

[54] **COAL PREPARATION PROCESS AND
MAGNETITE RECLAIMER FOR USE
THEREIN**

[75] Inventor: **Sherman C. Burkitt**, Arlington Heights, Ill.

[73] Assignee: **FMC Corporation**, San Jose, Calif.

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[51] Int. Cl.**B03b 7/00, B03c 1/30**

[58] Field of Search.....**209/10, 214, 232, 209/224-226, 209, 39, 172.5, 223, 40, 472, 3, 464**

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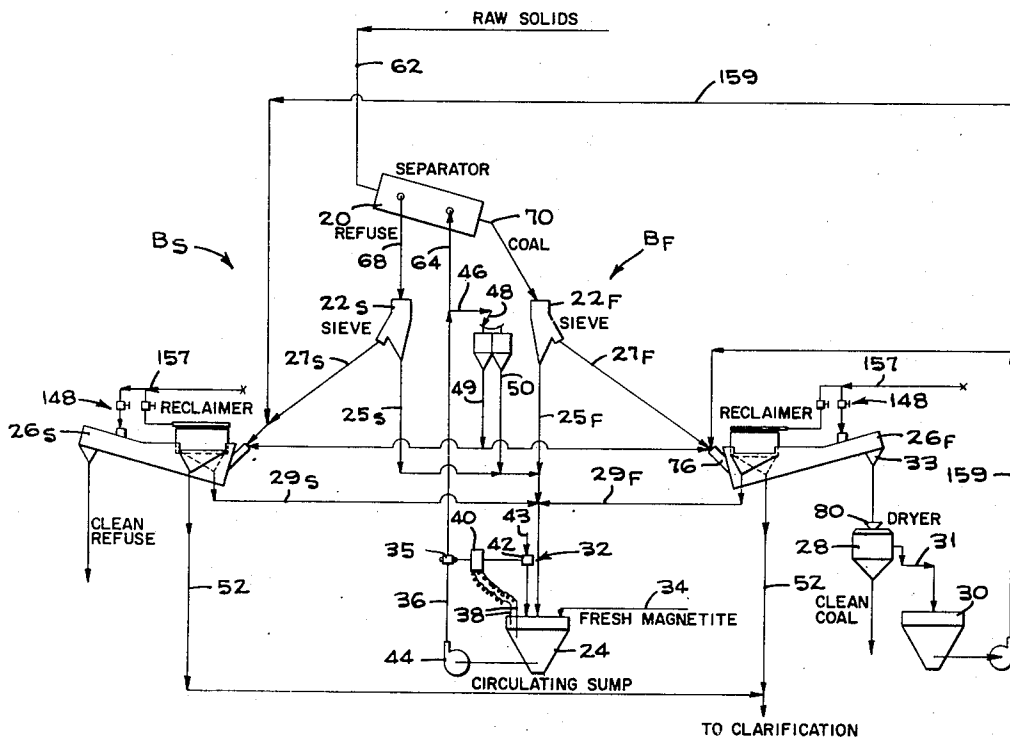
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Assistant Examiner—Robert Halper
Attorney—F. W. Anderson and C. E. Tripp

[57] **ABSTRACT**

A coal preparation process includes a dense medium coal separator which utilizes a magnetite media for separating raw coal from refuse. A sieve receives coal from the separator and is utilized to drain a portion of the magnetite media from the coal before the coal is passed into a new magnetite reclaimer wherein paddles agitate the coal causing abrasive contact between the coal particles to dislodge the magnetite which adheres to the coal. The magnetite free coal is conveyed out of the reclaimer by a screw conveyor while the released magnetite is removed by a magnetic drum. The magnetite removed from the coal is directed into a sump for re-use in the system. A similar process is utilized to treat the refuse so as to recover the magnetite which passes from the separator with the refuse.

21 Claims, 14 Drawing Figures



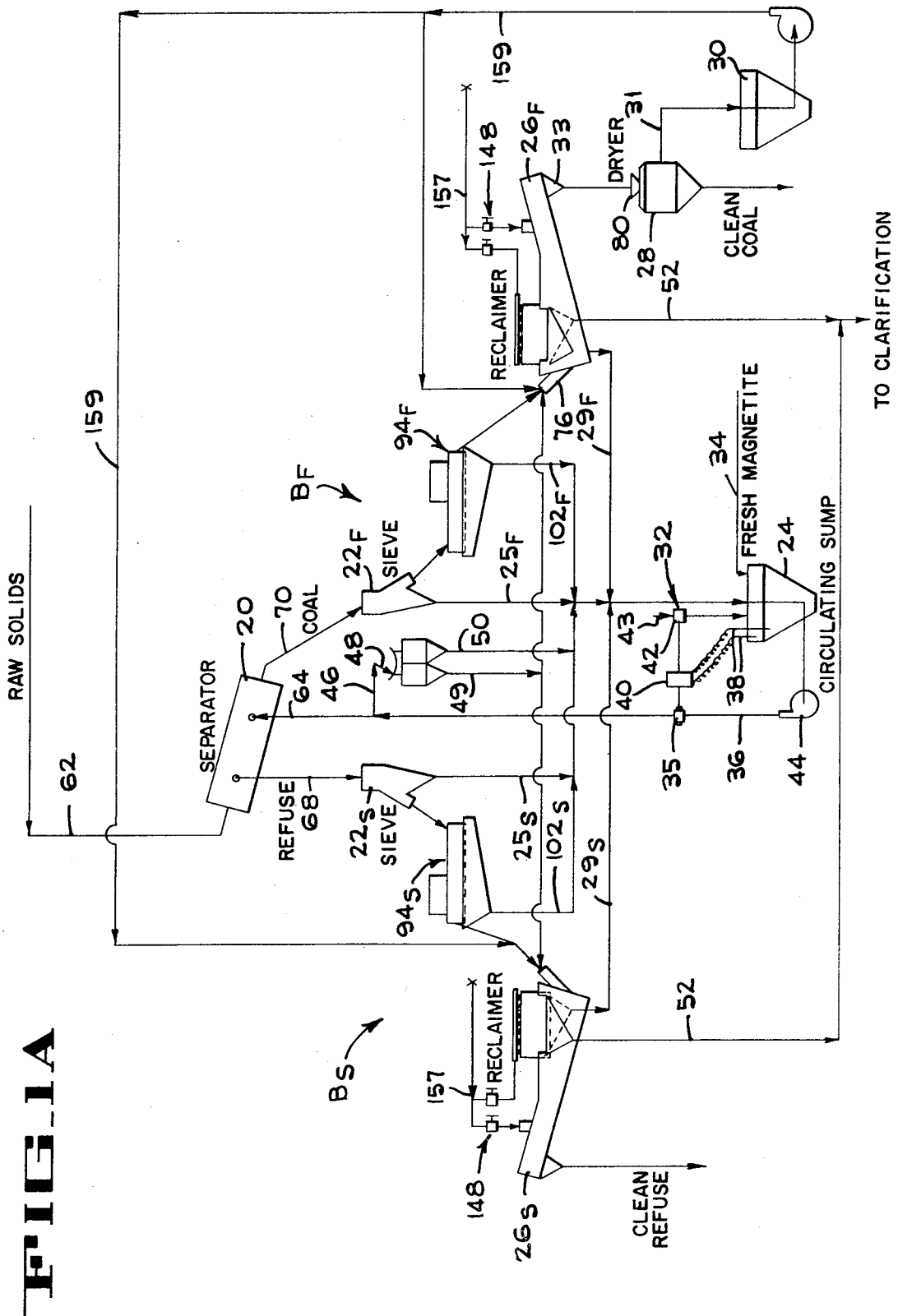


FIG 1C

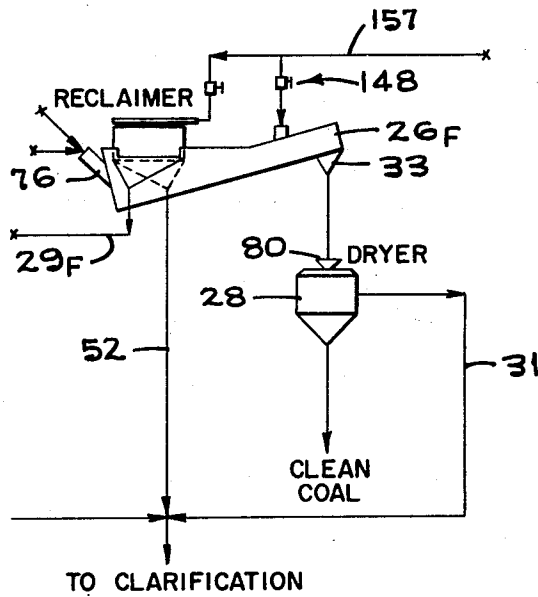


FIG 1D

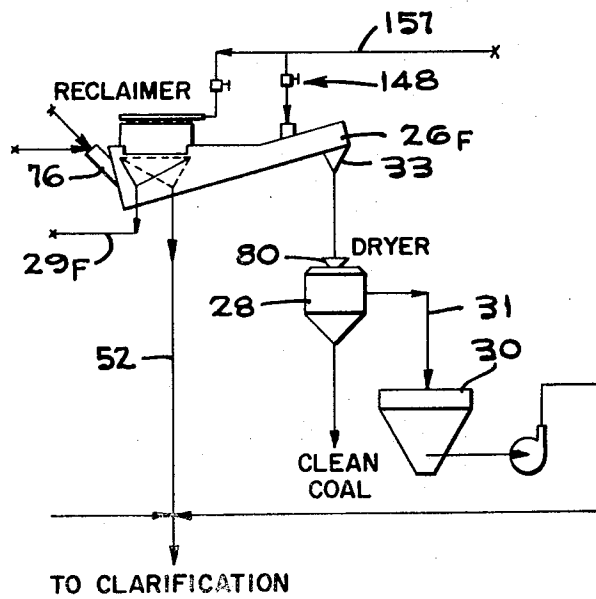
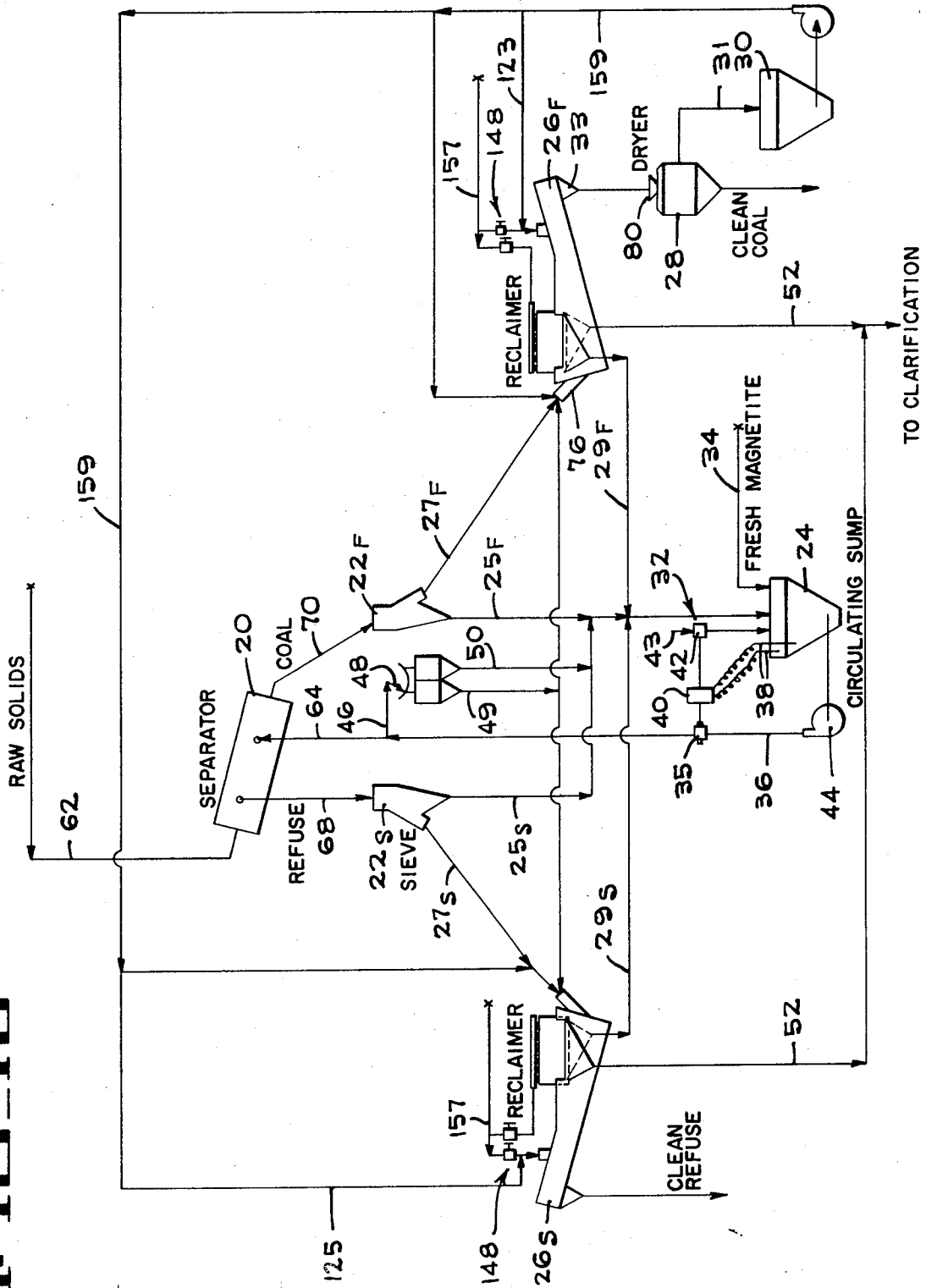


FIG. 1E



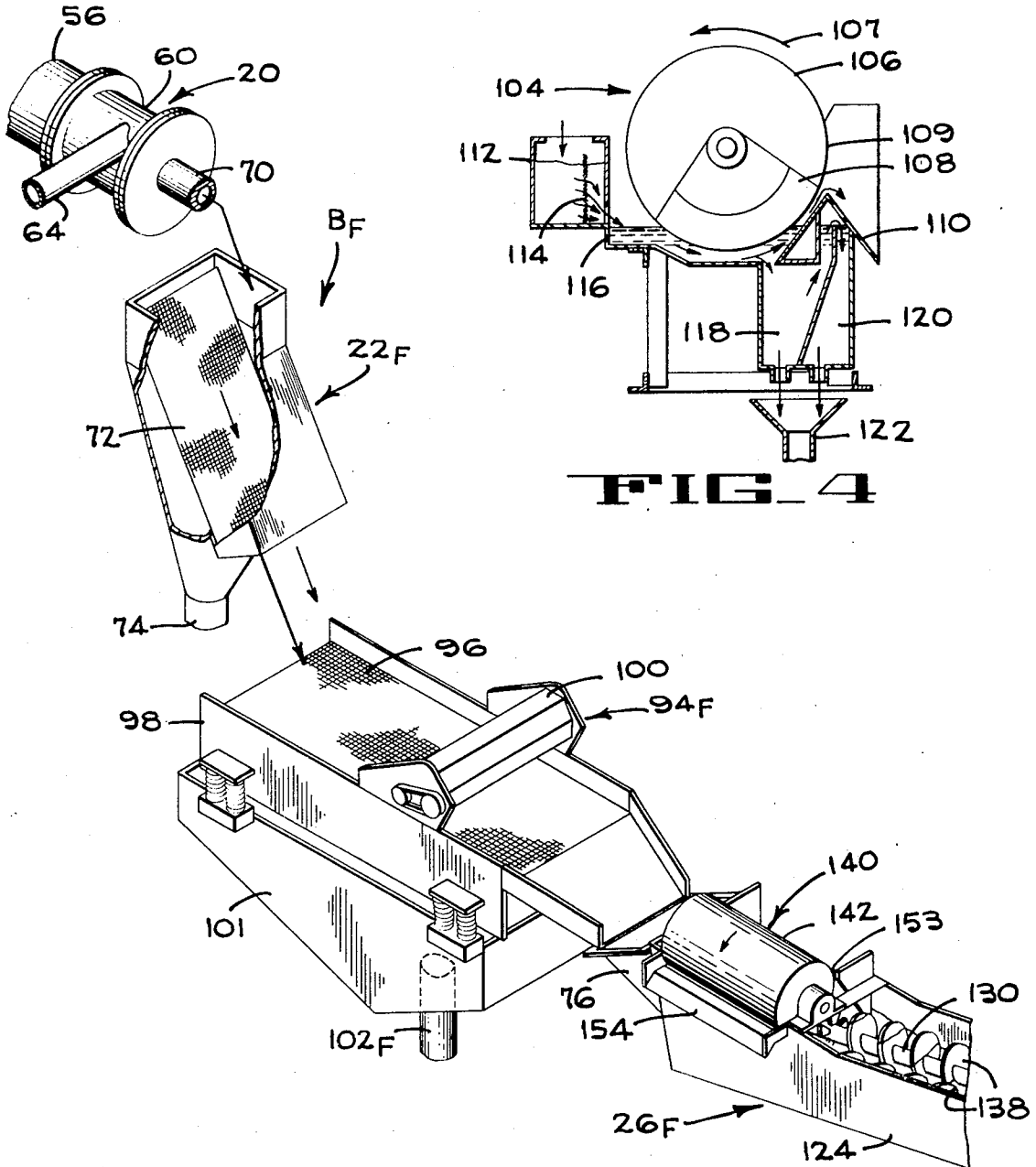
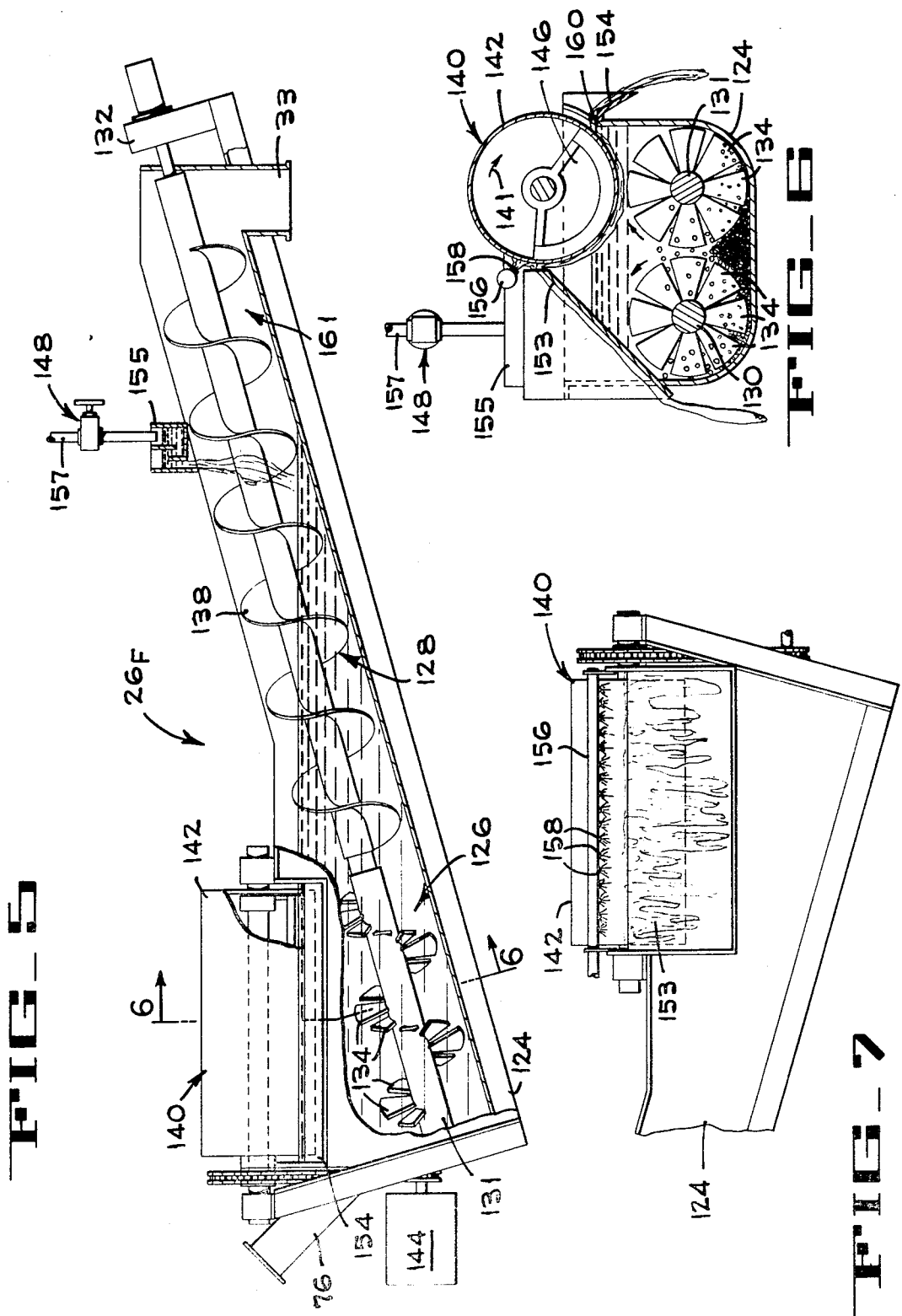


FIG. 4

FIG. 3



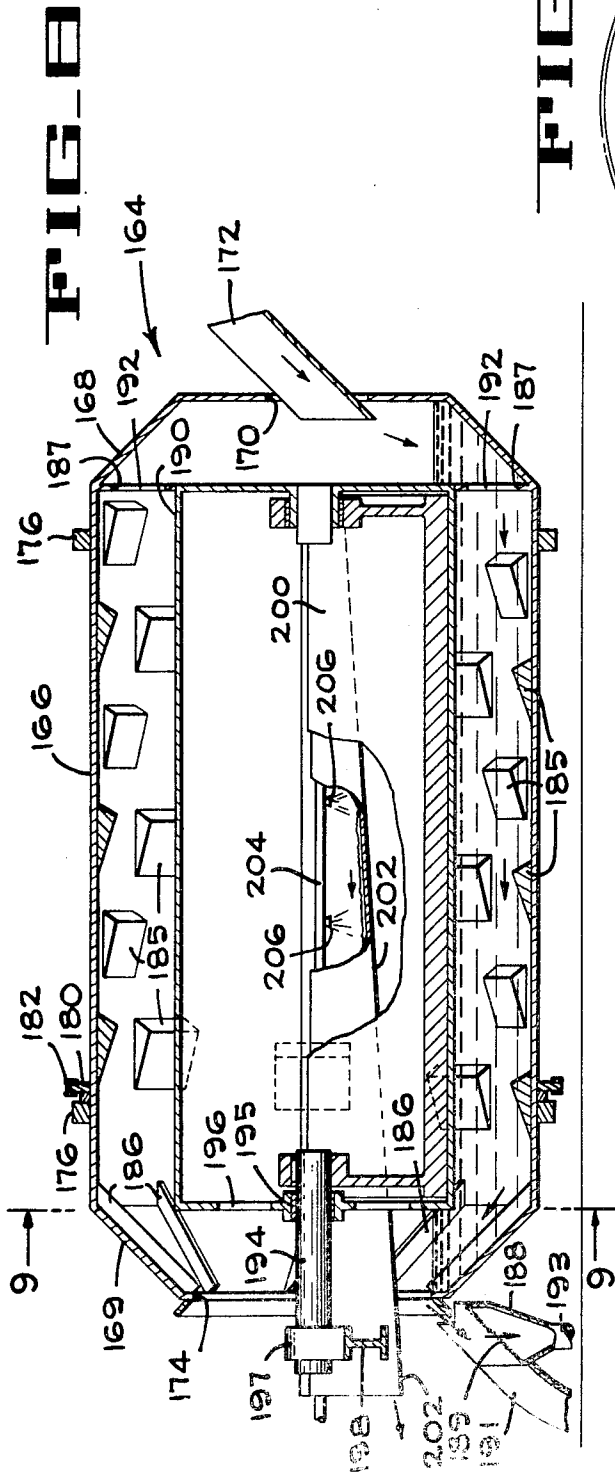
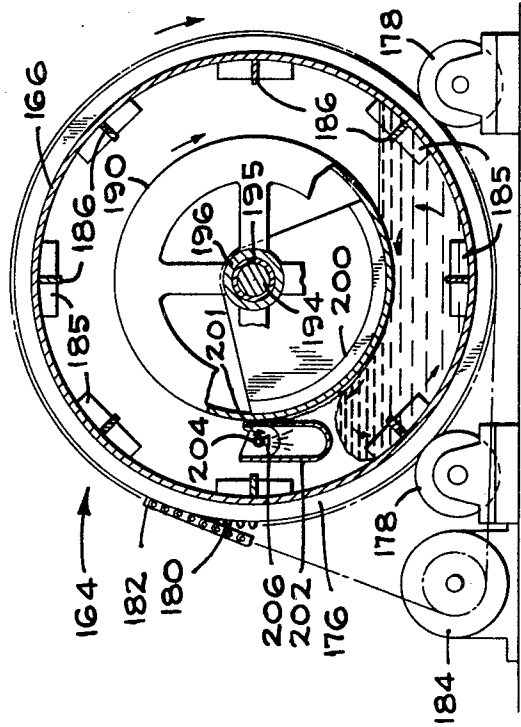


FIG. 9



COAL PREPARATION PROCESS AND MAGNETITE RECLAIMER FOR USE THEREIN

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to a process of preparing coal but more particularly relates to a process of reclaiming magnetite from coal or other solids which have been processed in a magnetic dense medium system. An important feature of the invention is a magnetite reclaimer for abrasively releasing the magnetite from the solids and separating the two materials for individual processing.

The use of heavy media, that is to say a suspension of finely divided high gravity solids such as magnetite in water or other liquids, for the beneficiation of coal by a sink and float process has achieved great commercial utility. In a sink and float process, raw coal is fed into a dense medium separator wherein the medium has a specific gravity which is greater than that of the coal but less than that of the refuse which is to be separated from the coal. There are numerous types of such separators but each functions similarly in that the raw coal is placed in contact with the dense medium so that the refuse, which is intermingled with the coal, sinks into the medium and is, therefore, called the sink product while the coal floats on the medium surface and is consequently called the float product. The coal can then be removed separately from the refuse. The coal, of necessity, however, entrains a certain quantity of the magnetite which must be removed from the coal if the coal is to be thoroughly cleaned. In addition, and more importantly, the recovery of the magnetite, which can be re-used in the process, is necessary for an efficient and economical operation.

The present invention is accordingly concerned with a system for separating float and sink products with a dense magnetite medium and with a system which removes and recovers the magnetite from the separated float and sink products with a new magnetite reclaiming apparatus.

2. Description of the Prior Art

In conventional coal preparation processes, each product discharged from the separating device is relieved of its magnetite coating by passing the product over a dewatering sieve and finally over a vibrating rinsing screen before removing the product from the system. While passing over the vibrating screen the material is rinsed with a liquid medium in an attempt to remove the adhering magnetite from the solids. The rinse medium, magnetite, and ultra fine non-magnetic solids are collected in a pan below the screen. To recover the magnetite from this solution, the solution is processed through a recovery system which may include various combinations of magnetic separators, cyclones, static thickeners, densifiers and storage tanks.

The conventional processes are not entirely satisfactory, however, as it has been found that the magnetite clings to the coal and is not adequately removed by a mere rinsing. This is particularly true in the preparation of smaller coal particles wherein there is a greater surface area of coal exposed to the magnetite media per unit weight of coal.

Typical of prior art devices used for removing magnetic particles from their carrying medium are disclosed in U.S. Pat. No. 2,002,978 issued to E.W. Davis on May 28, 1935 and U.S. Pat. No. 2,564,515 issued to

W. Vogel on Aug. 14, 1951. U.S. Pat. No. 2,998,882 issued to J.M.J. Leeman on Sept. 5, 1961 discloses a process and apparatus for purifying a suspension of fine magnetizable particles in a liquid solution containing contaminated particles of a non-magnetizable material.

SUMMARY OF THE INVENTION

The process of the present invention provides an efficient and effective system for the recovery of magnetic material from solids which have been processed in a magnetic dense medium system. A new magnetite reclaimer, which is part of the coal preparation system, makes it possible to omit in most installations the vibrating screen which is critical to the successful operation of conventional systems.

In general, raw coal is fed into a dense medium separator which utilizes the specific gravity of the medium to separate refuse from the coal. In other words a dense magnetic solution having a predetermined specific gravity peculiar to the separator type is passed through the separator with the coal. The coal being lighter than the refuse will be separated from the heavier refuse particles and consequently each will be separately carried out of the separator through different passages by a fraction of the solution. Inherently, a certain quantity of the magnetic solution will adhere to and be carried from the separator by both products. The float and sink products emanating from the separator are treated in a similar manner to remove the magnetic material from the surfaces thereof so that the magnetic material can be re-used in the dense medium separator.

For purposes of the present disclosure, the magnetic material will be referred to as magnetite, however, other magnetic type solids may be used.

It has been found by applicant that a scrubbing action of one particle on another has the ability to very effectively free the adhering magnetite from the particles. When this is done in a fluid pool with agitation, the magnetite is free to move through the liquid medium from which it can be removed by magnetic means. To treat the coal and refuse particles in this manner, applicant has developed a magnetite reclaimer for use in the coal preparation process.

The magnetite reclaimer contains a liquid bath and has means for agitating the magnetite laden particles to cause a scrubbing action between the particles to release the magnetite. The reclaimer is also provided with means for removing the released magnetite from the bath, means for removing the particles which formerly carried the magnetite, and means for removing non-magnetic fine particles which are unavoidably carried into the system by the raw coal.

Accordingly, it is an object of the present invention to provide a dense medium coal preparation process wherein a very efficient and effective recovery of the magnetite used in the dense medium can be made.

It is another object to provide an apparatus for removing magnetite from solids being processed and separately discharging the separated products.

It is still another object to provide an apparatus for removing magnetite from solids to which the magnetite is adhered by abrasively agitating the solids to thereby scrub the magnetite from the surface of the solids.

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collecting the magnetite by magnetic means and discharging the magnetite separately from the cleansed solids.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of the coal preparation process.

FIG. 1A is a schematic representation of an alternative embodiment of the process of FIG. 1.

FIG. 1B is a schematic representation of another alternative embodiment of the process of FIG. 1.

FIGS. 1C and 1D are fragmentary schematic representations of further alternative embodiments of the process of FIG. 1.

FIG. 1E is a schematic representation of still another alternative embodiment of the process of FIG. 1.

FIG. 2 is a diagrammatic isometric view of a portion of the apparatus used in the process schematically shown in FIG. 1.

FIG. 3 is a diagrammatic isometric view of a portion of the apparatus used in an alternative arrangement of the process schematically shown in FIG. 1.

FIG. 4 is a diagrammatic front elevation of the magnetic drum separator used in an alternative arrangement of the process schematically shown in FIG. 1.

FIG. 5 is a side elevation of a preferred embodiment of the magnetite reclaimer of the present invention with parts broken away for clarity.

FIG. 6 is an enlarged sectional view of the magnetite reclaimer of FIG. 5 taken along line 6—6 of FIG. 5.

FIG. 7 is an enlarged fragmentary view of the magnetite reclaimer of FIG. 5 showing the magnetite discharge chute.

FIG. 8 is a longitudinal vertical section of an alternative embodiment of the magnetite reclaimer.

FIG. 9 is a sectional view of the alternative embodiment of the magnetite reclaimer of FIG. 8 taken along line 9—9 of FIG. 8.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An understanding of the coal treating process of the present invention is best understood by reference to FIG. 1 wherein a schematic representation of one embodiment of the process is shown. It is seen that raw solids consisting of coal and refuse such as gravel, etc., are fed into a dense medium separator 20 wherein the coal is conventionally separated from the heavier refuse. The dense medium of the separator is comprised of magnetite and water constituting a magnetite slurry. The refuse or sink product is carried from the separator 20 with the magnetite slurry while the coal or the float product is removed separately. However, due to the manner in which the separator operates, a certain quantity of the magnetite slurry adheres to and is carried from the separator by the coal. The emitted float and sink products are subsequently similarly treated to recover the magnetite carried thereby for re-use in the system.

The float and the sink products are treated with identical equipment in two separate branches B_F and B_S of the system. The coal or float product branch B_F includes a drying apparatus not generally included in the sink or refuse branch B_S , but otherwise the systems are identical.

The coal and refuse products from the separator 20 are first respectively passed over identical dewatering

sieves 22_F and 22_S wherein most of the slurry is drained from the solid coal or refuse. The slurries leaving the sieves are directed through flow lines 25_F and 25_S respectively into a circulating medium sump 24 for re-use in the separator while the coal and refuse are respectively passed into identical magnetite reclaimers 26_F and 26_S through passages 27_F and 27_S. The magnetite reclaimer is an important feature of the invention, as will be seen hereinafter, and includes means for agitating the solids for abrasively releasing the magnetite from the surfaces thereof. The released magnetite is removed from the reclaimers by magnetic means and directed into the circulating medium sump 24 through flow lines 29_F and 29_S.

The clean coal is removed from the magnetite reclaimer 26_F in branch B_F by mechanical means through a solid particle discharge passage 33 and passed into a centrifugal dryer 28 wherefrom the coal is emitted as a clean and de-watered product. The moisture removed from the coal in the dryer 28 is directed into a liquid sump 30 through flow line 31 from which it is pumped back for use in the reclaimer in either the coal branch or the refuse branch of the system.

The clean refuse is mechanically removed from the magnetite reclaimer 26_S in the refuse branch B_S but is generally not passed through a dryer as there is usually no need to further process the refuse. Once emitted from the reclaimer, the refuse can be carried away from the system by a conveyor or any other suitable means.

The circulating medium sump 24 is provided with a regulated water supply 32 and a fresh magnetite supply 34 so that the specific gravity of the magnetite slurry in the sump 24 can be maintained at a predetermined value. The water supply 32 is regulated by conventional means including a density meter 35 in a flow line 36 from the sump 24 to the separator 20, level indicators 38 disposed in the sump 24, and a gravity control instrument 40 for operating a solenoid valve 42 in a water line 43. The fresh magnetite supply 34 is regulated manually or automatically as desired.

The magnetite slurry in the sump 24 is pumped by a pump 44 through line 36 to an inlet of the separator 20 to thereby recirculate the magnetite which was separated from the coal and refuse particles in the preparation system. A bleed-off line 46 is provided in the flow line 36 to divert slurry from the flow line 36 to help maintain the desired specific gravity of the magnetite slurry. The bleed-off line 46 is also useful to further purify the slurry by re-directing a portion of the slurry through the magnetite reclaimers 26_F and 26_S wherein the fine non-magnetic particles, which got into the circulating sump and consequently the flow line 36 through the sieves 22_F and 22_S, can be removed by a process to be described in more detail hereinafter.

The bleed-off line 46 is provided with a deflector valve 48 to selectively direct the flow of liquid in line 46 into one or both of two re-cycling lines 49 and 50. The re-cycling line 49 is connected to the inlet of the magnetite reclaimers 26_F and 26_S and re-recycling line 50 is directed back into the circulating medium sump 24. It has been found in some installations that fine non-magnetic particles will pass through the sieves 22_F and 22_S with the magnetite slurry and tend to undesirably increase the specific gravity and/or viscosity of the media in the sump 24. Therefore, to prevent this increase in specific gravity, the fluid passing in the bleed-

off line 46 can be primarily deflected into re-cycling line 49 leading back into the reclaimers 26_F and 26_S wherein the non-magnetic particles can be separated from the magnetite and directed through an overflow line 52 to clarification or other processing systems not comprising a part of the present invention, and the magnetite can be fed back into the sump 24. Thus, it is apparent that the bleed-off line 46 provides a means of ridding the system of undesirable non-magnetic fine particles and also provides an additional means for regulating the specific gravity of the media in the sump 24 completely independent of the water supply 32 or the fresh magnetite supply 34.

A portion of the apparatus used in the processing of the coal or float product is diagrammatically shown in FIG. 2, it being understood that the apparatus used in the processing of the refuse is identical except that normally there is no apparatus provided in the refuse ranch for drying the solid particles. The separator 20 is disclosed as being of the vessel type used for fine or intermediate size coal, preferably in the range between one-fourth inch to 28 mesh, but may be used on coal up to inches. The separator, may be similar to the Wilmot-OCC heavy media separator, which consists of a straight walled cylinder 56 (FIG. 2) of predetermined length and diameter, provided at each end with a head 58 and 60. The cylinder is operated in an inclined position. The raw solid feed enters the vessel through a feed pipe 62, while the magnetite slurry enters the unit tangentially under pressure through a pipe 64 at the lower end of the cylinder 56. The pipe 64 is in fluid communication with flow line 36. The pumped slurry rises to the top of the vessel creating an open longitudinal vortex 66 (FIG. 2). The slurry leaves the vessel through a refuse discharge pipe 68, and through a float discharge pipe 70. The actual separation takes place on the inner face of the vortex 66 in such a manner that the light float coal rides downwardly to be discharged as clean coal through the float discharge pipe 70 while the heavy refuse particles of feed penetrate the rising magnetite slurry toward the outer wall of the vessel and are discharged with the high gravity slurry through the refuse discharge pipe 68.

As stated hereinbefore, upon leaving the separator 20 the coal (or float product) passes into a branch B_F of the preparation system while the refuse (or sink product) passes into the similar branch B_S. With further reference to FIG. 2, it is seen that the sieve 22_F which receives the coal leaving the separator through discharge pipe 70, includes an inclined screen 72 having a mesh so that the magnetite slurry and other fine non-magnetic particles can pass therethrough but through which the larger coal particles cannot pass. The magnetic slurry and non-magnetic fines leave the sieve 22_F through a conduit 74 which is in fluid communication via flow line 25_F with the circulating medium sump 24. The coal which is still moist with the magnetite slurry, and to some extent the non-magnetic fines, is passed into the magnetite reclaimer 26_F through inlet conduit 76.

The magnetite reclaimer will be described in more detail later, however, it is important to note at this point that the reclaimer very efficiently separates the magnetite, coal, and non-magnetic fines into three distinct discharged products. The magnetite is passed through a flow line 29_F (FIG. 1) directly into the circulating medium sump 24, the non-magnetic fines are

passed through the overflow line 52 to clarification or other processing systems, and the coal is passed in a moist state into the centrifugal dryer 28.

One type of centrifugal dryer can also be seen in FIG. 2, and comprises a feed chute 80 made of two frusto-conical members to first funnel the coal and then disperse it onto the bottom surface of a screen-walled tub 82. The tub 82 is rotated through a belt-pulley drive 84 by a motor 86. The screen wall of the tub is outwardly flared and is non-symmetrically weighted so that centrifugal force and vibratory action will cause the coal particles to rise up and over the top of the wall and into a stationary annular solids discharge passage 88 wherefrom they flow by gravitational force out of the bottom of the dryer. As the coal is rising up the flared screen wall of the tube 82, the moisture on the coal is centrifugally forced through the screen wall into an annular liquid discharge passage 90 wherefrom it flows out of the dryer through opening 91 which communicates with the flow line 31 (FIG. 1) going to the liquid sump 30.

The above described coal preparation process may be varied to meet various requirements determined by the installation size or the quality of the raw coal to be processed in the system. Various alterations are shown in FIGS. 1A through 1E. One variation (FIG. 1A) can be seen to be adding identical vibrating screens 94_F and 94_S into the system between the sieves 22_F and 22_S and the magnetite reclaimers 26_F and 26_S respectively. This vibrating screen can be used in either or both branches B_S and B_F if it is found that the sieves 22_F and 22_S are not adequately removing a substantial quantity of the magnetite slurry. The screen would merely provide an additional means for draining the slurry from the solids.

One type of vibrating screen which could be used in the system is shown diagrammatically in FIG. 3, wherein branch B_F of the system is depicted, and can be seen to include a horizontally disposed screen 96 rigidly secured in a resiliently mounted frame member 98. A vibrator 100 is secured to the frame at an acute angle to the screen so that the screen is vibrated in a manner so as to throw the solid particles passing thereover forwardly in small increments. The moisture carried by the particles is thereby shaken from the particles as the particles advance over the screen causing the moisture to fall through the screen into a discharge pan 101 from where it is directed into the circulating sump 24 via flow line 102_F. Of course, the vibrating screen 94_S in branch B_S would operate the same way with the moisture falling through the screen being passed through flow line 102_S.

Another variation in the coal preparation process (FIG. 1B) would be the addition of a conventional magnetic drum separator 104. The drum separator can be incorporated into the system to aid in recovering any magnetite escaping the reclaimer in the overflow water. The magnetic drum separator is useful in separating the magnetite that is carried in liquid suspension from other liquid suspendable material such as non-magnetic fines. One type of separator consists of a metallic cylindrical drum member 106 (FIG. 4) rotatably driven in the direction of arrow 107 with the lowermost portion of the drum submerged in a liquid medium. A stationary arcuate magnet 108 is disposed within and adjacent the solid cylindrical drum wall 109 of the drum 106, so that the magnetic field of the magnet is always effective on the portion of the drum wall passing through the liquid medium to attract magnetic material

suspended in the liquid medium to the outer surface of the drum. The magnet 108 extends arcuately a finite distance above the liquid medium level on the upwardly moving side of the drum to define a magnetic material discharge position at its uppermost extent. The outer surface of the drum wall carries the magnetic material out of the liquid and to the magnetic material discharge position. As the drum wall rotates past the magnetic material discharge position the magnetic material on the drum wall leaves the magnetic field of the magnet 108 and falls therefrom into a discharge chute 110. The chute 110 communicates with a flow line 111 which directs the magnetic material into the circulating medium sump 24 for re-use in the system.

A liquid feed passage 112 is provided on the opposite side of the drum from the magnetic discharge chute 110 having a filtering screen 114 therein to prevent the entry of oversize tramp material. The liquid passes from the feed 112 into the main tank 116 wherein the magnetic material is picked up by the drum 106. A tailing discharge 118 is provided to remove the non-magnetic solids from the tank along with a good portion of the liquid, and an overflow liquid discharge 120 is provided to maintain an effective operating level. Both discharges 118 and 120 are directed into a common duct 122 and the combined flow passes into the overflow line 52 for removal from the system.

The drum separator 104 can be incorporated into the system to receive the overflow from the magnetite reclaimers 26_F and 26_S. The drum would in this case be used as a check to remove any magnetite from the reclaimer overflows that was not removed in the reclaimers. The drum can also be used to receive the liquid medium flowing in recycling line 49 in lieu of directing the flow in line 49 into the reclaimers, inasmuch as the same result would be achieved, namely separation of the magnetic particles from the liquid, and as a consequence thereof an overload on the reclaimers could be avoided. The vibrating screens 94_S and 94_F could also be incorporated into the system of FIGS. 1B just as they were incorporated into the system of FIG. 1A.

Another variation (FIG. 1C) in the preparation process is to direct the liquid effluent from the dryer 28 directly into the overflow line 52 and thus out of the system rather than directing the effluent into the sump 30 and subsequently to the feed chute of the reclaimers as in the first described arrangement of the system. This variation would be useful when it was evident that the magnetite was sufficiently separated from the wetting liquid in the reclaimer 26_F and there was no need to feed the liquid back into either or both of the reclaimers for further separation. To provide better control over the liquid flow from the dryer to the overflow line 52, the effluent liquid from the dryer could be directed into sump 30 (FIG. 1D), as in the first described arrangement of the system, wherein it can be collected and pumped as desired into the overflow line 52. It should also be noted that the vibrating screens 94_S and 94_F and/or the drum separator 104 could also be added to the systems of FIGS. 1C and/or 2D.

Still another variation (FIG. 1E) from the basic process described hereinbefore would be to use the liquid in sump 30 as a water source via flow lines 123 and 125 to maintain the liquid baths in the reclaimers in either or both branches B_F and B_S of the system which will be more clearly understood with the detailed description of the reclaimers which follows hereinafter. Again it

should be noted that the system variations shown in FIG. 1A (vibrating screens 94_S and 94_F) and/or FIG. 1B (magnetic drum separator 104) could also be incorporated into the system of FIG. 1E.

As mentioned before, an important feature of the present invention is the magnetite reclaimer. The description of the reclaimer will be made with reference to the reclaimer 26_F, shown in detail in FIGS. 5 to 7, it being understood that the reclaimer 26_S in the branch B_S is identical, differing possibly in size in some installations. The reclaimer 26_F can be seen to include an elongated and inclined liquid bath retaining tank 124 having a lower agitating section 126 and an upper screw conveyor section 128.

Extending longitudinally through the tank 124 are two parallel and inclined shafts 130 and 131 (FIG. 6) rotatably driven in opposite directions by a motor and drive unit 132. It is of course possible that more than two shafts could be used without altering the overall function of the machine. The lower portion of the shafts in the agitating section 126 of the tank is provided with a plurality of paddles 134 rigidly mounted on each of the shafts in a helical configuration. The upper portion of each of the shafts in the conveyor section 128 of the tank is provided with a helical plate screw blade 138. The paddle and plate screw blade helixes on shaft 130 are left-handed while the paddle and plate screw blade helixes on shaft 131 are right-handed so that when the shafts are counter-rotated, material in operative contact with any one of the helixes will be conveyed in the same direction.

Disposed vertically above the shafts 130 and 131 in the agitating section of the tank is a magnetic drum separator 140 having a stainless steel cylindrical drum wall 142. The drum wall has substantially enclosed ends and is rotatably driven in the direction of arrow 141 by a motor 144. It is not critical that the drum wall be made of stainless steel, however, it is desirable that the drum wall be made of a non-magnetic material that will not deteriorate rapidly with constant exposure to the liquid medium in the tank. A stationary elongated magnet 146 of arcuate cross section is mounted adjacent the interior surface of the drum wall so that the magnetic field of the magnet is always effective on the portion of the drum wall passing through the liquid medium of the bath to attract magnetic particles suspended in the liquid medium to the outer surface of the drum. The magnet extends arcuately a finite distance above the liquid bath level on the upwardly turning side of the drum wall to define a magnetic material discharge position at its uppermost extent.

The tank 124 is provided with a water supply 148, the inlet or feed passage 76 for magnetite laden solid particles which are to be cleaned in the reclaimer, and three discharge passages 33, 153 and 154 for removing the separated products from the reclaimer. The water supply 148 may consist of a trough 155 which extends across the entire width of the tank near the upper end and is provided with water through water pipe 157. The pipe 157 is connected to a suitable water source (not shown). However, the trough 155 could be supplied with liquid from the sump 30 via flow line 123 as was pointed out hereinbefore with regard to the alternative arrangement of the coal preparation system in FIG. 1E.

The discharge passage 33 is for removal of the heavier solid particles which have been relieved of substantially all of the magnetite which they carried into

the reclaimer, discharge passage 153 is for removal of the magnetite which is separated from the solid particles in the reclaimer, and discharge passage 154 is an overflow passage to remove water and suspended non-magnetic solids from the tank.

The overflow discharge passage 154 and the water supply 148 determine the liquid level in the tank. This level is maintained so that a lower portion of the drum separator 140 is submerged in the liquid.

In operation, solid magnetite bearing particles are fed into the agitating section of the reclaimer through feed passage 76 and have a tendency to settle to the bottom. The rotating paddles 134 on the shafts 130 and 131 serve to agitate the particles causing a scrubbing action of one particle on another thus dislodging magnetite which is carried by the particles. It is important to note that shaft 130 rotates counterclockwise while shaft 131 rotates clockwise as viewed in FIG. 6, thus throwing the solid particles into abrasive contact in a region between the respective shafts. This scrubbing action is particularly beneficial in the treatment of fine solids as opposed to larger solids inasmuch as there is a greater surface area per unit weight of material for the magnetite to occupy and consequently more magnetite to be removed.

As the solids are agitated and the magnetite scrubbed from the surface of the solids, the magnetite and ultra-fine non-magnetic material become suspended in the liquid of the tank because of the turbulence created by the agitating paddles 134. The magnetic particles are drawn against the outer surface of the magnetic drum wall 142 and thereby withdrawn from the liquid bath as that portion of the drum wall is rotated out of the liquid. As can be seen in FIG. 6, the upper-most extent or longitudinal edge of the permanent magnet 146 which defines the magnetic material discharge position is disposed opposite the magnetite discharge passage 153 so that as the magnetite held against the drum wall passes this position the magnetic attraction is lost and the magnetite will fall from the drum wall into the passage 153. To assure complete removal of all the magnetite from the drum wall, a water manifold 156 may be provided adjacent the discharge passage 153 with a plurality of spray nozzles 158 distributed along its length to wash the magnetite from the drum wall. The manifold is connected to a water supply which is not shown. The opposite longitudinal edge of the magnet 146 extends a slight distance beyond the overflow discharge passage 154 so that any magnetic material approaching the overflow discharge 154 will be drawn against the drum wall and will thus be prevented from passing over an overflow weir 160 and into the overflow passage 154.

Along with agitating the solid particles in the reclaimer, the paddles 134, due to their helical arrangement, also convey the material up the inclined bottom wall of the tank to the screw conveyor section 128. Therein the plate screws 138 on the shafts 130 and 131 serve to transfer the material up through and out of the liquid in the tank and through a dewatering area 161 before subsequently depositing the material into the solid particle discharge passage 33.

It should be noted that the water supply 148 is situated near the upper end of the inclined tank so as to induce a water flow toward the recovery area of the reclaim magnet 146. Magnetite scrubbed from the solids in the agitating section 126 of the tank and which becomes suspended in the liquid bath will thus be urged

by the water currents to remain in the recovery area thus assuring more complete recovery of the removed magnetite. Also the fresh water pumped into the tank through water supply 148 serves to rinse the solids as they are being conveyed up the incline of the tank by the plate screw conveyor 138. Once emerged from the rinse water, the solids are conveyed by the screw conveyor through the dewatering section 161 to relieve the solids of all but a thin moisture coating before they are discharged out passage 33.

The reclaimer of the present invention is designed to maintain a constant liquid level for efficient operation of the magnetic drum separator 140. In conventional magnetic separators, the majority of the feed medium is discharged from the bath through fixed orifices in the bottom of the tank and a small portion overflows a weir in an attempt to maintain a fixed bath level. This bath level is extremely important to the performance of the separator. Loss of the bath can cause the loss of most of the magnetite contained in the separator feed. Inasmuch as the bath underflow orifices are fixed, any reduction in medium flow to the separator such as might be caused by a plugged rinsing water line or a reduction in rinse water pressure, can cause loss of the separator liquid and consequent loss of large quantities of magnetite. In the reclaimer of the present invention, there are no underflow orifices and all liquid leaving the unit, must overflow the weir 160 arranged to bring all magnetic particles into the magnetic field of the permanent magnet 146.

It will be appreciated from the description of the magnetite reclaimer that an apparatus is provided that will efficiently and effectively separate adhering magnetite from the surface of solid particles and recover the magnetite for re-use in the coal preparation process. The solid particles are, as a consequence, cleaned and prepared for commercial use.

An alternate embodiment of the magnetite reclaimer is shown in FIGS. 8 and 9 and is designated 164. The reclaimer 164 is seen to include a tank having an outer cylindrical shell 166 with inlet and discharge end walls comprised of generally frusto-conical housings 168 and 169 respectively, so that a liquid bath medium can be retained in the tank. The inlet housing 168 is provided with a central opening 170 through which a feed chute 172 can be inserted to pass magnetite laden solids into the reclaimer, and the discharge housing 169 is provided with a central opening 174 through which the solids can be removed from the reclaimer in a manner to be described hereinafter.

The shell 166 has two exteriorly disposed annular tracks 176 which rest upon supporting rollers 178. A ring sprocket 180 also circumscribes the exterior of the shell and meshes with a drive chain 182 which is driven by a motor-sprocket unit 184 so that the shell can be continuously rotated about a horizontal axis.

The inner surface of the cylindrical shell 166 has a plurality of lifters 185 affixed thereto to tumble the solids in the liquid bath. The lifters are wedge-shaped and disposed in a helical pattern so as to advance the solids through the reclaimer as the shell is rotated. The tumbling solid particles are thus abrasively thrown against each other causing a scrubbing action which releases the adhered magnetite from the surface of the particles. The frusto-conical housing 169 of the shell has affixed on its inner surface a plurality of angularly disposed lifting discharge shelves 186 that pick-up, as the reclaimer

rotates, the solid particles which have been relieved of the adhering magnetite and dump the particles through the opening 174 into a solids discharge chute 188. The chute 188 constitutes a sieve having a screen 189 through which liquids will drain but through which the solids cannot pass. The solids slide off the screen and pass through a conduit 191 while the drained liquid falls into a passage 193.

Connected to the shell 166 and internally concentric therewith is a cylindrical drum 190. The drum 190 is linked to the shell 166 by spokes 192 at the inlet end of the reclaimer so that material fed into the reclaimer can pass through openings 187 between the spokes. At the discharge end of the reclaimer, the drum 190 is rotatably supported by a non-rotatable shaft 194 passing through a bushing 195 in the center of the drum end 196. The shaft 194 is supported externally of the shell by a support block 197 on an externally supported I-beam 198. The drum 190, is therefore, mounted to rotate with the reclaimer shell and is large enough in diameter so that its lowermost portion at any given time is submerged in the liquid bath.

An arcuate magnet 200 is disposed within the drum 190 and is fixed to lie adjacent the lowermost submerged portion of the drum as the drum rotates, thereby establishing a magnetic field through the cylindrical drum wall to attract magnetic particles in the liquid bath against the outer surface of the wall. The uppermost extent of the arcuate magnet 200 on the upwardly turning side of the drum is above the liquid bath level in the reclaimer and defines a magnetite discharge position 201 at which the magnetite falls from the drum wall into an adjacent inclined magnetite removal chute 202.

The inclined magnetite removal chute 202 projects into the reclaimer from the discharge end between the drum 190 and the shell 166. It is disposed immediately adjacent the cylindrical drum wall on the upwardly rotating side of the drum at the magnetite discharge position so that as the particles pass the end of the magnet and lose their attraction to the outer surface of the drum wall, they will fall into the removal chute. A water manifold 204 having spaced spray nozzles 206 extends along the entire length of the chute to fluidize the magnetite falling into the chute so that it will flow freely down the incline of the chute and out of the reclaimer.

It is readily seen that this embodiment of the reclaimer will very effectively separate by agitation the solid feed particles from the adhering magnetite so that the magnetite may be recovered in a concentrated solution for re-use in the coal preparation process. To incorporate the reclaimer 164 into either or both branches of the hereinbefore described process, the feed chute 172 would be connected to the flow line 27_F or 27_S emanating from the sieve 22_F or 22_S respectively so that magnetite laden solids leaving the sieve would be fed into the reclaimer. The magnetite removal chute 202 would be connected to the flow line 29_F of branch B_F, or the flow line 29_S of branch B_S, leading into the circulating medium sump 24. The solids discharge conduit 191 would be aligned in branch B_F with the feed chute 80 of the dryer 28, or in branch B_S with a discharge line from the system. The drained liquid passage 193 would in either branch be connected to overflow line 52 for passage to clarification or other processing systems not comprising a part of the present invention.

Although the best mode contemplated for carrying out the present invention has been herein shown and described, it will be apparent that modification and variation may be made without departing from what is regarded to be the subject matter of the invention.

What I claim is:

1. Apparatus for separating finely sized high gravity magnetic material from a liquid medium having non-magnetic solids carrying the magnetic material on their surface, and ultra-fine non-magnetic particles, comprising in combination:

a. a tank structure for maintaining a liquid bath having an inclined bottom wall establishing an upper and lower end of the tank, said tank having a feed inlet passage at the lower end for admitting the liquid medium a discharge outlet passage for the non-magnetic solids at the upper end, a liquid supply adjacent the upper end of said tank, and an overflow weir adjacent the lower end of said tank, whereby a constant flow of liquid can be maintained through the tank and the ultra-fine non-magnetic particles which are carried into the tank with the said non-magnetic solids and which become suspended in the liquid bath can be removed from the tank over the overflow weir;

b. agitating means in the tank for abrasively agitating the non-magnetic solids in the liquid bath, said agitating means including at least two counter-rotating shafts parallel to the inclined bottom wall of the tank, each shaft having a lower section with a plurality of agitating paddles mounted in a helical configuration followed by a helical plate screw blade, said paddles and said screw blade on one shaft being of opposite hand to those on the other shaft so the material in contact with said paddles and said screw blade will be conveyed in the same direction toward the discharge outlet for the non-magnetic solids, the counter rotation of said agitating paddles mixing and throwing the solids into abrasive scrubbing contact with each other in a region between the respective shafts to thereby dislodge the finely sized magnetic material from the surface of the solids; and

c. a magnetic drum separator rotatably mounted about a horizontal axis and positioned vertically above the agitating paddles in the lower end of the tank with the longitudinal axis of said drum separator parallel to the longitudinal axis of said counter-rotating shafts of said agitating means, said drum separator having a non-magnetic cylindrical wall extending below the surface of the liquid bath into the region above and between the counter-rotating agitating paddles, said drum separator further having an elongated magnet of arcuate cross section stationarily mounted adjacent the interior surface of said drum wall so the magnetic field of the magnet is effective on the portion of the drum wall passing through the liquid bath to thereby attract the freed magnetic particles suspended in the agitated liquid medium to the outer surface of the drum.

2. The apparatus of claim 1 wherein said overflow weir is located on one longitudinal side of the lower end of the tank structure and said magnetic drum separator is disposed parallel to and closely adjacent said overflow weir to define a relatively narrow channel through which the liquid and suspended ultra-fine non-

magnetic particles pass to said overflow weir, one longitudinal edge of the magnet in said magnetic drum separator extending arcuately a slight distance above said overflow weir and projecting over the narrow channel to the overflow weir.

3. The apparatus of claim 2 wherein the drum wall of said magnetic drum separator rotates oppositely to the flow of the liquid and suspended ultra-fine non-magnetic particles in said narrow channel passing to said overflow weir, said drum wall being partially submerged in the liquid bath, whereby the counterflow motion of the drum wall in the liquid bath in the narrow channel tends to agitate the liquid to further separate any magnetic material from the ultra-fine particles so the magnetic material will be attracted by the magnet to the drum wall and thereby prevent the magnetic material from passing over the overflow weir.

4. The apparatus of claim 3, wherein the other longitudinal edge of the magnet of said magnetic drum separator extends arcuately a finite distance above the level of the liquid bath on the upwardly turning side of the drum wall of the magnetic drum separator to define a magnetic material discharge position at its uppermost extent, the magnetic material falling off said drum wall beyond said uppermost extent of said magnet as the magnetic attraction is lost, the magnetic material then being collected in a magnetic material discharge passage extending longitudinally parallel to said drum wall and located below said uppermost extent of said magnet, but above the liquid bath level, said magnetic material discharge passage thus being located on the opposite side of said magnetic drum separator from said overflow weir to further minimize the magnetic material remixing and being discharged over the overflow weir with the liquid and ultra-fine particles.

5. The apparatus of claim 4, further including a liquid spray at said magnetic material discharge position to wash the magnetic material off the outer surface of the drum wall into said magnetic material discharge passage.

6. The apparatus of claim 1, wherein said tank structure further includes a dewatering area through which the solid particles are transferred by said helical plate screw blades subsequent to leaving the liquid bath, but prior to being discharged through said solid particle discharge passage, said liquid supply further serving to rinse the solid particles in the dewatering area to release any remaining magnetic material and ultra-fine particles and serving to induce a counter flow, opposite to the flow of the solid particles, of the released magnetic material and ultra-fine particles into the lower agitated section of the liquid bath where the magnetic material may be separated and recovered by the magnetic drum separator and the ultra-fine particles may flow out over the overflow weir.

7. An apparatus for separating finely sized high gravity magnetic material from a liquid medium having non-magnetic solids carrying magnetic material on their surface and having ultra-fine non-magnetic particles and for removing the magnetic material from the apparatus separately from the solids and the ultra-fine particles, comprising in combination:

- a. an outer cylindrical shell having frusto-conical end housings and an inner concentric cylindrical drum connected to said outer shell arranged so that a liquid bath can be retained in the shell, one end housing having a central feed inlet opening and the

other end housing having a central discharge opening, said inner drum having a wall portion extending below the surface of the liquid bath;

- b. means for rotating said shell about a substantially horizontal axis;
- c. a plurality of lifters disposed in a helical pattern and attached to the inner surface of said shell, said lifters lifting and tumbling the solids in the liquid bath as the shell is rotated so the solids are thrown against each other in an abrasive scrubbing action to release the magnetic material from the surface of the solids and to suspend the magnetic particles in the liquid bath, said helical pattern of said lifters advancing the solids toward said discharge opening; and
- d. an elongated magnet of arcuate cross section stationarily mounted adjacent the interior wall portion of said inner drum so the magnetic field of said magnet is effective on the portion of the drum wall passing through the liquid bath to thereby attract the freed magnetic material, suspended in the agitated liquid medium, to the outer surface of said rotating inner drum, the uppermost extent of said arcuate magnet on the upwardly turning side defining a discharge position for the magnetic material.

8. The apparatus of claim 7 further including a stationary discharge chute for the separated magnetic material projecting longitudinally into the interior of said outer shell and located between the outer shell and said inner drum on the upwardly turning side of the drum, said discharge chute further located adjacent the drum wall and slightly below said discharge position for the magnetic material so that as the magnetic material passes the upper end of the magnet and loses its attraction to the outer surface of the drum wall the magnetic material falls into the discharge chute, said discharge chute for the magnetic material providing for the removal of the magnetic material through said central discharge opening separately from the non-magnetic solids, the ultra-fine particles and the liquid.

9. The apparatus of claim 8 further including a water manifold having spaced sprays extending longitudinally along said discharge chute for the magnetic material to insure that the magnetic material will flow in this discharge chute and pass out of the apparatus.

10. The apparatus of claim 8 further including a discharge hopper stationarily supported outside said rotating shell and positioned to receive the separated non-magnetic solids, the ultra-fine particles and the liquid discharging from said central discharge opening separately from the magnetic material, said discharge hopper including a screen section permitting the ultra-fine particles and the liquid to pass through the screen section into a collection passage and said screen section retaining the non-magnetic solids so they pass off over the end of the screen section into a separate conduit.

11. The apparatus of claim 10 further including a feed chute stationarily supported outside of said rotating shell and positioned to project into said central feed inlet opening so as to feed the liquid medium into the liquid bath inside of said rotating shell.

12. A coal preparation process for treating fine or intermediate size raw coal in a dense medium type of separator using a finely sized high gravity magnetic material in a liquid to establish the dense medium of a particular specific gravity required to separate the coal

from the refuse and for recovering the magnetic material, comprising the steps of:

- a. passing the raw coal through a dense medium separator vessel to separate the raw coal into a coal fraction and a refuse fraction, each fraction having some adhering magnetic material from the dense medium on the surface of the solids in each fraction;
- b. passing both coal and refuse fractions over separate fixed sieves;
- c. collecting the undersize of the coal and refuse fractions and liquid from the separate fixed sieves in a magnetic material slurry sump;
- d. feeding the oversize solids of the coal and refuse fractions from the separate fixed sieves into separate magnetic material reclaimers;
- e. agitating the oversize solids in a liquid bath within the separate reclaimers to throw the solids into abrasive scrubbing contact with each other to dislodge the magnetic material from the surface of the solids and to put the freed magnetic material into suspension in the liquid bath;
- f. magnetically attracting the magnetic material in suspension to a wall surface of a rotary drum of each reclaimer partially submerged in the liquid bath through the action of a magnetic field of a stationary arcuate magnet suspended inside the rotary drum;
- g. collecting the separated magnetic material dropping from the rotary drum surface after the magnetic material passes out of the liquid bath and beyond the upper end of the magnet;
- h. conducting the collected magnetic material from the magnetic material reclaimers to the magnetic material slurry sump;
- i. recirculating the magnetic material slurry in the sump to the dense medium separator vessel for separating the raw coal; and
- j. discharging the coal from the coal fraction and the refuse from the refuse fraction from the bath in their respective magnetic material reclaimers free of any magnetic material.

13. The process of claim 12 further including the step of controllably adding makeup water and fresh magnetic material to the magnetic material slurry sump to maintain the specific gravity of the magnetic material slurry in the sump at a predetermined value.

14. The process of claim 12 further including the step of removing moisture from the wet coal discharged from the coal fraction magnetic material reclaimer.

15. The process of claim 14 further including the step of utilizing centrifugal force to extract the moisture from the wet coal.

16. The process of claim 14 further including the step of recirculating the moisture removed from the coal to the magnetic material reclaimers.

17. The process of claim 12 further including the step of bleeding-off a portion of the recirculated magnetic material slurry to maintain the desired specific gravity in the medium of the dense medium separator vessel.

18. The process of claim 17 further including the step of removing ultra-fine non-magnetic particles, which pass into the magnetic material slurry sump with the undersize from the sieves, from the bled-off portion of the recirculated magnetic slurry by passing the bled-off portion to the magnetic material reclaimers and by discharging the ultra-fine non-magnetic particles with the liquid from the overflow weirs of the magnetic material reclaimers.

19. The process of claim 12 further including the step of passing the coal from the coal fraction sieve over a de-watering vibrating screen to remove an additional quantity of the finely sized magnetic material and liquid before feeding the oversize coal solids to the coal fraction magnetic material reclaimer and conducting this additional quantity of magnetic material and liquid to the magnetic material slurry sump.

20. The process of claim 12 further including the step of passing the refuse from the refuse fraction sieve over a de-watering vibrating screen to remove an additional quantity of the finely sized magnetic material and liquid before feeding the oversize refuse solids to the refuse fraction magnetic material reclaimer and conducting this additional quantity of magnetic material and liquid to the magnetic material slurry sump.

21. The process of claim 12 further including the step of passing the overflow from both coal and refuse fraction magnetic material reclaimers through a magnetic separator to remove any magnetic material escaping in the overflow liquid, conducting the separated magnetic material to the magnetic material slurry sump and discharging the balance of the liquid from the magnetic separator.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,737,032 Dated JUNE 5, 1973

Inventor(x) SHERMAN C. BURKITT

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

Column 5, line 23: before "inches" insert --1 1/2--.

Signed and sealed this 4th day of February 1975.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents