United States Patent [19]

Adkison

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[54] **CYCLONE SEPARATOR**

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[52] **U.S. Cl.** **209/144;** 209/141

[51] **Int. Cl.**^{2} **B04C 3/00**

[58] **Field of Search** .... 209/144, 211, 140–142, 209/148, 150, 138, 139 R, 158–161, 493; 220/8; 138/120; 285/302; 48/178

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Primary Examiner—Frank W. Lutter
Assistant Examiner—Ralph J. Hill
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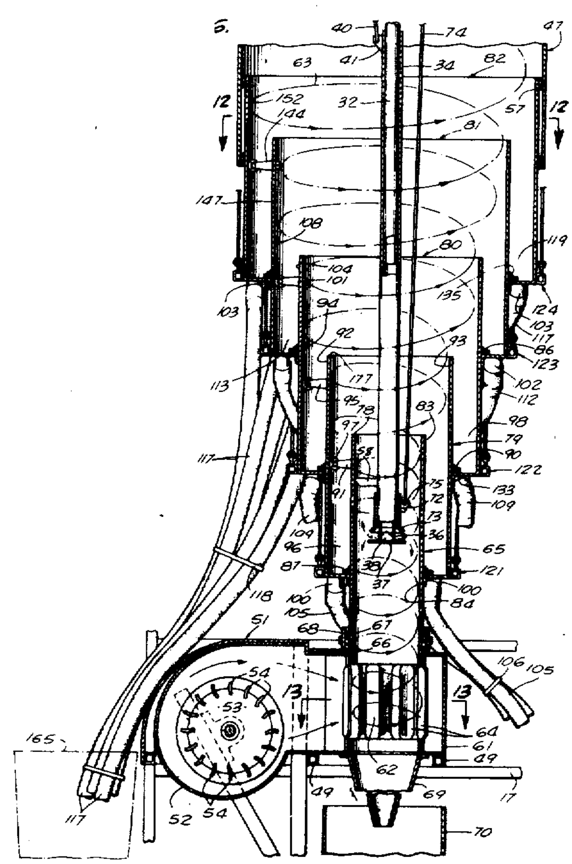
[57] **ABSTRACT**

A cyclone separator is provided comprising a fixed upper cylinder and a fixed lower cylinder with a plurality of vertically adjustable cylindrical chambers telescopically disposed there between. Each telescoping chamber extends part way up into the next higher larger chamber such that the opposing walls thereof define an annular cavity. A hopper for the material to be treated is disposed above the fixed upper cylinder and a feed tube on the bottom of the hopper extends down through the axis of the cyclone separator with its lower discharge end located in the feed cylinder. A spiral whirling stream of air directed up through the feed cylinder picks up the material discharged from the feed pipe and, as the whirling air passes upwardly into each of the larger chambers, particles of successively smaller specific gravity are released by the combined action of gravity and the whirling air into the respective annular cavities associated with the chambers. Cable-and-pulley means are provided for raising or lowering each of the telescoping chambers so as to vary the distance that each extends up into the adjacent larger chamber. To accomodate changes in level of the adjustable chambers, flexible tubes connected to openings on the bottom of the annular cavities are provided to convey the particles collected in each of the annular cavities to a different outlet receptacle.

10 Claims, 16 Drawing Figures



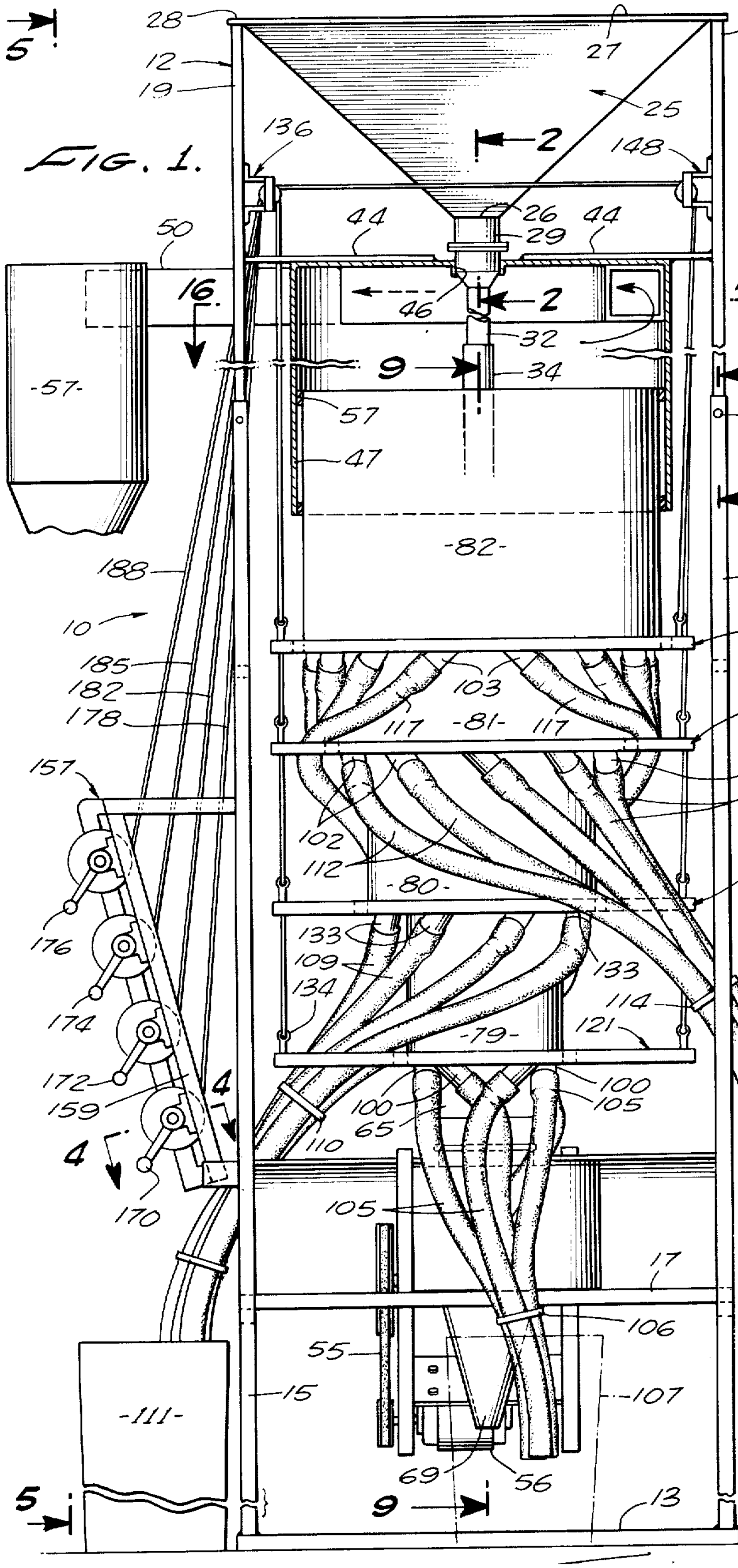


FIG. 1.

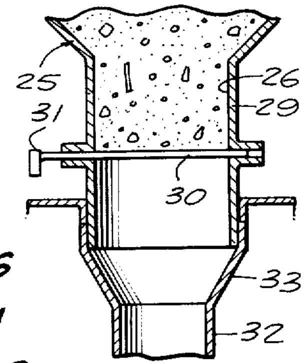


FIG. 2.

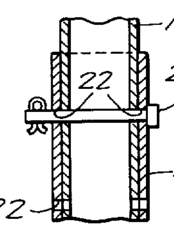


FIG. 3.

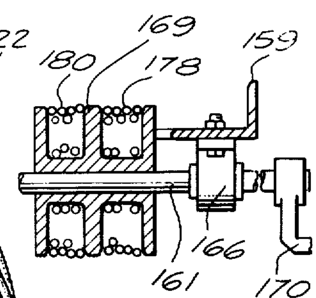
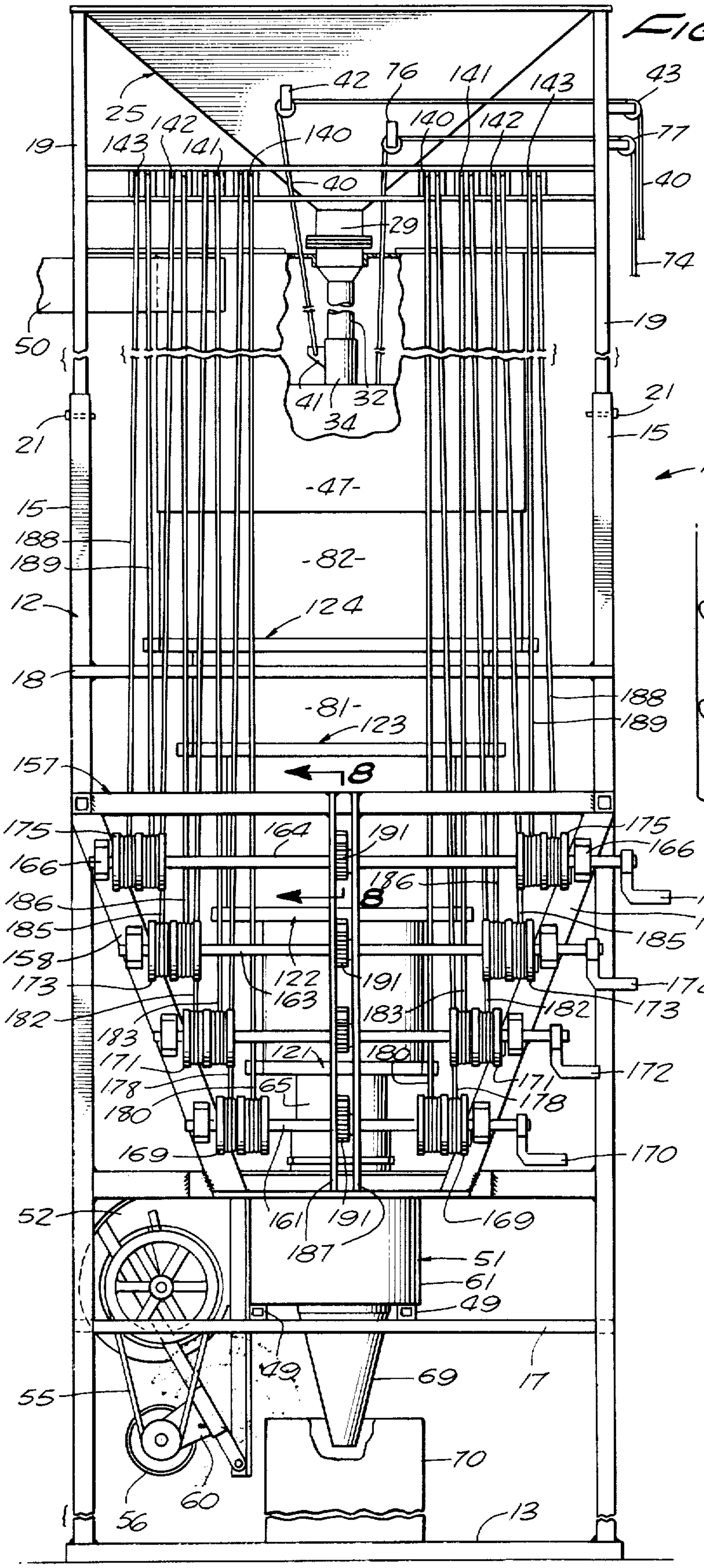


FIG. 4.

FIG. 5.



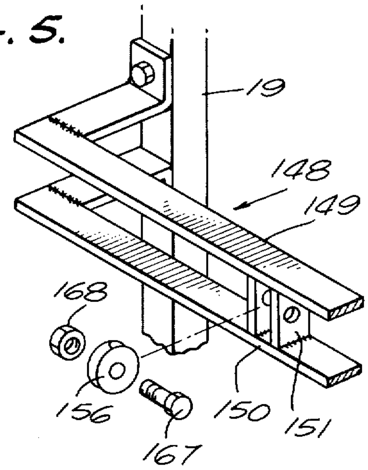


FIG. 6.

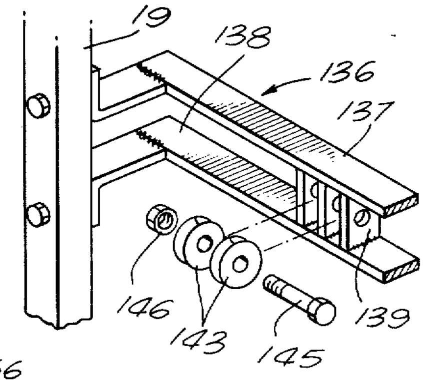


FIG. 7.

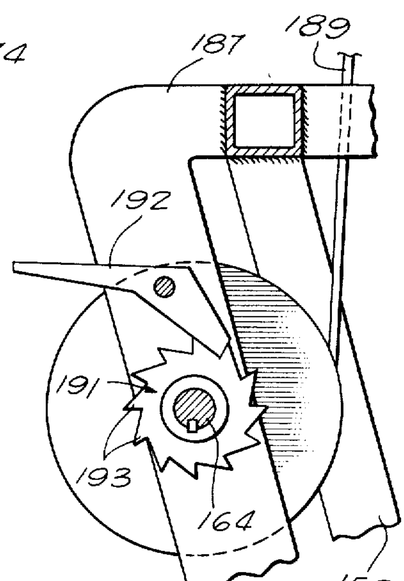


FIG. 8.

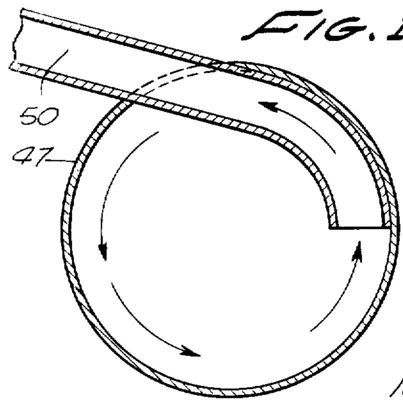


FIG. 16.

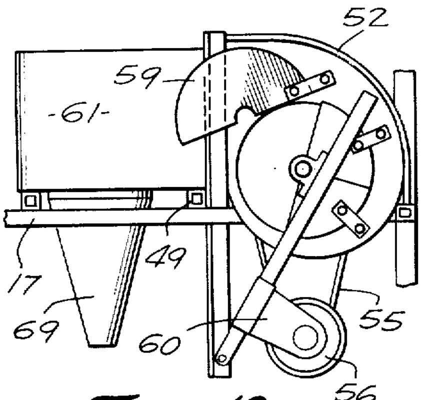


FIG. 10.

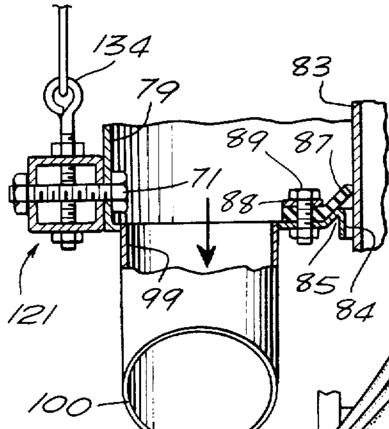


FIG. 11.

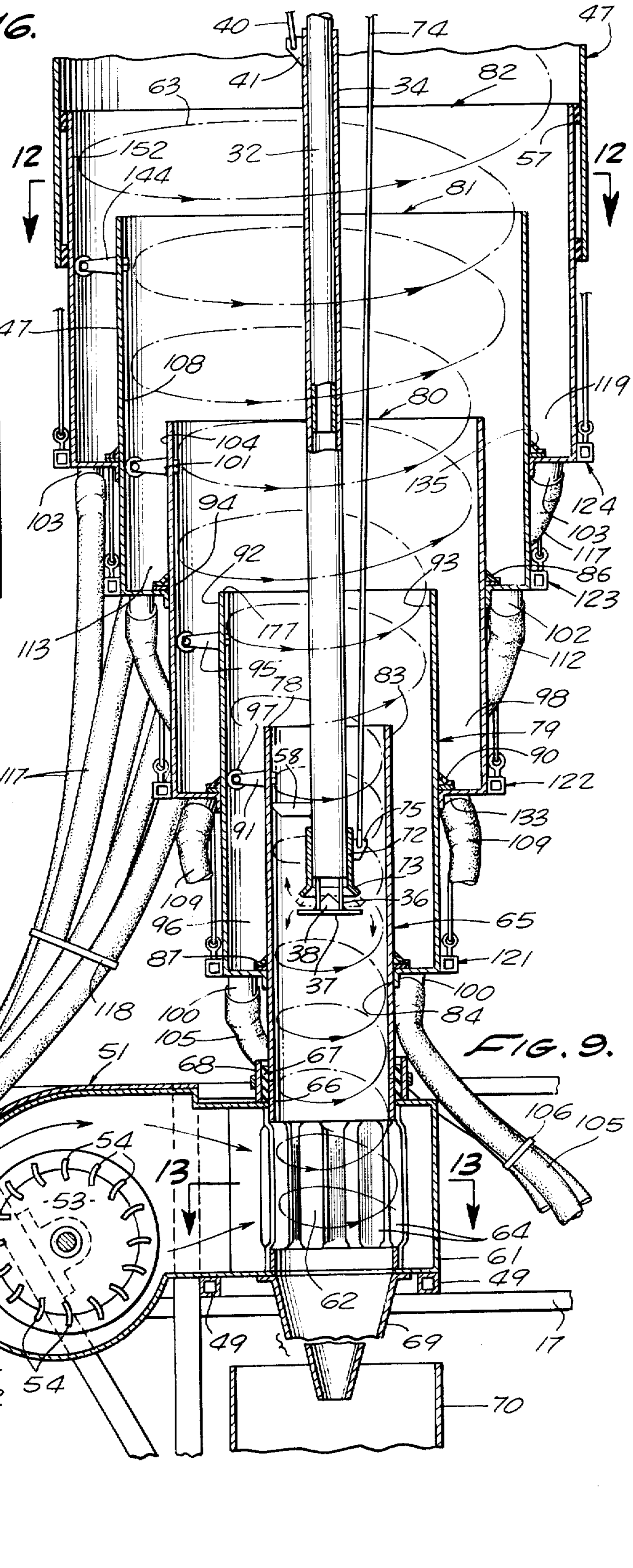


FIG. 9.

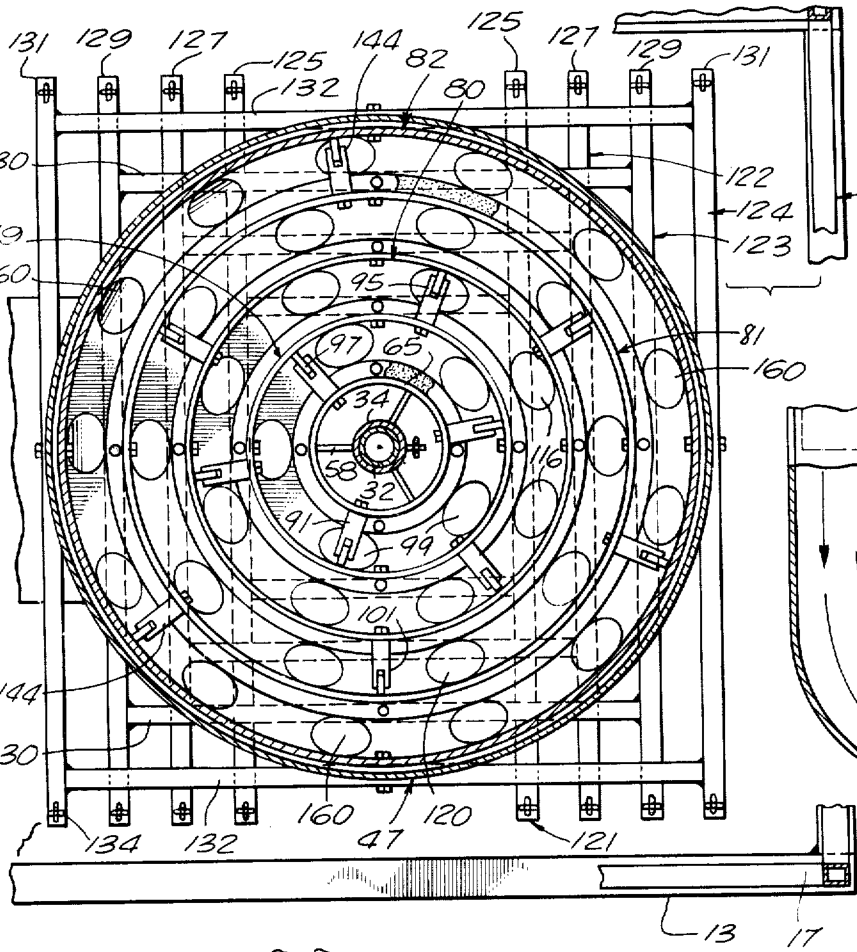


FIG. 12.

FIG. 13.

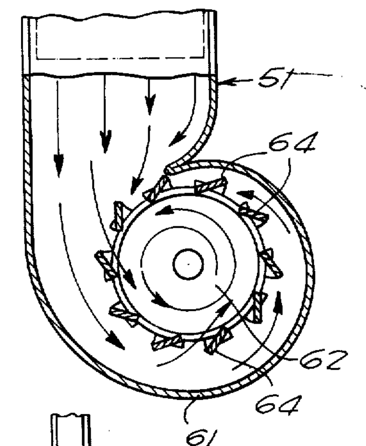
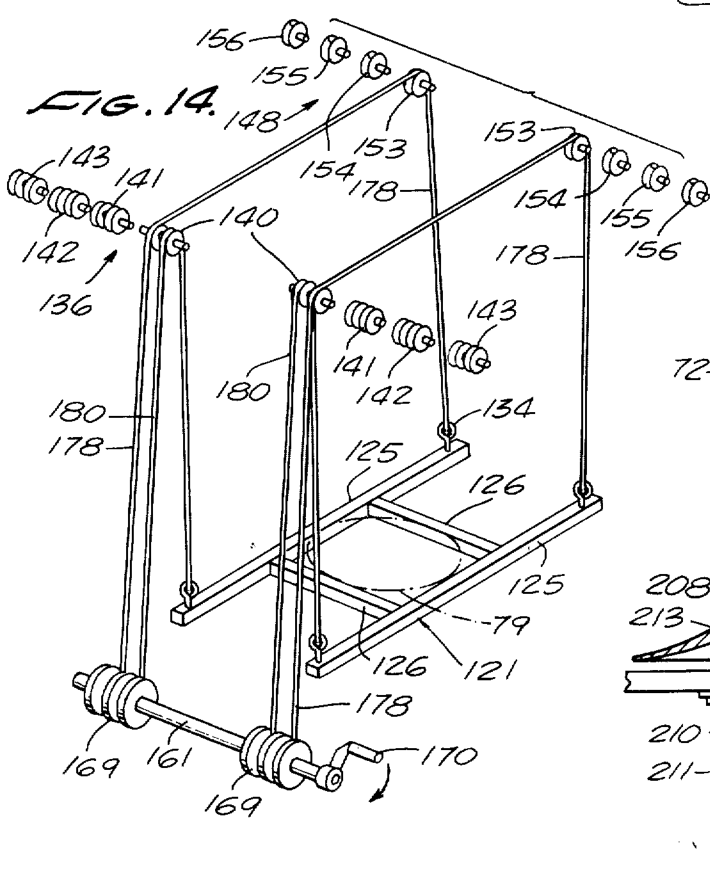


FIG. 14.



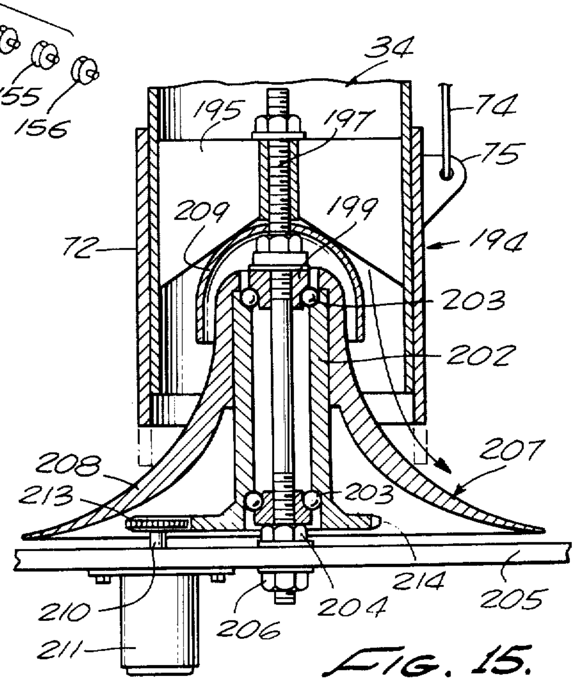


FIG. 15.

CYCLONE SEPARATOR

This invention relates to cyclone separators for separating particles from a mixture of material in accordance with their size or specific gravity, and more particularly to improved structure for selectively adjusting a cyclone separator to improve the effective operation thereof.

It is frequently desirable to separate materials such as ores, grains, and other mixtures of materials to provide different classes or classed of the particles forming the material. In devices previously provided for such purposes, the construction is such that particles of the materials are carried upwardly to different heights by a spiral whirling blast of air so that particles differing in specific weight will be released by gravity and the whirling action of the air to enter successive collecting chambers.

The problem with these prior devices is that the vertical spacings of the successive collecting chambers are fixed relative to each other. Thus, although the lifting effect of the air introduced by a blower into the cyclone separator can be controlled by well known means, the relative incremental drop in the lifting effect of the air from one of the chambers to the next is necessarily fixed in these prior art devices. Since the sizes and specific gravity of the different grades of the material to be classified are undeterminable and may vary with respect to each other and from one batch of the material to the next, the lifting effect needed to release the particles so that they can be thrown out by gravity and centrifugal force at each of the chambers must likewise be variable. Thus the providing of a cyclone classifier with fixed chambers does not provide the flexibility needed to classify materials in a highly efficient manner.

Accordingly, one of the objects of the present invention is to provide an improved cyclone separator wherein the separation of the different size particles of the material being graded is accomplished in a plurality of collecting chambers each of which is adjustable relative to the other.

Another object of the invention is to provide a novel structure for adjusting a cyclone separator while it is being operated so as to ensure that a desired grade of particles is being separated from the material at each of the collecting chambers provided along the height thereof.

Another object of the invention is to provide an improved rotary feeder for discharging material to be treated into the whirling air currents rising within the feed cylinder.

With these and other objects in view the invention consists of the construction, arrangement and combination of the various parts of the device, whereby the objects contemplated are attained as hereinafter more fully set forth, pointed out in the claims and illustrated in the accompanying drawings, in which:

FIG. 1 is a side elevation view of the cyclone separator;

FIG. 2 is a view as taken along line 2—2 in FIG. 1;

FIG. 3 is a view as taken along line 3—3 in FIG. 1;

FIG. 4 is a view as taken along line 4—4 in FIG. 1;

FIG. 5 is a front elevation view of the cyclone separator;

FIG. 6 is a perspective view of the back pulley support;

FIG. 7 is a perspective view of the front pulley support;

FIG. 8 is a view as taken along line 8—8 in FIG. 5;

FIG. 9 is a vertical sectional view of the cyclone separator as shown in FIG. 5;

FIG. 10 is a rear view of the blower;

FIG. 11 is an enlarged view showing the lower side portion of a cylindrical chamber;

FIG. 12 is a transverse view of the cyclone separator as taken along line 12—12 of FIG. 9;

FIG. 13 is a cross sectional view of the vortex chamber as taken along line 13—13 of FIG. 9;

FIG. 14 is a schematic showing of the pulley arrangement for raising and lowering the chambers in the cyclone separator;

FIG. 15 is a showing of an alternate feeder for use in the cyclone separator of FIG. 1; and

FIG. 16 is a cross sectional view of the fixed top chamber as taken along line 16—16 of FIG. 1.

Referring to the drawings, the cyclone separator **10** of the present invention comprises a main frame **12** having a rectangular base **13** with fixed legs **15** extending upwardly from the four corners thereof. Horizontally disposed cross braces **17** are connected across the fixed legs **15** on all four sides of the lower portion of the main frame **12.** In addition, a cross brace **18** is connected across the front side of the intermediate portion of the main frame **12.** Each of the fixed legs **15** is formed of square tubing which telescopically receives on the upper end thereof an adjustable leg **19** which is held at a desired elevated position by a pin **21** that passes through aligned holes **22** in the fixed leg **15** and the adjustable leg **19.**

Located on the top of main frame **12** is a feed hopper **25** provided with a rectangular opening **27** on its upper end and four flat sides which slant inwardly and downwardly to form a central square opening **26** on the bottom thereof. The upper end of the hopper **25** has shoulders **28** whose corners contact the ends of the adjustable legs **19** and are secured in position by welding, for example. As shown in FIG. 2, the bottom central outlet of the hopper **25** is in the form of a vertical spout **29** having a square cross section. Pivotally disposed within the vertical spout **29** is a gate valve **30** provided with an external lever **31** which can be manipulated to open or close the spout **29.**

Attached to extend downwardly from the lower end of the spout **29** on the hopper **25** is a fixed feedpipe **32.** The feed pipe **32** which has a circular cross section is formed with an upper end portion **33** having a square opening which fits on the square end of the spout **29.** The feed pipe **32** extends down into the intermediate portion of the main frame **12.** Slideably fitted on the fixed feed pipe **32** to extend beyond the lower end thereof is an adjustable feed pipe **34** having a circular cross section. Suspended by pins **36** below the end of the movable feed pipe **34** is a spreader plate **37.** The spreader plate **37** is formed with a conical projection **38** on its upper surface. The lower end of the adjustable feed pipe **34** is supported at a desired level within the cyclone separator **10** by taking up or releasing a cable **40** attached to an ear **41** extending from the upper end of the pipe **34.** The cable **40** is guided by a first pulley **42** attached on the bottom surface of the hopper **25** and a second pulley **43** attached on the side of the main frame **12.** The free end of cable **40** is thus arranged to hang down from the side of the main frame **12** for easy access.

Extending inwardly from each of the adjustable legs 19 toward the vertical spout 29 on the upper portion of the main frame 12 is a support member 44. Suspended from the four support members 44 is a fixed cylindrical chamber 47 having a top cover 48 with a square opening 46 in the center thereof which conforms with the square vertical spout 29 on the output of the hopper 25. The bottom of the fixed cylindrical chamber 47 is open. The upper portion of chamber 47 is provided with a tangentially disposed outlet 50 which leads to a dust extractor 57.

Mounted on tube supports 49 straddling the cross braces 17 on the lower portion of the main frame 12 is a housing 51 provided with a blower portion 52 and an outlet portion 61. As shown in FIG. 9, the blower portion 52 encloses a fan rotor 53 having a plurality of axial blades 54. The fan rotor 53 is rotated by a belt 55 driven by a motor 56 supported by a bracket 60 below the blower portion 52 of housing 51. As shown in FIG. 10, the blower portion 52 of the housing has movable damper segments 59 covering the side air intake opening to the fan rotor 53. The output portion 61 of housing 51 encloses a vortex chamber 62 provided with a circular array of stationary, vertically disposed axial blades 64. Blades 64 are shaped to receive the pressurized air from the fan output that surrounds the vortex chamber 62 and direct this air upwardly through the vortex chamber so as to provide a spiral whirling flow of air into a feed cylinder 65 positioned above the vortex chamber 62. The feed cylinder 65 rests on a cylindrical outlet 66 on the upper side of the output portion 61 of housing 51 and the adjoining surfaces are surrounded by a rubber gasket 67 and held by a metal band 68. Mounted on the bottom of the outer portion 61 of the housing 51 below the vortex chamber 62 is a conical outlet 69 whose lower open small end is positioned over a receptacle 70.

As shown in FIG. 9, the adjustable feed pipe 34 on the lower end of the hopper 25 extends down so as to be centralized within the feed cylinder 65 by three radial members 58 attached to the outer surface of the feed pipe 34. The axial position of the feed pipe 34 in the feed cylinder 65 can be selectively adjusted by use of the cable 40 extending down the side of the main frame 12. Slideably fitted on the lower end portion of the adjustable feed pipe 34 is a cylindrical gate member 72 provided with an outwardly flaring lower end 73. A cable 74 attached by an ear 75 to the side of the cylindrical gate member 72 extends upwardly along the feed pipe to a pulley 76 attached to the bottom of the hopper 25 and is guided by a pulley 77 attached to the side of the main frame 12 so as to extend down along the side of the main frame 12 for easy access.

Mounted between the relatively smaller diameter feed cylinder 65 attached to the lower portion of the main frame and the relatively larger diameter, cylindrical chamber 47 attached to the upper portion of the main frame 12 are a first, second, third and fourth cylindrical chamber 79, 80, 81, 82, respectively. These chambers have such a diameter size and are so supported in the cyclone separator 10 that they are telescopically, vertically adjustable relative to each other along a common axis between the fixed top chamber 47 and the fixed feed cylinder 65. Thus, first chamber 79 is concentrically positioned on the feed cylinder 65, second chamber 80 is concentrically positioned on the first chamber 79, third chamber 81 is concentrically positioned on the second chamber 80, and fourth chamber 82 is concentrically positioned on the third chamber 81. The fourth chamber 82 is also concentrically positioned within the fixed top chamber 47.

Describing the relative mounting of the chambers 79, 80, 81 and 82 in more detail, the bottom of the first chamber 79 is provided with a circular opening 84 by which it is fitted over the outer wall 83 of feed cylinder 65. As shown in FIG. 11, the inner edge of the bottom circular opening 84 of the first chamber 79 is bent to form an upwardly angled shoulder 85 against which a rubber gasket 87 is positioned and held by a metal ring 88 which clamps the gasket 87 to the edge of the bottom circular opening 84 of the first chamber 79 by the use of bolts 89.

Three radial spacers 91 are attached to the upper portion of the outer wall 83 of the feed cylinder 65. These radial spacers are equally positioned about the feed cylinder and provided with end rollers 97 which contact the inner wall 93 of the first chamber 79. The end rollers 97 serve to center the first chamber 79 and assist in axially moving the first chamber 79 relative to the feed cylinder 65.

It should be evident that the outer wall 83 of the feed cylinder 65 together with the opposing inner wall 93 of the first cylindrical chamber 79 form a first annular cavity 96 in the cyclone separator 10. Located on the bottom of the first annular cavity 96 are five equally spaced openings 99. A short metal pipe 100 is welded on the underside of the bottom 97 below each of the openings 99.

The second cylindrical chamber 80 is similarly constructed and provided with a gasket 90 on the bottom central opening thereof to slideably engage the outer wall 92 of the first chamber 79. Three radial spacers 95 are attached to the outer wall 92 of the first chamber. The outer wall 92 of the first chamber 79 together with the inner wall 94 of the second chamber 80 thus form a second annular cavity 98 in the cyclone separator 10. Located on the bottom of the annular cavity 98 are eight equally spaced openings 116. A short metal pipe 133 is welded below each opening 116.

The third chamber 81 is similarly constructed with a gasket 86 on the central opening thereof to slideably engage on the outer wall 104 of the second chamber 80. Three radial spacers 101 are provided on the outer wall of second chamber 80. The outer wall 104 of the second chamber 80 together with the inner wall 108 of the third chamber 81 thus forms a third annular cavity 113 in the cyclone separator 10. Located on the bottom of the third annular cavity 113 are 10 equally spaced openings 120. A short metal pipe 102 is welded on the annular bottom below each opening.

Likewise, the fourth chamber 82 is constructed with a gasket 135 on the bottom central opening thereof to slideably engage on the outer wall 147 of the third chamber 81. Three radial spacers 144 are attached to the outer wall 147 of the third chamber 81. The outer wall 147 of the third chamber 81 together with the inner wall 152 of the fourth chamber 82 thus form a fourth annular cavity 119 in the cyclone separator 10. Located on the bottom of the fourth annular cavity 114 are 13 equally spaced openings 160 each leading to a short metal pipe 103 welded to the bottom surface thereof. The fourth chamber 82 has teflon gaskets 57 attached to its outer wall by which it slides within the fixed cylindrical top chamber 47.

It should be noted that the short metal pipes attached below the annular bottoms of each of the chambers are curved so as to be directed about the periphery of the next lower chamber towards a different side of the main frame **12.** Thus, long flexible tubes **105** attached by their upper ends to each of the pipes **100** on the annular bottom of the first chamber **79** are enabled to be directed toward the near side of the main frame **12** in FIG. **1,** whereat the tubes **105** are combined together by a band **106** and the free ends thereof directed toward an outlet receptacle **107** placed on the near side of the main frame **12.**

Likewise, long flexible tubes **109** attached by their upper ends to each of the pipes **133** on the annular bottom of second chamber **80** are enabled to be directed toward the left side of the main frame **12** (FIG. **1**) whereat the tubes **109** are combined, i.e., bundled together, by a band **110** and the free ends thereof directed toward an outlet receptacle **111** placed on the left side of the main frame **12.**

Similarly, long flexible tubes **112** attached by their upper ends to each of the short pipes **102** on the annular bottom of the third chamber **81** are enabled to be directed toward the right side of the main frame **12** in FIG. **1** whereat the tubes **112** are bundled together by a band **114** and the free ends directed toward an outlet receptacle **115** placed on the right side of the main frame **12.**

In a like manner, long flexible tubes **117** attached by their upper ends to each of the pipes **103** on the annular bottom of the fourth chamber **82** are enabled to be directed toward the back side of the main frame **12** whereat the tubes **117** are bundled together by a band **118** and the free ends directed toward an outlet receptacle **165** placed on the back side of the main frame **12.**

Each of the chambers **79, 80, 81,** and **82** is supported within the cyclone separator **10** on a platform **121, 122,** 123, and **124,** respectively. As shown in FIG. **14,** the platform **121** for the first chamber **79** comprises a pair of spaced long members **125** provided with a pair of spaced shorter cross members **126.** The lower end of the chamber **79** is positioned within the square opening formed between the spaced members **125, 126** and secured in position by bolts **71,** for example.

Similarly, the platform **122** for the second chamber **80** comprises a pair of long members **127** and a pair of short members **128,** the platform **123** for the third chamber **81** comprises a pair of long members **129** and a pair of short members **130,** and the platform **124** for the fourth chamber **82** comprises a pair of long members **131** and a pair of short members **132.** It should be noted that the pair of long members **125, 127, 129** and **131** on each of the platforms **121, 122, 123** and **124,** respectively, is of the same length but that the pair of short cross members **126, 128, 130** and **132** on each of the platforms is longer for the next higher positioned chamber inasmuch as the spacing of the pair of long and short members is greater to accomodate each of the larger diameter chambers. An eyebolt **134** for the end of a supporting cable is attached to either end of each of the long members **125, 127, 129** and **131** of these platforms.

Next to be described is the cable and pulley arrangement provided for supporting and controlling the relative heights of the first, second, third and fourth chambers **79, 80, 81** and **82,** respectively, in the cyclone separator **10.**

As shown in FIGS. **1** and **7** attached to the front side of the main frame **12** below the hopper **25** is a front pulley support **136** comprised of upper and lower horizontal members **137** and **138.** Provided on front of pulley support **136** at four spaced locations on each side of members **137** and **138** are vertical members **139** between which four double pulleys **140, 141, 142** and **143** are mounted (FIG. **14**). Each double pulley, such as double pulley **143,** is held between the vertical members **139** by a bolt **145** and a nut **146.**

Similarly, as shown in FIGS. **1** and **6,** attached to the back side of the upper portion of the main frame **12** below the hopper **25** is a back pulley support **148** comprised of an upper and lower horizontal member **149** and **150.** Provided on back pulley support **148** at four spaced locations on each side of the members **149** and **150** are vertical members **151** between which four single pulleys **153, 154, 155** and **156,** are mounted (FIG. **14**). As shown in FIG. **6,** each single pulley, such as single pulley **156,** is held between the vertical members **151** by a bolt **167** and a nut **168.**

As shown in FIGS. **1** and **5,** mounted on the front side of the main frame **12** is an angular bracket **157** comprised of a pair of angular side arms **158** and **159** which are inclined inwardly towards each other and toward the main frame **12** from the upper end to the lower end thereof. Four horizontally disposed shafts **161, 162,** 163 and **164** have their ends rotationally mounted by bearing clamps **166** in spaced parallel relation on the angular side arms **158** and **159.** It should thus be noted that the lowest mounted shaft **161** is the shortest in length and each of the next higher mounted shafts **162,** 163 and **164** is longer in length. As shown in FIG. **4,** a double reel **169** is keyed to either side of the shaft **161** and a crank **170** is keyed to the outer end thereof. Similarly, a double reel **171** is keyed on either side of the shaft **162** and a crank **172** is keyed to the outer end thereof, a double reel **173** is keyed on either side of the shaft **163** and a crank **174** is keyed to the outer end thereof, and a double reel **175** is keyed on either side of the shaft **164** and a crank **176** is keyed to the outer end thereof. It should be noted that by making each of the shafts longer than the lower adjacent shaft, each of the shafts can have its double reels placed further out on each of the sides thereof, as shown in FIG. **5.**

It should now be clear, as shown in FIG. **14,** that a pair of back cables **178** respectively extend up from one of the double reels **169** on each side of shaft **161,** over one of the double pulleys **140** on each side of the front pulley support **136,** over one of the single pulleys **153** on each side of the back pulley support **148,** and down to the back ends of the pair of long members **125** on the platform **121** for the first chamber **79.** Also, a pair of front cables **180** respectively extend up from the other of the double reels **169** on each side of the shaft **161,** over the other of the double pulleys **140** on each side of the front pulley support **136,** and down to the front ends of the pair of long members **125** on the platform **121** for the first chamber **79.**

In a similar manner, a pair of back cables **182** respectively extend up from one of the double reels **171** on each side of shaft **162,** over one of the double pulleys **141** on each side of the front pulley support **136,** over one of the single pulleys **154** on each side of the back pulley support **148,** and down to the back ends of the pair of long members **127** on the platform **122** for the second chamber **80.** Also, a pair of front cables **183** respectively extend up from the other of the double reels **171** on each side of the shaft **162**, over the other of the double pulleys **141** on each side of the front pulley support **136**, and down to the front ends of the pair of long members **127** on the platform **122** for the second chamber **80**.

Likewise, a pair of back cables **185** respectively extend up from one of the double reels **173** on each side of the shaft **163**, over one of the double pulleys **142** on each side of the first pulley support **136**, over one of the single pulleys **155** on each side of the rear pulley support **148**, and down to the back ends of the pair of long members **129** on the platform **123** for the third chamber **81**. Also, a pair of front cables **186** respectively extend up from the other of the double reels **173** on each side of the shaft **163**, over the other of the double pulleys **142** on each side of the front pulley support **136**, and down to the front ends of the pair of long members **129** of the platform **123** for the third chamber **81**.

Likewise, a pair of back cables **188** respectively extend up from one of the double reels **175** on each side of shaft **164**, over one of the double pulleys **143** on each side of the front pulley support **136**, over one of the single pulleys **156** on each side of the back pulley support **148**, and down to the back ends of the pair of long members **131** on the platform **124** for the fourth chamber **82**. Also, a pair of front cables **189** respectively extend from the other of the double reels **175** on each side of the shaft **164**, over the other of the double pulleys **143** on each side of the front pulley support **136**, and down to the front ends of the pair of long members **131** on the platform **124** for the fourth chamber **82**.

As shown in FIGS. **5** and **8**, a pair of vertical spacer members **187** are located on the angular bracket **157** centrally between the ends of the shafts **161, 162, 163** and **164**. Each of these shafts has a ratchet wheel **191** keyed thereon which is located between the vertical spacer members **187**. A pawl **192** is pivotally supported on the spacer member **187** above each wheel. The end of the pawl **192** engages the teeth **193** of the ratchet wheel **191** and prevents reverse motion of the shaft, such as the shaft **161**, when the chamber **79** is being raised by rotating the crank **170** in a clockwise direction. Then when it is desired to lower chamber **79**, the outer end of the pawl **192** is pushed down to clear the ratchet teeth **193** and thus enable the shaft **161** to be rotated in a counter clockwise direction. When the desired height of the chamber **79** is reached, the pawl **192** is released to again engage the ratchet teeth **193** and thus hold the chamber **79** in position.

Next to be described in connection with FIG. **15** is an alternate feeding means **194** for the bottom of the adjustable feed pipe **34**. Feeding means **194** includes a spider **195** positioned within the lower end of the feed pipe **34** for supporting in the center thereof a threaded rod **197** secured by a nut **198** on the top thereof. The rod **197** has spaced upper and lower inner fixed ball bearing members **199** and **200** for balls **203** secured on the depending portion thereof. A sleeve **202** is mounted between the balls **203** to surround and rotate relative to the inner fixed members **199** and **200**. A shield **209** is provided on the upper end of the rod **197** below the spider **195** to cover the upper end of the ball bearing member **199**. A fixed spreader plate **205** is supported on the bottom of rod **197** and held thereon by upper and lower nuts **204** and **206**. A feed impeller **207** is fixed on the sleeve **202** to rotate therewith. The feed impeller **207** has an upper surface **208** which flares out over the surface of the spreader plate **205**. A motor **211** attached to the underside of the fixed spreader plate **205** has its shaft **210** extending upwardly through an opening in the plate **205**. The shaft **206** has a gear **213** thereon which meshes with a gear **214** on the lower end of the sleeve **202**.

When the motor **211** is energized and the gate member **72** is lifted by pulling on the cable **74** extending down along the side of the main frame **12**, the rotating impeller **207** of the feeding means **194** shown in FIG. **15** provides for throwing out the material in the feed pipe **34** into the path of the upwardly spiraling whirling stream of air. A rheostat (not shown) is provided for controlling the speed of the impeller **207**.

OPERATION

To operate the cyclone separator **10**, after the material to be treated has been poured into the feed hopper **25** and the motor **56** has been energized, the lower end of the feed pipe **34** is opened by lifting the gate member **72** by use of cable **74**. As the air whirls spirally upwardly in the feed cylinder **65**, the material in the feed pipe **34** is introduced into the airstream **63**. The heaviest particles which are not lifted by the whirling stream of air are immediately dropped down through the vortex chamber **62** and into the conical outlet **69** leading to the output receptacle **70**.

As the air stream with the remainder of the material particles suspended therein moves spirally upwardly, it experiences a drop in velocity upon passing from the upper end **78** of the feed cylinder **65** into the larger diameter of the first chamber **79**. While rising through the first chamber, the centrifugal force of the spiral whirling airstream **62** thus throws particles of a given size range, which can no longer be suspended by the reduced upward velocity of the airstream, against the inner wall **93** of the first chamber **79** from which the particles settle down into the annular cavity **96** of the first chamber **79** and flow through the flexible tubes **105** into the outlet receptacle **107**. As the whirling air stream **63** continues to rise beyond the upper end **177** of the first cylinder **79** it experiences another drop in velocity due to the increase in diameter of the second chamber **80** such that while rising through the second chamber **80** the centrifugal force of the spiral whirling airstream **62** throws out particles of the next smaller size range against the inner wall **94** of the second chamber **80** from which the particles then drop down into the annular cavity **98** associated therewith and then down through flexible tubes **109** to the outlet receptacle **111**.

In a similar manner, the spiral whirling air stream **63** continues upward through the cyclone separator **10** experiencing a velocity drop on passing from each chamber to the next higher chamber and throwing out by centrifugal force a range of particles of lesser size range against the inner wall of the third and the fourth chambers **81** and **82** into the associated annular passages **113** and **119** and then through the tubes **112** and **117** into the outlet receptacles **115** and **165**, respectively. The spiral whirling airstream **63** with the lighter dust particles still being bourne thereby then continues upwardly into the fixed chamber **47** on the upper portion of the main frame **12** and is then passed into and through the tangential outlet 50 On the upper portion of the fixed chamber 47 into the dust receptacle 57.

It should be noted that as the spiral whirling air stream 63 passes from each chamber into the next higher larger chamber, the air experiences a loss in upwardly velocity due not only to the abrupt larger cross section of the upper chamber but also due to the turbulence and eddy current losses. Thus as the spiral whirling air stream proceeds upwardly through the cyclone separator 10 there is a drop in the lifting force of the airstream at the points corresponding to the top of each chamber and these points can be selected by adjusting the positions of the upper ends of the walls of each of the chambers 79, 80, 81 and 82 relative to each other by the use of the pulley and cable arrangements connected to the respective cranks 170, 172, 174 and 176 on the angular bracket on the front side of the main frame.

It should further be noted that as the particles are thrown out by the centrifugal force against the inner wall of each of the chambers, some of the particles depending on their specific gravity will drop into the annular cavities associated therewith while others will continue to climb the wall of the respective chambers. If the wall is too high, as when adjacent chambers are spaced apart by their maximum length, many of the particles will not be able to pass over the upper end of the wall, such as the upper end 177 of the wall for the first chamber 79 and will instead settle back into the annular cavity associated with that chamber. However, if the wall is lower at that point, as when adjacent chambers are telescopically closed on each other, many of the particles are lifted over the upper end of the wall and thrown by centrifugal force against the inner wall of the next chamber and thus dropped into the annular cavity of the next higher chamber. It should now be evident that the extent of the height of the wall of a particular chamber above the end of the wall of the next smaller, lower chamber, affects the range of the particles that will be trapped in the annular cavity associated with that particular chamber.

It should now be clearly understood that by varying the heights of the first, second, third and fourth chambers 79, 80, 81 and 82, respectively, relative to each other, the sizes of the particles that will be thrown by the centrifugal force of the airstream against the inner walls of the respective chambers and will settle down into the respective annular cavities associated therewith can be made to vary.

For example, assume that it is desired to trap particles of a desired specific weight and size out of the annular cavity associated with the second chamber 80. Upon starting up the cyclone separator 10 particles sizes of a certain range will initially be observed being trapped in the output receptacle 111 associated with the annular cavity 98 of the second chamber 80. Then, by adjusting the relative height of the second chamber 80 by rotating the crank 172, it will be observed that there will be a change in the range of the size of the particles that will be collected in that receptacle 111. Likewise, the heights of each of the other chambers 79, 81 and 82 can be raised or lowered by the cranks associated therewith as needed to obtain the desired range of the size of particles collected in their respective output receptacles. Having once determined by sampling that the cyclone separator 10 has been set to supply particles of the desired size, the material obtained in the output receptacles during the setting up of the chambers by adjusting the relative heights thereby can then be placed back into the feed hopper 25 and the cyclone separator 10 will thereafter continue to treat the material in the hopper 25 to supply the desired particle sizes in the respective output receptacles.

There may be times when it is necessary to change the quantity and the pressure of the air being pumped through the cyclone separator 10 in order to obtain the desired operation thereof. Such changes can be effected by adjusting the setting of the damper segments 59 which admit air into the blower housing 51 and/or by adjusting the speed of the fan rotor 52 of the blower. It should be appreciated that an optimum ratio of lifting force to the centrifugal force of the spiral whirling airstream 63 is important to the proper operating of the equipment.

While the foregoing disclosure has been primarily concerned with a particular exemplary embodiment of the present invention, it is to be understood that the invention is susceptible of many modifications in construction and arrangement as well as for a variety of related uses. The present invention, therefore, is not to be considered as limited to the specific disclosure provided herein, but is to be considered as including all modifications and variations coming within the scope of the invention as defined in the pending claims.

What is claimed is:

1. In a cyclone separator for classifying material, the combination comprising:

a fixed upper cylinder;

a fixed lower cylinder;

a plurality of telescoping cylindrical chambers concentrically disposed between said fixed upper and lower cylinders;

each said telescoping chamber extending part way up into the next higher larger diameter chamber such that the opposing walls thereof define an annular cavity;

a hopper for the material to be treated disposed above said fixed upper cylinder;

a feed pipe extending down from said hopper with its lower discharge end located in said fixed lower cylinder;

means for directing a spiral whirling stream of air up into the fixed lower cylinder wherein the air picks up the material discharged from said feed pipe and carries it upwardly through the cyclone separator to cause particles of successively smaller specific gravity to be released by the combined action of gravity and the whirling action of the air into the respective annular cavities of the successive telescoping chambers;

means for individually vertically raising or lowering each of the telescoping chambers so as to vary the distance that each extends up into the next higher larger diameter chamber, to thereby adjust the height of the wall of each of said chambers against which the particles are thrown by the whirling action of the air;

an outlet receptacle associated with each of said annular cavities; and

flexible conveying means connected to openings on the bottom of each of the annular cavities to convey the particles collected therein to the respective outlet receptacles.

2. The invention in accordance with claim **1** wherein radial spacers with rollers on the ends thereof are secured to the outer wall of each inner telescoping chamber to bear upon the inner wall of the next larger diameter outer telescoping chamber to enable the chambers to be axially raised or lowered relative to each other.

3. The invention in accordance with claim **1** including rotary means located on the discharge end of said feed pipe for throwing the material to be treated out into said upwardly whirling stream of air.

4. The invention in accordance with claim **1** wherein said flexible conveying means includes short pipes connected below openings on the bottom of said annular cavities, the short pipes connected to each of the annular cavities being curved toward a different side of said cyclone separator; and

flexible tubes connected to each of the short pipes to convey the particles collected in each of said annular cavities to the respective outlet receptacles located on said different sides of the cyclone separator.

5. The invention in accordance with claim **1** wherein said means for directing a spiral whirling stream of air up through the fixed lower cylinder includes;

a blower for providing pressurized air; and

a vortex chamber disposed below the lower fixed cylinder for directing the pressurized air of said blower into said fixed lower cylinder with an upward spiral whirling movement.

6. The invention in accordance with claim **1** including a gasket on the bottom edge opening of each of said outer telescoping chambers which rides on the outer wall of the next lower smaller diameter inner chamber when the chambers are vertically raised or lowered relative to each other.

7. The invention in accordance with claim **1** wherein said feed pipe is adjustable, and including means for changing the level of location of the discharge end of said feed pipe in said lower fixed chamber.

8. The invention in accordance with claim **1** including

a main frame for supporting said upper and lower fixed cylinders;

a platform attached to the bottom of each of said telescoping chambers;

pulleys on said main frame;

a bracket on the side of said main frame;

a plurality of shafts rotatably mounted on said bracket, each of said shafts having reels thereon;

cables guided by said pulleys for respectively connecting one of said platforms to the reels on one of the shafts mounted on said bracket and thereby supporting said plurality of telescoping chambers between said fixed upper and lower cylinders; and

means for rotating said shafts to vertically raise and lower each of said telescoping chambers.

9. The invention in accordance with claim **8** including a ratchet wheel provided on each of said shafts and a pawl provided on said bracket for each of said ratchet wheels, whereby said ratchet wheels and pawls provide for holding each of said chambers at a desired level in said cyclone separator.

10. The invention in accordance with claim **8** wherein each of said platforms includes a pair of spaced long members and a pair of spaced short cross members,

wherein a telescoping chamber has its lower end positioned in the opening formed by the spacing of the pairs of long and short members of each platform; and

wherein separate lengths of cables extend upwardly from the ends of the pair of long members of each platform and are guided by the pulleys mounted on the main frame so as to be wound on the reels on one of the shafts rotatably mounted on said bracket.

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