

March 10, 1936.

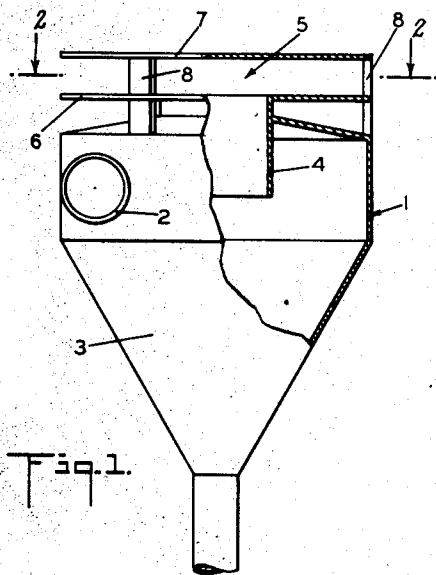
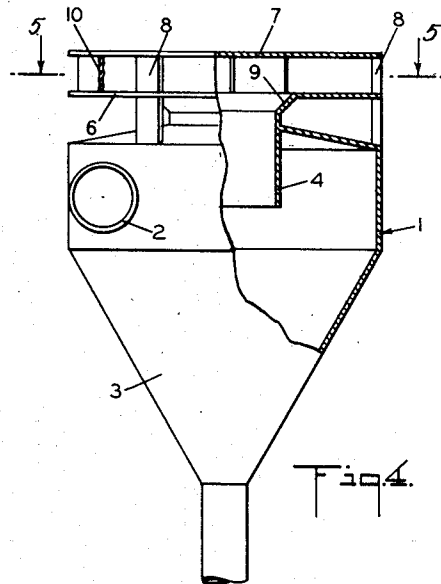
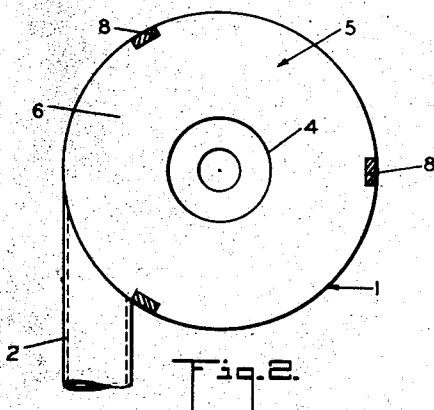
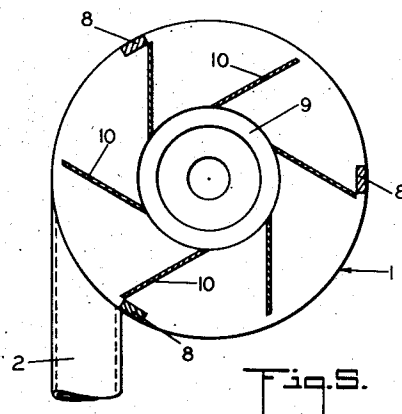
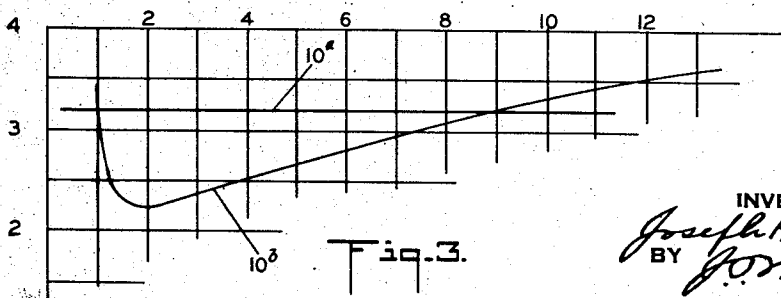
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2,033,470

CYCLONE SEPARATOR

Filed Aug. 30, 1933

2 Sheets-Sheet 1



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CYCLONE SEPARATOR

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2 Sheets-Sheet 2

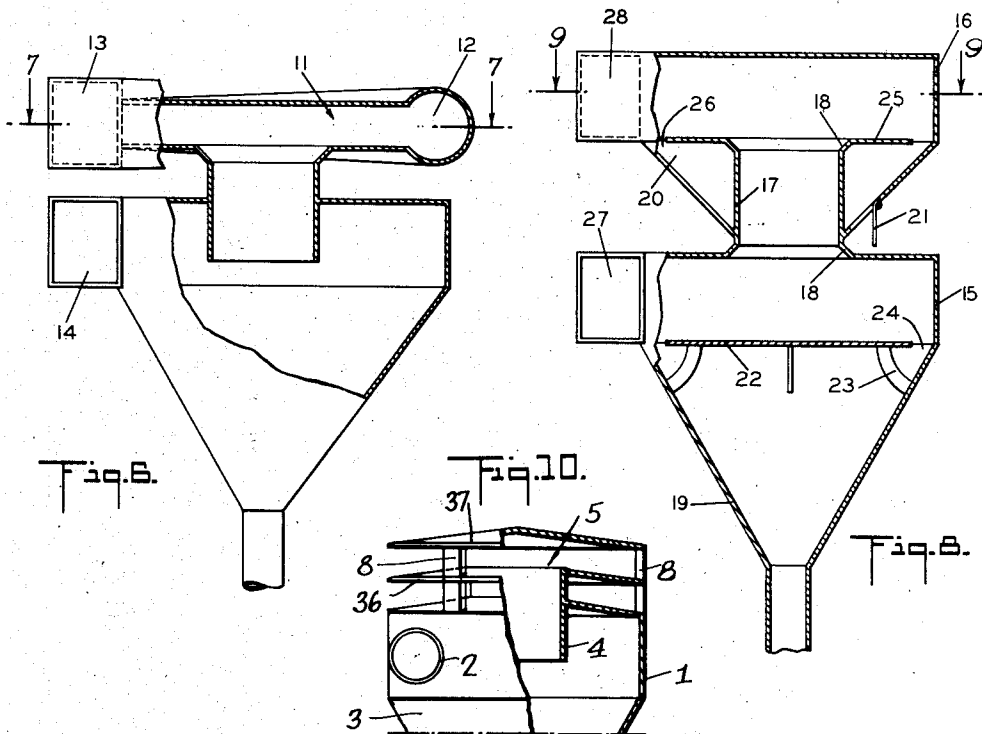
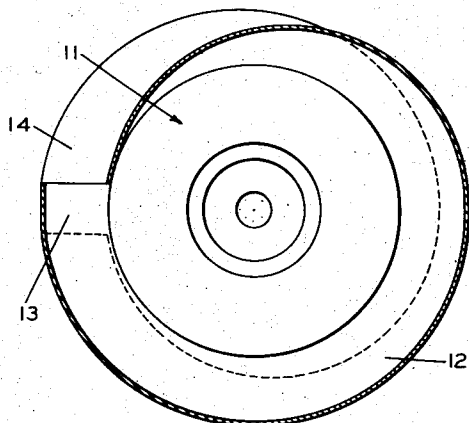


Fig. 2.

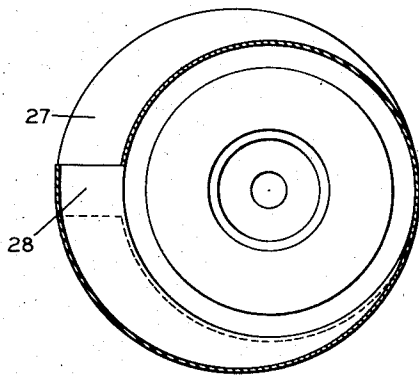


Fig. 3.

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2,033,470

CYCLONE SEPARATOR

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Application August 30, 1933, Serial No. 687,401

10 Claims. (Cl. 183—83)

This invention relates to improvements in devices for separating particles of denser substance from liquid or gas streams by swirling the stream and its particles in a free or constrained vortex. I shall refer to all such devices, whether for completely separating particles and stream or merely for concentrating the particles within a portion of the stream, as cyclone separators.

The common type of cyclone separator consists of the following parts: a cylinder into which the particle-laden stream is introduced through a duct of round or approximately square cross-section, the outside wall of the duct being tangent to the cylinder wall at entrance; a conical chamber below the cylinder for collecting or leading off the separated material; a central outlet pipe, attached to the top of the cylinder and projecting down some distance into it, leading directly to the atmosphere or to a duct.

There are, of course, many variations on this common type of design. In some cases the inside wall of the incoming stream, instead of the outside wall, is made tangent to the cylinder. This arrangement usually involves a departure from the usual circular cross-section of the cylinder toward a spiral cross-section. In some cases there is no outlet pipe projecting down into the cylinder. Sometimes a number of cylinders of various diameters are placed one below the other in the order of descending size and connected by truncated conical pieces. In some designs guide vanes are arranged within the cylinder. My invention is applicable to all of these types.

In any vortex or swirl in a fluid stream which completely fills the vortex chamber, (that is, it is not bounded at the top by a liquid surface) there is a pressure gradient, the pressure decreasing toward the center of the vortex. This pressure gradient provides the radially inward accelerations to the stream which are necessary to the swirling motion. If, as in the usual cyclone separator, the stream leaves the cylinder or separating chamber through a central hole at the top and passes directly to the atmosphere or to a duct then the minimum drop in static pressure across the most perfect collector of this type would be the pressure gradient integrated along a line passing through the vortex center between the inlet opening and the rim of the outlet hole.

The pressure drop along the stream path in a vortex results in an increase in the kinetic energy of the stream which, except for friction effects, is an essentially reversible process; that is, the kinetic energy could, presumably, be reduced again to the original or entrance magnitude with a rise in pressure equivalent (except for friction) to the drop experienced in the separating vortex.

My invention includes devices for recovering a large part of the pressure drop through the separating chamber by reducing the velocity of the

stream after it leaves the separating cylinder in a properly designed chamber or passage. In its preferred form it consists of two parallel horizontal plates, substantially circular in plan view and of about the same diameter as the separating cylinder. The lower plate has a central hole which fits the outlet pipe of the separating cylinder. The fluid stream passes from the outlet pipe of the separating cylinder into the space between the two plates and flows spirally outward until it reaches the atmosphere. If the device is intended to discharge into a duct instead of into the atmosphere, a scroll-type passage may be arranged around the perimeters of the top plates which will lead off the stream tangentially into a duct.

The stream enters this top passage with an angular momentum per unit time which is smaller than the angular momentum at the entrance to the separating cylinder by the wall friction moments only. This angular momentum results in a vortex in the top passage similar to the one in the separating chamber except that the direction of flow is spirally outward instead of spirally inward. The usual vortex pressure gradient is established in this top passage and the fluid stream flows from the low pressure region at the small radius from the center of the vortex at which it enters to the higher pressure region at the large radius at which it leaves. The pressure drop across the whole device is thus smaller than the pressure drop across the ordinary cyclone separator by the pressure rise which occurs in the top chamber.

The process of increasing the pressure along the path of a fluid stream by reducing its velocity I shall hereafter refer to as diffusion, and the passage or chamber in which the process is carried out I shall call a diffuser, a diffusing passage, or a diffusing chamber. A diffuser is essentially a reversed nozzle since in a nozzle the stream increases in velocity and decreases in pressure in the direction of flow while in a diffuser the stream decreases in velocity and increases in pressure in the direction of flow.

It is interesting to follow the pressure distribution through a separator fitted with a diffusing passage which discharges to the atmosphere. The pressure in the exit opening is necessarily atmospheric. The pressure in the connecting hole between the separating cylinder and the diffusing passage is lower than atmospheric because the vortex in the diffusing passage sets up a higher pressure at its periphery than in the center. If this were an ordinary separator the pressure in this hole would be atmospheric, and the inlet pressure, and all other pressures which the blower of the system must pump against, would be higher by an amount equal to the vacuum obtained in the connecting hole of my device.

The utility of this device consists in the reduction in power consumption in the fan or compressor which provides the pressure differential for overcoming the various frictional resistances in the path of the stream. It is obvious that any device which reduces the pressure drop in any part of the flow path will reduce the power input to the fan almost in direct proportion for the same rate of fluid flow.

I am aware that some manufacturers of cyclone separators design the top of the separator so that the fluid leaves the central exit pipe tangentially and in the direction of rotation. This results in a limited utilization of the kinetic energy of the stream leaving the exit pipe, but it does not involve the compression of the stream to higher pressure by reducing velocity. Neither does it involve the use of a vortex with spirally outward flow to obtain a rise in pressure before discharging.

The difference between a separator with a diffusing passage and a separator of the ordinary sort may be emphasized by pointing out the inherent reversibility of my combination. A separator may be fitted with a diffusing passage and an outlet scroll, the discharge cross-section of which may be made equal to the inlet area of the separating cylinder. If a stream of frictionless fluid were introduced into the separating cylinder at a certain pressure it would leave the outlet scroll at the same pressure. Across an ordinary separator, on the other hand, the pressure of the fluid would have decreased by the integrated pressure gradient through the separating vortex. In this new design the fluid flow could just as well have been reversed in direction, entering through the top scroll opening and leaving through the opening in the lower cylinder wall. The diffusing passage has now become the separating chamber, and the separating chamber has become the diffusing passage. Such reversal of flow would be impossible in the ordinary separator because the entering fluid in the reversed case, having no rotation, would produce no vortex and would do no separating.

This invention can be modified by inserting vertical guide vanes in the diffusing passage to aid the diffusion process or to reduce the length of the fluid path through the diffusion passage.

In the accompanying drawings:

Fig. 1 shows my invention in its simplest form and arranged to discharge the stream directly to the atmosphere.

Fig. 2 is a transverse section on line 2-2 of Fig. 1.

Fig. 3 shows experimental data on the saving realized from the use of the device shown in Fig. 1.

Fig. 4 shows my invention with two modifications, first, a conical connecting piece between the cylinder outlet pipe and the diffusing passage and, second, guide vanes in the diffusing passage to aid diffusion.

Fig. 5 is a transverse section on line 5-5 of Fig. 4.

Fig. 6 shows my invention arranged to discharge into a duct.

Fig. 7 is a transverse section on line 7-7 of Fig. 6.

Fig. 8 is a separator arranged to permit the stream to flow in either direction.

Fig. 9 is a transverse section on line 9-9 of Fig. 8.

Fig. 10 shows a modification of Fig. 1 with conical instead of flat diffusing plates.

The separator shown in Figs. 1 and 2 comprises vertical cylinder 1 in which the denser particles are separated from the fluid stream which enters through approach pipe 2, lower conical hopper 3 for collecting or leading off the denser separated material, discharge pipe 4 through which the stream passes on its way to diffusing passage 5, which is bounded by circular plates 6 and 7 resting on supports 8. Plates 6 and 7 need not be horizontal but may be formed into substantially parallel cones with apexes at the top or at the bottom of the cone. Slight departures from parallelism between 6 and 7 will not necessarily destroy the effectiveness of the diffusion passage and in some instances might be advantageous.

The distance between plates (or cones) 6 and 7 for minimum pressure drop across the entire device must be determined in each instance by experiment. Fig. 3 shows experimentally determined pressure drops plotted against distance between plates 6 and 7 for a separator, similar to that shown in Figs. 1 and 2, the separating cylinder of which was 72 inches diameter and the outlet pipe 27 inches diameter. The ordinate is pressure drop in inches of water, the abscissa is distance between plates 6 and 7 in inches. Line 10a shows the pressure drop for the separator with only a weather shield over the outlet pipe. Line 10b shows the pressure drop for the same flow through the same separator fitted with plates 6 and 7. A maximum gain of about 30% is realized in this case when the plates are two inches apart.

The separator shown in Figs. 4 and 5 is similar to that shown in Figs. 1 and 2 except for conical connecting piece 9 and guide vanes 10. Connecting piece 9 guides the fluid stream more smoothly into the diffusing passage and reduces the eddy disturbances which may be caused by the sharp corner between discharge pipe 4 and plates 6 shown in Fig. 1. The connecting piece need not, of course, be conical in shape, but may have a curved cross-section. The relative ease with which the conical piece may be manufactured will recommend it even above designs which might give slightly smoother flow. The guide vanes are desirable to promote diffusion under certain circumstances, particularly in cases where the tangential component of the velocity would otherwise be high where the fluid passes out from between the plates.

In Figs. 6 and 7 is shown a separator with diffusing passage 11 fitted with scroll 12. The scroll collects the stream leaving the diffuser and leads it to exit opening 13 which is approximately of the same cross-section area as separator inlet 14. A duct may be connected to the scroll at 13 to lead the stream off to other apparatus or to an outlet pipe.

A separator arranged for flow in either direction is shown in Figs. 8 and 9. It comprises lower cylinder 15 and upper cylinder 16 connected by central pipe 17 and conical pieces 18. The lower cylinder is fitted with conical hopper 19 to lead off or to collect separated material. The upper cylinder is fitted with conical hopper 20 for the same purpose. Hopper 20 surrounds pipe 17 and is fitted with cleanout door 21. An annular dust passage leading down to some collecting chamber may be substituted for hopper 20, but modifications of this kind are of secondary importance and are included within the scope of my invention. The lower cylinder plate 22 is supported on brackets 23 leaving between the edge of the plate and the hopper wall an annular opening 24 through which separated material may pass into 75

the hopper. Similarly in the top cylinder is fitted plate 25 around the edge of which is left clearance space 26. Plates 22 and 25 are not essential to my invention, but they aid diffusion when diffusion is occurring in their respective cylinders. In the absence of plates 22 and 25 the fluid in the hopper, being retarded by wall friction may be reduced in velocity to the point where its kinetic energy is inadequate to permit it to flow outward against the pressure gradient. A reverse flow inward would then be set up within the hopper. Fluid flowing inward must ultimately be carried outward again by friction drag from the main diffusing stream, and this process reduces the momentum of the diffusing stream and reduces the rise in pressure realized in the diffusion process. Plates 22 and 25 prevent transfer of momentum from the main stream to the fluid in the hopper. The lower cylinder is provided with opening 27 and the upper with opening 28 of equal area. Both openings may be connected with ducts.

Now, if the fluid stream is led into opening 27 separation of denser particles will occur in the vortex set up in cylinder 15; the stream will pass from cylinder 15 through pipe 17 to cylinder 16 in which it will flow outward against the vortex pressure gradient to opening 28. The device will work equally well if the direction of flow is reversed, the stream entering opening 28 and leaving through opening 27, separation occurring in cylinder 16 and diffusion in cylinder 15.

The device shown in Figs. 8 and 9 may be used in cases where separation of denser particles is desired from a stream which flows alternately in opposite directions, as in certain regenerative processes in industry.

Fig. 10 shows a somewhat better design for outdoor use than Fig. 1 in which plates 36 and 37 are coned instead of flat as are plates 6 and 7 in Fig. 1, but the operation is the same.

The invention claimed is:

1. A diffusing passage comprising two substantially parallel and horizontal plates in combination with a cyclone separator, including a separating cylinder and a centrally disposed exit pipe, the lower plate being in the form of an annulus supported above the top of the separating cylinder and attached to the exit pipe of the separating cylinder.

2. A diffusing passage comprising two substantially parallel and horizontal plates separated by vertical guide vanes in combination with a cyclone separator, including a separating cylinder and a centrally disposed exit pipe, the lower plate being in the form of an annulus which is attached to the exit pipe of the separating cylinder.

3. A diffusing passage comprising two substantially parallel conical plates in combination with a cyclone separator, the lower cone being provided with a central hole, and being attached to the exit pipe of the separating cylinder so that the hole in the cone is concentric with the exit pipe of the cylinder, said conical plates being disclosed substantially close together to insure diffusion.

4. A diffusing passage comprising two substantially parallel plates, a peripheral chamber surrounding these plates, communicating with the space between them and open at one point on the periphery where connection may be made with a duct, in combination with a cyclone separator, including a separating cylinder and a centrally disposed exit pipe, the lower of the two plates

being provided with a central hole, and being attached tightly to the exit pipe of the separating cylinder so that the hole in the plate is concentric with the exit pipe of the cylinder, the upper plate extending over and beyond the hole in the lower plate a sufficient distance to insure diffusion.

5. A cyclone separator consisting of two vortex chambers each having a peripheral opening and placed one above the other on a common center line, the chambers communicating with each other through a central hole or pipe, with a chamber at the bottom of the lower vortex chamber for collecting or leading off separated material, and an annular chamber attached to the bottom of the upper vortex chamber for collecting or leading off separated material, whereby the fluid stream may flow in either direction through the separator with effective separation.

6. The combination with a cyclone separator having a cylindrical separating chamber, a tangential inlet for dust-laden air, means for collecting material separated from the air in said chamber, and a centrally disposed exit pipe for the air from said chamber, of means for reducing the velocity and increasing the pressure of the air discharged from said exit pipe comprising a lower plate connected to the end of the pipe above the top of said separating chamber and an upper plate overlying the lower plate and the pipe whereby to reduce the pressure drop in the flow path and reduce the power input.

7. The combination with a cyclone separator having a cylindrical separating chamber, a tangential inlet and a centrally disposed exit pipe, of a diffuser comprising a pair of superposed plates of substantially the same diameter as said separating chamber, the lower plate being in the form of an annulus attached to the exit pipe of said separating chamber above the top of said separating chamber.

8. The combination with a cyclone separator having a cylindrical separating chamber, a tangential inlet and a centrally disposed exit pipe, of a diffuser comprising a pair of superposed cones of substantially the same diameter as said separating chamber, the lower cone being in the form of an annulus attached to the exit pipe of said separating chamber, said cones being disclosed substantially close together to insure diffusion.

9. The combination with a cyclone separator having a cylindrical separating chamber, a tangential inlet and a centrally disposed exit pipe, of a diffuser comprising a pair of superposed plates of substantially the same diameter as said separating chamber, the lower plate being in the form of an annulus attached to the exit pipe of said separating chamber, and vertical guide vanes arranged between said plates to promote diffusion.

10. The combination with a cyclone separator having a cylindrical separating chamber, a tangential inlet and a centrally disposed exit pipe, of a diffuser comprising a pair of superposed plates of substantially the same diameter as said separating chamber, the lower plate being in the form of an annulus attached to the exit pipe of said separating chamber, and a scroll connecting the peripheries of said plates and having an exit opening of approximately the same cross-sectional area as the inlet of said separating chamber.

CERTIFICATE OF CORRECTION.

Patent No. 2,033,470.

March 10, 1936.

JOSEPH H. KEENAN.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, first column, line 66, claim 3, for "disclosed" read disposed; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 21st day of April, A. D. 1936.

Leslie Frazer

Acting Commissioner of Patents.

(Seal)