Nov. 3, 1936. C. G. HAWLEY 2,059,521

MULTISTAGE CENTRIFUGAL SEPARATION

Original Filed June 13, 1932 4 Sheets-Sheet 1

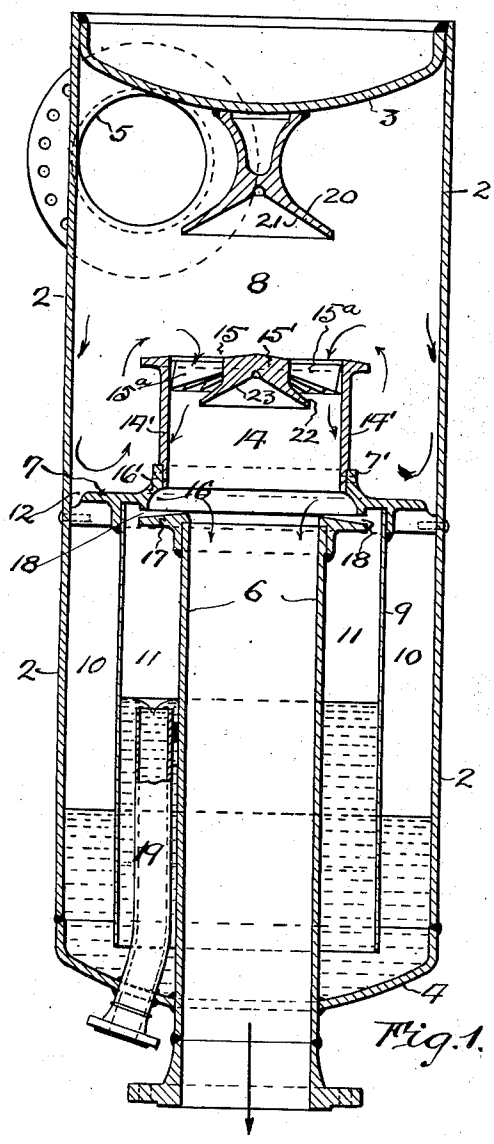


Fig. 1.

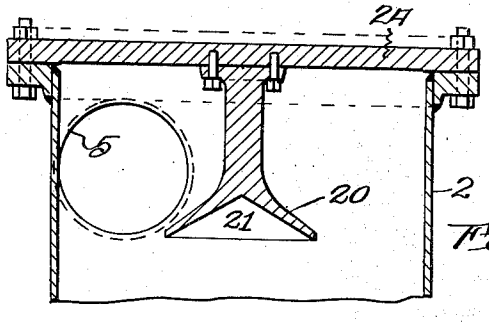


Fig. 2.

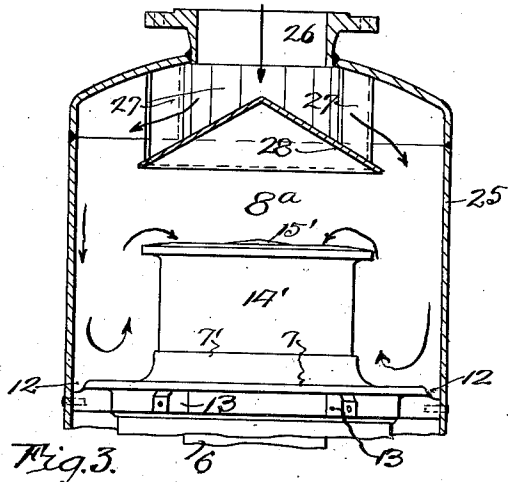


Fig. 3.

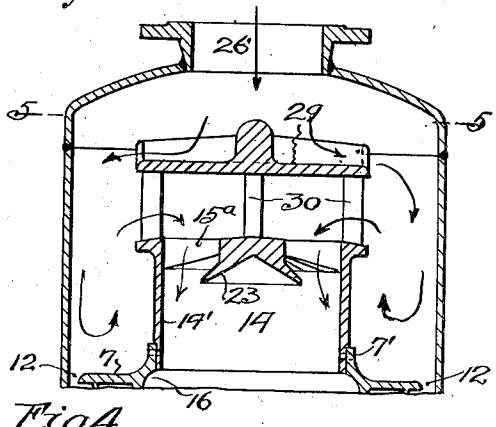


Fig. 4.

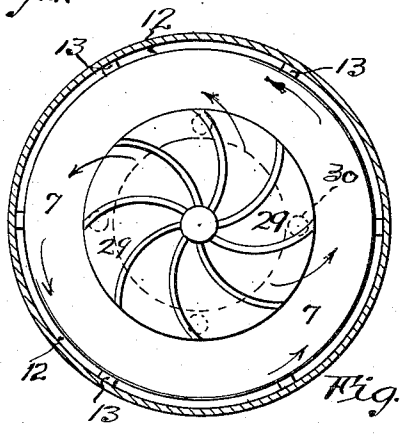


Fig. 5.

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MULTISTAGE CENTRIFUGAL SEPARATION

Original Filed June 13, 1932 4 Sheets-Sheet 2

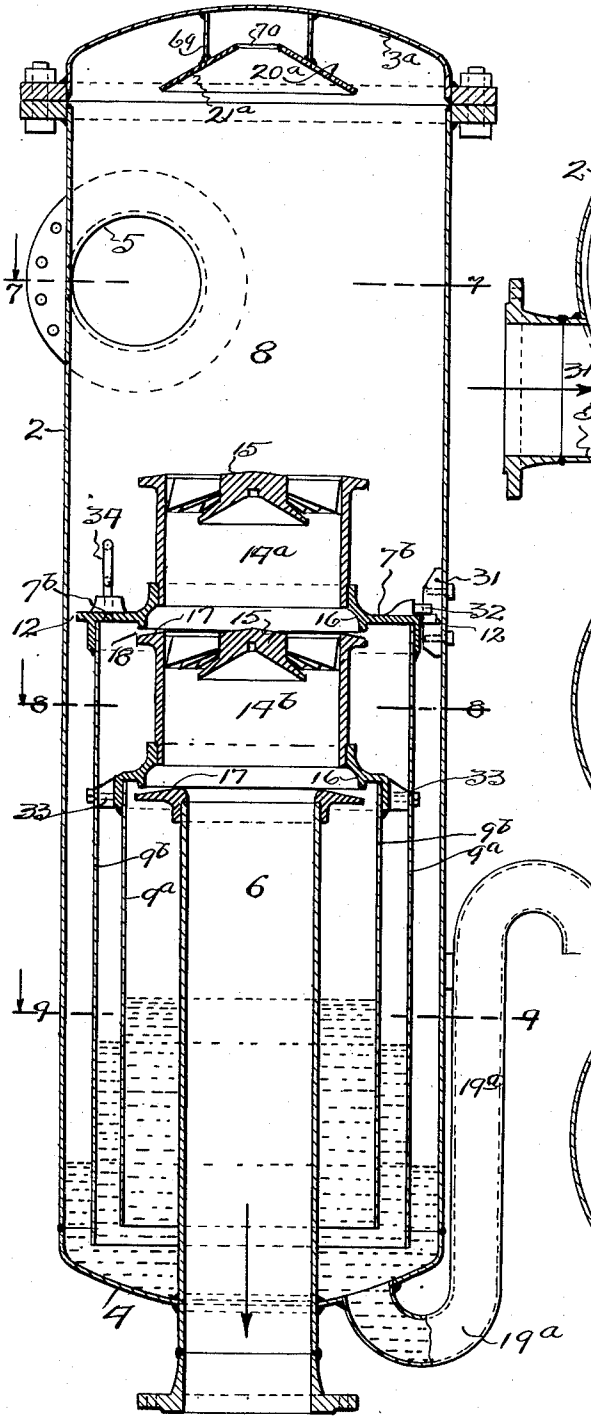


Fig. 6.

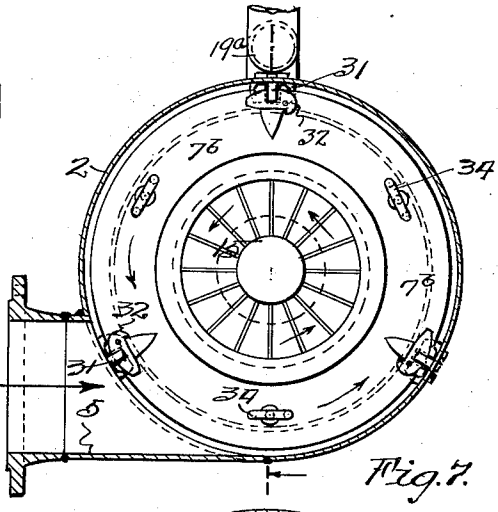


Fig. 7.

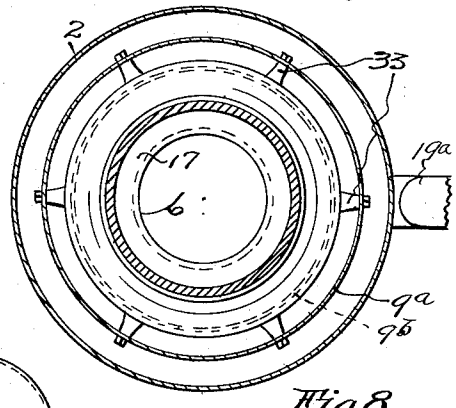


Fig. 8.

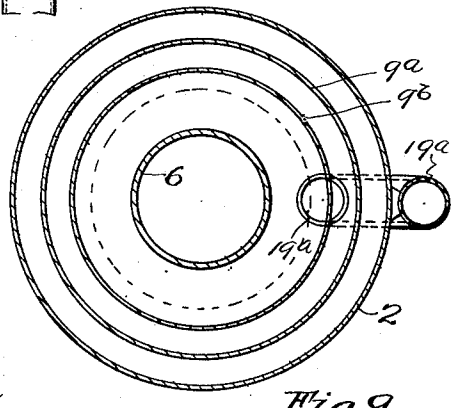


Fig. 9.

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MULTISTAGE CENTRIFUGAL SEPARATION

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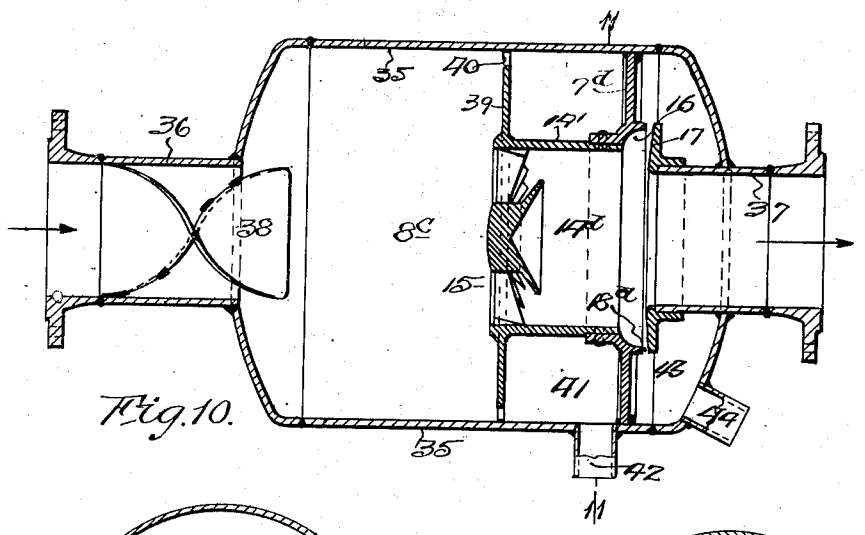


Fig. 10.

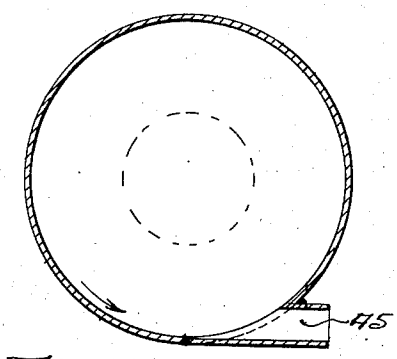


Fig. 11.

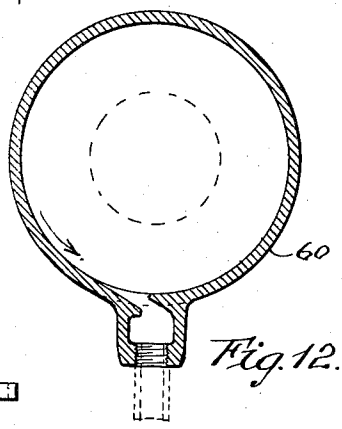


Fig. 12.

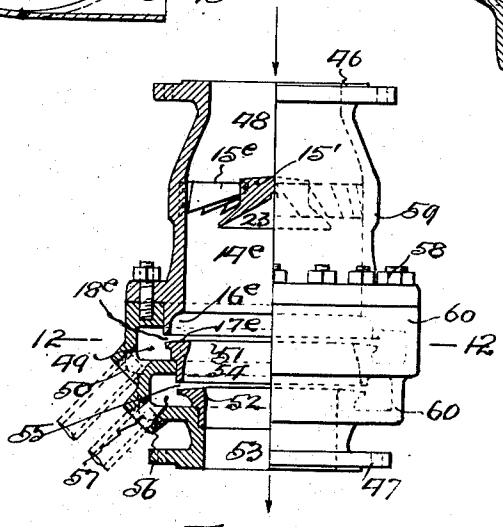


Fig. 13.

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MULTISTAGE CENTRIFUGAL SEPARATION

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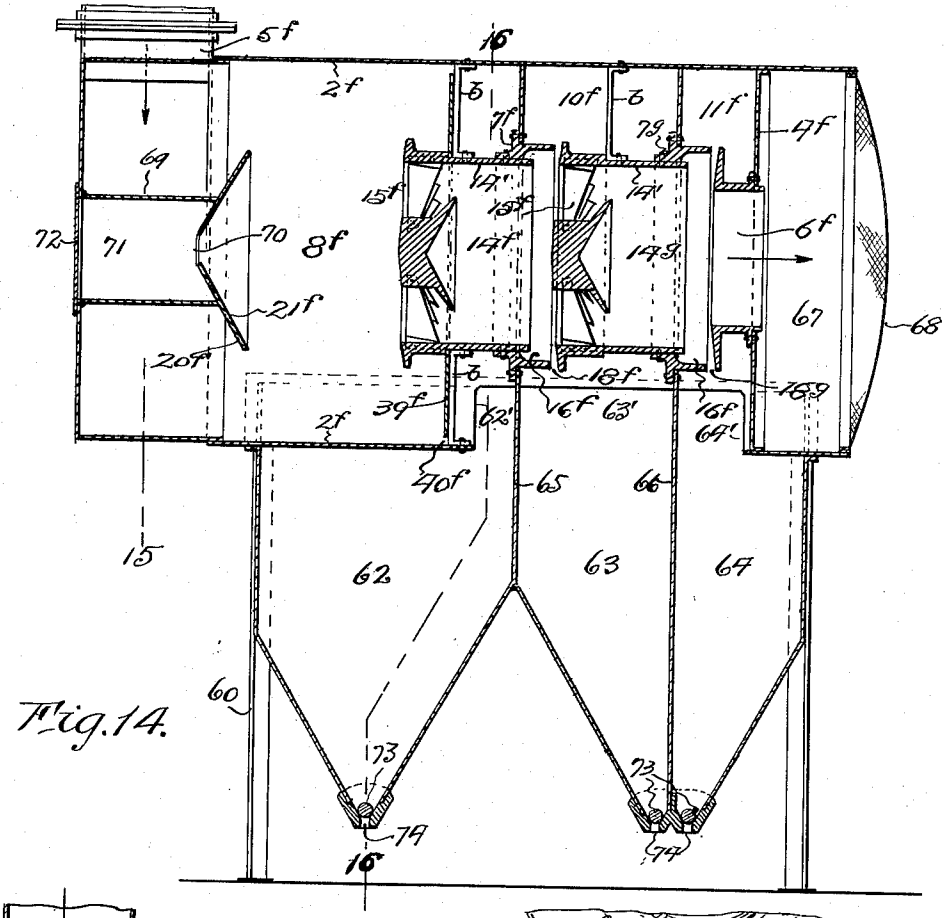


Fig. 14.

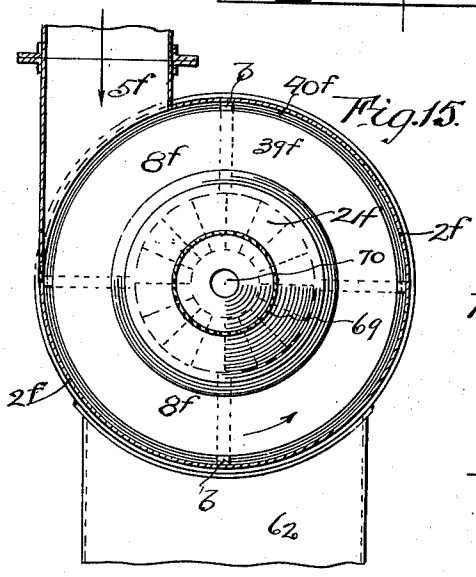


Fig. 15.

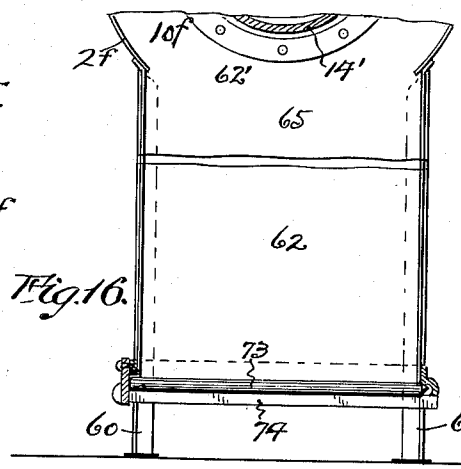


Fig. 16.

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Patented Nov. 3, 1936

2,059,521

UNITED STATES PATENT OFFICE

2,059,521

MULTISTAGE CENTRIFUGAL SEPARATION

Charles Gilbert Hawley, Cleveland, Ohio, assignor to Centrifix Corporation, Cleveland, Ohio, a corporation of Ohio

Application June 13, 1932, Serial No. 617,028
Renewed March 30, 1936

13 Claims. (Cl. 183—80)

This invention relates to improvements in centrifugal separators of the non-rotative type and is adapted for service in and with pipe lines. Special reference will be made to the provision of separating apparatus of very high efficiency and suitable for the most exacting uses, such as inclusion in distillation systems.

The vapors discharged by stills of various kinds, such as those used in oil distillation, water distillation and in the production of some food products and many chemicals, should be as nearly as possible free from entrained liquids and solids.

It is difficult to control the operation of the still in such manner as to prevent the discharge of non-vaporized particles and it is desirable to interpose between the still and the vapor treating apparatus (engine, condenser, fractionating tower or the like) an apparatus which shall function to separate or remove the objectionable substances before the vapor passes to the point of use or further treatment. Many of the costs and charges attending the operation of boilers and stills may be reduced and avoided by so doing. And in the case of petroleum, the distillates may be greatly improved in matter of color and purity. This is also true where pure distilled waters are sought. The foregoing are the purposes of the present invention.

By reason of the constructions involved in the present invention it is adapted to uses other than in the treatment of vapors; for example, and as hereinafter explained, the invention may be used for separating dry solids from various carrier fluids that require purification.

The principle of the invention consists in first making a bulk separation of entrained matters within an initial separating chamber and then taking control of the moving fluid within smaller compass, as within a channel leading from said chamber and there, at the relatively high velocities incident to the smaller compass, separating the residue of entrained substances, to the end that the fluid shall be discharged in a substantially pure or unburdened state.

As will presently be explained in detail, this principle is augmented by the utilization of centrifugal forces that are developed within and from the moving stream of fluid; and further, all necessary operations are accomplished within an apparatus of comparatively small size, and, without resort to moving parts of any kind.

The invention as a whole and the many constructions comprising various forms of the novel apparatus will be readily understood upon reference to the accompanying drawings; in which, Fig. 1 is a vertical section of a multi-stage centrifugal separator embodying the invention;—Fig. 2 illustrates a modified construction of the top thereof;—Fig. 3 illustrates a further modification of the construction of the upper part of the separator, adapting the same for the reception of the fluid through the top of the separator;—Fig. 4 illustrates another construction which is suitable for the admission of the fluid through the top of the separator;—Fig. 5 is a horizontal section on the line 5—5 of Fig. 4;—Fig. 6 is a vertical section of a separator of the type shown in Fig. 1 but presenting an added separating stage and being particularly adapted for inclusion or use between an oil still and a fractionating tower or the like;—Fig. 7 is a horizontal section on the line 7—7 of Fig. 6;—Fig. 8 is a horizontal section on the line 8—8 of Fig. 6:—Fig. 9 is a horizontal section on the line 9—9 of Fig. 6;—Fig. 10 is a longitudinal section of a multi-stage separator that may be employed upon either a vertical or a horizontal axis;—Fig. 11 illustrates a tangential drain or entrainment offtake that may be embodied in any of these separators; as upon the line 11—11 of Fig. 10;—Fig. 12 illustrates another form of tangential drain that may be used therewith, as upon the line 12—12 of Fig. 13;—Fig. 13 is a compound elevation and longitudinal section of a novel self-contained line separator which is a derivative or modification of this invention;—Fig. 14 is a vertical section of a multi-stage centrifugal separator embodying the invention and adapted for use in removing entrained substances from low pressure carrier fluids, and chiefly, though not exclusively, used for the removal of dry solids from air streams;—Fig. 15 is a vertical section on the line 15— of Fig. 14;—and, Fig. 16 is a fragmentary cross-section, on the line 16—16 of Fig. 14.

In principle each of the multiple stage separators herein depicted comprises a bulk or primary centrifugal separator and one or more centrifugal separators of smaller working diameter and incorporated therein, said smaller separators forming or representing the outlet of the primary separator. The principle is based on the fact that a rough centrifugal separation may be accomplished within a separating chamber or drum of generous diameter but the completion of the centrifugal separating operation must be accomplished by a whirling movement which takes place within a separating chamber which is not much

larger than the pipe which is required for the accommodation of the stream of carrier fluid.

The burdened carrier fluid passes successively through the primary and secondary portions of this separator and the burdening impurities, after being centrifugally separated are ejected from the path of the carrier fluid and are removed into parts of the separator which are shielded from violent agitation by the passing stream of fluid. Thus shielded the ejected substances are safely held until they may be discharged from the separator. Meantime, reentrainment is prevented and the carrier fluid is caused to be discharged in a highly purified state.

Progressive movement of the fluid through the different parts of this separator is marked by slight losses of pressure. Further, the method of discharging the ejected substances necessarily varies with the character of those substances. In dealing with dry substances it is best to separate the compartments or drains which represent the different parts of the separator, thus nullifying the effect of slight differences of pressure therein. Where the ejected substance is a liquid this invention unifies the discharges from the different parts of the separator. The method of so doing consists of employing the lower part of the separator as a cistern or well which is common to the several centrifugal parts of the separator. That cistern, however, is subdivided in a manner which employs the liquid as a seal, which effectively isolates the several parts of the separator allowing each to function at its characteristic pressure, the liquid rising to different levels in different parts of the separator and automatically compensating for the pressure differences commented upon. Other novel features of the invention will appear in the detailed descriptions which follow.

Fig. 1 presents a good example of a separator embodying the principles above stated. The body thereof comprises a vertical cylindrical drum **2** closed at top and bottom by the heads **3** and **4**, respectively. The part **5** represents the fluid inlet which enters the upper part of the drum tangentially after the manner shown in Fig. 7. The part **6** is a centrally positioned vertical standpipe which extends through the bottom **4** and the upper end of which rises to about one-half the height of the drum. The pipes **5** and **6** are presumed to be adequate for the transmission of the volume of steam or other fluid to be treated, and as usual it is to be assumed that the fluid enters and departs at high velocity.

Due to the manner of its entrance the carrier fluid whirls within the upper part of the drum and it is there that the primary centrifugal separation of entrained substances takes place. The fluid leaves the drum axially. Obviously this separator may be compared with a separator of the "Cyclone" type but it is to be noted that the body of the separator is very much smaller in relation to the diameter of the inlet pipe. This minimization of drum size is also made possible by limiting the exit or outlet of the separator virtually to the size of its inlet, coupled with the safeguarding of that exit by the employment of a secondary separating unit therewith, directly within the drum. The advantages of the small diameter drum are unmistakable, it being apparent that the centrifugal separating force of such a drum increases as its diameter is reduced; the cost is lessened; and, the separator is made to occupy less space. Further, the internal safeguarding of the exit results in reducing the height of the primary separating chamber as compared with former practices. These differences are also to be noted in comparing this invention with the so-called receiver separators which are commonly employed in steam lines. The volumetric capacity of the separator here disclosed is only a fraction of that of a receiver separator of equivalent operating capacity.

The present invention attains high efficiency by reason of these facts and because the fluid under treatment is everywhere held within close control and every separating operation takes place at high velocity. In brief, the commonly observed factors of time, distance of travel and velocity of discharge are disregarded and instead there is observed a new principle of restricting the diameters of the centrifugal separating elements. The diameter of the drum of this separator need not be more than three times the diameter of the pipe connections and obviously the secondary separating element is smaller than the drum and is of only slightly greater diameter than the outlet of the separator. And as pointed out the height of this separator is less than that of any other separator with which it may be compared.

A horizontal floor **7**, fixedly secured within the drum, divides it into upper and lower compartments. The upper compartment **8** is open throughout its diameter. The lower compartment comprises the annular space surrounding the exit pipe **6**. By means of a cylindrical shell or skirt **9**, that space is divided into the two annular spaces **10** and **11**. The shell or skirt **9** has its upper end tightly attached to the under side of the floor **7** and it hangs therefrom. The lower end of the shell is spaced from the bottom **4** of the drum and hence the lower parts or ends of the annular spaces **10** and **11** are always in open communication.

It is now to be noted that the floor **7** is of less diameter than the interior of the drum **2** so that its peripheral edge is separated from the inner wall thereof. Thus a narrow annular slot **12** (see Fig. 5) is provided at the periphery of the floor and that slot provides a limited but constantly open avenue of communication between the primary separating chamber **8** and the underlying annular space **10**. The substances that are separated from the carrier fluid fall or flow spirally downward through the slot **12** and come to rest within the larger spaces **10** and **11**. This statement that the separated residues come to a rest, means that they are held protected from violent agitation, as aforesaid, but it does not mean that the residues remain actually quiescent in the bottom of the drum. The bottom portion of the drum being open and unobstructed, the liquid residue rotates slowly therein, being always exposed to the propulsive effect of the gas, vapor and accompanying substances which are centrifugally discharged spirally downward through the annular slots **12** and **18**. Such propulsive effect serves to keep that liquid in a slow rotation; and, as a most important result all component solids are held in a state of suspension within the body of residual liquid; preventing the settlement of solids upon the bottom of the drum. The peculiar importance of this last is specially noticeable in dealing with petroleum products; this invention operating continuously, without danger of becoming clogged with petroleum coke.

The spacing lugs **13** belonging to the floor **7** are pinned. welded or otherwise attached to the

inner wall of the drum, as required to support the floor 7 and the parts associated therewith. The floor 7 does not contact the pipe 6. Instead it is separated therefrom and the secondary separator of this invention comprises parts which are erected upon or combined with the floor and said exit pipe, as about to be explained.

The secondary separating element of this invention, which may also be spoken of as the refining element, comprises the small cylindrical separating chamber 14 coaxial with the exit pipe and having the whirl promoting tuyère 15 that forms the upper end of said chamber and a larger collecting race 16 which is provided at or in the lower end of said chamber 14, together with a flange 17, mounted upon the end of the pipe 6 and forming the floor of said race and which is spaced therefrom to provide the narrow annular eject slot 18 in the periphery of the annular race 16, the exit pipe 6 providing a central outlet for the purified fluid. Obviously, the chamber 14 and the race 16 form a central passage which is in communication with the exit pipe 6 and the tuyère portion 15 may be regarded as the central outlet of the primary separating chamber 8.

Both the chamber 14 and the race 16 may be provided in the same casting with the floor 7. But most conveniently, only the race portion 16' is made integral therewith and the cylindrical wall 14' of the chamber 14 has its lower end fixedly jointed to an upstanding flange 7' belonging to the floor. By preference, the whirl promoting element or tuyère 15 is of the radial tangential type shown in Fig. 1, comprising a central hub portion 15' together with a circumferential series of inclined tuyère blades 15a that extend from the hub 15' to the wall 14'. The blades 15a are best made of sheet metal and the ends of the blades are embedded within the parts 15' and 14' in the process of casting those parts, so that the tuyère or whirl promoting element as a whole becomes a unitary part of the cylindrical element 14'.

A plan view of such tuyère appears in Fig. 7 and it is to be noted that the blades together with the parts 14' and 15' form a circumferential series of inclined or tangential tuyère openings leading into the chamber 14. The swift passage of the fluid through such openings causes the fluid to take on a rapid whirling motion within the chamber 14 and by that motion a centrifugal separation of any heavier substances is accomplished.

The centrifugally separated substances are projected against the wall of the chamber 14 and spiral downward thereon, toward the race 16. The whirling vortex expands somewhat within the said race in advance of its passage into the smaller exit pipe 6 and the race 16 performs as a momentary collecting groove for the accommodation of the separated substances. As the whirling motion of the fluid is accentuated by the presence of the race floor 17, the whirling substances are centrifugally and positively ejected through the slot 18 at corresponding pressure and fall into the annular space 11, joining the accumulation in said space and in the space 10. In the case of Fig. 1 the separated substances are assumed to be of liquid form and are discharged through the drain pipe 19, as will be further explained.

Attention is now directed to two elements which are of a corrective nature. The first comprises a conical element 20 that is centrally suspended within the upper part of the chamber 8. It is spaced from but is coaxial with the whirl-promoting tuyère 15 to allow ample room for the movement of the fluid toward the secondary separator 14. Its underside contains the conical sink 21. This device is called a vortex-defeating cone and it functions within the vortex of fluid, whirling within the chamber 8. Being positioned within the downgoing or axial portion of that vortex, the conical part 20 accentuates a partial void therein with the result that stray substances which may be swept upward within the outer part of the chamber 8, thence across the top of the vortex and thence downward, are intercepted by the part 20 and are caught within the conical sink 21 to the surface of which they momentarily adhere. The intercepted substances are there held under the influence of the whirling fluid, that is, in the presence of the underlying portion of the vortex, and as they accumulate upon the concave side of the cone they attain sufficient weight and whirling motion to be detached therefrom centrifugally and are thrown outward by centrifugal force. Thus such separated substances are excluded from the axial portion of the vortex and are thus prevented from entering the secondary separating chamber 14. The second corrective device comprises the like conical part 22 containing the sink 23 and which is incorporated with the hub portion 15' of the whirl promoting tuyère 15. That cone 22, 23 functions in the manner above described as to the element 20; having the effect of substantially excluding stray substances from the respective outlet 6 and ensuring their discharge centrifugally against the inner wall of the chamber 14 and thence through the slot 18, along with the other substances collected in the race 16.

The heavy walled separator of Fig. 1 is adapted for pressure employment, for example, in a high pressure steam line and may be assumed to be installed in such a line. Further, the drain pipe 19 is assumed to be connected with an automatic discharge trap or like closed vessel adapted to normally prevent the escape of steam through that avenue. The steam enters through the tangential nozzle 5 and departs through the exit pipe 6. The entering stream obviously encounters the inner wall of the drum and takes on rapid rotation within the chamber 8 and the entrained liquid and solids are centrifugally precipitated against the inner wall of the drum, and spiral downward thereon toward the floor 7. At that point the collected liquid leaves the chamber 8 and enters the compartment 10 through the slot 12. Meantime, the downwardly whirling steam reacts against the floor 7 and takes its course inward and upward at the sides of the element 14', finally escaping inwardly and thence downwardly through the whirl promoting tuyère 15 and the chamber 14.

It is particularly to be observed that the whirling motion generated within the chamber 8 may assist but is not depended upon to ensure a further centrifugal separation of entrained substances within the smaller or more compact chamber 14. Instead, the outgoing fluid is affected by the tuyère element 15 and by reason of the presence thereof in the outgoing passage, the stream is very positively caused to whirl within the chamber 14 and hence upon a smaller and more effective radius. As a result of that motion the residue of entrained liquid is separated from the steam and is discharged into the compartment 11 through the slot 18. The highly purified fluid is permitted substantially free escape

through the standpipe 6. The vortex defeating cones 20 and 22 assist in completing the separation as before described.

The drainpipe 19, as illustrated in Fig. 1, rises within the collecting compartment 11 and the distance between the top of that pipe and the lower end of the skirt 9 is the measure of the maximum difference of pressure (maximum pressure drop) between the compartments 10 and 11. The higher pressure in the compartment 10 displaces the liquid therein with respect to the level which is maintained in the presence of the slightly lower pressure in the compartment 11. Obviously, the level in the latter is determined by the altitute or position of the drainpipe 19 in the compartment 11.

As will now be apparent, the collected and accumulated liquid within the lower part of the drum effectively serves to seal or separate the compartments 10 and 11, permitting the primary and secondary separating elements to function without interfering one with the other and yet accomplishing the unified discharge of the accumulated liquid from the compartments 10 and 11.

The invention comprehends the complete mechanical separation of the lower parts of the compartments 10 and 11 but such separation makes it necessary to provide independent discharge traps therefor and the construction here shown is to be preferred.

Figure 2 is here included for the mere purpose of showing that the drum may be provided with a cover plate 24 that may be removed whenever access to the internal parts of the separator is required.

Fig. 3 presents a substitute for the tangential nozzle arrangement shown in Fig. 1. Instead of that arrangement the drum 25 is provided with a tangential inlet of another form, the same having a central top inlet 26 and contains an angularly bladed tuyère 27 through which the fluid must pass to enter the separating chamber 8*a*. The presence of that tuyère 27 causes the fluid to whirl within the chamber 8*a* as before described. The vortex defeating cone 28 is combined with the closed bottom of the whirl promoting tuyère 27. The secondary tuyère occupies the before described position within the primary chamber and in order that the parts thereof may be readily recognized they bear, in Fig. 3, the same reference marks which are applied to them in Fig. 1.

Fig. 4 illustrates another tangential inlet or nozzle which may be employed in the upper part of the drum, the same including whirl promoting means. The drum is provided with a top inlet 26′ and the fluid, upon entering through that avenue, impacts an angularly ribbed or bladed fixed element 29 in front of but spaced from said inlet. Most conveniently, the part 29 is supported by posts 30, extending upward from the top of the secondary element 14′. It is another but less desirable way of imparting the primary rotation to the entering liquid.

The structure of Figure 6 is like that shown in Fig. 1 but represents an added or third stage of separation which is accomplished by duplicating the secondary separator, as illustrated by the elements marked 14*a* and 14*b* and by the provision of two cylindrical skirts 9*a* and 9*b*, one for each of the secondary separators. The drain 19*a*, most conveniently, is arranged upon the exterior of the drum; leading from the bottom thereof and thence upward as required to maintain in the drum 19*a*, a column of liquid which compensates the pressure normally maintained within the drum. The drum of Fig. 6 is provided with a removable cover plate or head 3*a* and that head carries the requisite vortex defeating cone 20*a*, the operation of which will be understood from the foregoing description.

While adapted for other purposes, the separator of Fig. 6 is primarily used in the pipe line between an oil still and a fractionating tower or the like, functioning to remove entrainment and ensuring the discharge of only clean vapor into the middle and upper parts of the fractionating tower. It is most convenient to discharge the separated liquid through the pipe 19*a* and into the lower part of the fractionating tower where it may be subjected to the action of the steam that is employed in the latter, but the invention also comprehends the discharge of the separated liquid into a supplementary still or the like for separate treatment. The effect of the employment of the separator here described is to improve the whiteness or color of the distillates taken from the fractionating tower, this being accomplished by the exclusion of discoloring matter from the condensing vapors.

For use in oil distillation and the like it is desirable that the internal parts of the separator shall be removable. Hence, the floor 7*b*, instead of being permanently attached to the wall of the drum is removably supported upon shouldered side blocks 31 and is normally locked in position thereon by means of wedges 32, as well shown in Figs. 6 and 7. The skirts 9*a* and 9*b* are rigidly connected by means of the bolted lugs 33 and lifting loops 34 are provided on the floor 7*b*. When the cap 3*a* is removed the wedges 32 may be knocked out and then both of the internal or secondary separators may be lifted out of the drum, together with their skirt portions 9*a* and 9*b*, exposing all internal parts for inspection and for easy access if cleaning is required.

The separators thus far detailed are employed in vertical positions whereas Fig. 10 illustrates one embodiment of the invention that is adapted for use in a horizontal position. It is of an abbreviated but highly efficient form. A closed drum 35 has an entrance nozzle 36 at one end and an exit nozzle or pipe 37 at the other. The entering fluid is caused to whirl by the presence of a scroll or helix generator 38 which is fixed within the nozzle 36. The distant end of the drum is divided by a floor portion 7*d*, but in this case the floor meets and is tightly joined to the wall of the drum. The secondary separator 14*d* is of the construction previously described but is modified by the addition of a flange 39 which extends nearly to the wall of the drum, leaving only a narrow marginal slot 40. The substances that are separated centrifugally within the chamber 8 are spirally discharged through the slot 40 and enter the annular space 41, thence to be discharged through a drain 42. The substances subsequently separated within the secondary device and discharged through the slot 18*d* thereof are received by the annular space 43 and are discharged through a drain 44. In lieu of the radially extended drains 42 and 44, the accumulation spaces 41 and 43 may be provided with tangential drains like the drain 45 illustrated in Fig. 11. Such drains best adapt the device for use in either vertical or horizontal position.

The separator illustrated in Fig. 13 is of a multiple stage type based upon the construction of the minimum diameter secondary separators above described. No external drum is employed

but instead the device is intended for direct inclusion in a pipe line, having end flanges 46 and 47 for attachment thereto. The fluid enters through the passage 48, encounters the whirl promoting tuyère 15e, and, rotates within the chamber 14e and its collecting race 16e. The discharge slot 18e of this device opens into an annular accumulation space 49 having a drain 50. The employment of the extended race 16e permits the use of an intermediate outlet 51 of larger size than the final outlet of this separator and such intermediate outlet is made in a ring portion which provides the floor 17e of the race 16e. A second ring 52 contains the final outlet 53 of the separator and the two rings form a second collecting race 54 and its discharge slot 55. The latter opens into an annular collecting space 56 having a drain 57. Most conveniently, the casing of this device comprises only two parts, which are joined by the bolts 58. One part 59 contains the entrance passage 48, the whirl promoting tuyère 15e, the separating chamber 14e and the collecting race 16e. The other part marked 60 contains the cavities 49 and 56 and is bored to receive the rings 17e and 52.

The separator illustrated in Figs. 14, 15, and 16 operates upon the principles herein described and requires little further explanation. It is like the separator shown in Fig. 6 in that it presents three stages of separation. However, it is of the horizontal and usually thin-walled type that is designed for the purification or clarification of moving gases (including air) set in motion from any suitable source. The horizontal and cylindrical drum 2f of Fig. 14 is raised upon standards 60 to make room for the closed hoppers 62, 63, and 64 which belong to the three stages of separation. The hopper partitions 65 and 66 also divide the body of the drum into successive compartments or spaces 8f, 10f and 11f. The floor portions 7f and 7g belonging to the secondary separators 14f and 14g penetrate and are attached to respective partition walls 65 and 66. Radial braces, b, aid in supporting them. As shown, the internal or secondary separators are coaxial with the primary separating chamber 8f, as is also the outlet 6f, which latter is secured in the drum end 4f.

A flange 39f radiating from the first internal element (14f) together with the wall of the drum 2f, forms an annular eject slot 40f, similar to that before described. The bottom of the drum is cut away to provide the openings 62', 63' and 64' establishing communication with respective hoppers 62, 63 and 64. By preference, the purified gases, upon leaving the outlet 65, enter an expansion chamber 67 the end of which is open; save that the latter may be optionally furnished with a porous diaphragm or cloth bag 68; used as a final precaution against the escape of stray dust particles. It will be understood that when this machine is to be operated under suction, a proper connection is provided between the expansion chamber 67 and the suction device.

The fluid (air or gas) to be treated enters the chamber 8f through the tangential nozzle 5f (or equivalent whirl-producing structure), whirls vigorously within the chamber 8f, and leaves that chamber through the first internal unit 14f. Under the central control of the vortex defeating cone 20f, very successful centrifugal separation of dust or liquid particles is accomplished and the latter being deposited against the wall of the drum 2f, are propelled spirally toward and depart through the narrow slot 40f, thus entering the space in advance of the partition 65 and falling into the hopper 62; while the partially purified fluid departs through the central avenue afforded by the first internal separator, 14f. A further separation of objectionable substances occurs in that separator, the same being ejected through the race slot 18f thereof and falling into the hopper 63. At the same time the fluid whirlingly advances through and is additionally acted upon within the second separating element 14g. The substances collected in the race 16f thereof are ejected through the slot 18g and fall into the hopper 64; causing the fluid to depart through the outlet 6f in a highly purified state. Any slight residue caught beyond that point, as by the cloth bag 68, is accumulated within the space 67. The bag is removable and that space and the cloth itself may be cleaned from time to time.

A novel feature of some importance is presented by the vortex defeating cones 20a and 20f of Figs. 6 and 14. In each case the cone is supported by a cylindrical part 69 and the apex of the cone contains an opening 70. The otherwise tight space 71 within the part 69 serves to accumulate any slight residue of fine substances which may reach the apex of the cone, thus removing them from the fluid stream. In the case of Fig. 14, the space 71 has a removable end plate 72, so that it may be opened and cleaned from time to time.

The hopper bottoms illustrated in Figs. 14 and 16 are of the type described and claimed in my earlier application (S. N. 602,765) and do not require special description herein. Each is of trough-like, V-shaped form and contains a cylindrical rod 73 which normally serves to close a long discharge slot 74 in the bottom of the hopper. In each case, the rod is removable, as required to open the discharge slot 74 and empty the hopper.

The inherent practical advantages of this invention and of its several elements will be fully apparent to those who are skilled in the art.

Having thus described my invention I claim as new and desire to secure by Letters-Patent:—

1. A multi-stage centrifugal separator of the non-rotative type comprising a primary separating drum, in combination with a secondary separating chamber of smaller diameter, positioned therein, coaxial therewith and forming the main fluid outlet thereof, said primary chamber having a fluid inlet adapted to cause the fluid to move vortexially therein, means dividing the lower part of said drum into concentric reception spaces, said primary chamber having at a point distant from said inlet a peripheral discharge slot for the ejection of separated substances into the outer reception space, said secondary chamber containing a peripheral discharge slot for the ejection of the separated substances into the inner reception space and terminating in a central outlet of less than its own diameter.

2. A multi-stage centrifugal separator of the non-rotative type comprising a primary separating drum, in combination with a secondary separating chamber of smaller diameter, positioned therein, coaxial therewith and forming the main fluid outlet thereof, said primary chamber having a fluid inlet adapted to cause the fluid to move vortexially therein, means dividing the lower part of said drum into concentric reception spaces, said primary chamber having at a point distant from said inlet a peripheral discharge slot for the ejection of separated substances into the outer

reception space, said secondary chamber containing a peripheral discharge slot for the ejection of the separated substances into the inner reception space and terminating in a central outlet of less than its own diameter, and, a drain common to said reception spaces.

3. The separator as claimed in claim 1 and in which the secondary separator and the means dividing the lower part of the drum are bodily removable from the drum.

4. A separator as claimed in claim 1 and in which the secondary separating chamber has an inlet portion formed by a plurality of angularly positioned fluid directing blades adapted to cause the passing fluid to move vortexially within said secondary chamber, toward the peripheral discharge slot thereof.

5. A separator as claimed in claim 1 and in which the bottom portion of the secondary separating chamber contains an internal race groove of larger diameter adapted to momentarily collect the substances separated therein and direct them into said peripheral discharge slot of said secondary chamber.

6. A multi-stage centrifugal separator of the non-rotative type comprising an axially extended primary separating chamber, in combination with a secondary separating chamber within and of smaller diameter and length than said primary chamber, coaxial therewith and providing the main fluid outlet thereof, said primary chamber having a fluid inlet axially distant from said secondary chamber and adapted to cause the fluid to move vortexially in the primary chamber and toward the outlet provided by said secondary chamber, said primary chamber at a point distant from the said inlet terminating in a narrow peripheral ejection slot for the free discharge of the substances separated within the primary chamber, said secondary chamber having a main fluid outlet of less than its own internal diameter and the bottom portion of said secondary chamber containing a narrow open slot coextensive with its periphery for the free ejection of the substances separated within said secondary chamber, said primary chamber presenting an extended portion which contains a reception space peripherally coextensive with and in open communication with the ejection slot of the primary chamber, said extended portion containing another reception space which is in like open communication with the ejection slot of the secondary separating chamber, and, means for emptying said reception spaces.

7. A multi-stage centrifugal separator of the non-rotative type comprising an axially extended primary separating chamber, in combination with a secondary separating chamber within and of smaller diameter and length than said primary chamber, coaxial therewith and providing the main fluid outlet thereof, said primary chamber having a fluid inlet axially distant from said secondary chamber and adapted to cause the fluid to move vortexially in the primary chamber and toward the outlet provided by said secondary chamber, said primary chamber at a point distant from the said inlet terminating in a narrow peripheral ejection slot for the free discharge of the substances separated within the primary chamber, said secondary chamber having a main fluid outlet surrounded by a peripheral flange and which marks the discharge end of the secondary chamber, forming an annular bottom therefor, the peripheral wall of said secondary chamber adjacent such bottom containing an open slot coextensive with its periphery for the ejection of the substances separated within said secondary chamber, said primary chamber having an extended portion which contains a reception space peripherally coextensive with and in open communication with the ejection slot of the primary chamber, said extended portion containing another reception space which is in like open communication with the ejection slot of the secondary separating chamber, and, means for emptying said reception spaces.

8. A multi-stage centrifugal separator of the non-rotative type, comprising a primary separating drum, in combination with a secondary separating chamber of smaller diameter, positioned therein, coaxial therewith and forming the main fluid outlet thereof, said primary chamber having a fluid inlet adapted to cause the entering fluid to move vortexially therein about the axis thereof, a circumferential series of angularly disposed fluid directing blades forming the inlet end of said secondary chamber into a whirl promoting tuyère adapted to cause fluid from the primary chamber to move vortexially within said smaller secondary chamber, means dividing the lower part of said drum into large and small reception spaces, said primary chamber having at a point distant from said inlet a peripheral discharge slot for the ejection of separated substances into the larger of said reception spaces, said secondary chamber containing a peripheral discharge slot for the ejection of its separated substances into the smaller reception space and terminating in a central fluid outlet leading from the separator, and, means for emptying said spaces.

9. A multi-stage centrifugal separator of the non-rotative type comprising a primary separating drum, in combination with a secondary separating chamber of smaller diameter, positioned therein, coaxial therewith and forming the main fluid outlet thereof, said primary chamber having a fluid inlet adapted to cause the fluid to move vortexially therein, said secondary chamber having a fluid inlet leading from the central part of the primary chamber and adapted to cause the fluid to move vortexially within the secondary chamber, means dividing the lower part of said drum into inner and outer reception spaces, said primary chamber having at a point distant from said inlet a peripheral discharge slot for the ejection of separated substances into the outer reception space, said secondary separating chamber containing a peripheral discharge slot for the ejection of the separated substances into the inner reception space, a central fluid outlet pipe leading from said secondary chamber and through a wall of the drum, and means for emptying said spaces.

10. A multi-stage centrifugal separator of the non-rotative type comprising a primary separating drum, in combination with a secondary separating chamber of smaller diameter, positioned therein, coaxial therewith and forming the main fluid outlet thereof, said primary chamber having a fluid inlet adapted to cause the fluid to move vortexially therein, the bottom portion of said secondary chamber being of increased diameter and forming a race groove, said secondary chamber having a fluid inlet leading from the central part of the primary chamber and adapted to cause the fluid to move vortexially within the secondary chamber, and toward the race groove thereof, means dividing the lower part of said

drum into inner and outer reception spaces, said primary chamber having at a point distant from said inlet a peripheral discharge slot disposed for the ejection of separated substances into the outer reception space, the grooved portion of said secondary separating chamber terminating in a peripheral discharge slot disposed for the ejection of the separated substances into the said inner reception space, a central fluid outlet pipe coaxially leading from said secondary chamber and through a wall of the drum, and means for emptying said spaces.

11. A multi-stage centrifugal separator of the non-rotative type, comprising an axially extended drum, in combination with fluid inlet means at the top of said drum and adapted to cause the entering fluid to move vortexially about the axis of the drum, a main fluid outlet duct coaxial with and opening out of the drum at a level below said inlet, a floor element fixed in said drum substantially at said level and together with the wall thereof forming a peripheral ejection slot for the discharge into the lower part of the drum of substances separated in the upper part of the drum, said floor element containing an opening coaxial with but of larger diameter than said duct, a secondary separating chamber fixed to said floor element, occupying the said opening therein and leading to said duct, an angularly bladed tuyère forming the fluid inlet of said secondary chamber and adapted to cause whirling fluid from the upper central part of the drum to whirl more rapidly in said secondary chamber, the lower part of said chamber being expanded to form a race groove for the collection of the substances separated in said chamber, means forming a race bottom below said expanded part of said chamber and together with the lower edge thereof forming a narrow ejection slot for the discharge of the substances from said race, means depending from said floor and forming an inner reception chamber, larger than the opening in said floor, to receive the substances discharged from the race groove of the secondary chamber, and, means for emptying such substances from the lower part of the drum.

12. The herein described small diameter centrifugal separator of non-rotative type comprising an axially extended separating chamber having a whirl promoting tuyère which forms its fluid inlet and having a bottom portion which contains a circumferential groove adapted to collect momentarily the substances separated in said chamber and terminating in a depending edge, in combination with a bottom forming member having its top spaced from said edge and therewith forming a peripheral ejection slot for the discharge of substances from said groove, said bottom member containing a main fluid outlet which is coaxial with said chamber and of smaller diameter than said groove, means uniting said depending edge and said member to maintain the spacing thereof and itself containing a circumferential space outward of said peripheral slot for the reception of substances therefrom, and, means for emptying such space.

13. A separator as claimed in claim 1 and in which the secondary separating chamber has an inlet portion formed by a plurality of angularly positioned fluid directing blades adapted to cause the passing fluid to move vortexially within said secondary chamber, toward the peripheral discharge slot thereof and in which said blades are radially disposed in the inlet end of said secondary chamber and are united by a central hub portion containing a vortex defeating concavity opening toward said central outlet.

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