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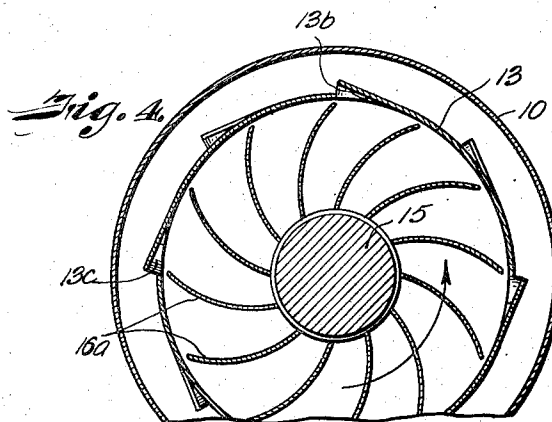
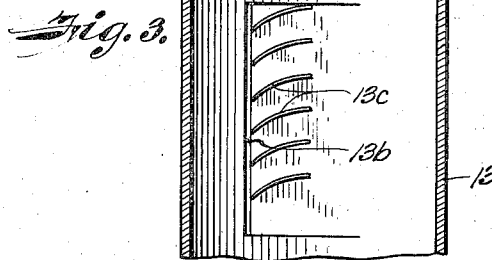
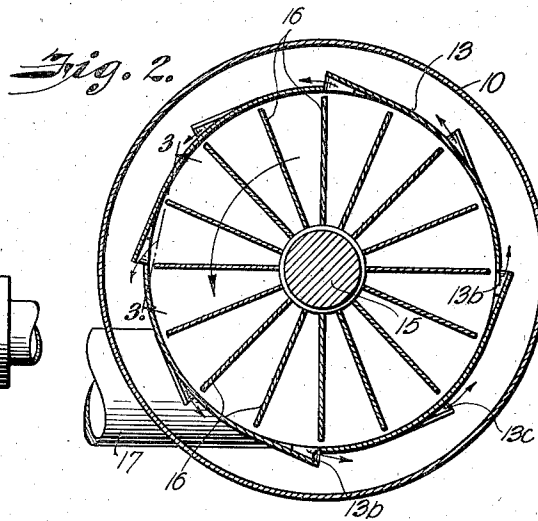
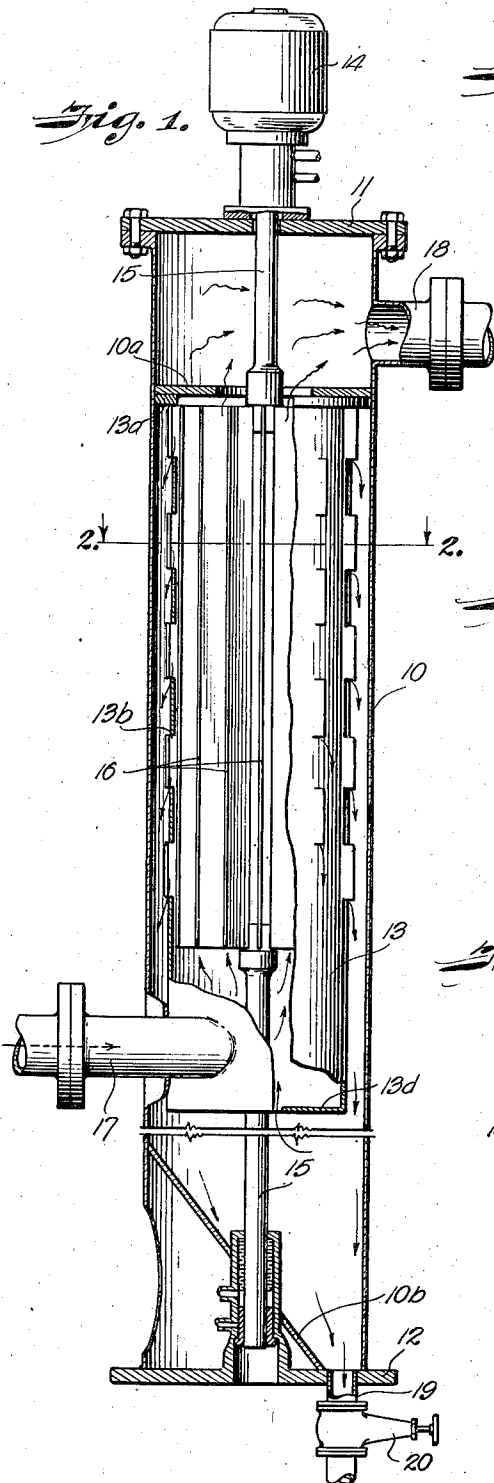
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APPARATUS FOR SEPARATING ENTRAINED SOLIDS FROM GASES

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2 Sheets-Sheet 1



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APPARATUS FOR SEPARATING ENTRAINED SOLIDS FROM GASES

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2 Sheets-Sheet 2

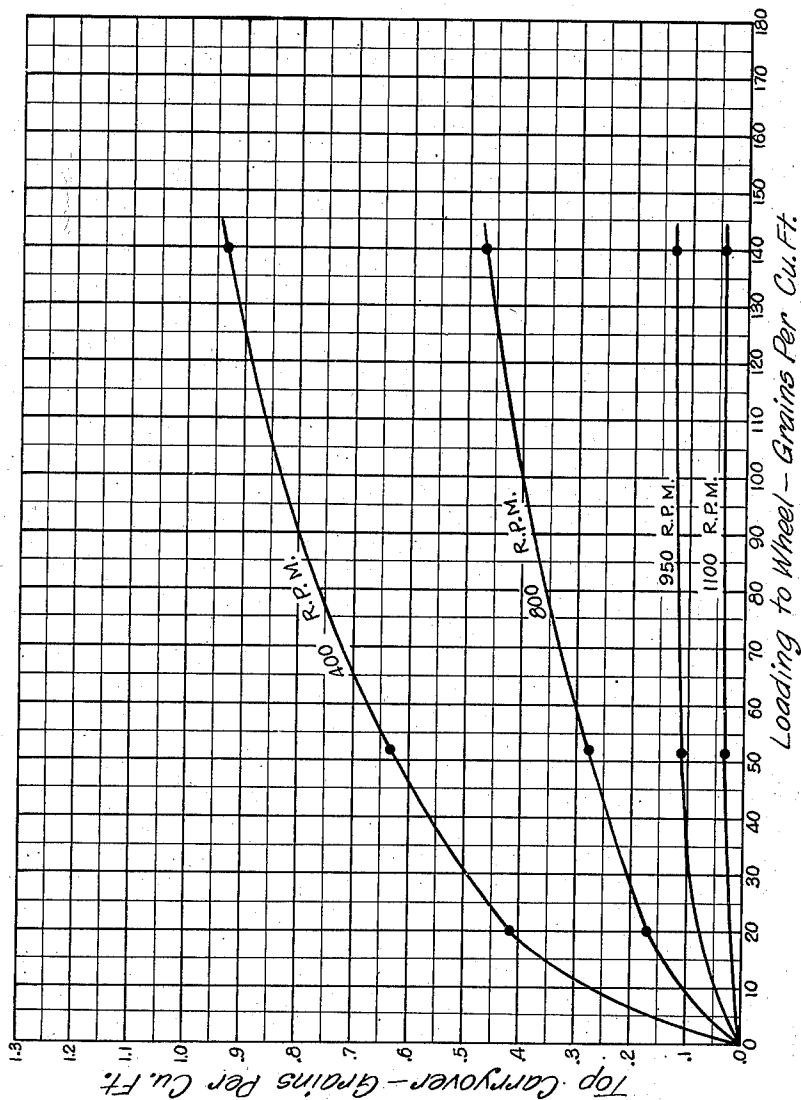


Fig. 3.

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APPARATUS FOR SEPARATING ENTRAINED
SOLIDS FROM GASESDavid H. Putney, Kansas City, Mo., assignor to
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This invention relates to improvements in apparatus for separating entrained solids from gases and refers more particularly to a centrifugal separator for removing finely divided particles of solid from gases or vapors.

The essential features of novelty reside not only in the method employed but also in the apparatus. The apparatus includes a wheel having a plurality of vertical blades designed to impart rotative velocity to the mass of gas and entrained solids passed axially through a skimming cylinder which surrounds the wheel and which contains slotted openings through which solid particles together with some gas are discharged. An outer shell of larger diameter surrounds the skimming cylinder forming an annular space therebetween through which solid particles and gas expelled from the rotative mass pass in a downflowing stream to be discharged from the bottom of the outer vessel.

An object, therefore, of the invention is to provide a gas centrifuge or clarifier for stripping or denuding gases or vapors of entrained solid particles.

Another object is to provide a centrifugal separator utilizing not only the principle of centrifugal separation for removing the solid particles from the gaseous material but also a skimming cylinder equipped with slotted openings for stripping the solid particles from the outer periphery of the rotating mixture of gas and solids.

Another object is to provide a separator comprising concentric vessels, the inner vessel having apertures therein and a rotating wheel for imparting rotating velocity to the gaseous mixture passed through the inner vessel whereby, due to the pumping action of the wheel, a downflowing stream is created in the annular space between the vessels which is effective in removing solid particles projected through the apertures in the inner vessel.

A further object is to provide a centrifugal gas separator or clarifier able to handle large volumes of gas in a relatively small space.

Other and further objects will appear from the following description.

In the accompanying drawings which form a part of the instant specification and are to be read in conjunction therewith and in which like reference numerals indicate like parts in the various views,

Fig. 1 is a sectional side elevational view of an apparatus embodying the invention with parts broken away,

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Fig. 2 is a view taken along the line 2-2 in Fig. 1 in the direction of the arrows,

Fig. 3 is an enlarged view taken along the line 3-3 in Fig. 2 in the direction of the arrows,

Fig. 4 is a view similar to Fig. 2 showing a modified type of spinning wheel, and

Fig. 5 is a graph indicating the effectiveness of separation at different speeds of the spinning wheel.

Referring to the drawings and particularly Fig. 1, at 10 is indicated a cylindrical outer shell closed at the top by a plate 11 bolted or otherwise fastened to flanges at the top of the outer vessel. The bottom of the vessel is supported on a suitable standard such as plate 12. Within the outer vessel and concentric therewith is a cylindrical vessel or skimming cylinder of smaller diameter designated by the numeral 13. The skimming cylinder is supported within the outer vessel from the top by an annular flange 13a, welded or otherwise rigidly affixed to an annular baffle 10a in the upper portion of the outer vessel. Mounted at the top of the outer vessel on closure plate 11 is a prime mover, such as a motor diagrammatically indicated at 14. This motor is coupled to and drives shaft 15 positioned centrally of the outer vessel and skimming cylinder. The shaft rotates upon suitable bearings at the top and bottom of the vessel. Provision is made for preventing solid particles contained in the gases from entering the bearings of the shaft by introducing clean gas or vapor into the machine through labyrinth seals or by other conventional method. Fixedly mounted upon the shaft within the skimming cylinder is a spinning wheel consisting of vanes 16 extending radially from a central hub.

The skimming cylinder 13 has slotted apertures 13b in its shell throughout the area surrounding the spinning wheel. Below the wheel the shell of the skimming cylinder is without openings except for the single tangentially connected inlet pipe 17. Extending over the slotted apertures 13b in the skimming cylinder are louvers or baffles 13c pitched downwardly to deflect solids and gases discharged through the apertures into the annular space between the vessels in the direction indicated by the arrows. The pitch of the baffles is best indicated in Figs. 2, 3 and 4. The skimming cylinder has relatively small openings at the top and at the bottom provided by the annular plates 10a and 13d. The annular space between the vessels is open at the bottom and closed at the top by flange 13a of the skimming cylinder and baffle plate 10a. A gas outlet pipe 18 is connected into the upper part

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of the outer vessel above the baffle plate 10a. The outer vessel has an inclined or truncated conical bottom 10b which directs solids accumulated in the vessel to a discharge pipe 19 controlled by valve 20.

In operation the gas or vapor containing the entrained solids enters the lower portion of the skimming cylinder through the tangential connection or inlet pipe 17. This inlet is so arranged that the velocity of the gases supplies an initial rotation to the entering gas and in the same direction as the rotation of the shaft and separating wheel. The gas-solid mixture rises through the skimming cylinder and in doing so must pass axially the entire length of the separating wheel. Since the spinning or separating wheel has continuous radial blades 16 throughout its length its rapid rotation imparts rotative velocity to the gaseous mass passing along the blades of the wheel. These blades may either be flat vertical blades, as shown in Fig. 2, or may be curved, as indicated at 16a in Fig. 4. Such curvature is intended to increase the outward pumping action or ability of the wheel thus assisting in the centrifugal separation of the solid fines. The wheel may be operated at any desired speed and it should be of sufficient length so all the gases passing through it will be brought up to the rotative speed of the wheel before leaving its upper end. The rotary motion imparted to the mixture of gas and solid particles causes the solid fines to be projected from the periphery of the wheel by centrifugal force because of the greater difference in density between the solids and gas-carrying medium. The solid particles projected from the extremities of the rotating blades impact the inner wall of the skimming cylinder and, due to the movement of the mass, slide around the wall in the direction of the rotation of the wheel. During their passage around the inner wall the particles enter and pass through the apertures in the skimming cylinder. The walls of the slots or apertures 13b are open tangentially to the skimming cylinder so particles sliding along the wall are readily discharged through the openings.

The annular space between the skimming cylinder and the outer vessel is closed at the top. The rotation of the wheel 16 and the pumping action its rotation imparts to the mass builds up a pressure at the slotted openings in the skimming cylinder higher than the pressure at the shaft. This higher pressure is transmitted to the gases in the annular space through the slots and since the annular space is closed at the top the gases and separated solids discharged through the slots flow in a downward direction through the annular space which is open at the bottom end. The fines discharged through the slots pass downwardly along the inside of the outer shell in a spiral path to the lower portion of the vessel which serves as a hopper or collecting chamber.

The lower end of the skimming cylinder may either be left open or it may be partially or wholly closed by plate 13d. In order to provide a down-flowing stream of gases in the annular space for carrying the separated solids more rapidly downward it is necessary to permit the return of these gases to the inside of the skimming cylinder. If no closure plate is used on the lower end of the skimming cylinder the quantity of gases or vapors recycled to the wheel will be large whereas if the lower end of the cylinder is completely closed the amount of recycled gases will be nil. Best results are obtained if plate 13d is installed with a

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small annular opening around the shaft for passage of a relatively small flow of recycle gases. Since the separated solids descend spirally against the inner surface of the outer vessel wall only a very small quantity of the separated solids will be recycled with the recycle gases to the wheel if the recycle gases are required to return to the vicinity of the shaft before reentering the skimming cylinder.

Since the gas-solid mixture passing up through the wheel has at all times a certain amount of vertical velocity as well as rotative velocity imparted by the wheel, the resultant direction of discharge through the slots would normally have a vertical component. This vertical component would oppose the downward flow of the separated fines from other slots above. For this reason it is advisable to install louver type deflecting baffles at the slotted openings. These baffles are pitched downwardly and mechanically change the direction of the separated fines and carrying gas so the discharge from the slots into the annular space is at a downward angle. Consequently, any tendencies for fine solid particles to hang up or collect in the annular space are thus avoided.

The doughnut-shaped baffle plate, installed above the separating wheel and sealed against the outer shell and skimming cylinder, provides an opening at its center around the shaft through which clean gas or vapor is discharged. By the time the uprising mixture reaches the top of the wheel substantially all solids have been eliminated through the skimming cylinder slots and this upper baffle plate 10a is a further safeguard against any solid fines being discharged from the top of the skimming cylinder since it is extremely difficult for the solids rotating at a rapid velocity to return to the hub of the wheel.

It is intended that the apparatus shown may be installed as a separating device wherever it is desired to denude gases or vapors of solid particles. It may be built integral with other apparatus where it is employed to separate solids from gases which are mixed in other portions of the apparatus. It is particularly adapted for use in the separation of finely divided catalyst from hydrocarbon vapors or combustion gases in catalytic cracking units, the separation of dust from the exit gases of cement kilns, etc.

Experiments have been conducted with the apparatus utilizing a 10" diameter separating wheel and skimming cylinder of the type shown. To test the separating efficiency, air was blown through a bed of standard aluminum hydrosilicate powdered catalyst such as is used in fluid type catalytic cracking units. The finer particles of powdered catalyst were thus entrained in the air stream leaving the catalyst bed and were introduced into the apparatus. The results of these tests are indicated in Figure 5. Loadings to the wheel as shown were obtained by measuring the carry-over rates from the top of the machine during periods when the wheel was not being rotated. The top carry-over as plotted in Figure 5 was obtained by measuring the catalyst fines carried over during periods of time when the wheel was being rotated at the various speeds shown. The superficial axial velocity of gas passing through the wheel was 9 feet per second for all points indicated. As an indication of the excellent separating efficiency obtained in this apparatus the graph shows that under conditions where 140 grains of catalyst dust per cubic foot were carried overhead with

the wheel idle, only 0.04 grain per cubic foot were carried over under the same conditions when the wheel was operated at 1100 R. P. M. This represents a separating efficiency of 99.97%. For lower velocities of gas passing through the wheel the separating efficiency is even higher. In general, the separating efficiency increases with R. P. M. of the wheel and decreases with gas velocity passing axially through the wheel. The design and the speed of the wheel can be chosen to suit any specific separating problem.

The details of design of the wheel and skimming cylinder shown in the drawings are not intended as a limitation to the particular design shown, as any structure utilizing the principle is within the scope of the invention. For example, the height of the slots is of little importance and although the slots have been shown in staggered formation around the cylinder such slotted openings may be continuous from the top to the bottom of the cylinder and of greater or lesser number. Likewise, it is contemplated, particularly in cases where used with gases or vapors carrying a large amount of entrained fines, to make the openings of the lower slots of greater width than the openings of the top slots to more nearly coincide with the amount of separated solids discharged through each.

From the foregoing it will be seen that the invention is well adapted to attain the ends and objects hereinabove set forth together with other advantages which are obvious and which are inherent to the structure.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter

herein set forth or shown in the drawings is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, I claim:

1. An apparatus for separating entrained solids from gaseous materials comprising concentric vessels of different diameters, the annular space therebetween closed at the top and open at the bottom, an inlet opening into the outer vessel, an outlet opening in the upper portion of the inner vessel having communication with an outlet in the upper portion of the outer vessel, a solids discharge opening in the bottom of the outer vessel, said inner vessel having an opening in the bottom and thereby being in communication with the outer vessel, rotative elements within the inner vessel adapted to rotate the gaseous mass passing through it and peripheral apertures in the shell of the inner vessel for the passage of solids and gases.

2. An apparatus as in claim 1 wherein the apertures in the shell of the inner vessel comprise longitudinal slotted openings having downwardly deflecting baffles whereby the gases and solids passing through said apertures are deflected downwardly in the annular space between the vessels.

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