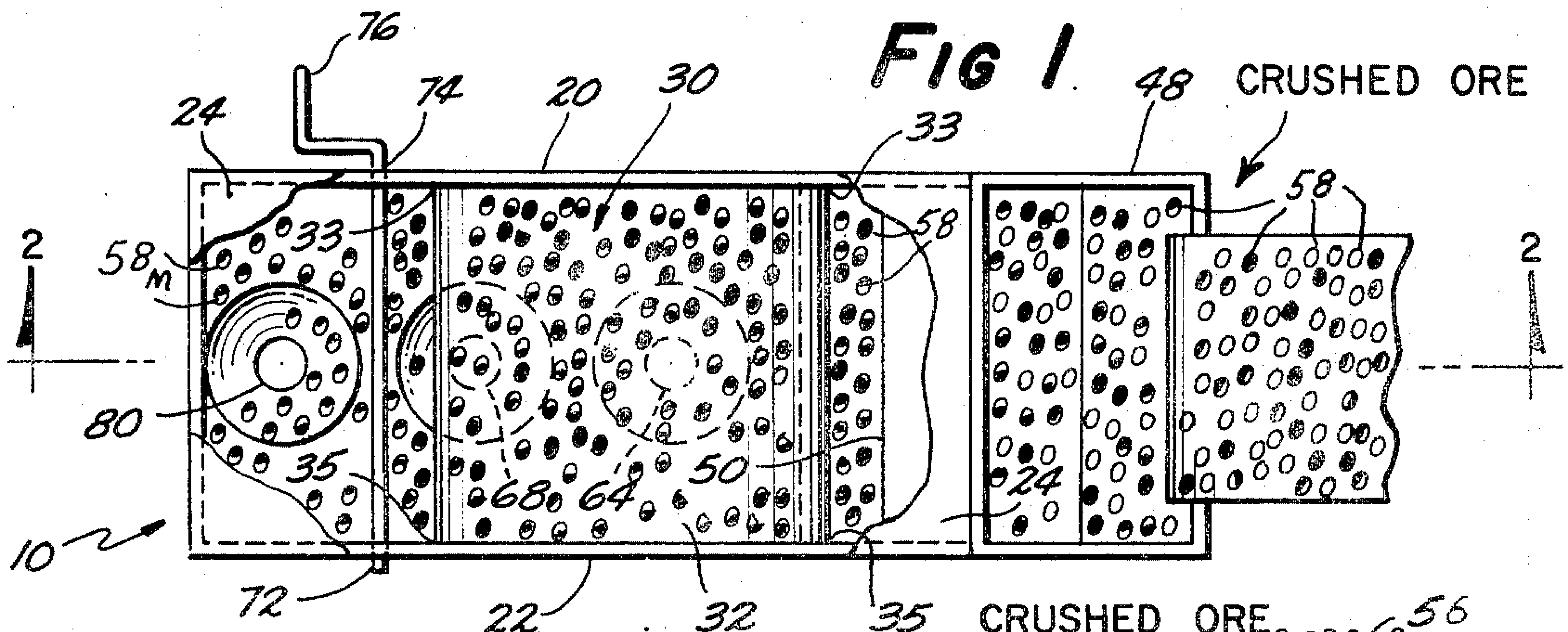

FIG 2

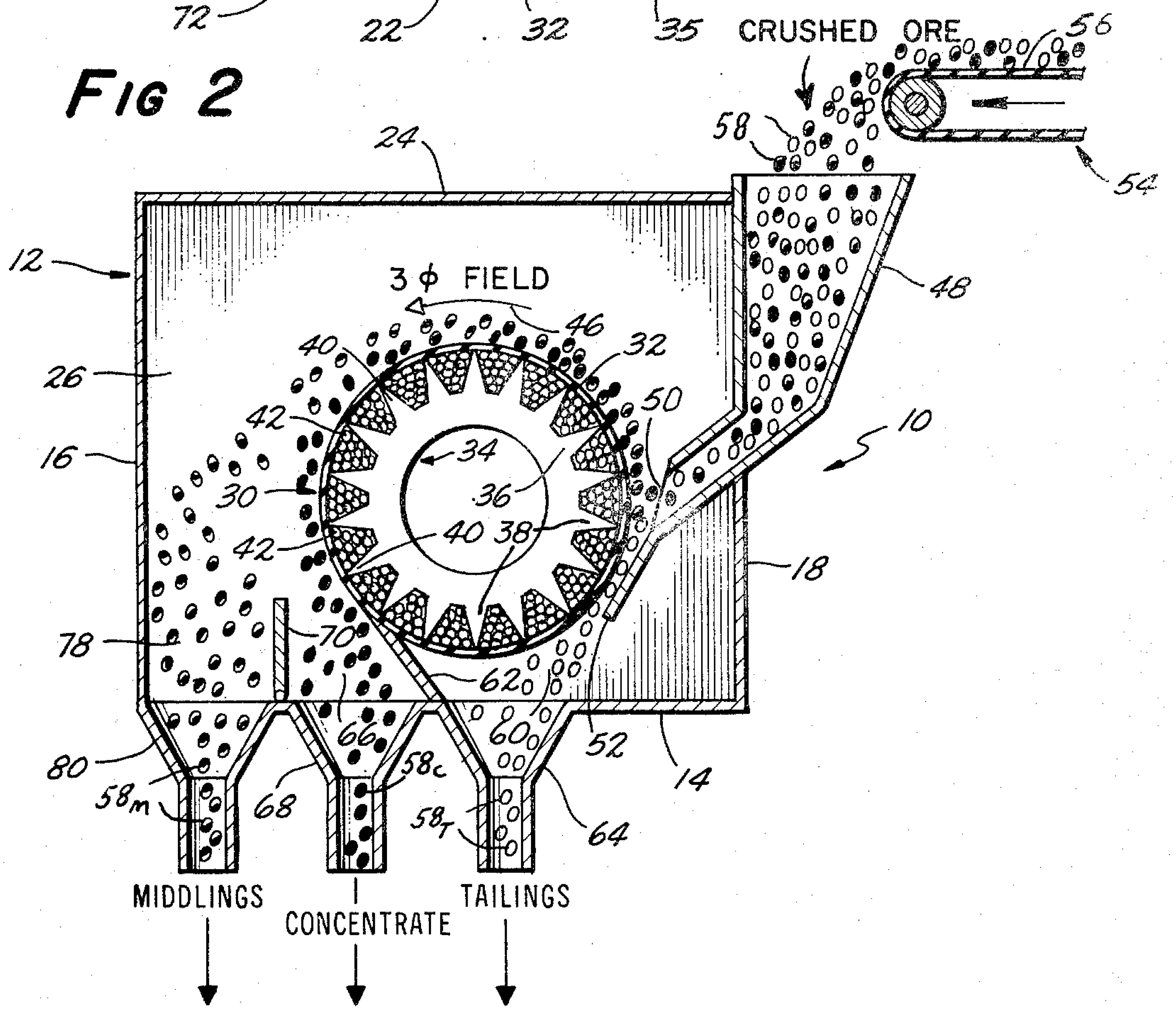

FIG 3

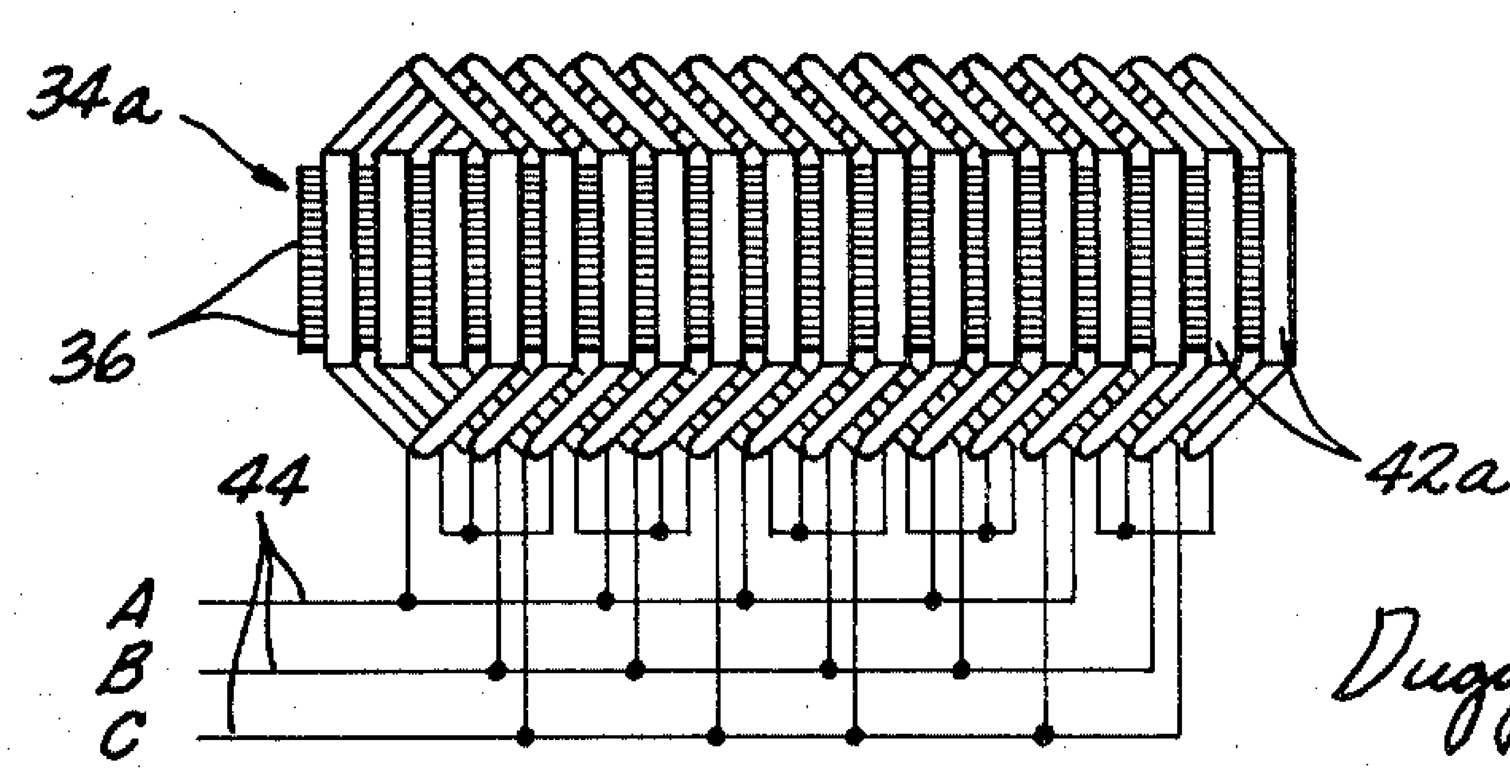

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FIG 4

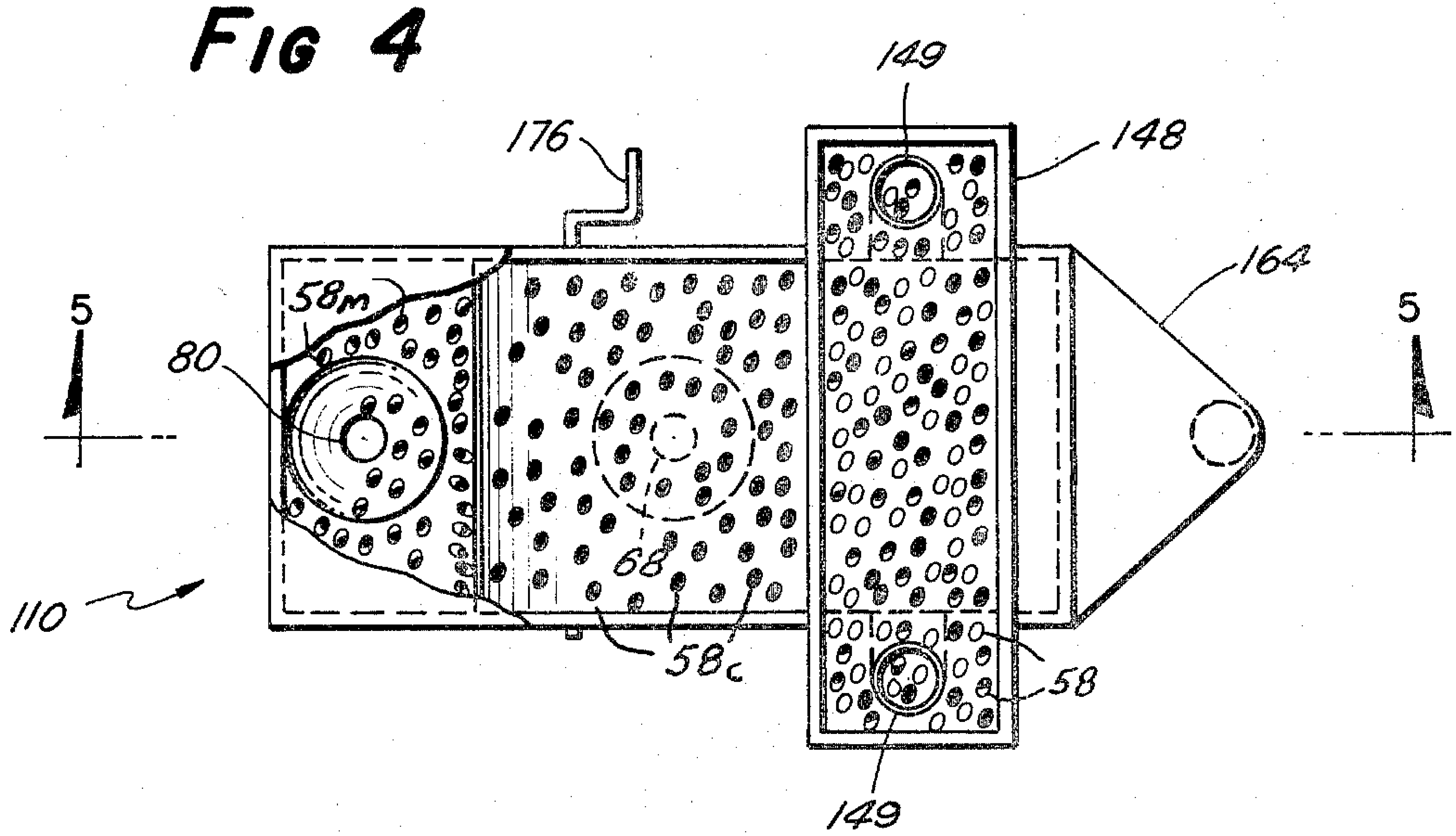

FIG 5

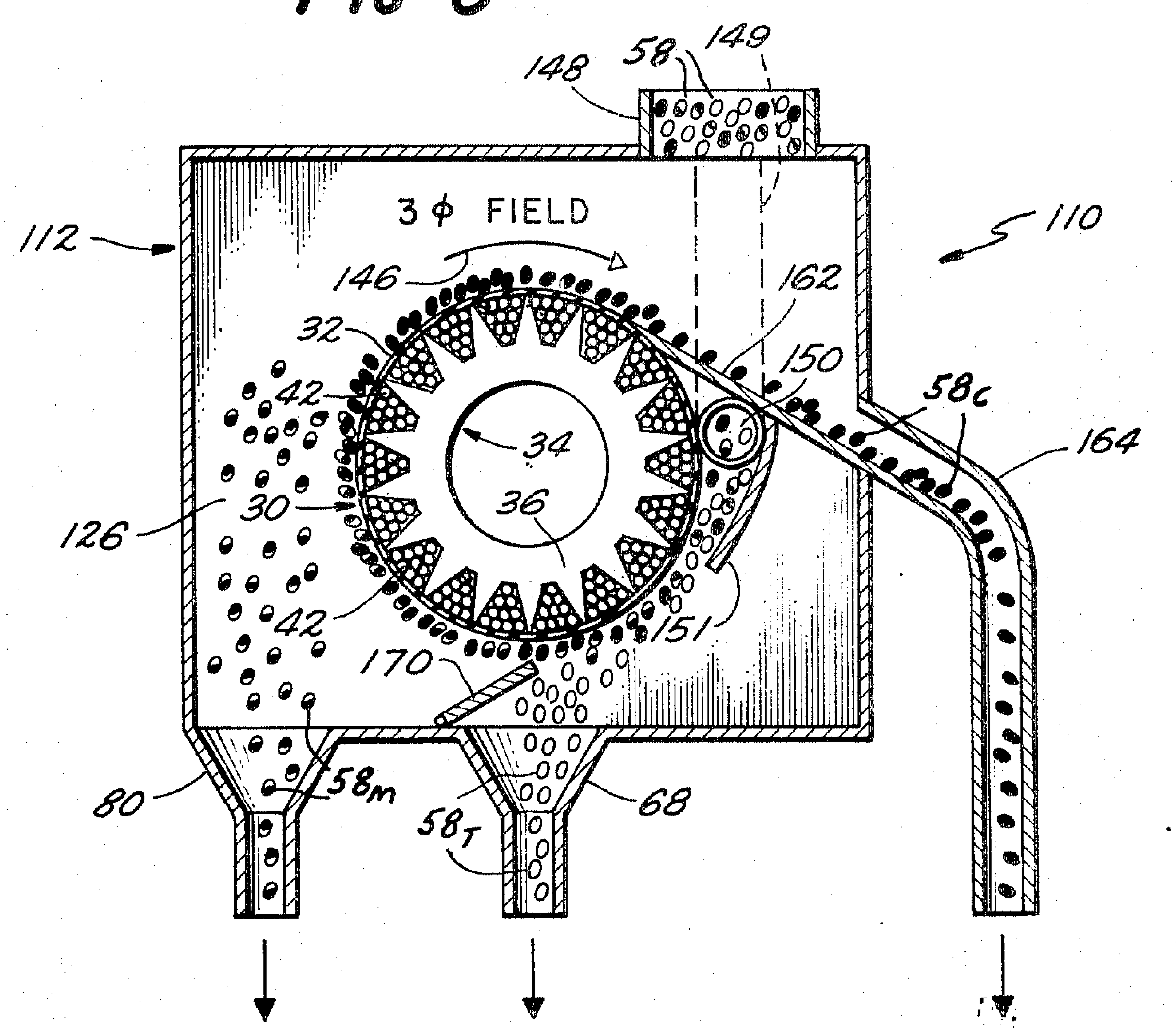

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FIG 6

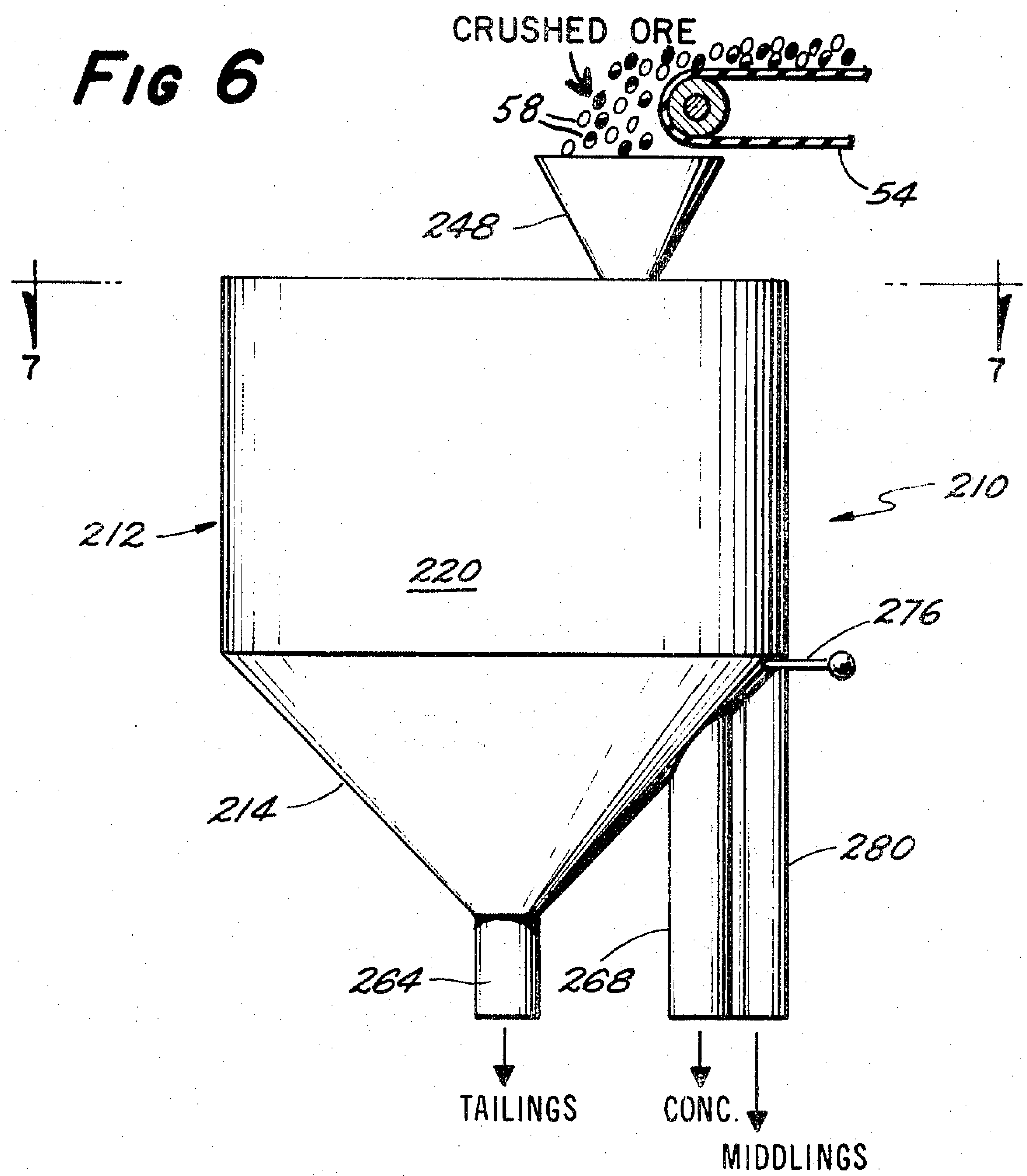
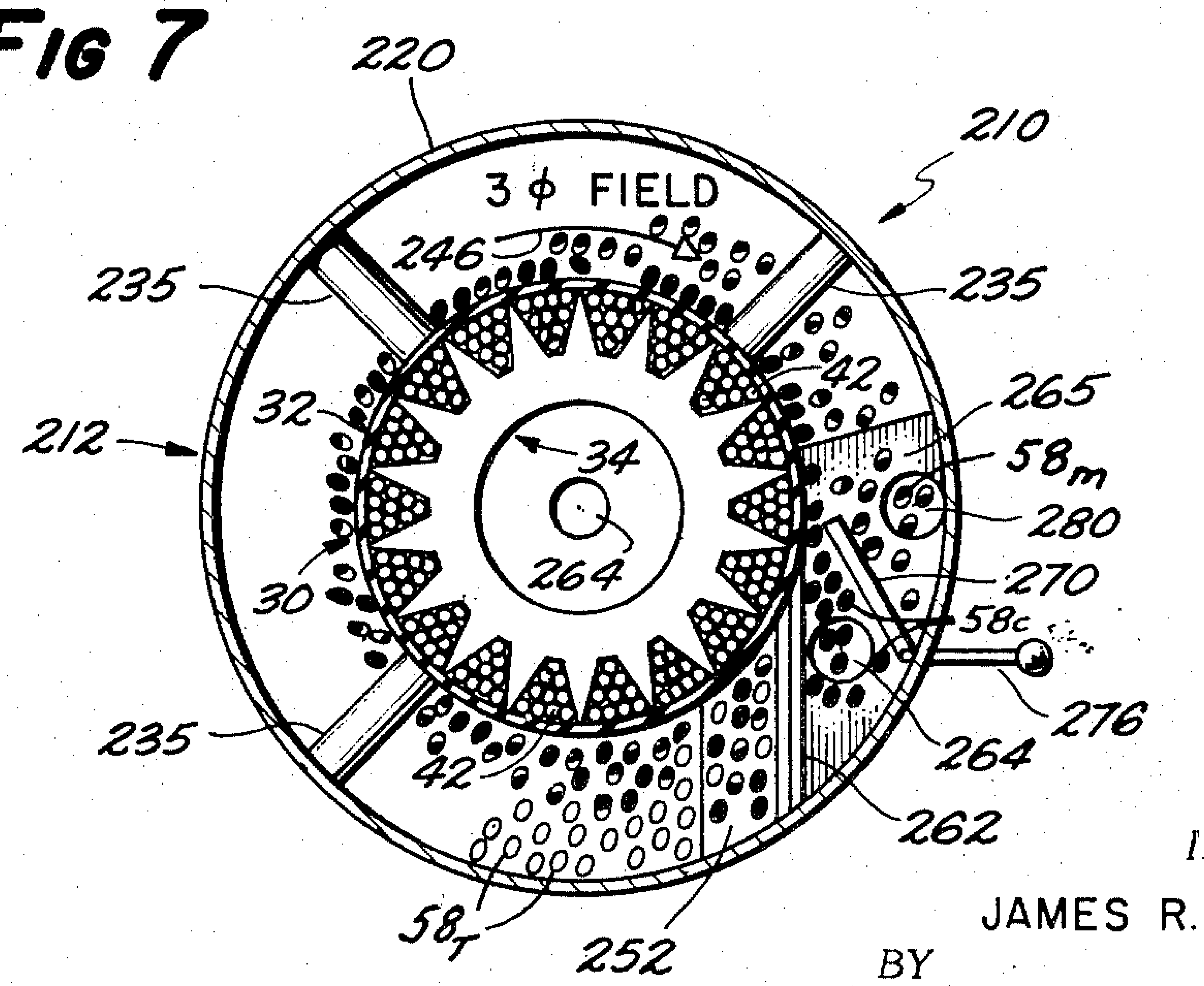


FIG 7



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METHOD AND APPARATUS UTILIZING A ROTATING ELECTROMAGNETIC FIELD FOR SEPARATING PARTICULATE MATERIAL HAVING DIFFERENT MAGNETIC SUSCEPTIBILITIES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to electromagnetic separation, and pertains more particularly to a method and apparatus utilizing centrifugal force developed from a rotating electromagnetic field to remove certain particles having an intermediate degree of magnetic susceptibility.

2. Description of the Prior Art

Apparatus and methods have heretofore been devised which employ either a rotating electromagnetic field or a rectilinearly traveling field for separating crushed iron ore into what is commonly referred to as concentrate, middlings and tailings. One prior art separator is embodied in U.S. Pat. No. 1,605,117 granted Nov. 2, 1926 to Mitsuo Koizumi titled "Ore Separator of Alternate Current Electromagnet." The alluded to patent uses a number of spiral baffles to effect the separation. Each magnetic particle, however, must travel around the stator as may times as there are baffles, resulting in only a limited capacity and also a rather inefficient method of obtaining the separation inasmuch as a considerable amount of friction is present by reason of the fact that the particles have to roll along the baffles and a sufficiently strong rotating electromagnetic field must be resorted to in order to move the particles. Also, the apparatus constituting the patented separator is quite complex and costly to build.

Another prior art attempt is to be found in the disclosure of U.S. Pat. No. 1,564,731, granted Dec. 8, 1925 to Joseph Weatherby titled "Method and Apparatus for Separating Ore Particles." The invention therein described relates to a separator employing a rectilinearly moving electromagnetic field, which is even more dissimilar from the instant invention than is the Koizumi invention, but the second-mentioned patent is of interest because it goes into considerable detail with respect to the utilization of polyphase alternating current for producing or generating the traveling field. Actually, reference should be made to this particular patent for an understanding of the manner in which the field herein utilized is generated should there be the need for an additional technical explanation.

SUMMARY OF THE INVENTION

Broadly, the invention has for an object the separation of material composed of particles having different magnetic susceptibilities: (1) those below a given level of susceptibility, (2) those having a relatively high degree of susceptibility, and (3) those having a lesser susceptibility but still above the given level.

A more specific object of the present invention is to provide an improved iron ore separator and a method of separating the ore components which employs not only an electromagnetic field but utilizes the centrifugal force developed thereby in achieving the separation. More specifically, the invention has for an aim the provision of a centrally disposed stator that generates a rotating magnetic field and use is made of the field for accelerating both the concentrate and the middling, the middlings developing a sufficient amount of centrifugal force so that they are flung or thrown outwardly from the stator. In this way the middlings are removed, whereas the concentrate remains in the rotating field and is subsequently withdrawn, although still within one revolution of the rotating field. Stated somewhat differently, the relatively weak magnetic particles in the ore are separated by centrifugal force, being thrown outwardly from the concentrate which remains in the field until physically deflected therefrom.

More specifically, an aim of the invention is to provide a separator that will concentrate magnetic taconite with a relatively low magnetic field intensity, although the separator can also be used to concentrate any mineral having various degrees of susceptibility.

Another object of the invention is to produce an excellent mixing action during the introduction of the crushed ore which liberates a high percentage of unwanted impurities at the outset, the mixing action continuing as far as the middlings and concentrate are concerned until the middlings are flung outwardly by the centrifugal force that results.

An additional object of this invention is to make the magnetic separations in a wet or dry atmosphere, that is the material can be made fluid in either a gaseous or liquid state.

Another object of the invention is to provide a separator that will require fewer stages of separation, actually a good quality separation being practical with only one pass, although additional stages can be resorted to, especially where a high level of purity is desired in the concentrate or where the middlings might very well contain valuable magnetic particles that should be removed through the agency of subsequent staging.

A still further object of the invention is to provide a method and apparatus of the foregoing character that can be easily adapted to large scale operations.

Still further, an object is to provide apparatus that is relatively simple, particularly as contrasted with separators now in widespread use that involve moving parts. Also, concommitant with the simplicity of the equipment, there is the added advantage of low maintenance costs.

Yet another object of the invention is to provide a separator that can be readily designed to separate a given size of particulate material, the design lending itself to easy selection or variation of field strength, that is the gauss rating thereof, and also with respect to the speed at which the field rotates.

Another object of the invention is to provide a separation in which the degree or quality of separation for the various classes of components can be adjusted, an appropriate baffle or splitter being employed.

Still an additional object of the invention is to provide a separator that will be highly efficient in its separating action, and an aim of the invention is to provide a stator having a design that maximizes the material flow through the separator for a given amount of power.

Briefly, the present invention envisages the production of a rotating electromagnetic field, the crushed iron ore being introduced at a first radial location with respect to the stator generating the field. The tailings fall immediately downwardly and are removed. The concentrate and the middlings, however, are accelerated from the first radial location and near the end of one rotation of the field, provision is made for removing the concentrate. The middlings, though, are removed as soon as they have developed a sufficient amount of centrifugal force to be flung out of the rotating electromagnetic field. In this way, there are three distinct classes of separation. Furthermore, the quality of separation is capable of being controlled or adjusted.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a top plan view of one form the apparatus exemplifying my invention may assume, most of the top cover of the casing being removed so as to expose to view the horizontally oriented liner of the stator that provides the rotating electromagnetic field;

FIG. **2** is a vertical sectional view taken in the direction of line **2—2** of FIG. **1** with a representative ore sampling added for the purpose of illustrating to better advantage how the separation occurs;

FIG. **3** is a flat or developed view of a stator resembling the preferred form employed in the embodiment of FIGS. **1** and **2**, and also FIGS. **4–7**, the view being diagrammatic inasmuch as the coil and slot configuration does not correspond precisely to the more effective tapered tooth arrangement depicted in FIGS. **2**, **5** and **7**;

FIG. **4** is a top plan view corresponding to FIG. **1** but illustrating a different embodiment that the invention may assume, although employing a horizontally arranged stator as in FIGS. **1** and **2**;

FIG. **5** is a sectional view taken in the direction of line **5—5** of FIG. **4**, a sampling of ore being depicted within the apparatus for the purpose of illustrating the method by which separation occurs in this instance;

FIG. **6** is a side elevational view of still a different embodiment of the invention, this modification utilizing a vertically oriented stator, and

FIG. **7** is a sectional view taken in the direction of line **7—7** of FIG. **6** for the purpose of revealing the internal construction of this particular modification of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to the embodiment depicted in FIGS. **1** and **2**, it will be perceived that the separator there illustrated has been denoted in its entirety by the reference numeral **10**. The separator **10** includes a casing or housing **12** having a bottom **14**, end walls **16**, **18**, side walls **20**, **22**, and a top cover **24**, the enclosure forming a chamber which has been generally labeled **26**.

Of extreme importance in the practicing of the instant invention is the stator indicated by the reference numeral **30**. The stator **30** comprises a cylindrical shell **32** of non-magnetic material, such as stainless steel of suitable wear-resistance plastic. The shell **32** has its opposite ends secured, as by welding (when metal), to the side walls **20** and **22** at locations **33** and **35**. The stator **30** has a core **34** comprised of a number of thin laminations labeled **36** which should be of high grade electrical steel, as is conventional with laminations utilized in various types of motors in order to minimize hysteresis and eddy current losses. As can be seen from FIG. **2**, each lamination is formed with a series of radially projecting teeth **38** that taper or converge to virtually a point at their outer ends, the extremities having been given the reference numeral **40**. In this way, the slots, formed between the angularly spaced teeth due to the stacking of the laminations **36**, are wider interjacent the shell **32** than at the base or root of the various teeth. It will be appreciated, especially as the description progresses, that the flow of material through the separator is maximized or increased by virtue of the tooth configuration herein employed, because the stator **30** functions as a polyphase electromagnet and in this way an optimum amount of flux is provided through the ore material undergoing separation. More specifically, there is a minimum amount of leakage flux that occurs between the teeth forming the slots owing to the tapered tooth configuration.

Continuing with the description of the stator **30**, it will be appreciated that the slots formed between the various teeth **38** contain therein the coils or windings identified by the reference numeral **42**. The way in which the coils **42** are wound and the manner in which they are energized by a three-phase source of alternating current can be understood, it is believed, from FIG. **3** where a developed or flat simulation of the winding arrangement appears. Actually, FIG. **3** has been taken from the previously mentioned Weatherby U.S. Pat. No. 1,564,731, which, as already indicated, goes into considerable detail concerning the production or generation of a three-phase electromagnetic field. It is to be recognized that the core labeled **34*a*** (the suffix "a" distinguishing the elements from their FIG. **2** counterparts) in FIG. **3** is not precisely identical to the core **34** of FIG. **2**, mainly because the various laminations indicated by the reference numeral **36*a*** do not have the pointed teeth formed thereon. It would be rather difficult to illustrate the winding pattern if the pointed teeth were actually pictured in FIG. **3**. Accordingly, the coils or windings have been given the reference numeral **42*a*** and it will be seen that they are connected to conductors **44** which are in turn supplied with three-phase power, the phase relationship having been indicated by the letters A, B and C. The source of power has not been shown, but it is to be appreciated that the source may have in circuit therewith means for varying the voltage and hence the power supplied via the conductors **44**. In actual practice, a three-phase Variac has been utilized for the purpose of controlling the voltage and in turn the amount of current flow to adjust the strength of the resulting rotating electromagnetic field. As will presently be understood, the physical configuration of the housing **12** requires that the field rotate in the direction of the arrow **46** applied to FIG. **2**.

Associated with the end wall **18** is a chute **48** having a horizontal slot or inlet opening **50** disposed at a first radial direction (3 o'clock position) with respect to the stator **30**. A fixed baffle **52** extends downwardly from the lower edge of the inlet opening **50**. Spaced somewhat above the upper end of the chute **48** is a feeder **54** which includes an endless belt **56**, only a portion thereof having been pictured. The iron ore has been indicated generally by the reference numeral **58** and it will be appreciated that the quality or iron content of the ore **58** will vary considerably. Actually, taconite, which is a rather low grade ore, will contain a high percentage of gangue or tailings, which have little or no magnetic susceptibility, and an appreciable percentage of the ore will constitute the middlings, whereas a smaller percentage will make up the concentrate having a relatively high magnetic susceptibility.

Inasmuch as the crushed iron ore **58** will include particulate material that will be virtually non-magnetizable, the inlet opening **50** will direct the ore **58** downwardly and since the rotating field is moving upwardly (that is, counterclockwise), the tailings, which constitute the non-magnetic material, will move gravitationally downwardly along the baffle **62** into a region indicated by the reference numeral **60**, the left side of the region **60** being defined by a fixedly disposed barrier or baffle plate **62** that extends between the side walls **20**, **22**. Hence, the tailings are directed downwardly into an outlet **64** via which they are removed from the apparatus.

On the other hand, the remainder of the ore **58**, which contains both the middlings and concentrate, will be introduced directly into the rotating field and will be accelerated upwardly and around the circumference of the stator **30** owing to the magnetic influence exerted by the moving field. Due to the fact that the middlings have a magnetic susceptibility that will be of an intermediate value, they will move along with the concentrate but will be subjected to centrifugal action that flings or throws the middlings outwardly, whereas the concentrate continues to be carried in the electromagnetic field and will complete a considerable portion of one revolution of the field. More specifically, the concentrate will be carried to a region labeled **66** which is approximately 270° from the location at which the ore enters through the opening **50**, this region **66** being just to the left of the fixed barrier **62** which literally scraps or deflects the concentrate from the liner **32** so that it then falls downwardly through the region **66** into an outlet **68** where it is removed from the apparatus. The region **66** is further defined by an angularly adjustable baffle or splitter vane **70**, being pivotally mounted at **72** and **74** as can be seen in FIG. **1**. Although provision would normally be made for holding the splitter **70** in an adjusted position, a handle **76** will serve the purpose of illustrating that the vane **70** can be swung either to the left or right with respect to the vertical position in which it is pictured in FIG. **2**. To the left of the vane **70** is a region **78** that accepts the middlings that are flung outwardly by centrifugal force. In other words, the middlings, being of intermediate magnetic susceptibility, are no longer retained in the rotating field when they reach a given speed and the region **78** serves to direct the middlings downwardly through an outlet **80**.

Due to the small scale of the drawing, it would be extremely difficult to depict the particles constituting the crushed ore **58** in the proper size relationship, especially since a considerable amount of the crushed ore will be of fine size, say on the other of 500 mesh and varying to a larger size of approximately 8 mesh. At any rate, it might be of help to indicate the concentrate by solid black circles, the middlings by partially blackened circles and the tailings by undarkened or white circles. To further assist in understanding the separation procedure, the concentrate has been denoted by the reference character 58_C, the middlings by the reference character 58_M, and the tailings by the reference character 58_T.

Having presented the foregoing description, which to a large degree contains an adequate description of the operational sequence, only a brief resume will be given as to what occurs in effecting the desired separation. In this regard, the crushed ore **58** is introduced into the electromagnetic field via the slot-like opening **50**, being carried in the rotating electromagnetic field and are progressively accelerated. The acceleration results in the middlings 58_M being subjected to a sufficient amount of centrifugal force so that they are flung outwardly from the concentrate 58_C, the middlings 58_M falling downwardly into the outlet **80** and the concentrate 58_C leaving via the outlet **68**. Thus, the ore **58** is introduced into the electromagnetic field at one radial location and the concentrate is removed at a radial location approximately ¾ (270°) of a revolution from the point at which the ore is introduced, the middlings 58_M being removed during an intermediate segment of the rotative travel of the concentrate 58_C.

Recapitulating, a given level of magnetic susceptibility may be selected, with the field intensity or gauss rating adjusted or determined for the particular level, the particles having less than this level will be removed gravitationally through the outlet **64** because they will be virtually unaffected by the rotating field. These particles would constitute the tailings above referred to. Those particles having A susceptibility above said level, yet relatively near thereto are carried along with the particles possessing a relatively high magnetic susceptibility, all particles above said given level being accelerated together although not necessarily at the same rate. Only those particles having a relatively high susceptibility, which have been termed concentrate, will be retained in the field until the plate **62** is reached which then deflects such particles from the field so that they then fall through the outlet **68**. Those particles having a lesser propensity for magnetization, that is those nearer the given susceptibility level and which have been called middlings, are the ones that are flung or thrown from the field so that they fall through the outlet **80**.

Passing now to a description of the embodiment illustrated in FIGS. **4** and **5**, this embodiment being labeled generally by the reference numeral **110**, it is believed of help to explain that some of the parts or components are virtually identical with those described in conjunction with the embodiment identified by the numeral **10**. Therefore, where the parts are the same, identical reference numerals have been utilized; where the parts have a general resemblance but differ in some aspect, then the order of the numerical designation has been raised by one hundred.

It will be initially of benefit to point out that the rotating electromagnetic field rotates in a direction opposite to that described in connection with the apparatus **10**. Thus, the arrow **146** indicates the specific direction.

The crushed ore **58** is fed into a chute **148**, and by means of a pair of laterally spaced pipes or conduits **149** the ore is fed downwardly into the interior **126** of the separator **110**. A curved baffle **151**, which has its ends fixedly attached to the side walls **120** and **122**, directs the ore inwardly into the intense rotating field.

However, the tailings 58_T fall gravitationally downwardly, whereas the concentrate 58_C and the middlings 58_M continue with the rotating field. When the acceleration of the middlings 58_M reaches a sufficient value, they are flung by centrifugal force outwardly and are removed. On the other hand, the concentrate 58_C continues for practically an entire revolution (almost 360°), actually farther than that in the separator **10**. In this instance, a fixed baffle **162** deflects or skims off the concentrate so that it then falls gravitationally downwardly through the outlet **164** via which it is removed from the apparatus.

By reason of the adjustable splitter vane **170**, the amount of ore **58** passing therebeyond can be controlled. Thus, if only a small portion of the concentrate 58_C, that is a superior quality concentrate, is to be permitted to pass, the vane **170** can be adjusted so that it assumes the position in which it appears in FIG. **5**, whereas it can be rotated clockwise to allow more particulate material to pass, that is a somewhat less pure concentrate to be realized. The embodiment pictured in FIGS. **4** and **5** will permit an accurate determination of the grade that the middlings is to constitute.

FIG. 6 and FIG. 7 represent still a third embodiment, the separator in FIGS. **6** and **7** having been denoted by the reference numeral **210**. In this situation, the casing **212** is cylindrical, being composed of a single wall **220**. Instead of the flat bottom, the bottom **214** is conical and the outlet **264** for the tailings 58_T is centrally located. The outlet for the middlings 58_M has been given the reference numeral **280**.

The inlet chute **248** receives the crushed ore **58** and it is directed gravitationally downwardly onto a sloping diverter or fixed baffle **252**. The baffle **252** extends virtually to the line 7—7 representing the plane in which FIG. 7 is taken. Actually, the baffle **252** can extend the full height of the cylindrical housing **212** but this is not necessary because the tailings 58_T fall gravitationally downwardly and strike the sloping sides of the conical bottom **214** and are immediately discharged via the outlet **264**. The field, which is rotating in the direction of the arrow **246**, carries both the concentrate 58_C and middlings 58_M will ultimately be flung outwardly due to the centrifugal action that occurs. Thus, a flat plate **265** is located just above the conical bottom **214**; the middlings 58_M will fall on to this particular plate and will exit via the outlet **280**.

On the other hand, the concentrate 58_C will continue and will literally be scraped off or deflected by the fixed baffle **262** so that the concentrate 58_C leaves through the outlet **264**. An adjustable splitter vane **270** having a handle **276** can be positioned so as to determine the percentage of middlings 58_M that are removed from the concentrate 58_C. Thus, if the middlings 58_M are to contain some concentrate, in effect making the concentrate 58_C of higher grade, the vane **270** can be moved so that it resides near the liner **32** of the stator **30**. When The percentage of middlings 58_M is to be reduced, then it will be moved outwardly away from the liner **32**, being nearer the outlet **280**. In this way, as with the other embodiments, the grade of separation can be controlled.

I claim:

1. A method of separating material composed of particles having several different magnetic susceptibilities, said material including first particles having a magnetic susceptibility below a given level, and second and third particles having magnetic susceptibilities above said level, said third particles having a higher susceptibility than said second particles, the method comprising the steps of producing a rotating magnetic field of uniform strength, introducing the material to be separated into the field at first location so that the first particles having a magnetic susceptibility below said given level flow gravitationally downwardly and said second and third particles having a susceptibility above said given level are accelerated entirely by said field to the extent that the second particles possessing a magnetic susceptibility nearer said given level are thrown outwardly due to centrifugal force developed solely by said rotating field and are thereby separated from the third particles having a higher susceptibility, and removing said higher susceptibility third particles from said field at a second location prior to the completion of a full revolution of said rotating field and prior to reaching said first location where the material to be separated is introduced, whereby said first particles are initially separated by gravity from said second and third particles, and said second particles are subsequently centrifugally separated from said third particles at a third location between said first and second locations.

2. The method set forth in claim **1** in which said field rotates about a substantially horizontal axis.

3. The method set forth in claim **2** in which said first location at which the material is introduced is spaced from said axis in a generally horizontal direction.

4. The method set forth in claim **3** in which said first location is disposed where the field is moving upwardly and said third particles having a higher magnetic susceptibility are removed at a location spaced angularly approximately 270° from said first location.

5. The method set forth in claim **3** in which said first location is disposed where the field is moving downwardly and said third particles having a higher magnetic susceptibility are removed at a location spaced approximately 360° from said first location.

6. The method set forth in claim **1** in which said field rotates about a substantially vertical axis.

7. The methods set forth in claim **6** in which said first location is disposed radially outward from said axis and at an elevation above the middle of said axis.

8. The method set forth in claim **1** in which the location for removing said first particles having a lesser magnetic susceptibility is beneath said first location.

9. Apparatus for separating material composed of particles having different magnetic susceptibilities comprising a stator including a stationary non-magnetic shell having a generally cylindrical outer surface and a generally cylindrical inner surface and a plurality of polyphase windings fixedly disposed within said shell in an adjacent relationship with the said inner surface thereof, said windings generating a rotating electromagnetic field that progresses circumferentially therearound, means for introducing said material into said field at one radial location so that particles having a magnetic susceptibility less than a given level fall gravitationally out of said field and the particles having a magnetic susceptibility above said given level are accelerated exclusively by said field to the extent that those particles possessing a magnetic susceptibility nearer said given level are thrown outwardly away from the outer surface of said shell due solely to centrifugal force developed only by said rotating field and thereby separated from those particles having a higher susceptibility which continue in a proximal relationship to said outer surface due to said rotating field, means for collecting said centrifugally separated particles so that they remain separated from those particles having a higher susceptibility so that said higher susceptibility particles continue in said proximal relationship to said outer surface, and means extending outwardly from the outer surface of said shell at a location less than 360° from said one location for deflecting those particles having a higher susceptibility which have continued along said outer surface from said field prior to the completion of a full revolution of said field.

10. The apparatus set forth in claim **9** in which said stator is disposed along a substantially horizontal axis.

11. The apparatus set forth in claim **12** including means having an inlet opening disposed generally horizontally at said one location where the electromagnetic field is moving outwardly, and means located generally beneath said stator via which those particles having a magnetic susceptibility less than said given level are gravitationally removed.

12. The apparatus set forth in claim **11** in which said means for deflecting said higher susceptibility particles from said field includes a barrier extending angularly from said stator, said means for gravitationally removing these particles having a magnetic susceptibility less than said given level being to one side of said barrier, and means to the other side of said barrier for removing the particles having the highest magnetic susceptibility after being deflected by said barrier.

13. The apparatus set forth in claim **12** including an adjustable splitter vane for determining the cross sectional area through which the highest magnetic susceptibility particles pass and thereby the amount thereof.

14. The apparatus set forth in claim **10** including means having an inlet opening disposed generally at said one location where the electromagnetic field is moving downwardly, and means located generally beneath said stator via which those particles having a magnetic susceptibility less than said given level are gravitationally removed.

15. The apparatus set forth in claim **14** in which said means for deflecting said high susceptibility particles from said field includes a barrier extending angularly from said stator immediately above said one location, and an adjustable splitter vane beneath said stator for determining the cross sectional area through which the particles above said given level of susceptibility pass and thereby the amount thereof.

16. The apparatus set forth in claim **15** in which said means for removing those particles having a magnetic susceptibility less than said given level is to one side of said splitter vane and said means for collecting said centrifugally separated particles is to the other side thereof.

17. The apparatus set forth in claim **9** in which said stator is disposed along a substantially vertical axis.

18. The apparatus set forth in claim **17** in which said one location is adjacent the upper end of said stator.

19. Apparatus for separating material composed of particles having different magnetic susceptibilities comprising a housing, a stator including a stationary non-magnetic shell having a generally cylindrical outer surface and a generally cylindrical inner surface and a plurality of polyphase windings fixedly disposed within said shell in an adjacent relationship with the inner surface thereof, said shell being arranged horizontally within said housing and said windings generating a rotating electromagnetic field that progresses circumferentially therearound, means for introducing the material to be separated into said field at one radially located position so that the particles having a magnetic susceptibility below a given level fall gravitationally toward the bottom of said housing and those particles having a magnetic susceptibility above said given level are carried by said rotating field, means located at a second radial position spaced angularly from said first position for deflecting the material having a high magnetic susceptibility out of said field, first means for collecting the material having a magnetic susceptibility nearer said given level which is thrown outwardly away from the outer surface of said shell by centrifugal force developed solely from said rotating field, and second means for collecting the material having said high magnetic susceptibility deflected by said deflecting means after said material having a magnetic susceptibility nearer said given level has been thrown outwardly away from said outer surface due to centrifugal force.

20. The apparatus set forth in claim **19** including a splitter vane adjustably positionable with respect to said stator so as to cause more or less concentrate to be removed.

21. The apparatus set forth in claim **20** in which said second collecting means includes an outlet in the bottom of said housing via which the material having a relatively high magnetic susceptibility is removed and said first collecting means includes an outlet in the bottom of said housing via which the material having a magnetic susceptibility nearer said given level is removed, and in which said splitter vane is pivotally mounted about a horizontal axis so that its upper edge can be swung to a position nearer said stator to divert more of said material having a magnetic susceptibility nearer said given level into said first collecting means and less of the material having a relatively high magnetic susceptibility into said second collecting means.

22. Apparatus for separating material composed of particles having different magnetic susceptibilities comprising a housing having a bottom, a stator including a stationary non-magnetic shell having a generally cylindrical outer surface and a generally cylindrical inner surface fixedly disposed in said housing and a plurality of polyphase windings fixedly disposed within said shell for generating a rotating electromagnetic field, the bottom of said housing having a first outlet formed therein located beneath said stator via which non-magnetic particles are gravitationally discharged, means for introducing said material into said housing at a location adjacent said stator so that the material enters the field at a relatively high intensity portion thereof whereby the particles having a magnetic susceptibility above a given level are accelerated entirely by said field to the extent that those particles possessing a magnetic susceptibility nearer said given level are thrown outwardly from the outer surface of said shell due to centrifugal force developed solely by said rotating field, said bottom having a second outlet therein laterally offset from said shell via which said centrifugally separated particles are removed, a barrier extending across said housing for deflecting those particles having a relatively high magnetic susceptibility from said field, said barrier being located a substantial angular distance from the location at which the material is introduced into said housing, said bottom having a third outlet opening located near said barrier so that material deflected thereby which has continued in a proximal relation along said outer surface is removed via said outlet.

23. The apparatus of claim **22** including a splitter vane between said second and third outlet for diverting more of said relatively high magnetic susceptibility material through said third outlet when moved into one position and less of said relatively high magnetic susceptibility material when moved into a second position.

24. In apparatus for separating materials composed of particles having different magnetic susceptibilities, a housing, a stator contained in said housing comprising a plurality of stacked laminations, each lamination having a series of angularly spaced pointed teeth projecting radially outwardly therefrom to form slots between the various angularly spaced teeth, a plurality of coils disposed in said slots, a non magnetic liner encircling the pointed ends of said teeth, whereby polyphase energization of said coils produces a rotating field sufficiently intense so as to carry with it particles having a magnetic susceptibility above a given level and which field will produce a sufficient amount of centrifugal force to throw outwardly from said stator those particles having a magnetic susceptibility nearer said given level, deflecting means extending between said liner and one portion of said housing for deflecting said material having a relatively high magnetic susceptibility from said rotating field, said means being located at an angular position with respect to said liner which is spaced from the location at which the material is introduced into said field, means for removing from said housing the material that is separated by centrifugal force from said field after reaching a sufficient angular velocity, means for removing from said housing the material that is separated by said deflecting means, and means for removing from said housing the material having a magnetic susceptibility below said given level.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,684,090 Dated August 15, 1972

Inventor(s) James R. Kilbride

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 67, "middling" should be --middlings--. Column 3, line 59, "of" (second occurrence) should be --or--; line 60, "resistance" should be --resistant--. Column 4, line 58, "direction" should be --location--. Column 5, line 60, "other" should be --order--. Column 6, line 30, "A" should be --a--. Column 7, line 45, after "58_M" insert --therewith. Depending upon the field strength, the middlings 58_M--; line 60, "The" should be --the--. Column 9, line 20, "Claim 12" should be --Claim 10--; line 23, "outwardly" should be --upwardly--.

Signed and sealed this 9th day of January 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

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