

[54] **METHOD AND APPARATUS FOR
REDUCING SULPHUR AND ASH CONTENT
OF COAL**[75] Inventor: **Larry T. Gay**, Frostburg, Md.[73] Assignee: **C-G Process Coal Company**, Tulsa,
Okla.[22] Filed: **Mar. 2, 1973**[21] Appl. No.: **337,590**[52] **U.S. Cl.** **209/3; 209/211; 259/18**[51] **Int. Cl.²** **B04C 9/00**[58] **Field of Search** **209/211, 3; 259/4, 18**[56] **References Cited****UNITED STATES PATENTS**

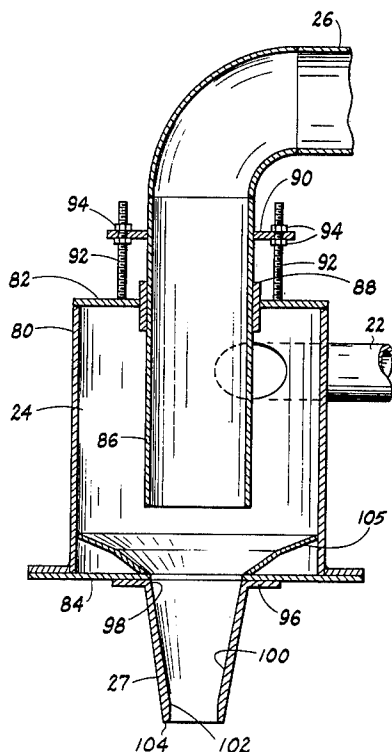
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Primary Examiner—Frank W. Lutter*Assistant Examiner*—Ralph J. Hill*Attorney, Agent, or Firm*—William S. Dorman[57] **ABSTRACT**

A method and apparatus for reducing sulphur and ash content of a solid material containing coal to a commercially usable product or to a commercially improved product by treating a pre-crushed and pre-screened quantity of the starting material in a size range of $1\frac{1}{4} \times 0$ inches; the so-crushed and so-screened starting material is fed through a mixing chamber where it is mixed with a quantity of water under prescribed conditions of pressure and turbulence to create a proper solids-water mixture; thereafter, the resulting solids-water mixture is conveyed to a cyclone separator under a predetermined pressure; the solids-water mixture is introduced tangentially into said cyclone separator which contains a vertically adjustable vortex finder which extends vertically upwardly out of the cyclone separator; the cyclone separator is also provided, adjacent its bottom, with three cones of successively decreasing cone angles; the size of the inlet pipe to the cyclone separator, the size of the separator itself, the cones, the size and location of the vortex finder and the size of the nozzle at the lower end of the cyclone separator are all interrelated and important for achieving the results desired. The method and apparatus will serve to reduce the sulphur and ash content in many different types of coal containing solids. In certain types of coal, the sulphur content can be reduced to a point where it will pass the standards of the Environmental Protection Administration where the initial product would not.

8 Claims, 7 Drawing Figures

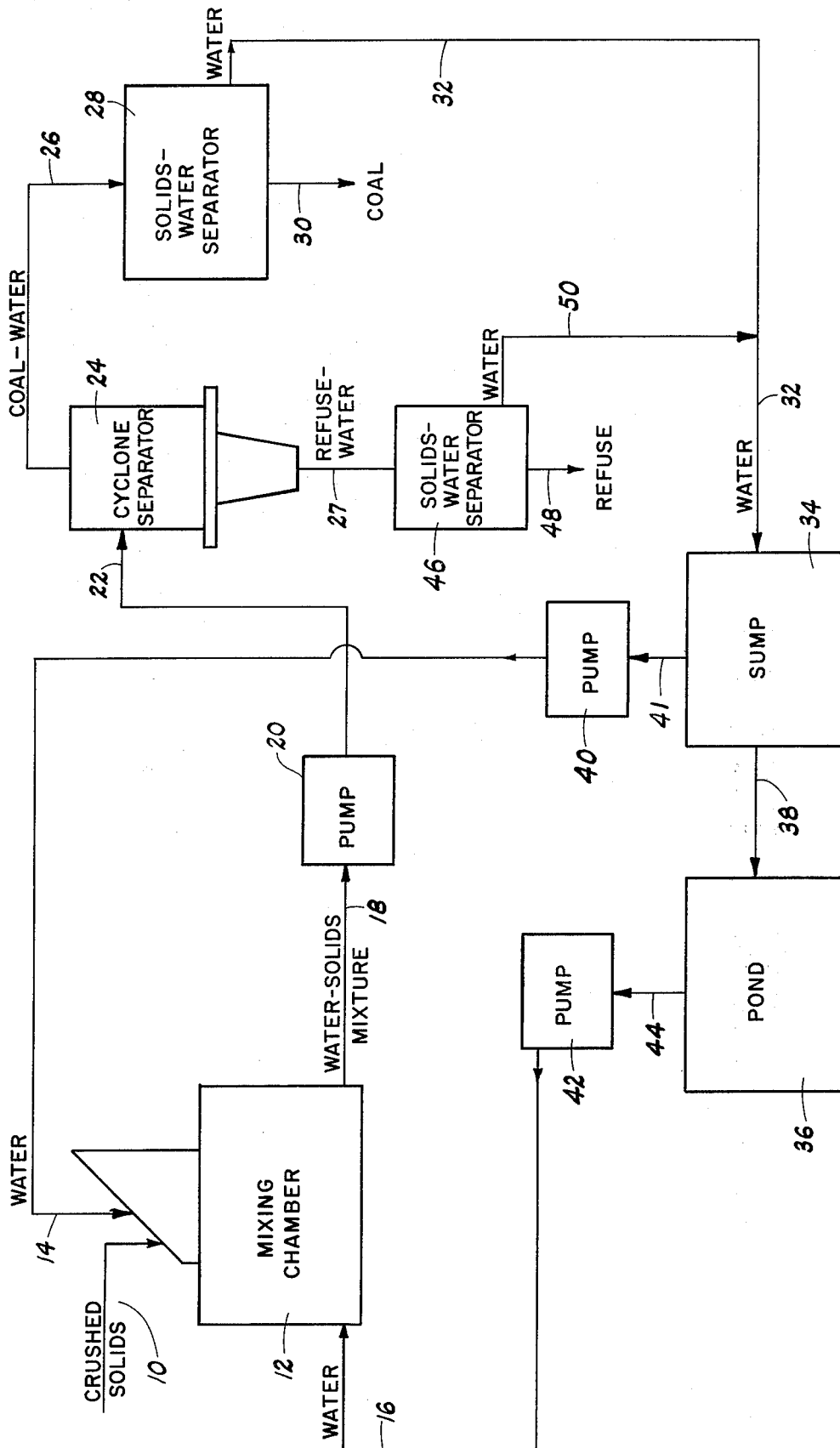


Fig. 1

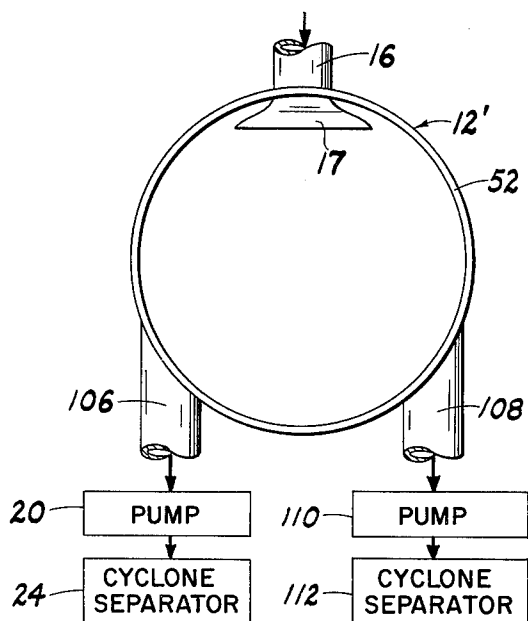


Fig. 7

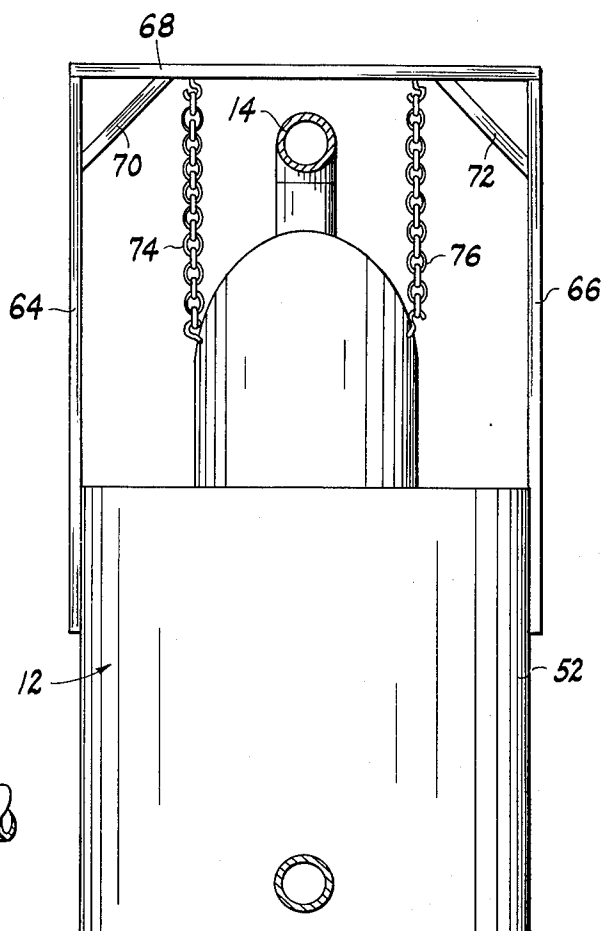


Fig. 2

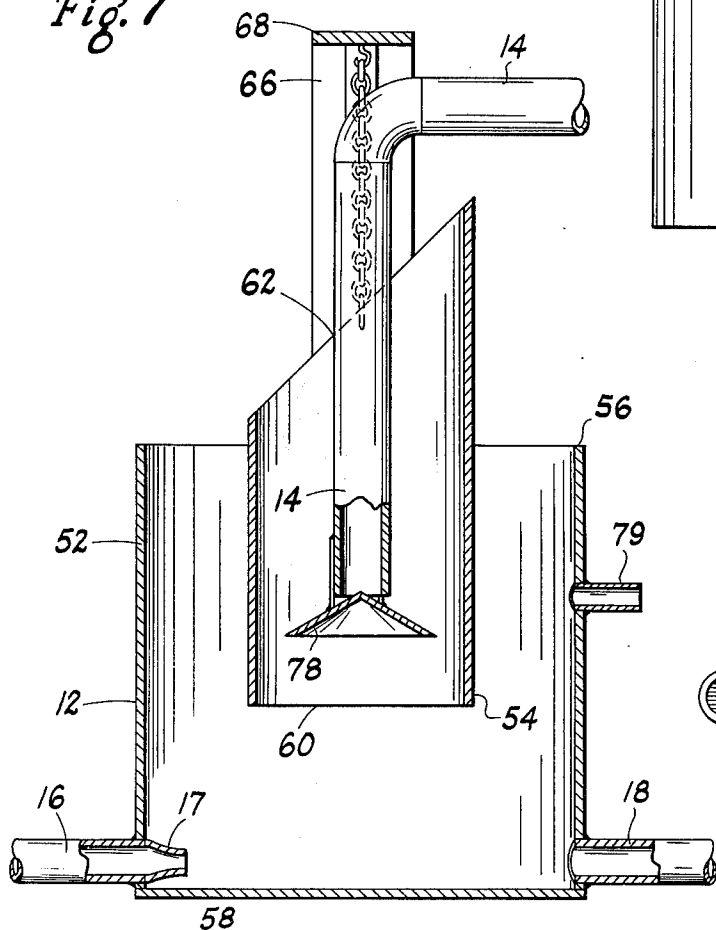


Fig. 3

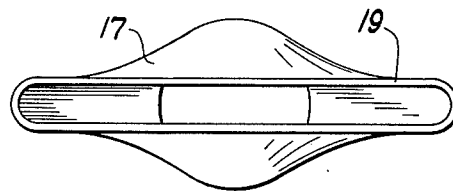


Fig. 4

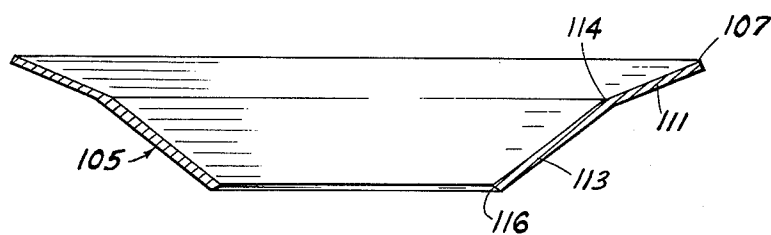


Fig. 6

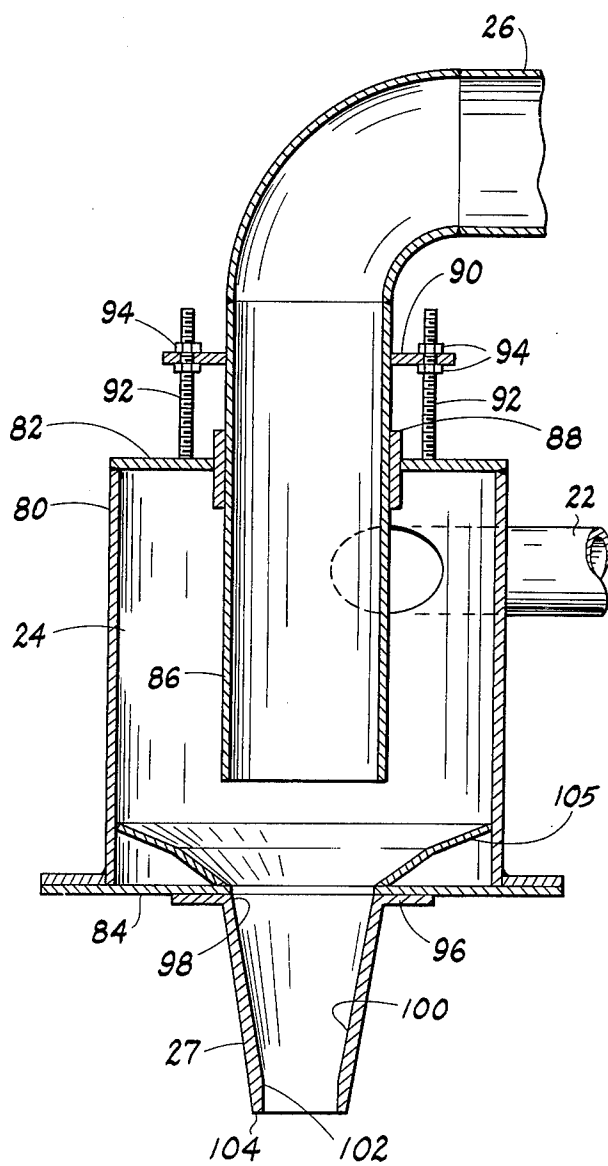


Fig. 5

METHOD AND APPARATUS FOR REDUCING SULPHUR AND ASH CONTENT OF COAL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method and apparatus for treating a solid coal-containing material to make a commercially salable or commercially more salable product therefrom. More particularly, the present invention involves a method and apparatus especially designed to reduce the sulphur and ash content of a solid coal-containing material.

2. Description of the Prior Art.

Many methods and apparatus have been proposed and put to use for the purpose of treating solid coal-containing materials. Some of these involve crushing and screening alone. Some of these involve chemical treatment. Some of these involve suspending the solid coal-containing material in a liquid and treating the resulting mixture in a hydrocyclone. However, none of the prior art methods and apparatus recognize the interdependence between the mixing step and apparatus and the separating step and apparatus as taught in the present invention, nor does the prior art specifically teach the details of the separating cyclone as set forth and described in the present application.

SUMMARY OF THE INVENTION

A quantity of coal-containing solid material is taken from a gob pile, for example, crushed and screened. A resulting feed from this quantity having a particle size of $1\frac{1}{4} \times 0$ inches is introduced into the apparatus of the present invention. The first part of the apparatus involves a mixing chamber which includes a substantially cylindrical tank in which is suspended an open ended cylinder of substantially one-half the diameter of the mixing tank itself. Approximately 48 to 62 tons per hour of solid material are introduced into the center of the cylindrical member. At the same time, approximately 625 gallons per minute of water are introduced into this cylindrical member intermediate the ends thereof to create a condition of turbulence which is effected by the pressure of this stream of water and the restriction at the lower end of the conduit through which this water is introduced. A second stream of water is introduced adjacent the bottom of the cylindrical mixing tank under substantially more quiescent conditions. This second volume of water is introduced at approximately 600 gallons per minute. A combined effluent of approximately 1225 gallons per minute of watercontaining solids is removed from the bottom of the mixing chamber and introduced tangentially adjacent the upper end of the cyclone separator.

The cyclone separator has a vortex finder of approximately eight inches in internal diameter, whereas the internal diameter of the cyclone separator is about 18 $\frac{3}{8}$ inches. The lower end of the vortex finder is spaced about 6 to 6 inches above the bottom of the cyclone separator. However, the vortex finder is adjustable by virtue of an adjustment means on the top of the cyclone separator. The bottom of the cyclone separator is provided with two conical members located above the bottom and a third conical member located below the bottom and terminating in a nozzle of about 3.5 inches in diameter. The three cones have successively decreasing angles of generation, to-wit, 68°, 53° and 7°. A product,

taken off the top of the cyclone separator through the vortex finder, is relatively rich in coal. A refuse, withdrawn from the bottom of the cyclone separator, is relatively poor in coal. The coal-containing product is passed through a fine screen where the water is removed and the coal product recovered. The same is done with the refuse to remove the water therefrom although the refuse is discarded. The water recovered from the latter two screening operations is recycled back to a sump for re-introduction into the mixing chamber.

In a second and preferred embodiment of the invention, the mixing chamber is adapted to feed two cyclone separators, each identical with the cyclone separator referred to above. Of course, the solid feed to the mixing chamber must be doubled and the quantity of water fed to the mixing chamber must also be doubled. In the operation of the mixing chamber for this second embodiment, the water introduced adjacent the bottom is substantially the same as that described in the first embodiment; however, the water introduced through the upper conduit is increased from about 625 gallons per minute to about 1900 gallons per minute. The effluent is withdrawn from the mixing chamber through two pipes tangentially disposed on opposite sides of the mixing tank and the solids-water mixture is withdrawn in a direction opposite from the introduction of the water to the bottom of the mixing chamber. Two pumps are provided to supply equal quantities of solid-water mixture to the two cyclone separators. The remainder of the operation of the second embodiment is substantially the same as that described above in relation to the first embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flow sheet or diagrammatic representation of the overall process involved in the present invention; FIG. 2 is a right side elevation of the one embodiment of the mixing chamber diagrammatically illustrated in FIG. 1;

FIG. 3 is a vertical section view taken along section line 3—3 of FIG. 2;

FIG. 4 is an elevation, on an enlarged scale, of the flow spreader shown in FIG. 3.

FIG. 5 is a vertical cross sectional view through the cyclone separator of the present invention;

FIG. 6 is a vertical cross sectional view of the dish which is employed at the lower end of the cyclone separator; and

FIG. 7 is a view of another embodiment of the mixing chamber diagrammatically illustrated in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a quantity of crushed solids 10, such as from a gob pile (not shown), is introduced into the upper end of a mixing chamber 12. The crushed solids 10 from the gob pile are preferably pretreated using conventional crushing and screening operations so that the size of the feed is about $1\frac{1}{4} \times 0$ inches. Preferably, the raw material is manually inspected on a picking conveyor or table (not shown) to remove large chunks of slate, rock or other refuse prior to the crushing and screening operations.

A first quantity of water is introduced into the top of the mixing chamber through the conduit 14. A second quantity of water is introduced into the bottom of the mixing chamber through a conduit 16. The water-solids

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mixture is removed from the bottom of the mixing chamber through the conduit 18. The water-solids mixture is pumped by means of a pump 20 into a conduit 22 which discharges tangentially into the upper end of a cyclone separator 24 to establish a vortex zone concentrically within the cyclone separator. A coal-water fraction is removed from the top of the cyclone separator 24 through the conduit 26. A refuse-water fraction is removed from the bottom of the cyclone separator 24 through the conduit 27.

The coal-water fraction from the cyclone separator 24 is fed by the conduit 26 to a solids-water separator 28 which is preferably in the form of an inclined (Heyl-Patterson) de-watering screen (the details of which are now shown). Crushed coal is discharged from the solids-water separator 28 at 30 from which point it can be conveyed into a coal pile (not shown) or directly into a rail car (not shown). The water which drains from the solids-water separator is conveyed by means of conduit 32 to a sump 34. Water from the sump 34 is conveyed to a pond 36 through a conduit 38.

Water from the sump 34 is directed to a pump 40 through a conduit 41. The discharge of the pump 40 is the conduit 14, previously described, which supplies water to the upper end of the mixing chamber 12. Another quantity of water is conveyed from the pond 36 to another pump 42 through the conduit 44. The discharge of this pump 42 is a conduit 16, previously described, which feeds water into the bottom of the mixing chamber 12.

The refuse-water fraction is introduced into a solids-water separator 46 through the conduit 27, previously described. The solids-water separator 46 is also preferably in the form of an inclined de-watering screen (not shown) similar to the solids-water separator 28, previously described. Refuse is discharged from the solids-water separator 46 at 48 from which point it can be discarded or otherwise conveyed to a refuse pile (not shown). Water drains from the solids-water separator 46 and is conveyed therefrom by means of a conduit 50 which joins with the conduit 32 to introduce additional water into the sump 34.

THE MIXING CHAMBER

The mixing chamber 12 shown in detail in FIGS. 2 and 3 is designed for operation in conjunction with a single cyclone separator 24 and includes a 6 foot diameter outer pipe or tank 52, a 3 foot diameter intermediate pipe 54 and an inner 6 inch pipe 14 (previously described), both of the latter being supported concentrically within the tank 52 as will hereinafter appear. The upper end 56 of the tank 52 is open and the lower end thereof is closed by a flat plate 58. The lower end 60 of the pipe 54 is spaced between twelve and sixteen inches above the bottom 58 of the tank 52. The upper end of the pipe 54 is inclined as at 62.

A pair of steel rods or pipes 64 and 66 are arranged in vertical parallel relationship and welded to the opposite sides of the outer tank 52 as best shown in FIG. 2. The upper ends of the rods 64 and 66 are connected by a steel cross member 68 and reinforced by inclined frame members 70 and 72. The frame structures consisting of members 64, 66, 68, 70 and 72 are suitably welded together and also welded to the tank, as indicated above. A pair of chains 74 and 76 are connected at their upper ends to the cross member 68 and at their lower ends to the upper side edge of the inner pipe 54. The chains 74 and 76 permit vertical adjustment of the

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lower end of the inner pipe 54 with respect to the bottom 58. These chains also permit a free swinging movement of the inner pipe 54, as desired, to prevent any possible clogging of solid material in the chamber 12.

As best shown in FIG. 3, crushed solids are introduced into the inner pipe 54. The inclined upper edge 62 is higher on the side opposite from the direction of feed to prevent solids from spilling over into the annular space between pipes 52 and 54. Conduit 14 which delivers water from the pump 40 goes through a right angle bend immediately below the cross member 68. The lower end of the pipe 14 is provided with a flare or cone 78 as indicated in FIG. 3. The cone 78 is imperforate, has a 12 inch outer diameter, and has a sixty degree cone angle. The upper surface of the cone is spaced one-half inch below the lower end of the pipe 14 and is held in position by rods (not shown) welded to the side of the pipe 14 and to the upper surface of the cone. The positioning of this cone 78 at the bottom of the pipe 14 causes two effects (a) the restriction of flow from the pipe 14 with the attendant increase in pressure therein, namely, the 65 p.s.i. referred to above and (b) a flaring out of the water stream issuing out of the bottom of the pipe 14. These two effects create a considerable turbulence in the pipe 54 and in the tank as well to facilitate the mixing and suspension of the solid particles in the liquid.

Approximately 48 to 62 tons per hour (depending upon the quantity of coal continued in the solid feed) are introduced into the inner pipe 54 as shown in FIG. 3. Approximately 625 gallons per minute of water at 65 pounds per square inch pressure are introduced into the mixing chamber 12 through the conduit 14. Another 600 gallons per minute of water are introduced into the mixing chamber 12 through the conduit 16 at approximately 2 to 5 pounds per square inch pressure. Approximately 1225 gallons per minute of water containing solid mixed therein, are removed from the mixing chamber through the conduit 18 and pumped into the cyclone separator through the conduit 22 by means of the pump 20 at a pressure of 4 to 6 p.s.i.

The pipe 16 is arranged to introduce water from the pond radially into the bottom of the tank 52. However, to provide a gentler flow and more even distribution at the end of the pipe 16, the latter terminates within the tank in a flow spreader 17 which is provided with an elongated opening 19 approximately 1½ inches high and 18 inches long as best shown in FIG. 4.

The tank 52 is approximately 6 feet high. An overflow 79 is located about 2 feet below the upper edge of the tank to prevent filling of the tank above this point. The lower end of the pipe 14 terminates about 18 inches below the level of the overflow. The capacity of the tank to the overflow is about 840 gallons. The volume of solid-water mixture removed from the conduit 18 per minute therefore is about 1½ times the capacity of the tank.

THE CYCLONE SEPARATOR

The cyclone separator 24 is shown in detail in FIGS. 5 and 6. The cyclone separator 24 includes an outer cylindrical member 80 which is closed at its top 82 and at its bottom 84. The cylindrical member 80 is a 20 inch standard pipe having an internal diameter of about 18¾ inches and an internal height of about 20 inches. A vortex finder 86 is supported concentrically within the cylinder 80. The vortex finder 86 has an 8 inch internal diameter and about an 8.5 inches external diameter. The

lower end of the vortex finder is spaced about 6 to 8 inches above the bottom 84 of the separator 24. As indicated heretofore approximately 1225 gallons per minute of water containing suspended or mixed solids is introduced into the separator 24 through the conduit 22 to establish a vortex zone concentrically within the separator. Preferably the mixture contains about 15% solids and 85% water. The conduit 22 is a 6 inch pipe, the center of which is spaced about 5 inches from the top 82 of the cylindrical member 80.

The vortex finder 86 passes through the upper end 82 of the cyclone separator 24 and is maintained in sealed relationship with respect to the top by means of a circular gasket 88. A circular flange 90 is connected adjacent the upper end of the vortex finder 86 and it has therein a plurality of holes through which pass a plurality of threaded rods 92, the latter being welded or otherwise secured at their lower ends to the upper plate 82 of the cylinder 80. Threaded nuts 94, 94, spaced above and below the flange 90 permit the vertical adjustment of the vortex finder 86.

The lower discharge 27 from the cyclone separator 24 is in the form of a conical nozzle having an upper flat flange 96 which is welded or otherwise secured to the lower flat plate 84. The upper end of the discharge nozzle 27 has an internal opening of about 7 inches in diameter. The internal surface 100 of the nozzle 27 tapers gradually downwardly from the upper opening 98 to a point 102 located about 1½ inches from the bottom 104 of the nozzle 27. The diameter at this point from 102 to the bottom 104 is approximately 3½ inches. The total height of the nozzle 27 is approximately 11½ inches.

Located immediately above the bottom plate 84 is a tapered dish 105 best shown in FIG. 6. The dish 105 is preferably about ¼ inch thick and has a vertical height of approximately 3½ inches. The upper external diameter of the dish 105 is preferably about 18¼ to 18½ inches in diameter so as to fit with a very small amount of clearance inside the internal diameter of the cylinder 80 which, as previously indicated, has an internal diameter of approximately 18¾ inches. The upper end of the dish 105 has an opening 107 of a diameter slightly less than the external diameter referred to above. The internal surface of the dish 105 is represented by the combined internal surfaces of two conical members 111 and 113 which intersect along a circular line 114. As shown in FIG. 6, the horizontal diameter of the internal surface at the line 114 is approximately 13 inches. The side of the cone 111 from the opening 107 to the circular line of intersection 114 extends (as measured along the side of the cone 111) approximately 3¾ inch and the angle that the side of the cone 111 bears with respect to a horizontal plane is approximately 22°.

The second cone 113 extends downwardly from the circular line of intersection 114 to a bottom opening 116 which is approximately 7¼ inch in diameter. The distance from the circular line 114 to the opening 116 measured along the side of the cone 112 is approximately 3½ inch and the angle that the cone 113 makes with the horizontal plane is approximately 37°.

It will appear from the above that the lower end of the separator terminates in three zones formed by three intersecting cones. The upper cone 111 has an angle (of generation) of about 68°; the intermediate cone 113 about 53°; and the lower cone 100 slightly less than 7°.

The internal vertical height of the cyclone separator 24 is approximately 20 inches. As indicated heretofore, approximately 1225 gallons per minute of liquid containing solid particles therein is introduced into the cyclone separator 24 through the pipe 22 at approximately 4 to 6 p.s.i. If it turns out that the percentage of larger particles increases in the feed, then the vortex finder 86 is moved downwardly.

THE MODIFIED MIXING CHAMBER

In contrast to the mixing chamber 12 previously described in relation to FIGS. 2 and 3, the mixing chamber 12' shown in FIG. 7 is designed for operation in conjunction with two cyclone separators each substantially identical to the cyclone separator 24 illustrated in FIGS. 5 and 6. More particularly, the modified mixing chamber 12' includes the same tank 52 with the same dimensions previously set forth, the same inner pipe 54, the same inlet pipe 14, etc. The only differences between the structure of FIGS. 2 and 3 and FIG. 7 are in (a) the spacing between the cone 78 and the bottom of the pipe 14 and (b) the replacement of the single discharge pipe 18 of FIGS. 2 and 3 with two tangentially located discharge pipes 106 and 108 in FIG. 7.

As to the first difference referred to above, since each cyclone separator will be fed approximately 1225 gallons per minute this will represent a total outflow of 2500 gallons per minute from pipes 106 and 108. Again, the water flowing through the pipe 16 and flow spreader 17 will remain the same, namely, 600 gallons per minute. This means that the water flowing from the sump 34, through the pipe 40 and through the pipe 14 will increase from 625 gallons per minute to 1900 gallons per minute. The spacing between the cone 78 and the pipe 14 will have to be increased for the FIG. 7 modification. It was determined that a vertical spacing of 1 inch between the cone 78 and the bottom of the pipe 14 would be adequate for the purpose of FIG. 7 while still maintaining the 65 p.s.i. in the pipe 14. Of course, it should be understood that the solids fed to the mixing chamber would have to be doubled; thus for the FIG. 7 operation the solids feed into the pipe 54 would be 96 to 124 tons per hour, again depending upon the quantity of coal contained in the feed as well as its ease of separation.

As far as the second difference is concerned, it will appear that FIG. 7 shows two outlet pipes 106 and 108 which are arranged tangentially with respect to the bottom of the tank 52 and on the opposite side thereof from the flow spreader 17. This arrangement is designed to balance the outflow of the two cyclone separators. Pipe 106, for example, can connect with the pump 20 which feeds the cyclone separator 24 previously described. Pipe 108 can feed to a pump 110, identical to pump 20, which, in turn, feeds cyclone separator 112 which is identical to cyclone separator 24. The total volume of solids-water mixture removed from the tank per minute through the pipes 106 and 108 is roughly 3 times the capacity of the tank itself.

The cyclone separators 24 and 112 of FIG. 7 would each feed to two solids-water separators such as separators 28 and 46, one for the coal product and one for the refuse. The water drained from the two separators 28 would be combined to feed a single sump 34 as would be the water drained from the separators 46. Similarly, the products of the cyclone separators 24, 112 could be combined and so also could the refuse. It is contemplated, therefore, that the arrangement of FIG. 7 would

involve a single pump, such as pump 40 to supply water from the sump 34 to the conduit 14; also a single pump, such as the pump 42 to supply water from the pond 36 to the pipe 16.

EXAMPLE I

About 800 tons of non-salable coal was taken from a gob pile near Johnstown, Pa. The material appeared to contain a large quantity of pyrites, principally in the binder. This non-salable coal was passed through the preliminary crushing and screening steps referred to above so that the raw material fed to the process and apparatus of the present invention was $1\frac{1}{4} \times 0$ inches. The process and apparatus employed in this example was the embodiment shown and described in relation to FIG. 7. The feed analyzed as follows:

Analysis of Feed		
	As Received	Dry Basis
% Moisture	7.98	
% Volatile Matter	13.86	15.06
% Fixed Carbon	48.29	52.8
% Ash	29.87	32.46
	100.00%	100.00%
% Sulphur	3.99	4.34
B.T.U. (Calorimeter)	9,010	9,791
B.T.U. (Moisture Ash Free)		14,497

The raw feed was further analyzed as to different particle sizes as appears below:

Analysis of $1\frac{1}{4}$ inches $\times$ 0 inch Raw Feed			
Size	Screen Test %	Ash	Air Dry % Sulphur
$1\frac{1}{4}$ inches $\times$ $\frac{3}{4}$ inch	5.73	61.36	4.28
$\frac{3}{4}$ inch $\times$ $\frac{1}{2}$ inch	6.07	48.77	5.05
$\frac{1}{2}$ inch $\times$ $\frac{1}{4}$ inch	13.81	40.22	4.98
$\frac{1}{4}$ inch $\times$ 28 Mesh	53.29	24.73	3.88
28 Mesh $\times$ 0	21.10	27.47	2.68

The 800 tons of material described above were processed through the equipment shown in the drawings. The product of about 682 tons was removed at 30 from FIG. 1. The recovered product was tested and analyzed as follows:

Analysis of Product		
	As Received	Dry Basis
% Moisture	10.58	
% Volatile Matter	15.26	17.06
% Fixed Carbon	65.16	72.87
% Ash	9.00	10.07
	100.00%	100.00%
% Sulphur	0.99	1.11
B.T.U. (Calorimeter)	12,335	13,795
B.T.U. (Moisture Ash Free)		15,340

The product was further analyzed according to the different particle size and the analysis was as follows:

Analysis of Product by Particle Size			
Size	Screen Test %	% Ash	Air Dry % Sulphur
$1\frac{1}{4}$ inches $\times$ $\frac{3}{4}$ inch	5.55	13.79	1.50
$\frac{3}{4}$ inch $\times$ $\frac{1}{2}$ inch	15.19	11.18	1.12
$\frac{1}{2}$ inch $\times$ $\frac{1}{4}$ inch	19.27	9.22	1.01
$\frac{1}{4}$ inch $\times$ 28 Mesh	49.37	7.70	0.99
28 Mesh $\times$ 0	10.62	17.94	1.72

Finally, the refuse was passed through a float-sink test to determine the quantity of ash and sulphur remaining therein. The refuse tested as follows:

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Float-Sink Test of Refuse

Float at 1.60 Sp. Gr.	37.82%
Sink at 1.60 Sp. Gr.	62.17%
Sink at 1.60 Sp. Gr.	Air Dry Ash 67.59%
Sink at 1.60 Sp. Gr.	Air Dry Sulphur 10.22%

From the above, it should appear that the initial feed had an ash content of 29.87% and a sulphur content of 3.99%; this was reduced by virtue of the process to 9% ash and 0.99% sulphur. The product was a salable coal.

EXAMPLE II

The following example involves the treatment of a gob pile from a red stone seam in Maryland. The feed is characterized by having a high ash and high sulphur content; the coal itself has an inherent sulphur content. Again, the preferred embodiment of FIG. 7 was employed in this example.

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Analysis of Feed

	As Received	Dry Basis
Moisture	1.36	
Volatile Combustible Matter	14.58	14.78
Fixed Carbon	60.71	61.55
Ash	23.35	23.67
Sulphur	4.09	4.15
BTU as received	11671	
BTU dry	11832	
BTU M & A Free	15501	
Fusion A.S.T.M. Softening Point	2560°F.	
Free Swelling Index A.S.T.M.	No. 8	
Moisture	0.87	
Volatile Combustible Matter	15.62	15.76
Fixed Carbon	67.30	67.89
Ash	16.21	16.35
Sulphur	2.38	2.40
BTU as received	12867	
BTU dry	12980	
BTU M. & A. Free	15517	
Fusion A.S.T.M. Softening Point	2380°F.	
Free Swelling Index A.S.T.M.	No. 9	

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From the above it will appear that the ash content was reduced from 23.35 to 16.21 and the sulphur was reduced from 4.09 to 2.38. Whereas the feed itself was non-salable, the product is a salable product under certain conditions. If the percentage of sulphur is higher than the requirements allow, this coal can be mixed with a product having a low sulphur content so as to bring the average down within acceptable limits.

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FURTHER DESCRIPTION

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All of the pipes for handling liquids or solids-liquids mixture are 6 inch pipes except for the discharge 26 from the cyclone separator 24; as previously described, this discharge pipe 26 is an 8 inch pipe. The conduit which connects with the outer end of the pipe 26 to the solids water separator 28 has to be somewhat flexible in view of the fact that the lower end of this pipe 86, which is the vortex finder, has to be adjustable; therefore, the connecting conduit from the pipe 26 to the separator 28 is a flexible conduit slightly larger in size than the eight inch pipe. Of course, the discharge cone 27 from the cyclone separator 24 has a lower opening which is $3\frac{1}{2}$ inches in diameter.

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The pressure in the pipe 14 and the turbulence created at the bottom of the pipe 14 is important to the operation of the process so as to keep all of the solids in suspension in the mixing chamber 12. The pump 20 is what is commonly referred to as a "trash pump" which is capable of handling mixtures of solids and liquids. The trash pump 20 has a standard housing but has a specially built impeller capable of passing material 3 inches in diameter. The same considerations hold true for the pump 110 shown in FIG. 7. Each trash pump 20 or 110, is provided with a variable speed electric drive such that the speed of the pumps can vary as the percentage of coal varies in the gob pile.

As indicated heretofore, the solids-liquid suspension fed to the cyclone separator 24 preferably has about 15% solids and 85% water. When treating a gob bank where the percentage of coal in the solids is relatively lower, the percentage of solids in suspension can run as high as between 20 and 30 per cent. However, in operating from a strip mine where the percentage of coal is relatively high, then 15% solids in the solids-water mixture to the cyclone separator is adequate. The pressure in the conduit 22 is important and should be in the range of 4 to 6 p.s.i. For example, if the flow through the conduit 22 is 875 gallons per minute the pressure can fall as low as 4 p.s.i.; conversely, if the flow is 1225 gallons per minute or slightly higher, then the pressure should be about 6 p.s.i. The 6 inch inlet pipe 22 compares with the diameter of 18 $\frac{1}{8}$ inch of the cyclone 24 which means that the cross sectional area of the pipe 22 is between 1/9 and 1/10 of the cross sectional area of the cyclone separator 24.

The cyclone separator 24 (or 112) is designed to create three separating zones formed by the cones 110, 112 and 100. The upper chamber whose lower end is formed by the cone 110 is designed to create a specific gravity to make the 1 $\frac{1}{4}$ to $\frac{3}{4}$ inch material enter towards the center of the core. The second zone formed by the cone 112 is designed to handle the $\frac{3}{4}$ to $\frac{1}{2}$ inch material and make it enter towards the center of the chamber of the cyclone. The last zone formed by the cone 110 is designed to handle the $\frac{3}{4}$ to 0 inch material and make it enter towards the center of the cyclone, and at that point a suction is created by the cyclone which sucks up the center core of the cyclone sucking the coal 1 $\frac{1}{4}$ inch all the way down to zero material out the top of the cyclone 26.

If, in the operation of the mixing chamber 12, it appears that liquid is passing out of the overflow 79 the quantity of liquid entering through the conduit 16 can be reduced to prevent this overflow.

Whereas the present invention has been described in particular relation to the recovery of a salable coal product from a gob bank, obviously, the method and apparatus of the present invention could be employed in conjunction with the mining of coal directly, for example, from a strip mine, where it is desired to improve the quality of the coal.

As far as the mixing chamber is concerned, the outer tank 12 has a diameter of approximately 6 feet and the inner pipe 54 has a diameter of about 3 feet. The cross sectional area of the pipe 54 is therefore, roughly, one to four, or, stated somewhat differently the cross sectional area of the pipe 52 is about one-third of the annular area between the pipe and the tank. The pressure of the water entering the conduit 14 is preferably about 65 p.s.i. and the water issuing from the bottom of the pipe 14 between it and the core 78 creates a condition

of turbulence which is essential to the operation of the mixing chamber 12 and to the entire process. When operating the mixing chamber using the single cyclone separator, the input of solids is 48 to 62 tons per hour as compared to a total water input of 1225 gallons per minute. This relationship reduces roughly to 1.3 to 1.7 pounds of coal per gallon of water.

Whereas the present invention has been described in particular relation to the drawings attached hereto, it should be understood that other and further modification, apart from those shown or suggested herein, may be made within the spirit and scope of this invention.

I claim:

1. A method of separating a salable coal product from a solid material containing coal therein comprising the steps of introducing a pre-crushed and pre-screened quantity of said solid material of particle size 1 $\frac{1}{4}$ $\times$ 0 inch into a mixing zone located centrally within a mixing chamber, said mixing zone being open at the top and the bottom and communicating at said bottom with said mixing chamber, introducing a first stream of water downwardly and centrally into said mixing zone at about 65 p.s.i. to create a condition of turbulence within said zone and within said mixing chamber, introducing a second stream of water into said mixing chamber at about 2 to 5 p.s.i. under substantially quiescent conditions and adjacent the bottom of said mixing chamber, withdrawing a stream of a solids-water mixture from the bottom of said mixing chamber, introducing said solids-water mixture tangentially into a cyclone separator at about 4 to 6 p.s.i., said cyclone separator having inner and outer vortex established by the tangential introduction of said solids-water mixture passing the tangentially moving solids-water mixture downwardly from the outer vortex into contact with a first conical member located above the bottom of said cyclone separator and adjacent the outer surface thereof, said first conical member having a cone angle of generation approximately equal to 68°, passing the tangentially moving solids-water mixture further downwardly into contact with a second conical member extending from said first conical member to the bottom of said cyclone separator and having a cone angle of generation approximately equal to 53°, passing the tangentially moving solids-water mixture still further downwardly into contact with a third conical member located below said bottom of said cyclone separator and having an upper opening of substantially the same size and mating with an opening provided at the bottom of said second conical member, said third conical member having a cone angle of generation approximately equal to 7°, withdrawing a solids-water mixture from the top of said inner vortex and treating the mixture to remove water therefrom and to recover a solid coal product, withdrawing a solids-water mixture from the bottom of said cyclone separator below said third conical member and treating the mixture to remove water therefrom and to obtain a refuse, and recycling the water removed from said mixtures.

2. A method of separating a salable coal product from a solid material containing coal as set forth in claim 1 which includes the step of feeding a portion of the solids-water mixture withdrawn from the bottom of said mixing chamber to a second cyclone separator at about 4 to 6 p.s.i., said second cyclone separator being fed in parallel with said first-mentioned cyclone separator and operating in substantially the same manner as said first cyclone separator.

3. A method of separating a salable coal product from a solid material containing coal therein as set forth in claim 1 wherein said solids are introduced into said mixing zone at a rate of about 1.3 to 1.7 pounds per gallon of total water introduced into said mixing chamber and mixing zone.

4. Apparatus for separating a salable coal product from a solid material containing coal therein comprising a mixing chamber, means establishing a mixing zone located centrally within said mixing chamber, said mixing zone being open at the top and the bottom and communicating at said bottom with said mixing chamber, means for introducing a precrushed and pre-screened quantity of said solid material of particle size $1\frac{1}{4} \times 0$ inches into said mixing zone, means for introducing a first stream of water downwardly and centrally into said mixing zone to create a condition of turbulence within said zone and within said mixing chamber, means for introducing a second stream of water into said mixing chamber under substantially quiescent conditions and adjacent the bottom of said mixing chamber, means for withdrawing a stream of solids-water mixture from the bottom of said mixing chamber, a cyclone separator, means for introducing said solids-water mixture tangentially into said cyclone separator, a vortex finder supported centrally within said cyclone separator, said vortex finder having a diameter equal to about $1\frac{1}{3}$ the diameter of said solids-liquid stream and having a lower opening located within said cyclone separator at a point spaced from the bottom thereof about equal to the diameter of said solids-liquid stream, said vortex finder having an upper end extending upwardly above the top of said cyclone separator, a first conical member located above the bottom of said cyclone separator and adjacent the outer surface thereof, said first conical member having a cone angle of generation approximately equal to 68° , a second conical member extending from said first conical member to said bottom of said cyclone separator and having a cone angle of generation approximately equal to 53° , a third conical member below said bottom of said cyclone separator and having an upper opening of substantially the same size and mating with an opening provided at the bottom of said second conical member, said third conical member having a cone angle of generation approximately equal to 7° , means for withdrawing a solids-water mixture from the upper end of said vortex finder and for treating the mixture to remove water therefrom and recover a solid coal product, means for withdrawing a solids-water mixture from the bottom of said cyclone separator and for treating the mixture to remove water therefrom and to obtain a refuse, and means for recycling the water removed from said mixtures.

5. Apparatus for separating a salable coal product from a solid material containing coal as set forth in claim 4 including a second cyclone separator, means for introducing a portion of the solids-water mixture withdrawn from the bottom of said mixing chamber to said second cyclone separator at about, said second cyclone separator being operated in parallel with said first mentioned cyclone separator, said second cyclone separator having the same internal components and dimensions as set forth above with respect to said first cyclone separator.

6. Apparatus for separating a salable coal product from a solid material containing coal therein comprising a mixing tank closed at the bottom and open at the top, a hollow cylinder suspended in said tank and lo-

cated substantially centrally therein, said cylinder being open at the top and the bottom, said cylinder having an internal horizontal cross sectional area equal to about one-quarter of the internal horizontal cross sectional area of said tank, a vertical inlet pipe having a diameter of approximately one-sixth of the diameter of said cylinder extending downwardly into said cylinder, the bottom end of said pipe extending below the upper end of said cylinder, a flat conical baffle suspended below the lower open end of said pipe with its conical surface arranged divergently downwardly, the side of said conical baffle being located below said open end of said pipe approximately one-twelfth of the diameter of said pipe, a second pipe communicating with the lower end of said tank radially with respect to the center of said cylinder, said second pipe having a flow diverter at the end thereof and within said tank, said second pipe being substantially of the same diameter as said first pipe, said flow diverter having an opening within said tank, the height of said opening being about one-quarter of the diameter of said second pipe and the horizontal length of said opening being equal to about three times the diameter of said pipe, a third pipe connected to said tank at the bottom thereof opposite from said second pipe and being of substantially the same diameter as said first and second pipes, a first pump for introducing water into said tank through said first pipe at about 65 p.s.i. to create a condition of turbulence within said cylinder and within said tank, a second pump for introducing water into said tank through said second pipe at about 2 to 5 p.s.i. under substantially quiescent conditions, means for introducing a quantity of precrushed and pre-screened solid material of particle size $1\frac{1}{4} \times 0$ inches at a rate equal to about 1.3 to 1.7 pounds of solid per gallon of water of the total water introduced into said tank, a cyclone separator having a vertical cylindrical outer casing whose inner diameter is substantially equal to its height, said cylindrical casing being substantially closed at the tops and bottoms thereof, a fourth pipe leading tangentially into said cylindrical casing adjacent the top thereof, the diameter of said fourth pipe being substantially the same as the diameter of said first pipe, the internal diameter of said cylindrical casing being slightly in excess of three times the diameter of said first pipe, a third pump having its inlet connected to said third pipe and its outlet to said fourth pipe for introducing a solids-water mixture into said cyclone separator at about 4 to 6 p.s.i. and at a rate equal to the rate of introduction of total water into said mixing tank, a vortex finder concentrically located within said cylindrical casing of said cyclone separator, said vortex finder having a lower opening located within said cyclone separator at a point spaced from the bottom thereof about equal to the diameter of said first pipe, the internal diameter of said vortex finder being equal to about $1\frac{1}{3}$ the diameter of said first pipe, the upper end of said vortex finder extending upwardly above the top of said cylindrical casing, means providing a seal between the side edge of said vortex finder and the upper end of said cylindrical casing, means for providing vertical adjustment of said vortex finder, a flat plate at the bottom of said cylindrical casing of said cyclone separator, an opening centrally located in said bottom of said casing substantially equal in diameter to the diameter of said vortex finder, a compound conical dish resting on said bottom of said casing and having a lower opening substantially equal to and mating with the opening in said bottom, said

compound conical dish being formed of two conical surfaces, the first of which extends from adjacent the internal surface of said cylindrical casing to a circular line of intersection intermediate the internal surface of said casing and said opening in said bottom and having a cone angle of generation approximately equal to 68°, said conical dish also having a second conical surface extending from said circular line of intersection to said bottom opening and having a conical angle of generation approximately equal to 53°, a nozzle connected below said bottom of said cyclone separator and having an upper opening of substantially the same size and mating with the opening in said bottom, the lower end of said nozzle terminating in an opening having a diameter slightly greater than one-half of the diameter of said first pipe, said nozzle having an internal conical surface extending from the upper opening of said nozzle to the lower opening thereof at a cone angle of generation approximately equal to 7°, the vertical height of said nozzle being slightly in excess of one-half of the diameter of said cylindrical casing, means for treating the effluent solids-water mixture issuing from the top of said vortex finder to remove water therefrom and recover a solid coal product, means for treating the solids-water effluent from the nozzle at the bottom of said cyclone separator for removing water therefrom and refuse, and means for recycling the water from said refuse and said product treating means.

7. Apparatus for separating a salable coal product from a solid material containing coal therein comprising a mixing tank closed at the bottom and open at the top, a hollow cylinder suspended in said tank and located substantially centrally therein, said cylinder being open at the top and the bottom, said cylinder having an internal horizontal cross sectional area equal to about one-quarter of the internal horizontal cross sectional area of said tank, a vertical inlet pipe having a diameter of approximately one-sixth of the diameter of said cylinder extending downwardly into said cylinder, the bottom end of said pipe extending below the upper end of said cylinder, a flat conical baffle suspended below the lower open end of said pipe with its conical surface arranged divergingly downwardly, the side of said conical baffle being located below said open end of said pipe approximately one-twelfth of the diameter of said pipe, a second pipe communicating with the lower end of said tank radially with respect to the center of said cylinder, said second pipe having a flow diverter at the end thereof and within said tank, said second pipe being substantially of the same diameter as said first pipe, said flow diverter having an opening with said tank, the height of said opening being about one-quarter of the diameter of said second pipe and the horizontal length of said opening being equal to about three times the diameter of said pipe, a third pipe connected to said tank at the bottom thereof opposite from said second pipe and being of substantially the same diameter as said first and second pipes, a first pump for introducing water into said tank through said first pipe to create a condition of turbulence within said cylinder and within said tank, a second pump for introducing water into said tank through said second pipe under substantially quiescent conditions, means for introducing a quantity of precrushed and pre-screened solid material of particle size $1\frac{1}{4} \times 0$ inches into the upper end of said cylinder, a cyclone separator having a vertical cylindrical outer casing, a fourth pipe leading tangentially into said cylindrical casing adjacent the top

thereof, the diameter of said fourth pipe substantially the same as the diameter of said first pipe, the internal diameter of said cylindrical casing being in excess of three times the diameter of said first pipe, a third pump having its inlet connected to said third pipe and its outlet to said fourth pipe for introducing a solids-water mixture into said cyclone separator, means for discharging a solids-water mixture from the top of said cyclone separator, means for discharging a solids-water mixture from the bottom of said cyclone separator, means for treating the solids-water mixture issuing from the top of said cyclone separator to remove water therefrom and recover a solid coal product, means for treating the solids-water mixture issuing from the bottom of said cyclone separator for removing water therefrom and refuse.

8. Apparatus for separating a salable coal product from a solid material containing coal therein comprising a mixing tank closed at the bottom and open at the top, a hollow cylinder suspended in said tank and located substantially centrally therein, said cylinder being open at the top and the bottom, said cylinder having an internal horizontal cross sectional area equal to about one-quarter of the internal horizontal cross sectional area of said tank, a vertical inlet pipe having a diameter of approximately one-sixth of the diameter of said cylinder extending downwardly into said cylinder, the bottom end of said pipe extending below the upper end of said cylinder, a flat conical baffle suspended below the lower open end of said pipe with its conical surface arranged divergingly downwardly, the side of said conical baffle being located below said open end of said pipe approximately one-twelfth of the diameter of said pipe, a second pipe communicating with the lower end of said tank radially with respect to the center of said cylinder, said second pipe having a flow diverter at the end thereof and within said tank, said second pipe being substantially of the same diameter as said first pipe, said flow diverter having an opening within said tank, the height of said opening being about one-quarter of the diameter of said second pipe and the horizontal length of said opening being equal to about three times the diameter of said pipe, a third pipe connected to said tank at the bottom thereof opposite from said second pipe and being of substantially the same diameter as said first and second pipes, a first pump for introducing water into said tank through said first pipe to create a condition of turbulence within said cylinder and within said tank, a second pump for introducing water into said tank through said second pipe under substantially quiescent conditions, means for introducing a quantity of precrushed and pre-screened solid material of particle size $1\frac{1}{4} \times 0$ inches into the upper end of said cylinder, a cyclone separator having a vertical cylindrical outer casing whose inner diameter is substantially equal to its height, said cylindrical casing being substantially closed at the tops and bottom thereof, a fourth pipe leading tangentially into said cylindrical casing adjacent the top thereof, the diameter of said fourth pipe being substantially the same as the diameter of said first pipe, the internal diameter of said cylindrical casing being slightly in excess of three times the diameter of said first pipe, a third pump having its inlet connected to said third pipe and its outlet to said fourth pipe for introducing a solids-water mixture from said mixing tank into said cyclone separator, a vortex finder concentrically located within said cylindrical casing of said cyclone separator, said vortex finder hav-

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ing a lower opening located within said cyclone separator at a point spaced from the bottom thereof about equal to the diameter of said first pipe, the internal diameter of said vortex finder being equal to about $1\frac{1}{3}$ of the diameter of said first pipe, the upper end of said vortex finder extending upwardly above the top of said cylindrical casing, means for providing a seal between the side edge of said vortex finder and the upper end of said cylindrical casing, means for providing vertical adjustment of said vortex finder, a flat plate at the bottom of said cylindrical casing of said cyclone separator, an opening centrally located in said bottom of said casing substantially equal in diameter to the diameter of said vortex finder, a compound conical dish resting on said bottom of said casing and having a lower opening substantially equal to and mating with said opening in said bottom, said compound conical dish being formed of two conical surfaces, the first of which extends from adjacent the internal surface of said cylindrical casing to a circular line of intersection intermediate the internal surface of said casing and said opening in said bottom and having a cone angle of generation approximately equal to 68° , said conical dish also having a sec-

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ond conical surface extending from said circular line of intersection to said bottom opening and having a conical angle of generation approximately equal to 53° , a nozzle connected below said bottom of said cyclone separator and having an upper opening of substantially the same size and mating with the opening in said bottom, the lower end of said nozzle terminating in an opening having a diameter slightly greater than one-half of the diameter of said first pipe, said nozzle having an internal conical surface extending from the upper opening of said nozzle to the lower opening thereof at a cone angle of generation approximately equal to 7° , the vertical height of said nozzle being slightly in excess of one-half of the diameter of said cylindrical casing, means for treating the effluent solids-water mixture issuing from the top of said vortex finder to remove water therefrom and recover a solid coal product, means for treating the solids-water effluent from the nozzle at the bottom of said cyclone separator for removing water therefrom and refuse, and means for recycling the water from said refuse and said product treating means.

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