CENTRIFUGAL SEPARATOR OF THE CONTINUOUS PROCESS TYPE

Filed Jan. 24, 1964 9 Sheets-Sheet 1

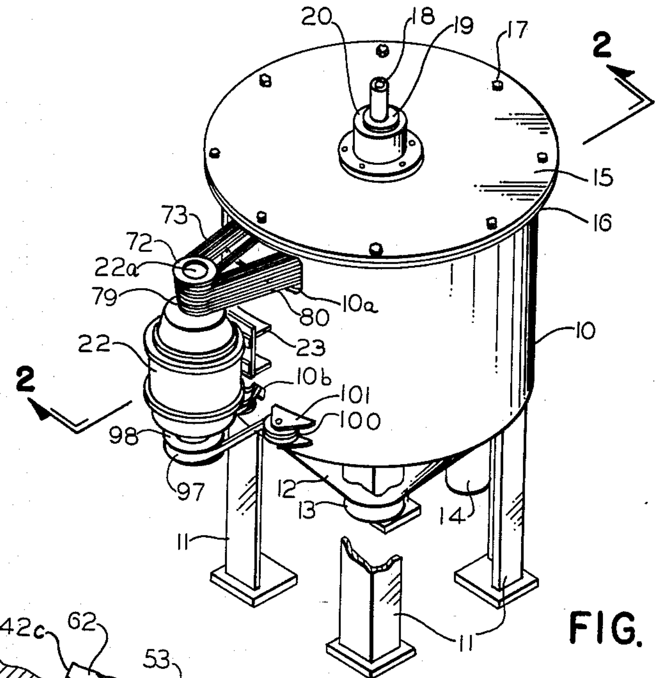

FIG. 1

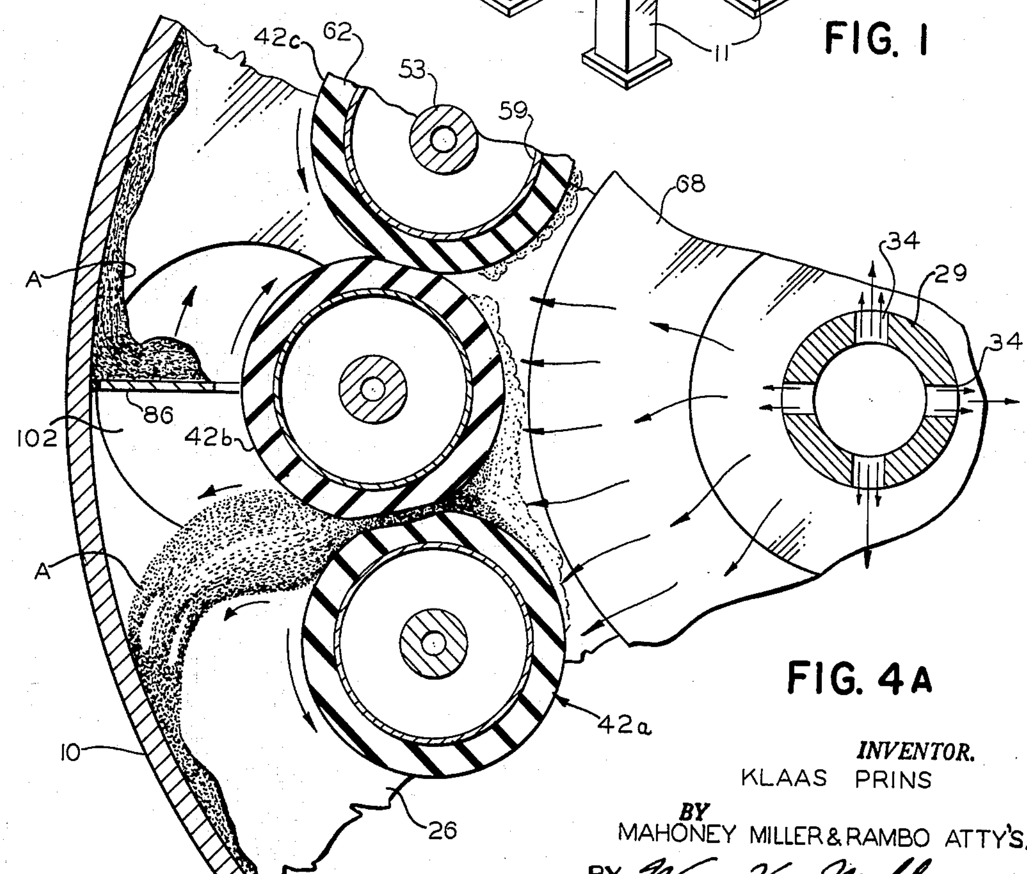

FIG. 4A

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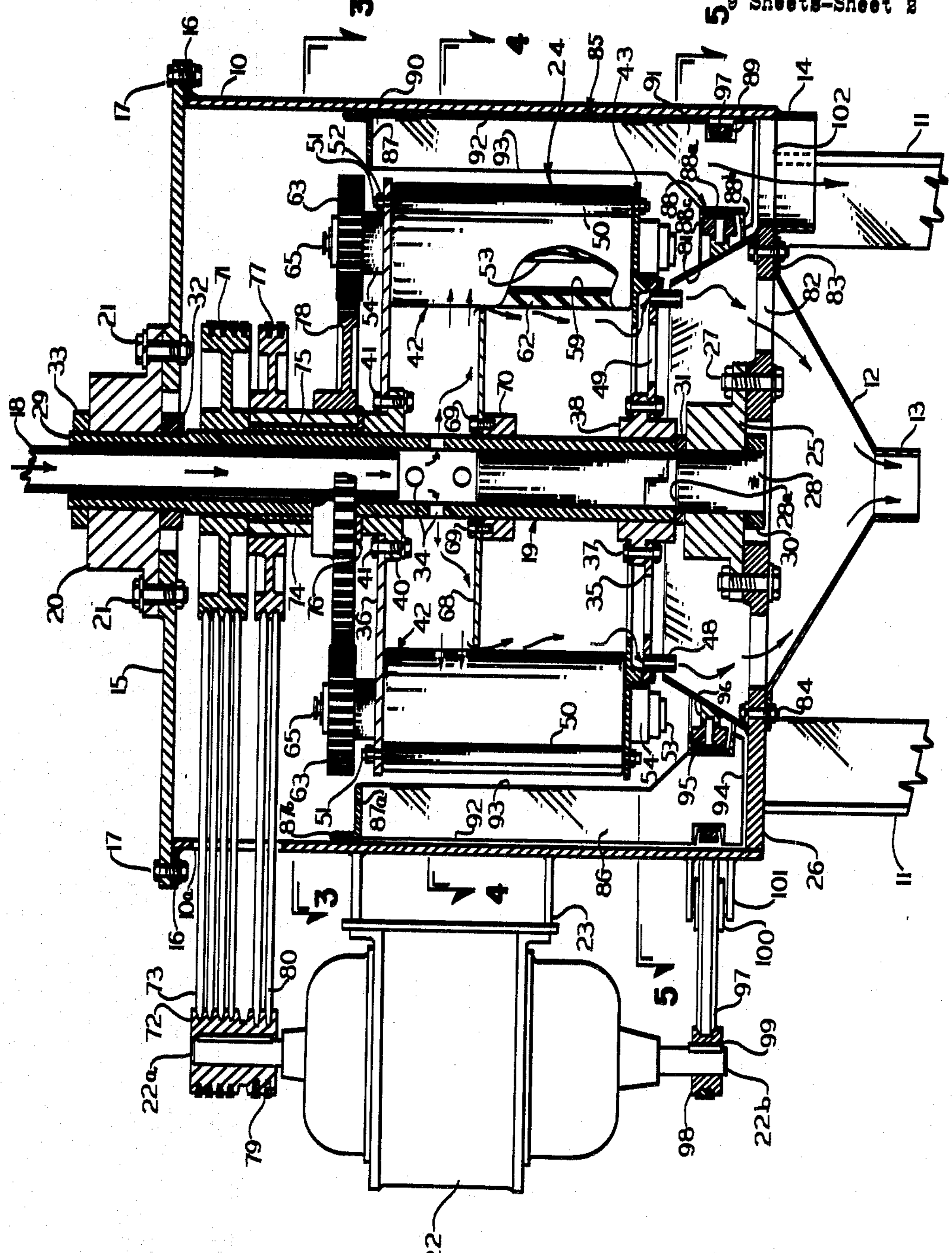

FIG. 2

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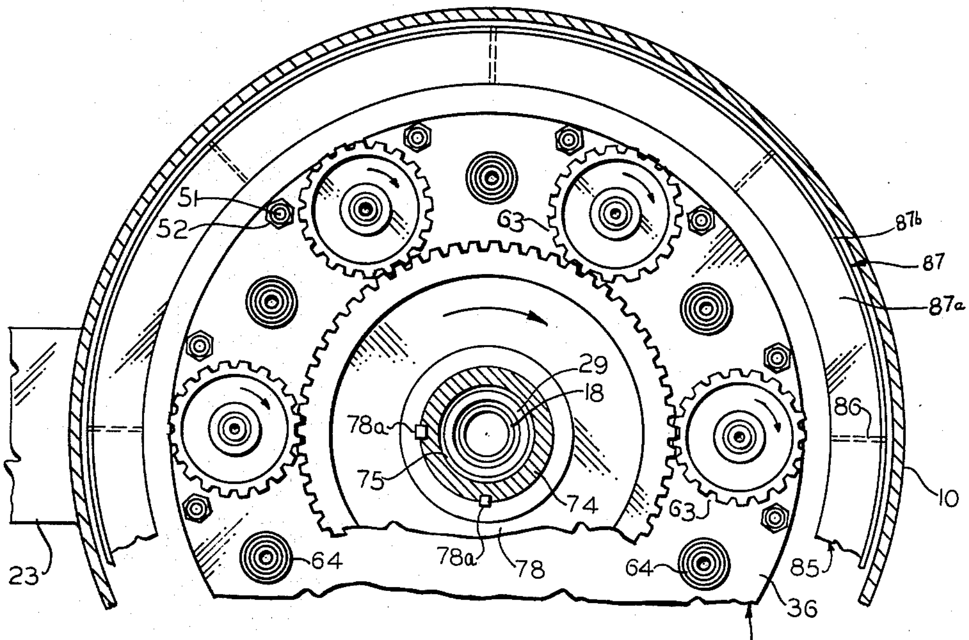

FIG. 3

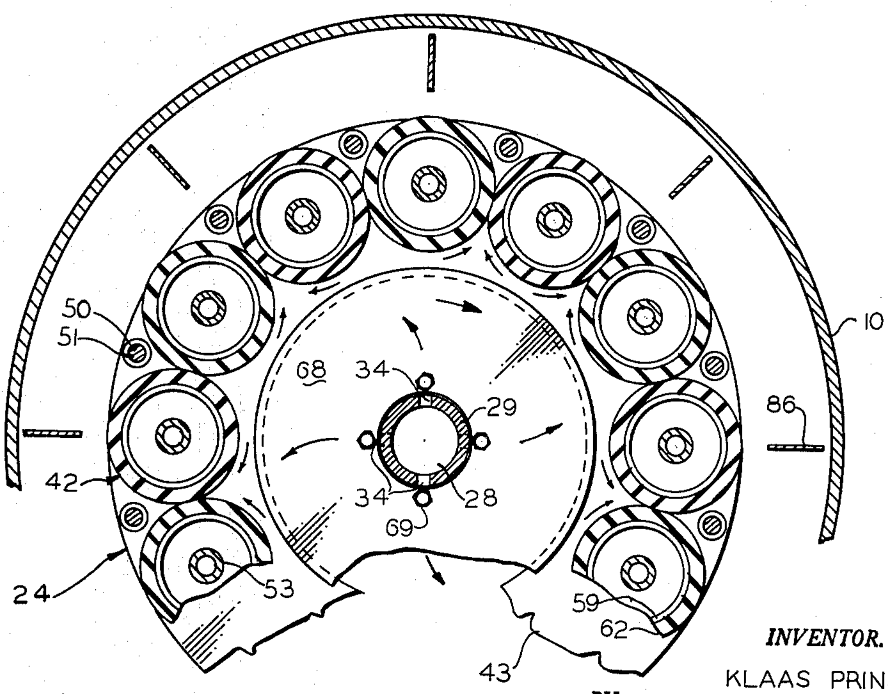

FIG. 4

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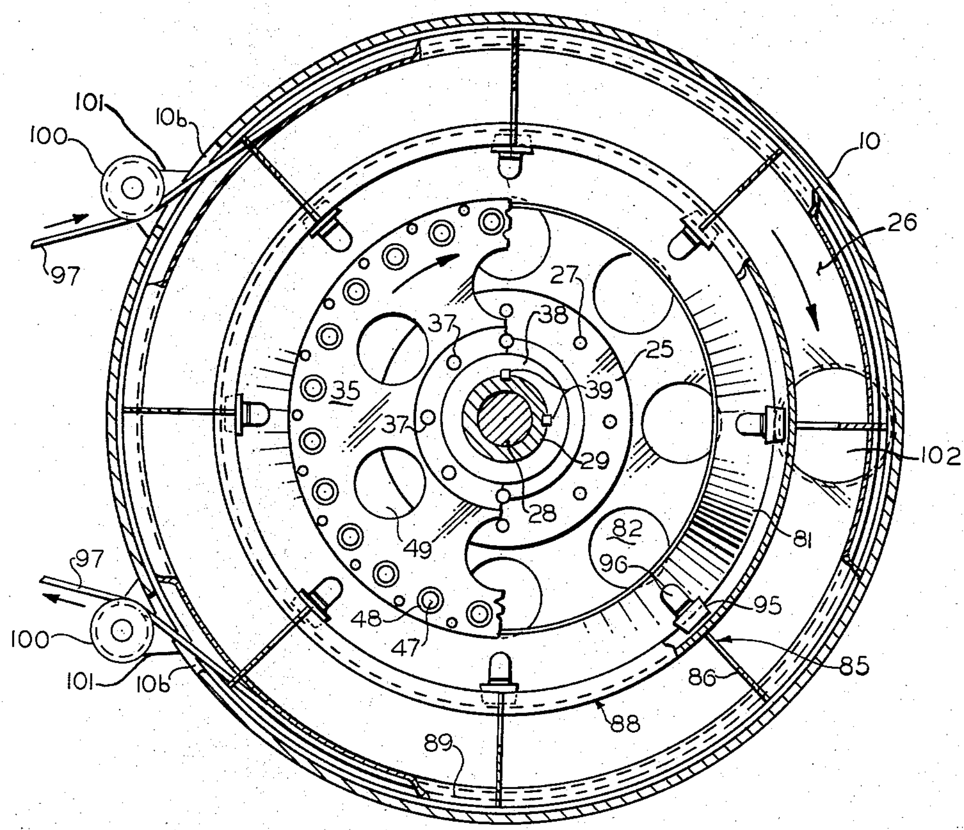

FIG. 5

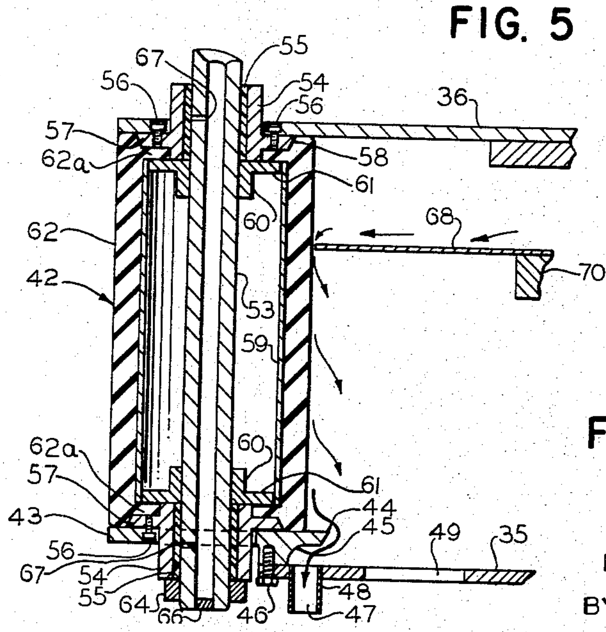

FIG. 6

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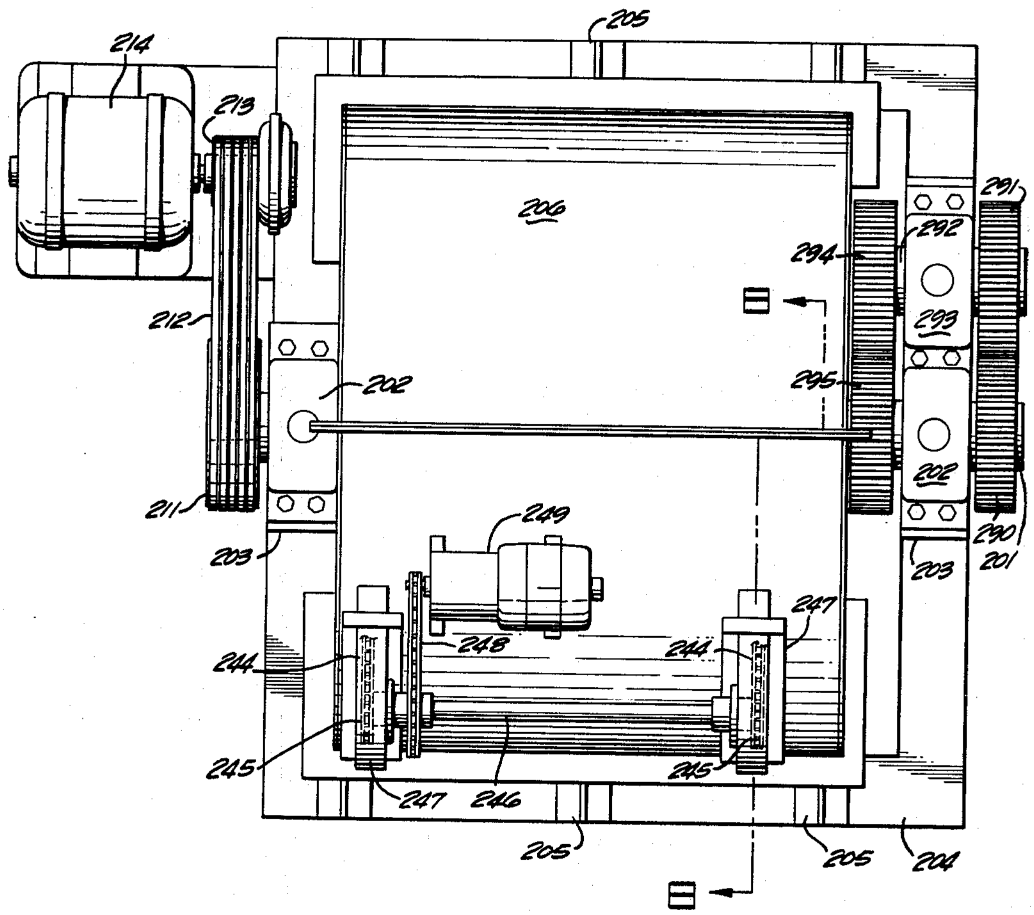

FIG. 7

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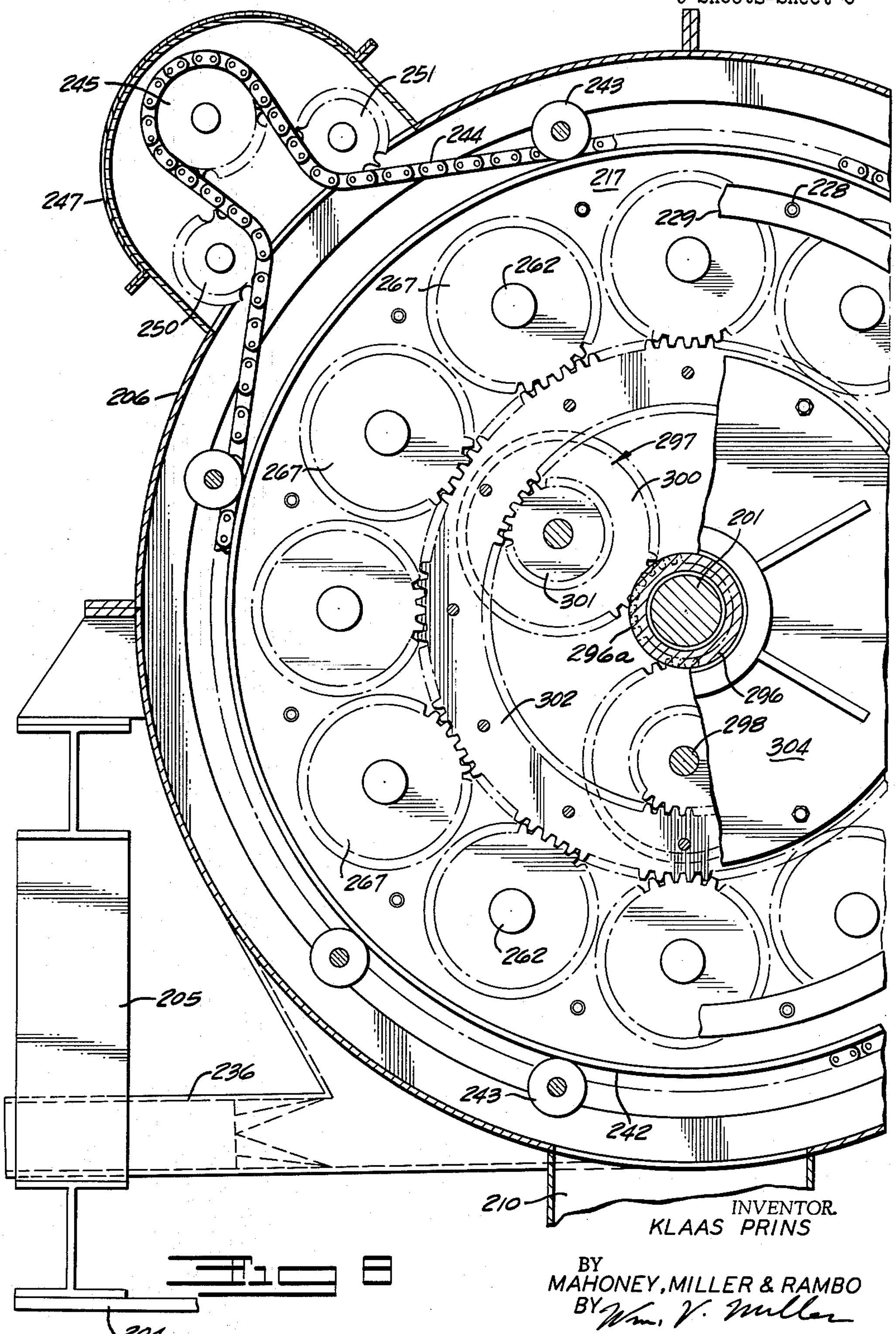

Fig. 6

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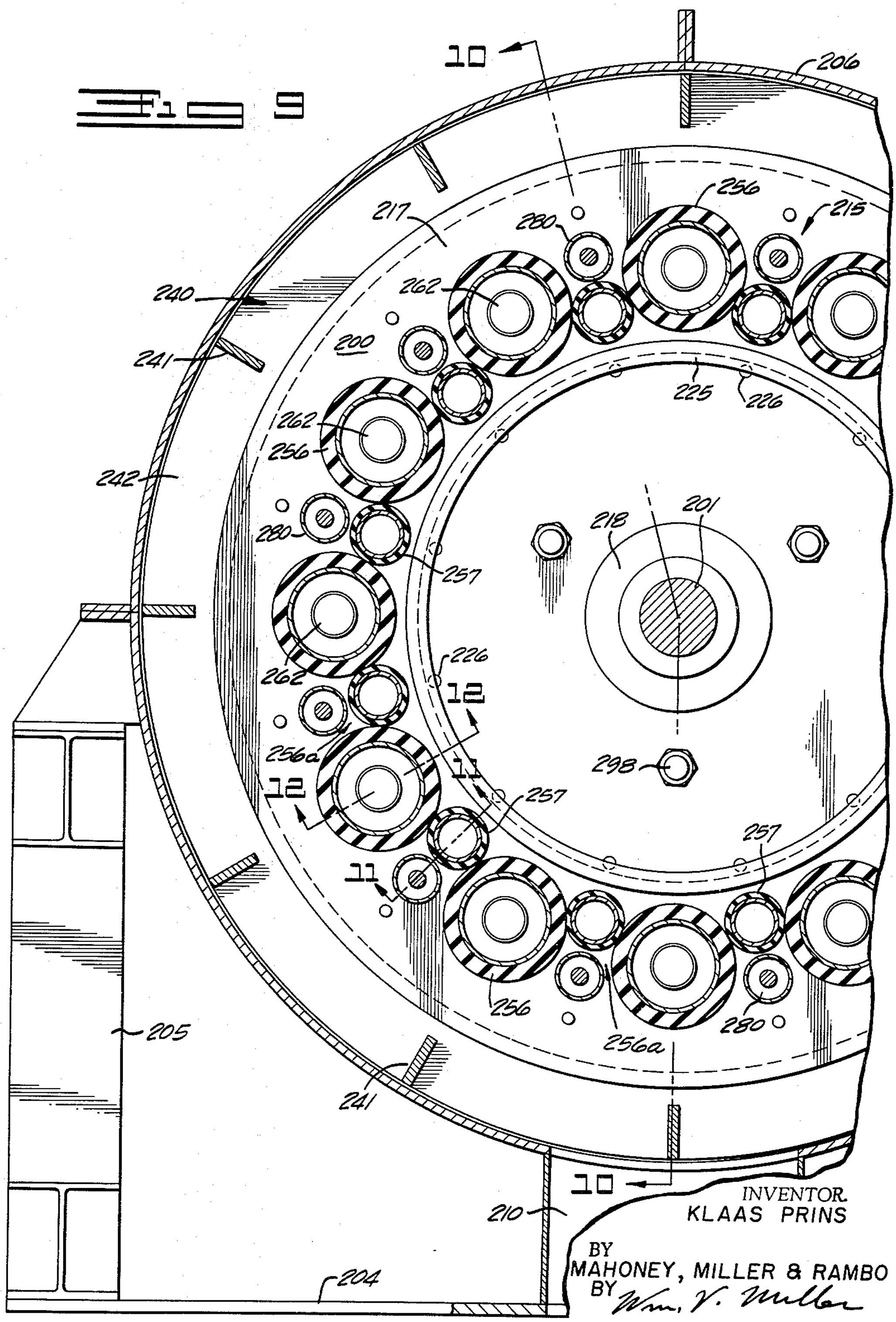
FIG. 9



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CENTRIFUGAL SEPARATOR OF THE CONTINUOUS PROCESS TYPE

Filed Jan. 24, 1964

9 Sheets-Sheet 8

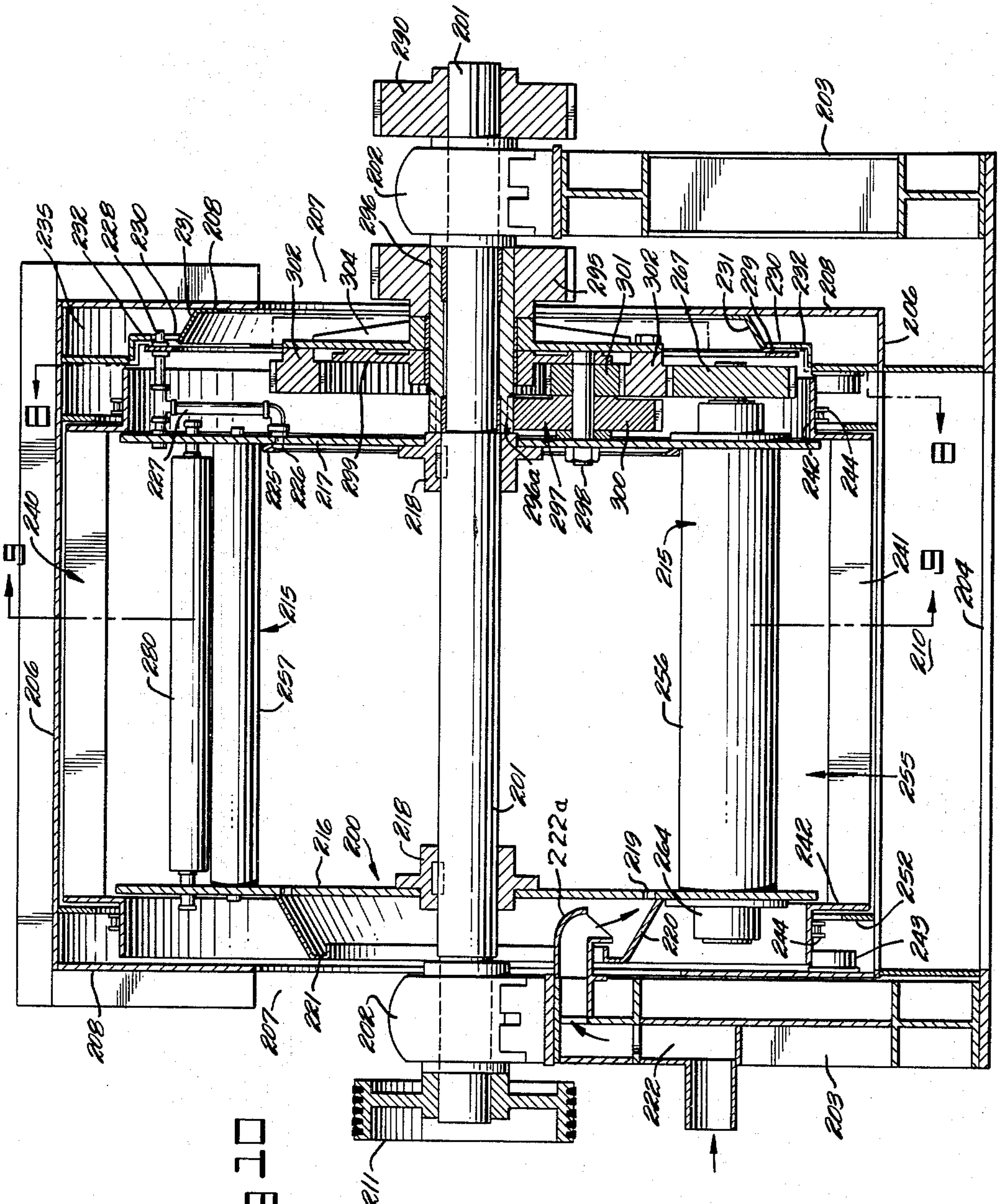

FIG. 10

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April 26, 1966 K. PRINS 3,248,045

CENTRIFUGAL SEPARATOR OF THE CONTINUOUS PROCESS TYPE

Filed Jan. 24, 1964 9 Sheets-Sheet 9

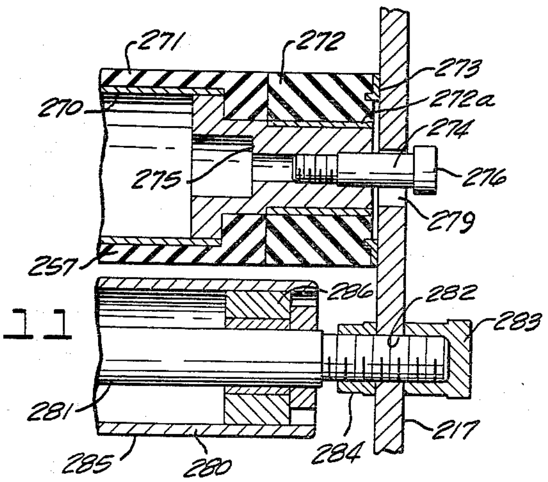

Fig. 11

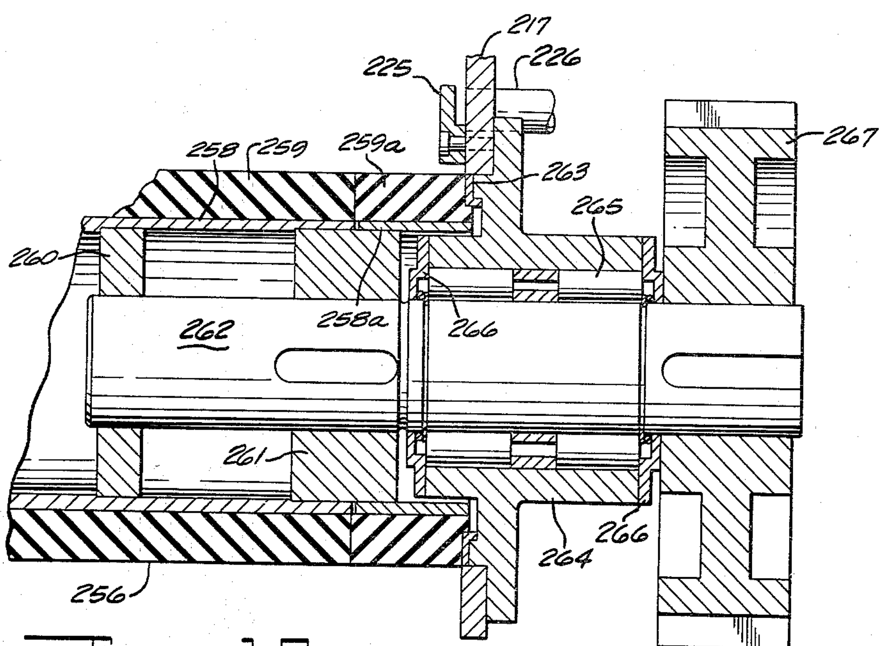

Fig. 12

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United States Patent Office 3,248,045
Patented Apr. 26, 1966

3,248,045
CENTRIFUGAL SEPARATOR OF THE CONTINUOUS PROCESS TYPE
Klaas Prins, 104 E. D St., Wellston, Ohio
Filed Jan. 24, 1964, Ser. No. 341,481
19 Claims. (Cl. 233—2)

This application is a continuation-in-part of my application Serial No. 122,343, filed July 6, 1961, and now abandoned.

This invention relates to a Centrifugal Separator of the Continuous Process Type for removing solid matter from a fluid wherein the separated solid matter and clean fluid are continuously removed from the centrifuge during the operation thereof.

It is a common practice in industry to utilize a centrifuge in extracting the water from a fluid containing solid matter and, for example, a centrifuge application for this purpose is in the ore processing industries where the ore is often subjected to a washing process and purification of the resultant waste water is required before it enters a disposal system. In the usual apparatus of this type, the fluid to be processed is directed into a rotary shell or drum and centrifugally thrown against the periphery thereof which is fabricated as a filter member permitting the water to be extracted from the fluid and retaining the solid matter within the rotary drum. The extracted water is collected by an enclosure extending circumferentially around the rotary drum where it may be withdrawn and disposed of in any convenient manner. It is, of course, necessary to also provide means for removing the solid matter from within the rotary drum to permit its continued use. In this respect, an obvious disadvantage of previously devised centrifuges is readily apparent as the retained solid matter or sludge will tend to remain packed against the peripheral filter member and clog the openings or passages through which the water is extracted, thereby reducing the effectiveness of the centrifuge. Prolonged operation under this condition therefore necessitates a means for removal of the solid matter from the filter member and the centrifuge. The usual methods of solid matter removal generally require stopping of the centrifugal separating process and replacement of the filter member or the cleaning thereof by, for example, back-flushing. Scraper members revolving within the rotary drum adjacent the filter member have also been utilized in an attempt to continuously remove the solid matter during the operation of continuous-process apparatus, however, they are not effective in removing material clogging the filter member. As a consequence of this inherent disadvantage of the usual centrifuges of this type, their effectiveness in extracting the water is substantially lowered as the solid matter accumulates on the filter member thereby reducing the efficiency of the apparatus and increasing the cost of operation.

It is the primary object of this invention to provide a centrifugal separator having a rotary drum with a substantially liquid impervious, solids collecting, peripheral wall member to extract the solid matter from a fluid contained within the rotary drum.

It is also an object of this invention to provide a centrifugal separator having a rotary drum with the peripheral wall thereof comprising a plurality of annularly disposed, adjacently contacting rollers that are continuously rotated about their axes as the drum is revolved, thereby continuously extracting the solid matter from the fluid centrifugally thrown against the inner peripheral wall and retaining the separated liquid within the drum wherein it is permitted to flow freely downward by gravitational force.

Another object of this invention is to provide a centrifugal separator having a rotary drum with the peripheral wall thereof comprising a plurality of rollers in contacting engagement continuously rotated about their axes as the drum is revolved acting as a substantially liquid impervious, solids collecting member in extracting solid matter from a fluid that is inherently self-cleaning as the extracted solid matter carried to the outer peripheral wall of the drum by the rollers is dislodged therefrom by centrifugal force and deposited in a collector enclosing the rotary drum.

A further object of this invention is to provide a centrifugal separator having a rotary drum wherein the solid matter extracted from the fluid and deposited in a collector enclosing the rotary drum is removed therefrom by a scraper for subsequent disposal in any convenient manner.

A centrifuge constructed in accordance with this invention is provided with a rotary drum having a substantially liquid impervious, solids collecting peripheral wall mounted for rotation about a vertical axis within a circumferentially enclosing collector. The peripheral wall of the rotary drum comprises a plurality of vertically disposed rollers circumferentially arranged therein. Each roller is in contacting engagement with the adjacent rollers forming a continuous peripheral wall impervious to the flow of a fluid with entrained solid matter introduced within the drum. Revolving the drum by a suitable driving means causes the fluid to be centrifugally thrown against the rollers where the solid matter will be separated and accumulated on the inwardly facing portions. A driving means is also provided for rotating the rollers about their axes as they revolve about the vertical drum axis. The rollers are constructed with resilient surfaces permitting the solid matter to deform the roller surfaces sufficiently to be drawn between a pair of cooperatively rotating rollers and extracted from within the rotary drum, and subsequently deposited by centrifugal force in the enclosing collector. Liquid retained within the drum will flow downwardly by gravitational force to the bottom of the drum where openings are provided for its escape into a suitable collecting chamber. Solid matter accumulated by the circumferentially enclosing collector is also continuously removed by a revolving scraper and deposited in a suitable receptacle.

The various objects and advantages of this invention will be readily apparent from the following detailed description thereof and the accompanying illustrative drawings in which:

FIG. 1 is a perspective view of a centrifugal separator embodying the present invention;

FIG. 2 is a vertical section taken along line **2—2** of FIG. 1;

FIG. 3 is a horizontal section taken along line **3—3** of FIG. 2;

FIG. 4 is a horizontal section taken along line **4—4** of FIG. 2;

FIG. *4a* is an enlarged detail of a section of FIG. 4 showing the extracting action of the rollers;

FIG. 5 is a horizontal section taken along line **5—5** of FIG. 2;

FIG. 6 is an enlarged sectional detail of a roller and its mounting structure;

FIG. 7 is a plan view of a modified form of centrifugal separator embodying the present invention;

FIG. 8 is an enlarged vertical transverse sectional view taken substantially along line **8—8** of FIGURE 7 and FIGURE 10;

FIG. 9 is a transverse sectional view taken along line **9—9** of FIGURE 10;

FIG. 10 is a longitudinal sectional view taken along line **10—10** of FIGURE 9;

FIG. 11 is a sectional view taken along line **11—11** of FIGURE 9; and

FIG. 12 is a sectional view taken along line 12—12 of FIGURE 9.

The external structure of the centrifuge embodying the principles of this invention, as is best shown by FIG. 1, comprises a vertically disposed cylindrical housing **10** with a closed lower end supported in an appropriately elevated position on four vertically extending standards **11** secured to the lower end thereof. An inverted frusto-conical shaped liquid accumulator **12** extending downwardly from the lower end of the housing **10** terminates in a cylindrical discharge pipe **13** at the lower end thereof for connection to an appropriate disposal system. A cylindrical sludge outlet pipe **14** also extends downwardly from the lower end of the housing **10** for connection to an associated disposal system. Such disposal systems are not pertinent to this invention and, therefore, are not illustrated. The open upper end of the housing **10** is provided with a cover **15** removably secured to the outwardly extending annular flanged rim **16** of the housing by the bolts **17**. A cylindrical fluid inlet pipe **18** enters the housing **10** through a hollow centriguge drum shaft **19** journaled in the upper bearing **20** which is secured to the cover **15** by the bolts **21**. The fluid inlet pipe **18** is, of course, connected to the apparatus of a process producing a fluid containing solid matter that must be separated before disposal. The source of the fluid is not illustrated as it may be any type of process such as, for example, coal washing. Rotative power required by the centrifuge may may be supplied by any suitable power means. In this instance, an electric motor **22** is conveniently adaptable for this purpose and is mounted on the housing **10** by means of an appropriate motor base **23**.

The primary internal structure of the centrifuge, as is best shown by FIG. 2, consists of a rotary drum **24**, mounted on the vertically disposed drum shaft **19** for rotation in a horizontal plane within the housing **10**. In addition to the upper bearing **20**, a lower bearing **25**, in which the shaft **19** is also journalled, is secured to the horizontal bottom plate **26** of the housing by the bolts **27**. Antifriction bearings are utilized which are adapted to carry an axially directed load as well as the usual radial load. For convenience of manufacture, the drum shaft **19** is constructed in two sections, a lower section **28** and an upper section **29**. The lower section **28** is an elongated cylindrical shaft extending upwardly through the bearing **25** and terminating at an intermediate point within the drum **24**. Two retaining collars, **30** and **31**, are fixed to the lower section **28** at either side of the bearing **25** for maintaining the section in the proper vertical position. That portion of the section **28** extending upwardly from the retaining collar **31** is of a reduced diameter forming an annular shoulder **28*a*** parallel to the upper horizontal surface of the collar **31**. The upper section **29** is an elongated cylindrical tube extending downwardly through the bearing **20** having an internal diameter of appropriate size to coaxially receive the reduced diameter portion of the lower section **28** inserted therein. Section **29** extends through the drum **24** with the lower end thereof in contacting engagement with the annular shoulder **28*a***. Although the drum shaft is fabricated in two sections for convenience of manufacture, the sections are rigidly secured together by, for example, a press fit to provide a unitary shaft construction. Two retaining collars, **32** and **33**, are also fixed to the upper end of the section **29** at either side of the bearing **20** to further aid in maintaining the vertical position of the drum shaft **19**. As previously indicated, the non-rotating inlet pipe **18** enters the centrifuge through the upper section **29** of the drum shaft with which it is coaxially aligned but has sufficient clearance relative to the inner wall of the section to avoid interfering with the rotation thereof. The pipe **18** terminates a distance above the upper enclosed end of the lower section **28** but within the rotary drum **24**. A plurality of fluid discharge orifices **34** are formed in the cylindrical wall of upper section **29** between the opposed ends of the pipe **18** and the lower section **28** permitting communication of the entering fluid with the drum **24**.

Two circular rotor plates **35** and **36** form the lower and upper ends, respectively, of the rotary drum **24**. The rotor plate **35** is secured by the bolts **37** to a central hub **38** fixed on the lower marginal end of the drum shaft section **29** by means of the keys **39** (FIG. 5). The rotor plate **36** of a larger diameter than the rotor plate **35** is similarly fixed on the shaft section **29** by a central hub **40** keyed thereto and secured to the plate **36** by the bolts **41** but is spaced upwardly on the shaft section **29** from the rotor plate **35** to accommodate the rollers **42** vertically disposed therebetween. An annular ring **43**, herein termed a weir plate, is secured to the periphery of the rotor plate **35** and extends outwardly to the same radius as the rotor plate **36** and also extends inwardly over the rotor plate with the inner circumferential edge **44** thereof tapered downwardly and outwardly (FIG. 6). Intermediate the inner and outer circumferential edges of the weir plate **43**, an integrally formed, depending annular flange **45** spaces the weir plate upwardly from the rotor plate **35**. A plurality of cap screws **46** extending through the rotor plate **35** engage cooperatively threaded holes appropriately spaced in the annular flange **45**. A plurality of liquid discharge orifices **47** are spaced in the periphery of the rotor plate **35** within the annular area of the rotor plate coextensive with the inwardly extending portion of the weir plate **43**. The orifices **47** are circular openings in the rotor plate **35** with short cylindrical tubes **48** secured therein extending a given distance downwardly from the rotor plate **35**. To facilitate assembly of the rotary drum **24**, a plurality of circular hand holes **49** in the rotor plate **35** are spaced in an annular ring intermediate the hub **38** and the weir plate **43**.

Rigidity of the rotary drum **24** is increased by providing a plurality of vertically disposed, cylindrical spacer tubes **50** (FIG. 2) having tie rods **51** extending coaxially therethrough interconnecting the lower rotor plate **35** and weir plate **43** and the upper rotor plate **36**. The tubes **50** spaced around the periphery of the drum are interposed between the rotor plate **36** and weir plate **43** with the opposite ends in contacting engagement with the respective plates. The tie rods **51** extend through the tubes **50** and the rotor plate **36** and the weir plate **43** and by means of the associated nuts **52** threaded on the outer ends thereof rigidly clamp the rotor and weir plates to the spacer tubes **50**.

The solids collecting peripheral wall of the rotary drum **24** consists of a plurality of vertically disposed rollers **42** rotatably mounted in the periphery of the drum. Each roller **42** (FIG. 6) is fixed on a tubular shaft **53** journalled at either end in bearings **54** having nylon bushings **55** secured to the rotor plate **36** and the weir plate **43** by the cap screws **56**. Each bearing **54** is an elongated cylinder extending through coaxial openings in the rotor plate and weir plate with an annular mounting flange **57** integrally formed intermediate the ends thereof. The bearings **54** are positioned on their respective plates with the mounting flanges **57** in contacting engagement with the inwardly facing surfaces thereof. The peripheral edge **58** of the mounting flange **57** is tapered outwardly and toward the surface of the associated rotor plate **36** or weir plate **43**. Each roller **42** is constructed with a rigid core consisting of an elongated cylindrical tube **59** secured to flanged hubs **60** located at the ends thereof which are in turn fixed to the shaft **53**. The annular flanges **61** disposed at the ends of the hubs **60** are positioned adjacent the inwardly facing ends of the bearings **54** forming annular cavities with the cylindrical surfaces of the bearings and the parallel surfaces of the flanges **57**. The surfaces of the cylindrical tubes **59** are covered with a resilient material, such as rubber, that is securely bonded thereto forming a cylindrical roller casing **62**. The roller casing

62 extends axially outward from the ends of the tube 59 to the weir plate 43 and the rotor plate 36 and is in contacting engagement therewith. The inner surface of the axially extending end portions of the casing 62 are formed to cooperatively engage the surfaces of the associated portions of the bearings 54 and the mounting flanges 57. For this purpose, the marginal ends of the inner wall surface of the casing 62 associated with the mounting flanges 57 is tapered similarly to the peripheral edges 58 thereof providing a contacting surface. Inwardly of the tapered surface, an annular flange 62*a* integrally formed with the inner wall surface of the casing 62 extends radially inwardly to fill the cavity defined by the hub flange 61, the outer cylindrical surface of the bearing 54 and the flange 57 providing a contacting surface therewith. The casing 62, although in contacting engagement with the surfaces of the rotor plate 36, weir plate 43, flanges 57 and bearings 54, is not secured thereto permitting rotation of the rollers while forming a fluid impervious seal. The tubular shafts 53 extend upwardly from the bearings 54 in the rotor plate 36 sufficiently far enough to accommodate the pinion gears 63 fixed thereto, as is shown in FIGS. 2 and 4. The lower ends of shafts 53 are held by the retaining collars 64. As adjacently disposed rollers are contra-rotating, driving one roller through the pinion gear 63 is effective in driving the adjacent rollers in frictional contact therewith requiring that pinion gears be fixed to every other shaft 53 only. The retaining collars 64 are secured to the remaining shafts 53. At the lower end of each shaft 53 extending downwardly from the bearings 54 in the weir plate 43, a retaining collar 64 is fixed completing the securing of the roller assembly to the rotary drum 24. Lubrication of the roller shafts 53 is facilitated by the insertion of a lubricating fitting 65 in the upper end of the tubular shaft permitting communication of lubricant with the interior of the shaft. A plug 66 inserted in the lower end of the shafts completes the sealing of the shaft. Radially drilled holes 67 in the shafts and opening to the surfaces thereof in the region of the bearings 54 permits lubricant to communicate therewith.

Within the interior of the drum 24 is a horizontally disposed, circular partition plate 68 secured by the bolts 69 to a central hub 70 keyed to the drum shaft section 29. The plate 68 is positioned on the shaft section 29 immediately below the lowermost orifices 34 located therein. The plate 68 extends outwardly substantially to the rollers 42 but has sufficient clearance therebetween to permit the fluid thrown centrifugally outward over the upper surface of the plate to flow downwardly along the inwardly facing roller surfaces.

A pulley 771 of the multiple V-belt type is keyed to the shaft section 29 and spaced a distance upwardly from the hub 40. An associated drive pulley 72 keyed to the upwardly extending shaft 22*a* of the vertically disposed motor 22 is aligned with the pulley 71. Flexible coupling of the pulleys 71 and 72 is completed by a set of V-belts 73 encircling them and passing through an opening 10*a* appropriately located in the vertical wall of the housing 10. The respective sizes of the pulleys 71 and 72 are of course determined by the required speed of the rotary drum 24 relative to the motor speed. Rotatably mounted on the shaft section 29 between the hub 40 and the pulley 71 is an elongated cylindrical sleeve 74. A cylindrical nylon bushing 75 coaxially inserted within the sleeve 74 and a nylon thrust washer 76 encircling the shaft section 29 between the hub 40 and the sleeve 74 provide the necessary antifriction bearing surfaces. A pulley 77 of the multiple V-belt type and of the same pitch diameter as the pulley 71 is keyed to the upper end of the sleeve 74 adjacent the pulley 71. A gear 78 fixed to the lower end of the sleeve 74 by the keys 78*a* (FIG. 3) is aligned with the pinion gears 63 for the proper intermeshing of their respective teeth. The diameter of the gear 78 is substantially larger than that of the pinion gears 63 with the respective diameters determined by the required rotational speed of the rollers 42. As previously indicated, the pinion gears 63 are secured only to every other roller shaft 53 with the remaining rollers 42 rotated in the opposite direction through the frictional contact between adjacent rollers. A second drive pulley 79 associated with pulley 77 of the roller drive train is also keyed to the shaft 22*a* of the motor but has a slightly smaller diameter relative to the other drive pulley 72. A second set of V-belts 80 extending through the opening 10*a* in the housing 10 and encircling the pulleys 79 and 77 completes the flexible coupling of the motor 22 to the rollers 42 through the roller drive train.

Within the housing 10 and concentrically mounted on the bottom plate 26 relative to the rotary drum 24 is a frusto-conical shaped liquid collector ring 81. The conical wall thereof tapers inwardly and upwardly terminating adjacent the lower horizontal surface of the rotor plate 35 with the lower marginal edge rigidly secured to the bottom plate 26 by, as for example, welding. The diameter of the open top of the ring 81 is slightly larger than that of the circle described by the revolving liquid discharge tubes 48 extending downwardly from the rotor plate 35 and terminating within the ring 81 below the upper marginal edge thereof. An annular ring of circular openings 82 provided in the bottom plate 26 intermediate the bearing 25 and the collector ring 81 permits the water collected therein to flow freely downward into the externally mounted, inverted frusto-conical liquid accumulator 12 and thence outward through the discharge pipe 13 into a disposal system. The diameter of the upper peripheral edge of the accumulator 12 disposed adjacent the bottom plate 26 is sufficiently large to enclose the opening 82. An outwardly extending annular flange 83 integrally formed around the upper periphery of the accumulator 12 and in contacting engagement with the bottom plate 26 secures the accumulator to the base plate by a plurality of bolts 84 extending therethrough.

Solid matter deposited on the inner wall of the cylindrical housing 10 is dislodged by a revolving scraper 85 which also aids in the removal of the solid matter from the housing. The scraper 85 comprises a plurality of vertically disposed blades 86 spaced radially in an annular ring between the rotary drum 24 and the housing 10 with annular members 87, 88 and 89 interconnecting the upper and lower ends 90 and 91 thereof. The blades 86 are plates of a generally rectangular shape with the outer edges 92 thereof disposed adjacent the inner wall of the housing 10 and extend upwardly from the bottom plate 26 terminating above the upper rotor plate 36. Interconnecting the upper ends 90 is the annular member 87 comprising a horizontally disposed web 87*a* rigidly secured to the blades 86 and a vertical flange 87*b* integrally formed therewith extending upwardly from the outer periphery of the web 87*a*. The width of the upper end 90 is, of course, limited by the annular space between the rotary drum 24 and the housing 10 with the inner vertical edge 93 thereof spaced from the drum. The lower end 91 is extended radially inward with the horizontal lower edge 94 thereof disposed adjacent the bottom plate 26. An L-shaped notch is formed in the inwardly facing edge of the lower ends 91 for reception of the U-shaped annular member 88 and interconnecting the blades 86 comprising a vertically disposed web 88*a* rigidly secured to the blade 86 and two integrally formed, horizontally disposed flanges 88*b* and 88*c* extending inwardly from the marginal edges of the web 88*a*. The lower flange 88*b* spaced upwardly from the horizontal edge 94 is also secured to the portion of the blade 86 extending inwardly to the collector ring 81 terminating in a correspondingly tapered edge. The inwardly facing edge of the lower end 91 tapers upwardly from the junction of the web 88*a* and the upper flange 88*c* intersecting the vertical edge 93 of the upper end 90 at a point slightly below the weir plate 43. A plurality of frusto-conical horizontally disposed rollers **95** spaced around the outer periphery of the collector ring **81** extend outwardly therefrom into the channel member **88** and support the revolving scraper **85**. The rollers **95** tapered downwardly and outwardly for contacting engagement with the cooperatively tapered inner surface of the upper flange **88c** are journalled on shafts **96** secured to the outer surface of the ring **81**. The annular channel member **89** extending around the periphery of the scraper **85** opening outwardly is rigidly secured in appropriately sized notches located in the vertically disposed edges **92** interconnecting the lower ends **91** of the blades **86**. A belt **97** extending substantially around the periphery of the scraper **85** in the channel member **89** and outwardly through a pair of openings **10b** in the housing flexibly couples the scraper **85** to the pulley **98** fixed on the downwardly extending shaft **22b** of the motor by the key **99**. The area of contact of the belt **97** with the channel member **89** and the pulley **98** is increased by two idler pulleys **100** journalled in brackets **101** externally mounted on the housing **10** to displace the belt **97** inwardly of the normal tangential position.

A circular opening **102** is formed in the bottom plate **26** with a diameter substantially equal to the distance between the housing **10** and the collector ring **81**. The solid matter discharge pipe **14** encircles the opening **102** and is secured to the bottom plate **26**.

In a centrifugal separator constructed in accordance with this invention, a quantity of fluid with entrained solid matter contained within a rotary drum is revolved, thereby creating centrifugal forces causing the solid matter to separate from the fluid leaving a clean liquid which, as an example, may be water. The fluid is thrown against the periphery of the rotary drum where the solid matter accumulates displacing the liquid inwardly permitting the separated solid matter and liquid to be separately withdrawn from the centrifuge for the subsequent disposal thereof. The fluid to undergo the separating process enters the rotary drum **24** through the inlet pipe **18** coaxially inserted in the hollow upper end of the drum shaft **19** and the orifices **34** in the upper shaft section **29** communicating with the interior of the drum as is indicated by the flow directional arrows in FIG. 2. The drum **24** is revolved at a high speed, preferably about 1000 r.p.m., by the motor **22** and the drive pulley **72** connected by the belts **73** to the pulley **71** causing the fluid to be centrifugally thrown outwardly over the partition plate **68** toward the inwardly facing surfaces of the rollers **42**. The partition plate **68** assures that fluid entering the upper portion of the drum through the orifices **34** will be thrown outwardly to the rollers **42** before it has an opportunity to drop to the bottom rotor plate **35**. Liquid is prevented from flowing outward through the peripheral wall of the drum as the resilient surfaces of adjacently disposed, contacting rollers **42** form a liquid impervious continuous peripheral wall as is best shown by FIG. 4. The liquid impervious sealing of the rollers **42** to the rotors of the drum is completed by the axially extended ends of the casing **62** contacting the bearings **54**, the flanges **57**, the tapered peripheral surfaces **58** of the flanges, the rotor plate **36** and the weir plate **43**. Centrifugal force causes the solid matter to accumulate on the surfaces of the rollers **42** displacing the liquid inwardly where it may flow downwardly over the inwardly facing roller surfaces through the space between the partition plate and the rollers where further separation occurs. The separation process is diagrammatically illustrated by FIG. *4a* where the dotted portions A represent the solid matter. The relatively clean liquid flows downwardly to the inwardly extending portion of the weir plate **43** where it will accumulate and flow over the tapered edge **44** and enter the space between the weir plate **43** and the lower rotor plate **35** (FIGS. 2 and 6). Communication of the downwardly flowing fluid directly with the liquid discharge orifices is prevented by the inwardly extending portion of the weir plate **43** permitting further separation of the solid matter as the liquid must flow inwardly before flowing over the edge **44** of the weir plate. Solid matter also reaching the weir plate **43** would be prevented from entering the orifice **47** by the inwardly projecting portion of the weir plate as the centrifugal force will prevent the inward movement thereof. The liquid accumulated between the rotor plate **35** and the weir plate **43** flows downwardly through the liquid discharge orifices **47** and associated tubes **48** into the collector ring **81**. The inwardly tapered wall of the collector ring **81** prevents the centrifugally thrown liquid from being forced upwardly and will direct it downwardly to the plate **26** where it may freely flow through the openings **82** therein to the accumulator **12** and thence through the discharge pipe **13** into a disposal system.

Removal of the separated solid matter that has accumulated on the inwardly facing surfaces of the rollers **44** from within the drum is accomplished by rotating the rollers. The motor **22** through the pulley **79** and the belts **80** drives the pulley **77** at a slower speed due to the smaller diameter of the pulley **79**. The gear **78** intermeshed with the pinion gears **63** is therefore rotated at a slower speed than the rotary drum **24** although in the same direction. Revolving the drum **24** causes the gears **63** to be turned by the slower rotating gear **78**. It has been found preferable to rotate the rollers **42** at about 10 r.p.m. and, therefore, the respective sizes of the gears and pulleys in the roller drive train are determined accordingly. Only every other roller **42** is driven through the gear train and the intermediately positioned rollers are driven by frictional contact with the adjacent driven rollers. As two adjacent contacting rollers **42a** and **42b**, as shown by FIG. *4a*, rotate in an outward direction, the next pair of rollers **42b** and **42c** rotate in an inward direction. Solid matter accumulated on the inwardly facing surfaces of the rollers is carried toward the converging surfaces of a pair of outwardly turning rollers, **42a** and **42b**, and drawn therebetween to the outer periphery of the drum **24** where the extracted solid matter is thrown outwardly by centrifugal force and deposited on the inner wall of the housing **10**. Solid matter accumulated between the diverging surfaces of a pair of inwardly turning rollers, **42b** and **42c**, is embedded in the resilient casing **62** by centrifugal force thereby providing adequate frictional contact to permit the solid matter collected therebetween to be carried inwardly by the rollers against the outwardly directed centrifugal forces to the converging surfaces of an outwardly turning pair of rollers, **42a** and **42b**. The resilient casings **62** of the rollers **42** facilitate the extraction of the solid matter without permitting the liquid to escape as the solid matter will deform the casings **62** and be embedded therein leaving the adjacent roller surfaces in a contacting relationship substantially impervious to the outward flow of the liquid. In FIG. *4a*, the deformation of the roller surfaces is exaggerated for illustrative clarity. As the roller surfaces carrying the embedded solid matter are rotated to an outwardly facing position, the resilient casings return to their normally annular shape thereby releasing the solid matter, further aided by centrifugal force. The pairs of inwardly turning rollers **42b** and **42c** of course always remain in a contacting relationship preventing the outflow of liquid or solid matter.

The moist solid matter deposited on the inner surface of the housing **10** tends to remain in position. The revolving scraper **85** is therefore utilized to dislodge the solid matter allowing it to drop to the bottom plate **26** where it is pushed around the periphery of the housing **10** by the lower ends **91** of the blades **86** to the opening **102** and is removed through the discharge pipe **14**. In the illustrated embodiment, the scraper **85** is revolved by the motor **22** through the belt **97** flexibly coupling the drive pulley **98** thereof to the annular channel member **89**, however, a separate driving motor may be advantageously utilized.

In FIGURES 7–12, inclusive, there is illustrated a modified form of centrifuge embodying the principles of this invention. In this embodiment, the centrifuge machine is shown as being disposed so that its axis is horizontal but it is to be understood that it could function equally as well if the axis were disposed vertically. This form of the centrifuge also employs as the outer peripheral annular solid-collecting wall a plurality of rollers disposed in yieldable sealing contact relationship.

The general arrangement of this modified centrifuge is illustrated best in FIGURES 7–10. It comprises a horizontally disposed centrifuge cylinder or drum **200** (see FIGS. 9 and 10). This drum **200** is keyed on a shaft **201** which is supported in a horizontal position in suitable bearings **202** on the upper ends of the opposed upright standards or supports **203**. The shaft **201** projects from each end of the drum **200** and is rotatably mounted in the bearings **202**, the opposite ends of the shaft projecting from these bearings. The standards **203** are carried on a base structure **204** and it will be noted from FIGURE 9 that located along the side edges of this base structure are the upstanding supports **205** which carry a drum-like casing or housing **206**. This casing **206** is concentric with the drum **200**, it being understood that the drum will rotate within the casing which is stationary since it is fixed to the supports **205** in a suitable manner. The casing **206** (FIGURE 10) is of greater axial extent, as well as diameter, as compared to the drum **200** and it will be noted that the shaft **201** projects through the central openings **207** in the ends of the casing, the bearings **202** and associated standards **203** being located just outside the ends of the drum-like casing. Each end of the drum-like casing **206** is partially closed by the inwardly extending, peripheral flange **208** within which the openings **207** are formed.

As will be explained more in detail later, the solids removed by the centrifuge action of the drum **200** are collected in the casing **206** and are removed therefrom through a radially extending discharge spout or outlet **210** which extends the full length of the casing at the lower side thereof. These solids or sludge may be carried to a suitable location away from the centrifuge by any suitable type of conveying means.

The shaft **201** may be driven by any suitable driving arrangement but in the example shown in FIGURE 7, there is illustrated a multiple V-belt pulley **211** keyed on the one end thereof which is driven by means of the multiple V-belt **212** from a second multiple pulley **213** that is driven by a suitable electric motor **214** carried by the base **204**. The drum **200** is keyed on the shaft **201** so that it will be driven with the shaft.

The detailed structure of the drum **200** is illustrated best in FIGURES 9–12. The outer solid-collecting annular or peripheral wall of the drum **200** is formed by a roller arrangement, as previously indicated, which embodies a plurality of rollers disposed in yieldable sealing contact relationship. The solid-collecting wall formed by this roller arrangement is designated generally by the reference character **215** and will be described in detail hereinafter. The substantially closed ends of the drum **200** are formed by the rotor plates or end plates **216** and **217** (FIGURE 10) which are disposed transversely of the shaft **201** and at right angles thereto. Each plate **216** or **217** is carried by a hub **218** which is keyed to the shaft **201** for rotating therewith. The plate **216** is provided with a plurality of inlet openings **219** disposed in an annular row of angularly spaced openings just radially inwardly of the solid collecting roller wall **215**. Through these inlets **219**, the mixture of solid and liquid to be separated is adapted to enter into the drum **200**. Surrounding this annular row of inlet openings **219** is a directing baffle **220** which is attached to the outer surface of the end wall **216** and which is of frusto-conical form having an angular lip **221** on its outer edge. A mixture feed or supply passageway **222** leads through the adjacent standard **203** and terminates in an elbow **222*a*** which will direct the mixture into the annular frusto-conical baffle **220**. The directing elbow **222*a*** will be stationary, during operation of the machine, but the baffle **220** will be rotating with the drum **200** at this time. Consequently, the mixture to be separated will be directed by centrifugal force outwardly along the outwardly flared baffle and through the inlet openings **219** into the drum **200**.

The plate **217** at the opposite end of the drum **200** (FIGURES 9 and 10) is provided with a skimmer lip which is on a ring **225** that is secured to the inner surface of the plate **217**, just radially inwardly of the solid collecting roller wall **215**. Located just inwardly of the skimmer **225** is an annular row of angularly spaced liquid outlet openings **226**. Connected to these outlets **226** are conducting pipes **227** which lead radially outwardly so that centrifugal force of the rotating drum **200** will aid in directing cleaned liquid outwardly from the drum. These pipes **227** have outlet nozzles **228** which extend outwardly parallel to the drum axis through ring **229** that rotates with the drum. This ring **229** overlaps an annular slot **230** provided between the flanges **231** and **232** which are attached to the adjacent inwardly directed flange **208** and the outer peripheral wall respectively of the casing or housing **206**. With this arrangement, there is provided a stationary annular collecting trough or chamber **235** in which the cleaned liquid is collected as it is discharged from the separating drum **200**. Leading substantially tangentially from this annular collecting chamber **235** (FIGURE 8) is a liquid outlet spout **236** that extends from one side of the base **204** and which may be connected to a conduit to conduct the cleaned liquid to a suitable location.

The solid matter that passes through the solid-collecting peripheral roller wall **215** deposits on the annular wall of the surrounding casing **206**. It is dislodged from this wall by means of a revolving scraper unit **240**, shown best in FIGURES 8, 9 and 10, which surrounds the centrifuge drum **200** and is disposed radially outwardly of the wall **215** and in direct association with the annular wall of the casing **206**. The scraper **240** comprises a plurality of angularly spaced scraper blades **241** which extend longitudinally along the wall of the casing **206**. The opposed ends of these blades are fixed to the mounting rings **242**. These rings are of angular cross section and are supported for revolving movement by means of the rollers **243** which are mounted in angularly spaced relationship on the inwardly extending annular end flanges **208** of the casing **206**. Thus, there is provided an annular revolving scraper and conveyor which will scrape the solid material from the annular inner surface of the casing **206** and will carry it around the annular casing wall until it is discharged through the radial bottom outlet **210**.

The scraper unit is revolved by means of a pair of endless chains **244** which cooperate with the respective rings **242**. Each of these chains extends around the outwardly directed horizontal flange of the ring and passes around a driving sprocket **245** which is shown in FIGURES 7 and 8. The pair of sprockets **245** are keyed on a longitudinal shaft **246** which is mounted in bearings in longitudinal spaced extensions or guards **247** projecting from the annular casing **206** (FIGURES 7 and 8). It will be apparent that each chain **244** will enter and leave the associated extension **247** through a suitable slot in the annular wall of the casing **206**. The shaft **246** is driven by a sprocket and chain drive **248** (FIGURE 7) from an electric motor **249** mounted on the casing **206** adjacent the housing extensions **247**. Associated with each chain **244**, within each housing extension **247**, is an idler sprocket **250** and an adjustably mounted take-up sprocket **251** but the details of these latter structures are not illustrated as they are not important to this invention. Any other suitable driving arrangement may be provided for the scraper unit **240**.

It will be noted (FIGURE 10) that the outer edges of the rotor end plates **216** and **217** overlap the outwardly extending radial flanges of the rings 242. It will also be noted that these latter flanges overlap radially inwardly extending rings or flanges 252 which are mounted on the inner surface of the outer annular wall of the casing 206. Thus, with this arrangement, the end plates 216 and 217, the rings 242 and the rings 252 will be relatively revoluble but they will provide a substantially tight annular joint which, in conjunction with centrifugal force, will prevent the solids from leaving the annular space or chamber 255 except at the discharge outlet 210.

As previously indicated, the solid-collecting peripheral wall 215 is in its basic arrangement similar to that previously described. However, in its specific roller structure, it is somewhat different from the roller structure previously described. This particular roller structure is illustrated best in FIGURES 9–12, inclusive. It is made up of a plurality of large positively-driven rollers 256 which are disposed in annularly spaced relationship and which are fixed radially in the drum 200 and a plurality of radially floating rollers 257 which are disposed for cooperation with the spaces 256*a* between pairs of adjacent rollers 256. All of these rollers are disposed for rotation about horizontal axes between the end plates 216 and 217, the axes being in parallel relationship with each other and with the axis of the shaft 201. The positively-driven rollers 256 are all driven in the same direction and, upon rotation of the drum 200, will frictionally engage the rollers 257 therebetween to drive them in an opposite direction.

Each of the rollers 256, as shown in FIGURES 11 and 12, is of a structure somewhat similar to the rollers previously described and comprises a cylindrical metal tube 258 which is covered by a tubular covering 259 of deformable resilient material, such as rubber, that is securely bonded thereto. The end of the roller adjacent each end plate 216 or 217 is renewable and therefore is made as a separate ring consisting of a metal sleeve extension 258*a* and the resilient cover extension 259*a*, the members 258*a* and 259*a* being formed as separate rings. The metal sleeve 258 is carried by an inner bearing disc 260 and an axially spaced outer bearing member 261 on a stub shaft 262 coaxial with the roller. The bearing 260 is fixed to the sleeve 258 and is rotatable on the shaft 262. The bearing 261 is also fixed to the sleeve 258 but is keyed to the shaft 262. The sleeve extension 258*a* is slidable axially off and on the bearing 261 and the rubber covering 259*a* carried thereby carries a thrust bearing ring or collar 263 at its outer edge which is of nylon or other suitable material to decrease friction between the rubber ring 259*a* and an associated tubular bearing housing 264. It will be apparent that the ring structure at the end of the roller which comprises rings 258*a* and 259*a* and ring 263 can be replaced, if necessary, because of wear. The bearing sleeve 264 is fixed in the associated end plate 216 or 217, the plate 217 being shown in FIGURES 11 and 12, and supports rotatably the outer end of the shaft 262. This sleeve housing 264 may be the housing for a suitable anti-friction bearing which may include the needles or rollers 265, the ends of the housing being closed by suitable sealing rings and plates 266. The shaft 262 extends outwardly through the housing 264 and has a driven gear 267 keyed on its outer projecting end.

Each of the rollers 257 (FIGURE 11) is of smaller diameter than the rollers 256 but is of similar construction in that it includes an inner rigid metal sleeve or core 270 and an outer deformable covering 271. An outer renewable end structure 272 of ring form is provided on the roller adjacent the end plate and this is provided with a thrust collar or ring 273 which is attached to the end of the roller. Instead of the roller being carried by a shaft, it is carried by an axle pin 274 provided at each end thereof. Each pin is mounted in a sleeve or hub 275 on which the sleeve 270 is fixed and the renewable ring 272 is carried by a metal collar 272*a* which is slidable on and off the outer end of the hub 275. The pins 274 at the opposed ends of the rollers 257 extend outwardly through radial slots 279 in the respective rotor end plates 216 and 217 and are provided with heads 276. The radially extending slots 279 are located in angular positions midway between the axes of the roller shafts 262. As previously indicated, the rollers 257 are not positively driven but since they are located with their axes inwardly of and between the axes of the pairs of adjacent cooperating rollers 256, as shown in FIGURE 9, and since the axles 274 are free to float radially outwardly in the slots 279, upon rotation of the drum 200, the rollers 257 will move outwardly into the radial spaces 256*a* between the rollers 256. Each of these spaces 256*a* will be of a width at its narrowest extent, which is less than the diameter of the associated roller 257. Therefore, centrifugal force will, upon rotation of the drum 200, move each roller 257 radially outwardly into the space 256*a* between the cooperating pair of rollers 256, the deformable sleeves 271 and 259 of the respective rollers deforming to permit a tight squeezing action between these three cooperating rollers.

As a safety factor to prevent any possibility of the rollers 257 working radially outwardly through the spaces 256, stop rollers 280 are provided in cooperation with these spaces. Each of these rollers 280 is carried by a spacer rod 281 which also serves as spacing means for the end plates 216 and 217. Each rod 281 has its axis (FIGURE 9) spaced radially outwardly of the axis of the cooperating roller 257 being located parallel to the axes of the adjacent pair of rollers 256 and outwardly of such axes. Each end of the rod 281 is threaded and extends outwardly through an opening 282 (FIGURE 11) in the adjacent end plate. The openings 282 are in radial alignment with the slots 279. The extreme outer end of the rod receives a threaded cap 283 and the nuts 284 are provided on the threaded end within the end plate. Thus, with this arrangement the plates 216 and 217 may be spaced axially accurately and retained in such spaced relationship so as to provide adequate sealing at the ends of the respective rollers 256 and 257 without undue friction and wear. One of the end plates, preferably the plate 216, is splined to the shaft 201 for limited axial movement relative to the other plate to permit this adjustment.

The stop roller 280 (FIGURE 11) comprises an outer cylindrical sleeve 285 of metal which is fixed on a bearing member 286 at each end and is rotatably mounted on the rod 281. Thus, the sleeve 285 can rotate on the pin 281. The rollers 285 are shorter than the other rollers with limited spaces at their ends to permit the limited relative adjustment of the end plates 216 and 217. If the associated roller 257 moves radially outwardly through the space 256*a* into engagement with the roller 280, its radial movement will be stopped by contact therewith but the roller 257 will still be free to rotate resulting in simultaneous rotation of the stop roller 280.

As previously indicated, the spur gears or pinions 267 are driven to rotate the respective rollers 256. These gears are provided at one end only of the rollers 256, being shown at the end adjacent the end plate 217. At the other end, the mounting shaft is similar to the shaft 262 but does not extend from the bearing housing 264 as indicated to the left of FIGURE 10. All of these gears 267 are driven simultaneously in the same direction about their axes as they revolve with the drum 200. Consequently, while the rollers 256 orbit about the central axis of the drum 200 (also the axis of rotation of the shaft or axle 201) upon rotation of the drum 200 about said central axis, each of the rollers 256 will be rotated simultaneously in the same direction about its axes, as illustrated in FIGURE 9.

The drive for accomplishing this is illustrated best in FIGURES 7 and 10. Thus, the end of the main drive shaft 201 opposite to that end where the pulley 211 is disposed, is extended through the adjacent standard 203 and has a spur gear 290 keyed thereto. This spur gear 290 meshes with a spur gear 291 (FIGURE 7) which is carried on a stub shaft **292** that has its axis parallel to the axis of the main drive shaft **201**. This shaft **292** is carried by a bearing **293** on the standard **203**. The inner end of the shaft **292** has keyed thereto a spur gear **294** which meshes with a spur gear **295** that is fixed to a sleeve **296** (FIGURE 10) which is rotatably mounted on the shaft **201**. The gear train comprising the gears **290, 291, 294,** and **295** is such that there will be a differential action which will cause the sleeve **296** to advance and rotate relative to the main drive shaft **201** whenever the shaft **201** is driven. This will result in the rollers **256** being driven about their axes whenever the shaft **201** is rotated to revolve the drum **200**. The drive for the rollers **256** continues through the sleeve **296** and through a plurality of double planetary pinion units **297** angularly spaced on the end plate **217**. Each double pinion unit **297** is rotatably supported by a pin **298** between the end plate **217** and a supporting disc **299** which is rotatably mounted on the sleeve **296**. The sleeve **296** has teeth **296a** on its inner end which engage with the inner section **300** of the planetary pinion unit. The outer section **301** of each planetary pinion unit engages with the inner teeth of a ring gear **302**. This ring gear **302** is carried by a support **304** which is rotatably mounted on the sleeve **296** between the member **299** and the gear **295**. The teeth on the outer surface of the ring gear **302** are in engagement with and drive all the spur gears **267** keyed on the outer ends of the roller shafts **262**.

As previously indicated, during driving of the shaft **201** to revolve the drum **200**, the sleeve **296** will be advanced on the shaft by the differential action of the gear train and this relative rotation of the sleeve **296** on the shaft **201** will drive the pinions **297** about their own axes as they revolve with the drum **200** and travel around the sleeve **296**. Rotation of the pinion units **297** about their own axes produces rotation of the ring gear **302** about the axis of the shaft **201**. Rotation of the ring gear will produce rotation of the gears **267** carried by the roller shafts of the rollers **256** and will produce rotation of these rollers about their own axes. Thus, as the drum **200** is revolved, the rollers **256** are rotated about their own axes.

As the drum **200** revolves about the axis of the shaft **201** and the rollers **256** are driven about their own axes, centrifugal force will, as previously indicated, move the floating rollers **257** out into firm engagement with the cooperating pairs of rollers **256**. Consequently, each roller **257** will be driven by frictional contact with a pair of cooperating rollers **256** and rotation of the roller **257** will be in a direction opposite to that of the direction of rotation of the cooperating rollers **256**.

It will be apparent that with this form of centrifuge, the separating action will be similar to that of the first form described and illustrated in FIGURES 1–6. A quantity of liquid with entrained solid matter will be introduced into the drum through the frusto-conical baffle **220** and the inlets **219** and as the drum **200** is rotated, the liquid is thrown against the periphery of the drum. The solid matter accumulates on the outer peripheral wall **215** as the drum is revolved at high speed. Liquid is prevented from flowing outwardly through the peripheral wall of the drum as the deformable resilient structures of adjacently disposed contacting rollers **256** and **257** form a substantially liquid-impervious, continuous peripheral wall **215**. Furthermore, the sealing against the substantial escape of liquid is also accomplished at the ends of the rollers by their described cooperation with the end plates **216** and **217**. Centrifugal force causes the solid matter to accumulate on the inwardly presented surfaces of the cooperating rollers **256** and **257**, the cleaned liquid flowing to the outlets **226**. The skimmer **225** will serve to skim off the liquid and tend to prevent solids from reaching the liquid outlets **226**.

Removal of the separated solid matter that has accumulated on the inwardly facing surfaces of the rollers **256** and **257** is accomplished by rotating these rollers outwardly about their own axes as previously indicated. These rollers will rotate relatively slow as compared to the speed of rotation of the drum **200**. Solid matter accumulated on each pair of cooperating outwardly rotating rollers **256** and **257** is carried by the converging surfaces of that pair of outwardly turning rollers and drawn therebetween to the outer periphery of the annular roller wall **215** where the extracted solid matter is thrown outwardly by centrifugal force and deposited on the inner surface of the casing **206**. Solid matter accumulated between the diverging surfaces of a pair of inwardly turning adjacent rollers **256** and **257** is embedded in the resilient casing thereof thereby providing adequate frictional contact to permit the solid matter collected therebetween to be carried inwardly by the rollers against the outwardly directed centrifugal forces to the converging surfaces of an outwardly turning pair of rollers. The resilient coverings of the rollers facilitate the extraction of the solid matter without permitting the liquid to escape, the solid matter deforming the casings and being embedded therein, leaving the adjacent roller surfaces in a contacting relationship substantially impervious to the outward flow of the liquid. As the roller surfaces carrying the embedded solid matter are rotated to an outwardly facing position, the resilient coverings spring back to their normally annular shape thereby releasing the solid matter, further aided by the centrifugal force created by the rotating drum. The pairs of inwardly turning rollers **256** and **257** always remain in contacting relationship preventing the outflow of liquid or solid matter between these rollers.

The moist solid matter deposited on the inner surface of the casing **206** will be scraped therefrom by the scraper unit **240** and will be moved to the outlet **210**.

The floating action of the rollers **257** will compensate automatically for any wear on the surfaces of the rollers **256** or **257**. Also, this floating action provides a means for compensating for the different amounts of solids in various liquids separated by the machine. The rollers **257** will adjust themselves automatically in accordance with the build-up of greater or lesser amounts of solids on the cooperating rollers. Furthermore, this automatic adjustment maintains the liquid-impervious nature of the peripheral roller wall. The ends of all these rollers are renewable when necessary.

It is readily apparent from the preceding detailed description that a centrifuge constructed in accordance with both embodiments of this invention effectively extracts the solid matter from the fluid and conveniently removes the separated liquid and solid matter from the centrifuge. This centrifuge greatly improves the performance of centrifugal separators utilized in industry to eliminate the solid matter entrained in waste fluids such as that resulting from a coal washing process as is generally required for the proper disposal thereof. Improved performance results from the separation of the solid matter from the liquid in the natural sequence, that is, the centrifugal force causes the solid matter to accumulate on the periphery of a rotary drum displacing the liquid inwardly. The solid matter is then conveniently extracted from the rotary drum through the peripheral wall which remains impervious to the flow of the liquid. The liquid which is then relative free of the solid matter and retained within the rotary drum will easily flow out of the rotary drum and into a disposal system. Utilization of a plurality of rollers disposed in yieldable sealing contacting relationship as the solids collecting, peripheral wall member is extremely effective in extracting the solid matter from the rotary drum without a concurrent leakage of liquid. Performance is further enhanced by the elimination of turbulence in the liquid at the inwardly facing wall surface that occurs with prior art separators when mechanisms such as scrapers or helical screws are utilized to remove the separated solid matter collected on the peripheral wall of the drum which will return some of the previously separated solid matter to suspension. Turbulence is substantially eliminated in this device as the rollers do not remove the solid matter adjacent the separated body of liquid but remove it from the regions where the liquid is not present, that is, the confined converging spaces between the outwardly turning rollers. Into these converging spaces, the solid matter is thrown by centrifugal force and is carried by the adjacent outwardly turning pairs of rollers so that it is gradually compacted and squeezed between the converging surfaces and is finally moved through and discharged outwardly of the roller wall. Expansion of the yieldable surfaces of the rollers after they move out of contact dislodges any solid matter tending to adhere thereto. These confined spaces are, in effect, substantially equivalent to the closed tubes used in laboratory type centrifugal separators where the separating action is most efficient but the spaces are provided in a commercial type separator where the solids are removed continuously.

Another highly important advantage of a centrifuge constructed in accordance with this invention is that the solids collecting, peripheral wall member is continuously self-cleaning during operation avoiding the necessity of an intermittent cleaning operation, reduced effectiveness between cleaning operations or loss of efficiency resulting from operation of partially clogged filters.

According to the provisions of the patent statutes, the principles of this invention have been explained and have been illustrated and described in what is now considered to represent the best embodiment. However, it is to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. In a centrifugal separator for extracting and separating solids from mixtures of solids and liquids of the type wherein there is provided:

a stationary housing;

a drum member mounted for rotation about its axis within said housing and for receiving a mixture of solids and liquids; said drum member having substantially liquid impervious end walls, having a substantially liquid impervious peripheral wall which comprises an annular series of a plurality of contiguous rotary rollers journalled in and connecting both of said end walls, and having a rotatable shaft positioned at the central axis of rotation of the drum;

an inlet means connected to said drum member to supply a mixture of solids and liquids to said drum member;

outlet means connected to said drum for removing and discharging the separated liquid frōm the interior of said drum member;

drive mechanism connected to said shaft and through it to said end walls and said peripheral wall for rotating said drum member including said shaft, said end walls and said peripheral wall;

means for rotating said rotary rollers each about its own axis;

wherein said plurality of contiguous rotary rollers are journalled in and connect both of said end walls on axes substantially parallel with said central axis and each roller has a resilient deformable surface;

the improvements wherein:

said drum member forms a substantially unobstructed chamber mounted for rotation about its axis within said housing;

said end walls comprise a pair of essentially circular plate members each connected to and parallel with but spaced from the other plate member and both secured to said shaft and with it mounted for rotation of said central axis;

said substantially liquid impervious peripheral wall of said drum member comprises an annular series of said rotary rollers contiguous to each other, extending completely around the periphery of said wall and thus forming the entire peripheral wall of said drum, the roller axes being spaced angularly in a continuous endless path about the drum and there is provided means for sealing the junctions between said rotary rollers and said circular plate members;

said drive mechanism connected to said shaft and through it to said spaced parallel plate member comprising means for rotating at high speed said drum including said unobstructed chamber, said shaft, said spaced parallel plate members and said continuous annular impervious peripheral wall to apply centrifugal force to cause the entire mixture of solids and liquids to be thrown by centrifugal force outwardly toward the inwardly facing surfaces of said annular series of the plurality of contiguous rotary rollers to deliver all of said solids to impinge upon said peripheral wall formed by said rollers;

said means for rotating said rotary rollers comprises drive means connected to at least every other roller for rotating all of said rotary rollers each about its own axis;

said resilient deformable surfaces of the contiguous rotary rollers of said substantially liquid impervious peripheral wall collect the solids which are forced outward by centrifugal force to the inner face of the wall and of said plurality of contiguous rotary rollers and comprise means to engage the solids, to convey the solids under pressure through said continuous annular liquid impervious rotary wall to forcibly release the solids from the rollers by the reflex action of the deformable surfaces, and supplemented by centrifugal force to discharge the solids from the chamber, and each roller closely contacting the two next adjacent rollers substantially throughout their length and thus forming said substantially cylindrical peripheral wall around the circumference of said closed drum; and

there is provided means comprising an independently driven scraper for continuously removing the solids from the housing.

2. A centrifugal separator according to claim 1 in which said peripheral wall comprises groups of three rollers with two rollers of each group being relatively radially fixed between said plate means during rotation of said drum and spaced apart angularly to provide a radial space therebetween and with a third roller of each group being mounted for radial outward movement between said plate means upon rotation thereof, to cover said radial space by contact with said first two rollers, the said converging space between each pair of rollers being provided by said radially movable roller and an adjacent radially fixed roller.

3. A centrifugal separator according to claim 2 in which said means for driving the rollers comprises means for positively driving the two radially fixed rollers of each pair in the same direction, said radially movable roller of each group being driven by contact with the two radially fixed rollers.

4. A centrifugal separator according to claim 2 in which a radially fixed stop roller is provided radially outward from said third roller and substantially within the space between said first two rollers.

5. A centrifugal separator according to claim 4 in which each stop roller is carried by spacer rods connected to said plate means for axial spacing thereof.

6. A centrifugal according to claim 1 in which said drum has plates at each end between which said rollers are mounted and one of said plates is provided with inlet openings, and is provided with a liquid inlet means comprising an exterior annular baffle of frusto-conical form overlying said inlet openings, and the other of said plates is provided with outlet openings and is provided with a skimmer lip adjacent said outlet openings at the inner surface of said plate.

7. A centrifuge according to claim 1 in which said scraper is positioned within said housing and is revoluble around said drum member and around said drum axis and the housing has a radial outlet for solids through the wall of said housing.

8. The centrifugal separator of claim 1 wherein said drive means for said rotary rollers is connected to alternate rollers to rotate said alternate rollers positively in the same direction.

9. The centrifugal separator of claim 1 wherein said drive means connected to the rotary rollers includes a planet gear connected to each of alternate rollers, and a rotary sun gear connected to said planet gears to rotate all of said planet gears in the same direction and to effect the rotation of all of said alternate rollers in the same direction.

10. The centrifugal separator of claim 1 wherein the rotary axes of said annular series of rotary rollers lie in two concentric circles each having a different radius, the first circle of rollers each having its rotary axis floatable radially of the circle, and the second circle of rollers each having its rotary axis radially fixed and each being intermediate and in surface contact with two of the rollers of said first circle and each being positively driven and driving the rollers of the first circle through surface contact.

11. The centrifugal separator of claim 1 wherein the rotary axes of said annular series of rotary rollers lie in two concentric circles each having a different radius, the first circle of rollers having their rotary axes floatable radially of the circle, and the second circle of rollers each having its rotary axis radially fixed and each being intermediate and in surface contact with two of the rollers of said first circle and each being positively driven and driving the rollers of the first circle through surface contact, and there being a third circle of rollers which are smaller than the rollers of the second circle, lying intermediate the rollers of the second circle, and being spaced from the rollers of the second circle to each function as a back up stop for a corresponding roller of said first circle of rollers as it is moved outwardly by centrifugal force.

12. The centrifugal separator of claim 1 in which there is also provided;

the independently driven scraper is a scraping structure surrounding said rotary peripheral wall and including a series of transverse blades each extending generally parallel to the axis of said rollers and a plurality of annular members interconnecting the ends of the blades and;

in which the stationary housing surrounding said scraper structure is formed with a discharge; and

in which there is provided means for independently driving said scraper structure to move the solid material through the discharge.

13. A centrifuge comprising:

a chamber member rotatable about a central axis, having end walls, and having a substantially liquid impervious axially parallel annular wall formed by a plurality of successively contiguous resiliently deformable rollers, every other of said rollers lying spaced from each other in an outer circle and the balance of said rollers lying in an inner circle concentric with the outer circle in a manner to close the spaces between said outer rollers; said rollers forming the impervious annular wall enclosing a substantially unobstructed space for radially containing a mixture of solids and liquid against the centrifugal force due to the rotation of said chamber member;

means for sealing the ends of said rollers against said end walls;

means connected to said chamber member for rotating said chamber member;

means connected to each of said outer rollers for rotating each of said outer rollers on its axis, each of said inner rollers being rotated on its axis by contact with an outer roller;

a housing surrounding said chamber member; and

means comprising a scraper for removing the solids from the housing.

14. A centrifuge according to claim 13 wherein said rollers of the inner circle are floatingly mounted for radial movement outwardly from said axis in response to rotation of said chamber member.

15. A centrifuge according to claim 13 wherein the peripheral surfaces of said successively contiguous rollers are each approximately tangent to a common circle concentric with and inward of said inner circle.

16. A centrifuge according to claim 13 wherein said rollers of the inner circle are floatingly mounted for radial movement outwardly from said axis in response to rotation of said chamber member and wherein said centrifuge also includes stop rollers positioned thereon for limiting the outward radial movement of said inner rollers, each said stop roller being mounted radially outward of an inner roller and substantially within the space between two successive outer rollers.

17. In a centrifugal separator for extracting and separating solids from mixtures of solids and liquids of the type wherein there is provided:

a stationary housing;

a closed drum member forming a chamber mounted for rotation about its axis within said housing and for receiving a mixture of solids and liquids: said drum member having substantially liquid impervious end walls formed by plate members each connected to and parallel with but spaced from the other plate member; having a substantially liquid impervious peripheral wall which comprises an annular series of a plurality of rotary rollers contiguous to each other, each closely contacting the two next adjacent rollers substantially throughout their length extending completely around the periphery of said wall and thus forming said entire substantially cylindrical peripheral wall around the circumference of said closed drum, the roller axes being spaced angularly in a continuous endless path about the drum, the rollers being journalled in and connecting both of said end walls and having inwardly turning convergence between each of the alternate pairs of rollers, and each roller having a resilient deformable surface; and having a rotatable shaft positioned at the central axis of rotation of the drum and having both the plate members secured thereto and with them mounted for rotation about said central axes;

an inlet means connected to said drum member to supply a mixture of solids and liquids to said drum member;

liquid outlet means connected to said drum for removing and discharging the separated liquid from the interior of said drum member;

drive mechanism connected to said shaft and through it to said end walls and said peripheral wall for rotating said drum member including said shaft, said end walls and said peripheral wall; and

means for rotating said rotary rollers each about its own axis;

the improvements wherein:

said chamber is substantially unobstructed;

there is provided means for sealing the junctions between said rotary rollers and said plate members;

said drive mechanism comprises means for rotating said drum at high speed to apply centrifugal force to cause the entire mixture of solids and liquids to be thrown by centrifugal force outwardly toward the inwardly facing surfaces of said annular series of the plurality of contiguous rotary rollers to deliver all of said solids to impinge upon said peripheral wall formed by said rollers and into said converging spaces;

said means for rotating said rotary rollers comprises drive means connected to at least every other roller for rotating all of said rotary rollers each about its own axis;

said resilient deformable surfaces collect the solids which are forced outward by centrifugal force to the inner face of and into the converging spaces of said plurality of contiguous rotary rollers and comprise means to convey the solids under pressure through said continuous annular liquid impervious rotary wall, and, supplemented by centrifugal force, to discharge the solids from the chamber into the space between the housing and the rotating drum member; and

there is provided means comprising an independently driven scraper for continuously removing the solids from the housing.

18. In a centrifugal separator for extracting and separating solids from mixtures of solids and liquids of the type wherein there is provided:

a stationary housing;

a drum member mounted for rotation about its axis within said housing forming a substantially unobstructed chamber for receiving a mixture of solids and liquids, said drum member having substantially liquid impervious end walls; having a substantially liquid impervious peripheral wall which comprises an annular series of a plurality of contiguous resiliently deformable rotary rollers journalled in and connecting both of said end walls on axes parallel with each other;

an inlet means connected to the drum member to supply a mixture of solids and liquids to said chamber;

outlet means connected to said drum for removing and discharging the separated liquid from the interior of said chamber;

drive mechanism connected to said shaft and through it to said end walls and said peripheral wall for rotating said drum member including said chamber, said shaft, said end walls and said peripheral wall;

means for rotating said rotary rollers each about its own axis;

the improvements wherein:

said drive mechanism is connected to said spaced parallel plate members and comprises means for rotating at high speed said drum including said unobstructed chamber, said spaced parallel plate members and said continuous annular liquid impervious peripheral wall to apply centrifugal force to cause the entire mixture of incoming solids and liquids to be thrown radially by centrifugal force directly outwardly through said unobstructed space toward the inwardly facing surfaces of said annular series of the plurality of contiguous rotary rollers to deliver all of said solids to impinge upon and enter into the converging surfaces of the rotary rollers and said peripheral wall formed by said rollers;

sealing means are positioned at the junctions between said rotary rollers and said circular plate members;

said resilient deformable surfaces of the contiguous rotary rollers of said substantially liquid impervious peripheral wall collect the solids which are thrown directly outward by centrifugal force to the inner face of the wall and of said plurality of contiguous rotary rollers and comprise means to engage the solids, to convey the solids under pressure through said continuous annular liquid impervious rotary wall to forcibly release the solids from the rollers by the reflex action of the deformable surfaces, and supplemented by centrifugal force to discharge the solids from the chamber, and each roller closely contacting the two next adjacent rollers substantially throughout their length and thus forming the closed drum around the circumference of said peripheral wall;

said means for rotating said rotary rollers comprises gears connected to alternate rotary rollers for rotating said alternate rotary rollers each about its own axis and all in the same direction of rotation and rotating the intervening rollers through the surface contact of said driven alternate rollers with said intervening rollers thus rotating said intervening rollers in the opposite direction about their own axes in their journals in the spaced parallel plate members, and comprises means for squeezing the solid matter through the peripheral wall continuously and for conveying the solids between the rollers and from the interior of the chamber member at the inner face of said wall through said peripheral wall to the exterior thereof into the space between the peripheral wall and the casing;

the outlet means connected to said chamber is aided by centrifugal force to discharge the separated liquid from the chamber at points within the circumference of the peripheral wall but closely adjacent thereto; and

there is provided means for continuously removing the solids from the housing.

19. In a centrifugal separator for extracting and separating solids from mixtures of solids and liquids of the type wherein there is provided:

a stationary housing;

a drum member mounted for rotation about its axis within said housing forming a substantially unobstructed chamber for receiving a mixture of solids and liquids, said drum member having substantially liquid impervious end walls; having a substantially liquid impervious peripheral wall which comprises an annular series of a plurality of contiguous resiliently deformable rotary rollers journalled in and connecting both of said end walls on axes parallel with each other, and having a rotatable shaft positioned at the central axis of rotation of the drum formed with an axial bore and having an opening from the radial bore into said unobstructed chamber;

an inlet means connected to the bore of said rotatable shaft to supply a mixture of solids and liquids to said bore and to said chamber;

outlet means connected to said drum for removing and discharging the separated liquid from the interior of said chamber;

drive mechanism connected to said shaft and through it to said end walls and said peripheral wall for rotating said drum member including said chamber, said shaft, said end walls, and said peripheral wall;

means for rotating said rotary rollers each about its own axis;

the improvements wherein:

said annular series of said rotary rollers are contiguous to each other, extend completely around the periphery of said wall and thus form the entire peripheral wall of said drum, form converging surfaces, the roller axes being spaced angularly in a continuous endless path about the drum, and there is provided means for sealing the junctions between said rotary rollers and said circular plate members;

said drive mechanism is connected to said axle and through it to said spaced parallel plate member and comprises means for rotating at high speed said drum including said unobstructed chamber, said shaft, said spaced parallel plate members and said continuous annular liquid impervious peripheral wall to apply centrifugal force to cause the entire mixture of incoming solids and liquids to be thrown radially by centrifugal force directly outwardly through said unobstructed space toward the inwardly facing surfaces of said annular series of the plurality of contiguous rotary rollers to deliver all of said solids to impinge upon and enter into the converging surfaces of the rotary rollers and said peripheral wall formed by said rollers;

said means for rotating said rotary rollers comprises drive means connected to at least every other roller for rotating all of said rotary rollers each about its own axis;

said resilient deformable surfaces of the contiguous rotary rollers of said substantially liquid impervious peripheral wall collect the solids which are thrown directly outward by centrifugal force to the inner face of the wall and of said plurality of contiguous rotary rollers and comprises means to engage the solids, to convey the solids under pressure through said continuous annular liquid impervious rotary wall to forcibly release the solids from the rollers by the reflex action of the deformable surfaces, and supplemented by centrifugal force to discharge the solids from the chamber, and each roller closely contacting the two next adjacent rollers substantially throughout their length and thus forming the closed drum around the circumference of said peripheral wall;

the outlet means connected to said chamber is aided by centrifugal force to discharge the separated liquid from the chamber at points within the circumference of the peripheral wall but closely adjacent thereto; and

there is provided means for continuously removing the solids from the housing.

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