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THREE-WAY GRAVITY LIQUID SEPARATION

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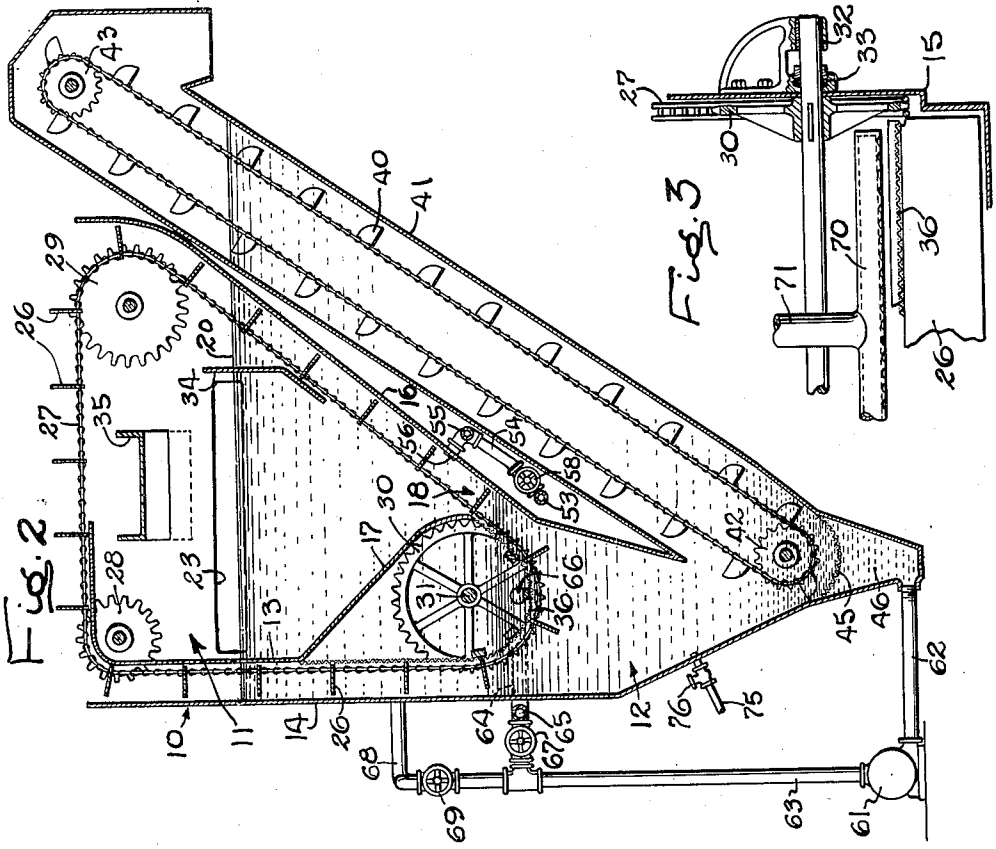


Fig. 2

Fig. 3

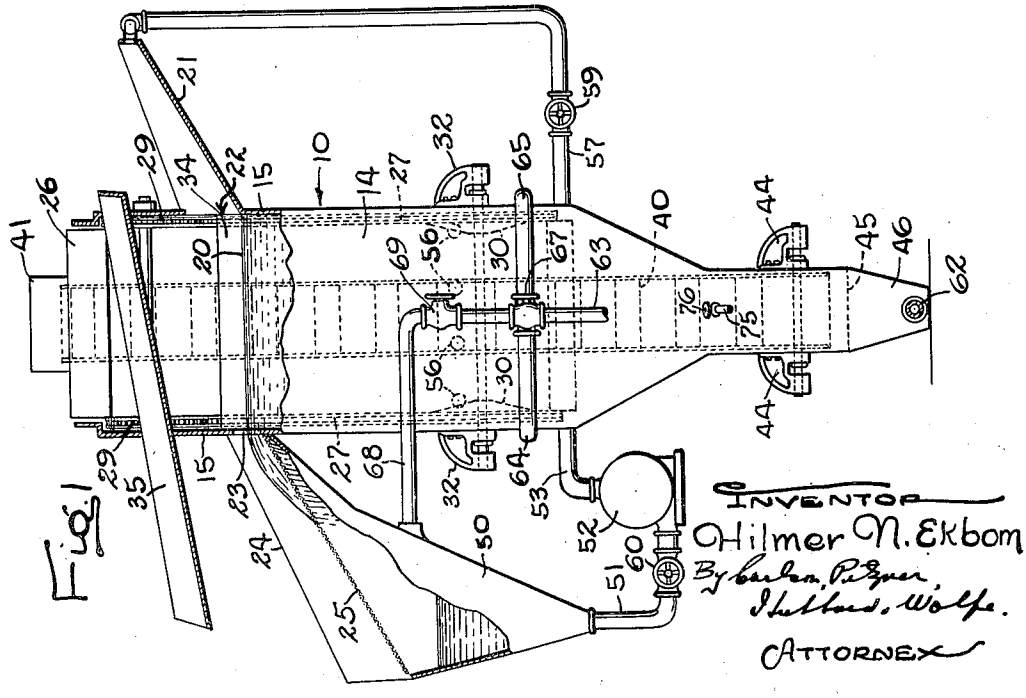


Fig. 1

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THREE-WAY GRAVITY LIQUID SEPARATION

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The invention relates to the art of separating solid materials of different specific gravities, and more particularly to the separation of such materials in a fluid medium of controlled density. Though the process, as described hereafter, mostly refers to coal separation, it may as well be used for various kinds of ore, or other materials where it is desired to separate one part from another of different specific gravities.

Raw coal as it comes from the mine ordinarily contains varying quantities of refuse, such as rock or shale, which has a substantially higher specific gravity than clean high-grade coal. Various processes for separating the refuse from the coal are known to the art. In one such process the raw coal is fed to a fluid medium consisting of fine sand, or other comminuted solids, suspended in water and contained in a vessel, the medium having a relatively uniform density such that the clean high-grade coal is caused to float, while the refuse sinks. This process, however, separates the raw material into two products only and the valuable intermediate product or "middlings" is either lost with the refuse or is allowed to mix with and reduce the quality of the clean coal. It is possible, of course, to separate the middlings from the refuse by a separate processing operation, but this will greatly add to the cost.

One known process purports to separate the raw coal into three products in a single operation by maintaining the fluid medium in vertically spaced layers of gradually increasing density. Horizontal currents are created in the various layers so as to carry the material floating therein to separate collecting or discharging means. This latter method has been found unsatisfactory because the fluid media tend to blend and no clean-cut separation is possible. Other known processes, intended for three product separation in a single vessel, are using subsurface currents for separation of the sink product, but this separation is dependent not only on the specific gravity of the particles of material, but upon their shapes due to the effect of the currents thereon.

With the above in view, the primary object of the present invention is to provide an improved process and apparatus for effecting in a single operation accurate three-way separation of solid materials according to their different specific gravities and entirely independently of the shape of the material particles.

Another object is to provide improved apparatus whereby the above-mentioned process may

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be carried out in a single vessel constructed in a novel manner which permits the maintenance of two fluid bodies of different densities in the vessel.

Another object is to provide means for maintaining the fluid bodies homogeneous and for accurately controlling their densities.

A further object is to effect a three-way separation of solid materials in which the materials are transferred from one fluid body to the other in a novel manner, which enables the material to be processed rapidly and at relatively low cost.

Other objects and advantages of the invention will become apparent from the following detailed description of the preferred embodiment illustrated in the accompanying drawing, in which:

Figure 1 is a front elevational view of separating apparatus embodying the features of the invention.

Fig. 2 is a front to rear vertical sectional view of the apparatus.

Fig. 3 is a fragmentary view showing a modified form of fluid distributing means.

While the invention is susceptible of various modifications and alternative constructions, I have shown in the drawings and will herein describe in detail the preferred embodiment, but it is to be understood that I do not thereby intend to limit the invention to the specific form disclosed, but intend to cover all modifications and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims.

The improved process of effecting a three-way separation of solid materials of different specific gravities is conveniently carried out in a vessel or tank providing chambers for two fluid bodies, one having a density effective to float the material of the lowest specific gravity and the other having a higher density effective to float all but the material of highest specific gravity. The materials to be separated are fed initially into one fluid body to separate out one end product and the remainder of the material is immediately transferred to the second fluid body to similarly separate the other two end products. In treating material such as raw coal, the clean high-grade coal, which has a lower specific gravity than the middlings and refuse, is preferably removed first, followed by separation of the middlings from the refuse in the second fluid body. Under some operating conditions and in the treatment of certain other material, such as mineral ores and the like, it may be desirable to reverse the order in which the separations are effected.

In order to make the process commercially practical, the chambers for the two fluid bodies are arranged in vertical staggered relation and connected by a passage opening from the lower end of the upper chamber into the intermediate portion of the lower chamber. With this arrangement the lower density fluid is placed in the upper chamber and the products which sink therein, namely the middlings and refuse, are transferred directly and continuously to the lower chamber through the connecting passage without requiring additional handling. The transfer is desirably controlled by mechanical means, such as a conveyor, and is effected at a rate such that the material collected in the upper chamber serves to maintain the passage substantially sealed against intermixing of the fluid media in the two chambers.

The fluid media used in carrying out the improved process may be of any suitable character. As a matter of economy, it is preferred to employ a comminuted solid such as magnetite suspended in water. The materials employed are relatively inexpensive and the magnetite may be readily recovered from the separated materials. In addition to this advantage of low cost, these materials permit the density of the fluid media to be accurately adjusted within the required range by simply regulating the amount of solid material added to the liquid. In the improved apparatus provided by the present invention, provision is made for the addition of the comminuted material or the liquid to the fluid bodies necessary to maintain them at the proper densities required for effecting the desired separation and for agitating the fluid media continuously to keep them homogeneous.

Referring to the drawing which shows a preferred form of apparatus for carrying out the improved process in an efficient and economical manner, 10 designates a vessel or tank which is divided into two separate but communicating fluid chambers 11 and 12 by a partitioning member or wall 13. The tank comprises an upright front wall 14, upright side walls 15 and an inclined rear wall 16 of sheet metal or other suitable material, and is supported by appropriate framework (not shown).

In the exemplary tank, the partition 13 is spaced rearwardly from and generally parallel to the front wall 14 and its lower end portion 17 is inclined rearwardly toward the oppositely inclined rear wall 16 of the tank, thus forming a V-shaped hopper-like body for the chamber 11. The inclined portion 17 of the partition is terminated short of the wall 16 to define a passage 18 opening from the bottom of the chamber 11 into the chamber 12. The latter chamber is substantially deeper than the chamber 11 and the two chambers are arranged in vertical staggered relation so that the passage 18 opens substantially midway between the top and bottom of the secondary chamber 12.

In the operation of the apparatus, the chambers 11 and 12 are filled with parting fluid, for example, water with a comminuted solid material such as magnetite suspended therein. As the chambers are in communication, they fill to the same level, as indicated by the line 20. Intermixing of the two fluids in the chambers is substantially prevented as will be explained hereinafter, thus enabling the fluid in each chamber to be maintained at the proper density for effecting the desired separation of the materials undergoing treatment. The density of course is regulated by addition of either comminuted solids or liquid, as required, and the mixture is kept homogeneous by constant agitation produced, in this instance, by a continuous circulation of the fluid in each chamber.

When used for treating raw coal, the fluid medium of lower density is placed in the upper chamber 11 and the coal to be treated is delivered thereto through the chute 21 opening at 22 through one side wall of the tank 10. An opening 23 in the tank wall substantially at the water line 20 provides an outlet for the circulating fluid and the clean coal which floats therein. Such material is discharged onto a chute or flume 24 having a perforated bottom 25 of wire screening or the like which permits the fluid to drain off, the clean coal being delivered to a suitable bin or the like for disposal.

The materials of higher specific gravity, that is, the middlings and refuse, sink to the bottom of the chamber 11 and pass out through the opening 18 to the chamber 12. Provision is made for regulating the rate of transfer of the material so as to maintain a continuous positive flow and to maintain a sufficient quantity at the bottom of the chamber 11 to form a barrier effective to substantially prevent intermixing of the fluids confined in the two chambers. The transfer means is preferably in the form of a mechanical conveyor, herein shown as comprising a plurality of scraper blades 26 carried between a pair of endless chains 27. The chains are guided by suitable sprocket wheels arranged in pairs and supported on the walls of the tank 10. As herein shown, one pair of sprocket wheels 28 is located at the upper end of the tank adjacent the top of the partition 13. A second pair of sprocket wheels 29 is located adjacent the rear of the chamber 12 and a third pair 30 is located in the chamber 12 below the inclined portion 17 of the partition and closely adjacent the chamber connecting passage 18. As the sprocket wheels 30 are immersed in the fluid in the chamber 12, the shaft 31 upon which they are mounted is preferably journaled in outboard bearings 32 supported on the outer walls of the tank 10. A stuffing box 33 is provided adjacent each bearing to prevent leakage of fluid around the shaft.

The location of the conveyor guiding sprocket wheels directs the conveyor in three flights, one flight running down the inclined wall 16 of the tank, which in this instance forms the bottom of the chamber 11. After passing over the sprocket wheels 30, the adjacent flight of the conveyor is led vertically upward between the partition 13 and the front wall 14 of the tank, which are preferably spaced apart just sufficiently to provide the necessary clearance for the scraper blades 26. The third flight of the conveyor extends rearwardly over the top of the chamber 11 between the sprocket wheels 28 and 29. One set of the sprocket wheels is driven by a motor or the like (not shown) so as to advance the conveyor in a direction to cause the first-mentioned flight to carry the heavy material from the chamber 11 through the passage 18 into the chamber 12. A partitioning member 34 extending transversely across the tank adjacent the rear of the chamber 11 prevents light weight floating material from being caught in the conveyor.

The second or vertical flight of the conveyor receives the floating material or middlings in the chamber 12 and carries such material upwardly through the restricted portion of the chamber and discharges it into the chute or flume

35 for disposal. A perforated plate or screen 36 underlying the sprocket wheels 30 directs the floating material into position to be engaged by the blades 26 of the conveyor so that it may be carried out of the chamber 12, as above explained.

Any suitable means may be utilized to remove the heavy material which sinks in the chamber 12. In the exemplary apparatus, the material removing means comprises an endless conveyor 40 of the bucket type enclosed within an upwardly sloping casing 41 opening from the bottom of the chamber 12. Sets of sprocket wheels 42 and 43 are supported on the casing for guiding the conveyor, the wheels 42 being journaled in outboard bearings 44 similar to the bearings 32 above described. To direct the material to the conveyor the front, side and rear walls of the tank 10 are inclined inwardly to provide a relatively close fit with the lower end portion of the conveyor. A perforated plate or screen 45 is provided adjacent the bottom of the chamber to facilitate the collection of material by the conveyor. As will be seen by reference to Fig. 2 of the drawings, the screen 45 is curved to conform to the path of the conveyor buckets and is spaced substantially above the bottom of the chamber, thus forming a sump 46 for collecting any comminuted solids which may settle in the chamber.

In order to maintain the fluid media in the chambers 11 and 12 at the densities required for effecting three-way separation of the raw materials and keep the media homogeneous, separate fluid circulating means is provided for each chamber. Thus, the fluid and floating solids passing from the chamber 11 through the outlet 23 are received by the chute 24 which carries the solid materials away for disposal and permits the fluid to drain into a reservoir 50 supported at one side of the tank 10. Fluid is drawn from the reservoir 50 through an intake pipe 51 by a pump 52 which discharges the fluid under pressure through a pipe 53 extending transversely across the rear of the tank below the chamber 11. The pipe 53 has one branch 54 terminating in a header 55 extending along the bottom of the chamber 11 and discharging therein through a plurality of nozzles 56 (Fig. 1). A second branch 57 of the pipe 53 leads to the intake end of the coal delivery chute 21.

Valves 58 and 59 are provided in the two-branch pipes so that the volume of fluid delivered through either branch may be conveniently regulated. A valve 60 in the intake pipe 51 controls the rate of fluid circulation. In practice, sufficient fluid is directed through the branch pipe 54 and into the bottom of the chamber 11 to keep the comminuted solids uniformly dispersed in the fluid in the chamber, the upward current required being too small to interfere with the sinking of the heavier material in the fluid. The remainder of the fluid is directed through the branch pipe 57 to assist in washing raw coal down the chute 21 and into the treating chamber.

For circulating the fluid medium in the chamber 12, a pump 61 is arranged to draw fluid from the sump 46 through an intake pipe 62 and to discharge it under pressure into an upright pipe 63 having two branches 64 and 65 opening into opposite sides of the chamber 12 through nozzles 66. The fluid is thus directed into the chamber at the rear of the screen 36, which acts to diffuse the incoming material uniformly through the chamber. The rate of circulation is controlled by a valve 67 interposed between the

pipe 63 and the branches 64 and 65. By maintaining the circulating velocity at a rate such that the descending velocity of the fluid in chamber 12 is equal to or greater than the settling velocity of the comminuted solids in still water, the density of the fluid in the chamber 12 is kept substantially uniform between the fluid inlet nozzle 66 and the outlet from the sump 46.

It is obvious that the fluid circuit for chamber 12 may be reversed, if found desirable for certain materials. The introduction of the circulating fluid into the chamber 12 at a point closely adjacent the passage 18 leaves the fluid in the restricted upper portion of the chamber substantially undisturbed so that the comminuted solids may settle therein. Accordingly, the fluid in the restricted portion of the chamber tends to become of relatively low density approaching clear water. As the middlings are carried through this restricted area by the conveyor blades 26, the comminuted solids collecting thereon are effectively washed away and returned to the treating chamber. This assists in maintaining the proper amount of comminuted solids in the chamber and additionally reduces loss of comminuted solids with the separated products. A similar washing of the refuse carried out by the conveyor 40 is effected in the casing 41 as the fluid therein is not circulated, thus allowing the comminuted solids to settle into the sump 46.

As the fluid level in both chambers 11 and 12 is the same, and moreover since the passage 18 is partially sealed by the heavy materials sinking to the bottom of the chamber 11, intermixing or blending of the fluids in the two chambers is negligible. However, a certain amount of comminuted solids is carried from the chamber 11 to the chamber 12 with the middlings and refuse, thus tending to gradually increase the density of the fluid in the chamber 12. To counteract this tendency, the circulating system for the chamber 12 is provided with a by-pass through which a predetermined volume of denser fluid may be returned to the chamber 11. The by-pass as shown comprises a pipe 68 branching from the pipe 63 and leading to the fluid reservoir 50. A valve 69 is provided for regulating the amount of fluid delivered to the reservoir. In practice, this valve may be set so that the volume of fluid bypassed back to the tank 11 is just sufficient to balance the loss of comminuted solids through the passage 18, thus providing a more or less automatic balance between the fluids of different densities in the two chambers.

Fig. 3 shows a modified form of fluid inlet for the chamber 12, particularly suitable for use where the tank 10 is of substantial width. For this a spreader pipe 70 having a series of longitudinally spaced openings in one side is arranged transversely of the chamber 12 between the sprocket wheels 30 and above the screen 36. The spreader is connected with the pipe 63 by a pipe 71 which enters the chamber through one side wall above the adjacent sprocket wheel 30 and extends down through the center of the chamber to connect with the spreader, as shown. Preferably, the spreader is arranged with its discharge openings facing downwardly so as to avoid excessive turbulence around the inlet.

When the apparatus is to be placed in operation, the tank 10 is initially filled with water until it overflows through the opening 23 in the tank wall 14. For convenience in filling, a supply pipe 75 with a control valve 76 therein is connected

with the lower part of the tank to open into the chamber 12. When the tank has been filled, the pumps 52 and 61 are started to circulate the water in the two chambers. The valve 58 is now closed so as to divert all water delivered by the pump 52 into the chute 21 and eliminate any upwardly flowing currents in the chamber 11. Comminuted solids may now be supplied to the tank, preferably by way of the chute 21 and, since there is no up current in the chamber 11, the solids quickly settle to the bottom of the chamber 11 and enter the chamber 12 by way of the passage 18. Preferably, the conveyor 26—27 is started at this time to assist the transfer of solids.

The introduction of comminuted solids is continued until the fluid in the chamber 12 reaches the desired density. Valve 58 is then opened to initiate circulation of fluid in the chamber 11 and thereby interrupt further passage of solids into the chamber 12. Sufficient solids may then be added to the fluid in the chamber 11 to bring it up to the required density.

Upon starting the conveyor 40, the apparatus is fully conditioned for operation and the separating process will proceed automatically upon the delivery of raw coal through the chute 21. As long as a continuous supply of raw materials is delivered to the apparatus, the three end products will be delivered continuously by way of the chutes 24 and 35 and the bucket conveyor 40. More particularly, clean high-grade coal will be discharged through the chute 24, middlings through the chute 35 and refuse through the action of the conveyor 40. It is obvious that, by regulating the valves 58 and 67, the relation between the densities in the two chambers 11 and 12 may be changed at will. If valve 58 is closed, the density in chamber 11 will approach clear water while the density in chamber 12 at the same time increases because of settling of suspended particles, and if valve 67 is closed, the density will be the same in both chambers, in which case the vessel will serve as a two product separator. Any relation between these two limits is possible by proper regulation of the valves.

It will be apparent from the foregoing that the invention provides an efficient and economical process and apparatus for effecting three-way separation of solid materials of different specific gravities in a continuous operation. It is capable of handling large quantities of material at a very rapid rate and at low cost, and is particularly suitable for treating raw coal and is effective to separate the same with a high degree of accuracy into clean high-grade coal, middlings and refuse. Handling of the materials is reduced to a minimum with a consequent reduction in labor and other costs. The process may be carried out in a single vessel which materially reduces the investment required for the treating apparatus.

I claim as my invention:

1. The process of effecting a three-way separation of comminuted solid materials according to their different specific gravities which comprises establishing in a single vessel two bodies of fluid of different densities, introducing the materials to be separated into the fluid body of lower density, removing from said lower density body the material which floats therein, collecting the material which sinks in said lower density body in a mass disposed between the two fluid bodies, transferring the collected material to the fluid body of higher density at a rate such as to maintain a barrier between the fluid bodies effective to substantially prevent intermixing of the fluids, and separately removing from said higher density fluid body the material which floats and the material which sinks therein.

2. The process of effecting a three-way separation of comminuted solid materials of different specific gravities which comprises establishing two superimposed bodies of fluid of different densities, introducing the materials to be separated into the upper fluid body, removing from said upper fluid body the material which floats therein, allowing the material which sinks in the upper fluid body to pass into the lower fluid body at a rate effective to establish and maintain a barrier between the bodies operative to substantially prevent intermixing of the same, and separately removing from the lower fluid body the material which floats and the material which sinks therein.

3. The process of effecting a three-way separation of comminuted materials of different specific gravities which comprises establishing two superimposed bodies of fluid, maintaining the specific gravity of the upper fluid body greater than that of the lightest of the materials and the specific gravity of the lower fluid body less than that of the heaviest of the materials, introducing the materials to be separated into the upper fluid body, removing from said upper fluid body the material which floats therein, said fluid bodies being relatively positioned so that the material which sinks in the upper fluid body passes directly into the lower fluid body, restricting the passage of said material from said upper fluid body so as to maintain a barrier of material between the two fluid bodies effective to substantially prevent intermixing of the same, and separately removing from the lower fluid body the material which floats and the material which sinks therein.

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