Aug. 31, 1954 F. R. CULHANE 2,687,780

GAS CLEANING APPARATUS

Filed Dec. 28, 1951 3 Sheets-Sheet 1

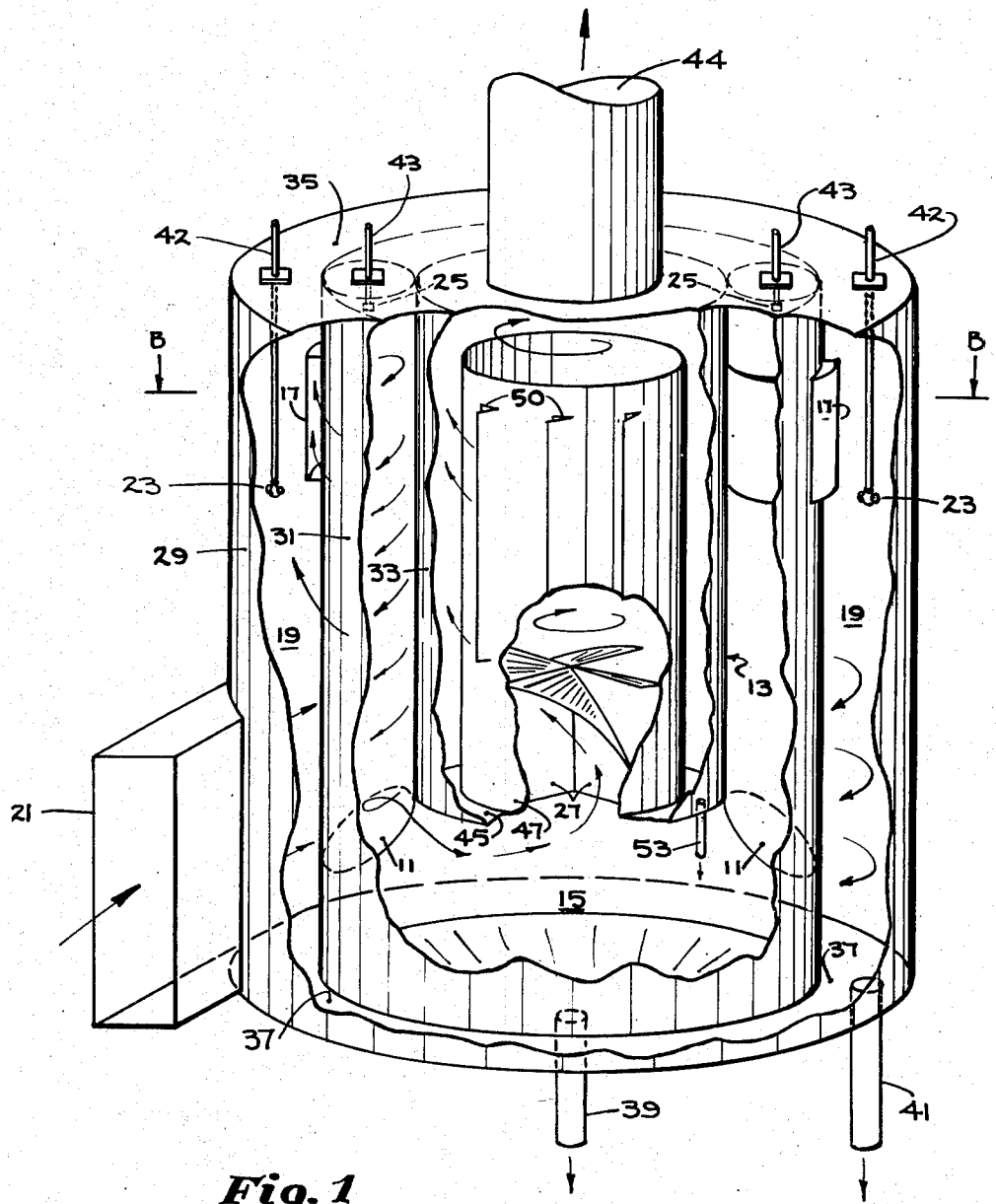

Fig. 1

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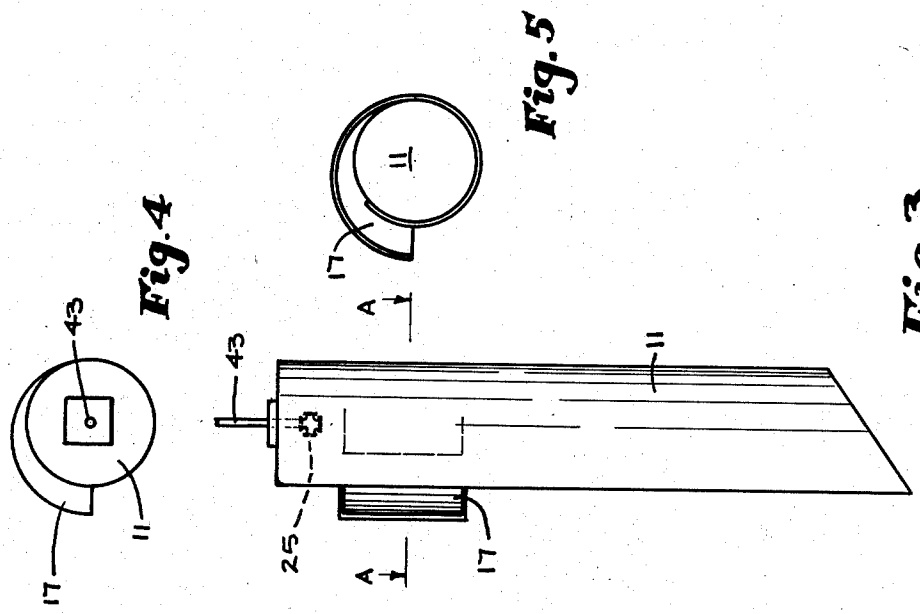

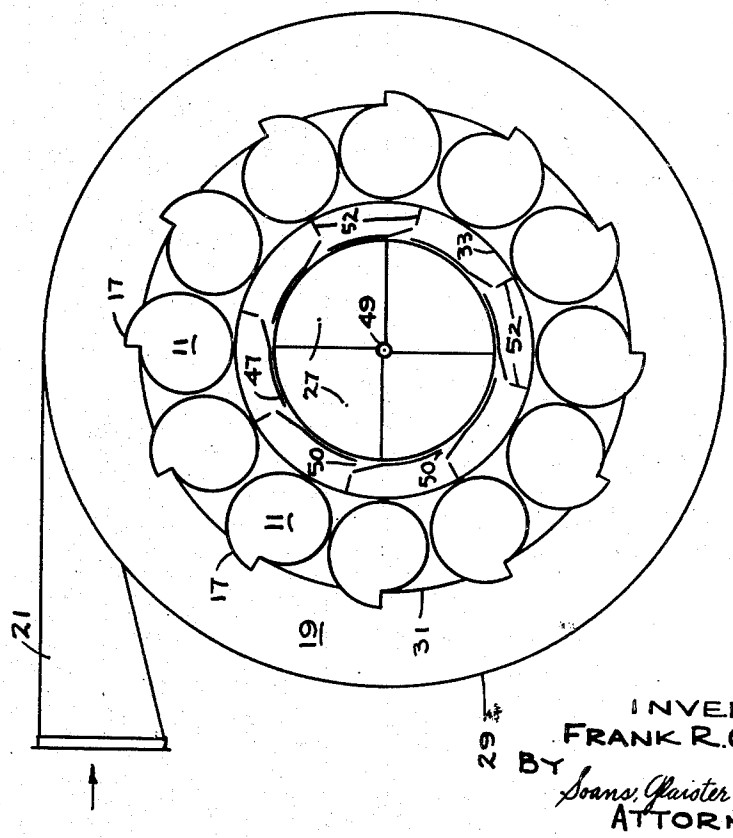

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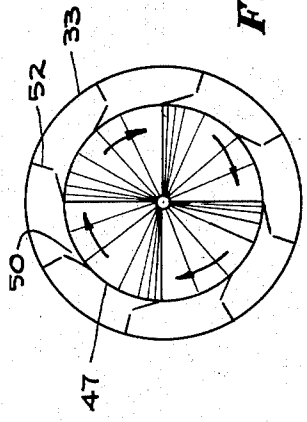

Fig. 7

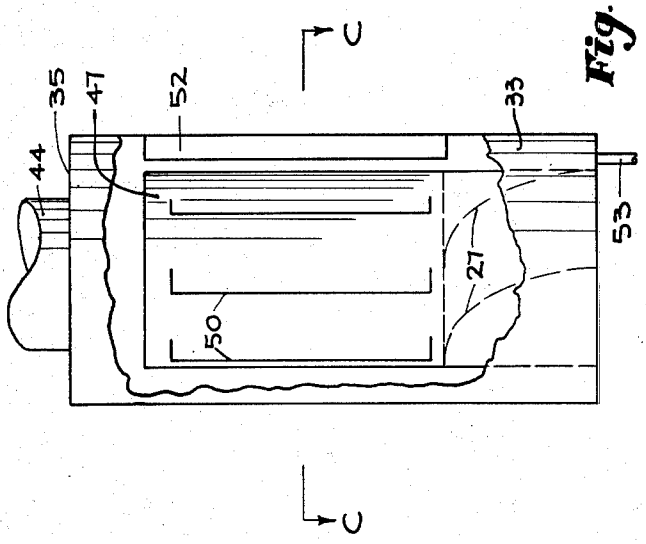

Fig. 6

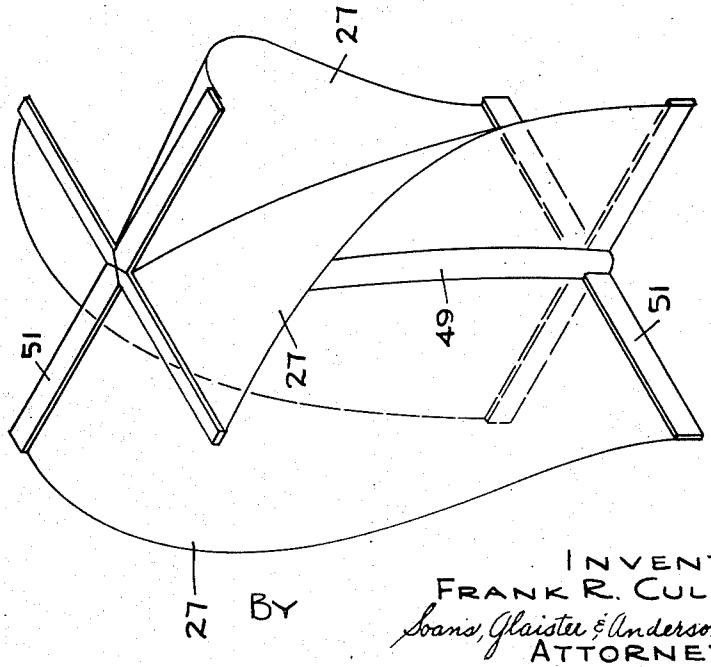

Fig. 8

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GAS CLEANING APPARATUS

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5 Claims. (Cl. 183—22)

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The present invention relates to the purifying of air and other gases, and is particularly concerned with an apparatus for removing dust or other particulate matter from a moving stream of gas by causing said particulate matter to become entrained in a liquid disposed in contact with the stream of gas.

Gas cleaning devices of this general type have been in general use in various forms, employing in their operation a variety of physical principles for presenting the liquid to the moving stream of gas or vice versa, in a manner calculated to cause the particulate matter carried by the gas to be assimilated by the liquid. Apart from the question of economic efficiency, gas cleaners of the wet or so-called "scrubber" types capable of treating large quantities of gas, have in common the inability to remove from the gas, in substantial quantity, extremely fine particles of the order, for example, of two microns (2×10^{-6} meters) and less in size. The efficient removal of particles in this range of sizes, at the present time and on a commercial basis, is considered the province of various types of true filter-type devices. The latter, however, are not suited to the handling of large volumes of gases at high velocities.

Accordingly, it is the primary object of the present invention to provide a gas cleaning apparatus of the wet or "scrubber" type of substantially increased efficiency in the removal from gas streams of extremely small particles. A further object of the invention is the provision of a highly efficient wet type cleaner in which large quantities of gas can be cleaned at high velocities without objectionable entrainment of the liquid by the gas leaving the cleaner. A still further object of the invention is to provide an improved gas cleaner which is capable of efficiently cleaning large quantities of gas at high velocities without the expenditure of unreasonable amounts of power.

Other objects and advantages will become apparent by reference to the following description and to the accompanying drawings, which illustrate a preferred embodiment of the invention.

In the drawings:

Figure 1 is a perspective view of the gas cleaning apparatus of the invention, partially broken away to show the inner construction and gas paths in greater detail.

Figure 2 is a diagrammatic sectional plan view of the gas cleaner taken along the line BB of Figure 1.

Figure 3 is an elevational view of one of a plurality of cleaner tubes forming part of the apparatus.

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Figure 4 is a plan view of the tube illustrated in Figure 3.

Figure 5 is a sectional view taken along the line AA of Figure 3.

Figure 6 is a fragmentary elevational view of that portion of the cleaner apparatus through which the gas is discharged, and is partially broken away to show its inner construction in greater detail.

Figure 7 is a diagrammatic sectional view taken along the line CC of Figure 6, and

Figure 8 is an enlarged perspective view of a guide vane assembly disposed within the discharge conduit illustrated in Figures 1, 6 and 7.

Briefly, the preferred embodiment of the invention illustrated in the drawing comprises a plurality of upright scrubber tubes 11 arranged in a cluster about a central discharge stack 13 to which the individual tubes are manifolded at their lower ends by means of a collection chamber 15. The individual scrubber tubes are closed at their upper ends, but are provided adjacent those ends with intake conduits or scoops 17 which are arranged to admit gas to the interior of the tubes in a tangential direction. The intake openings of the individual scrubber tubes 11 are in turn manifolded by an annular chamber 19 which surrounds the tube cluster, and into which the individual scrubber tube intake scoops 17 extend with their openings presented tangentially to the inner wall of the manifold chamber. For conducting the gas to be cleaned into the apparatus, the annular intake manifold is provided with an intake conduit 21 which introduces the incoming gas tangentially into the annular manifold chamber from the direction opposite to that in which the individual tube intake scoops face.

Disposed about the interior of the intake manifold chamber 19, is a plurality of spray nozzles 23 located slightly below the level of the tube intake scoops 17 and which, during the operation of the apparatus, provide a spray curtain through which the incoming gas spiralling upwardly through the intake manifold chamber must pass, and which direct a film of the spray liquid downwardly along walls of the manifold chamber. Each of the individual scrubber tubes 11 is similarly provided with a spray nozzle 25 disposed above the level of the intake scoops 17 for directing a film of liquid downwardly along the inner surfaces of the tube. The spent liquid with its entrained particulate matter collects in the form of a slurry or sludge at the bottom of the intake and dis-

charge manifold chambers from which it is continuously removed.

The streams of gas issuing from the lower ends of the scrubber tubes 11 are reversed in direction 180 degrees through the discharge manifold chamber 15 to pass upwardly out of the apparatus through the central discharge stack 13. This abrupt change of direction is effective to remove from the gas the major portion of any liquid which may have been entrained in droplet form in the intake manifold and in the scrubber tubes, but to complete the removal of these droplets, including what particulate matter they may contain, guide vanes 27 are provided at the base of the discharge stack to impart a whirling motion to the gas entering the stack, so as to remove by centrifugal action additional liquid not removed in the discharge manifold chamber 15. The additional moisture and entrained particulate matter thus removed is collected at the base of the stack by a novel construction, later to be described in detail, and removed from the apparatus, while the stream of gas leaves the cleaner apparatus in an upward direction through the discharge stack.

It will be understood, of course, that pump means, not forming part of the cleaner apparatus itself, is provided for forcing the gas into the apparatus, or drawing the gas through the apparatus, although it will usually be preferred to place the pump or fan on the discharge side of the apparatus so as to handle the gas only after it has been cleaned.

Referring initially to Figure 1 for a detailed description of the apparatus in preferred form, the cleaner comprises three upright concentric shells 29, 31 and 33 joined together at their upper ends by means of a top plate 35 to which the shells may be secured by welding. The outer shell 29 and middle shell 31 are co-extensive and connected together in similar fashion at their lower ends by a floor plate 37 so as to define between them the annular chamber 15, while the innermost shell 33 is somewhat shorter than the two outer shells 29 and 31, so as to define within the middle shell 31 beneath the inner shell, the discharge manifold chamber 15, which communicates with the annular space between the inner shell 33 and middle shell 31, and with the space within the inner shell 33. The floor plate 37 is preferably dished in its central portion and provided with a drain 39 for a purpose later to be described, and the entire floor plate is slightly inclined toward one side of the apparatus and provided near its lowermost point with a drain 41 leading from the annular intake manifold chamber 19 between the two outer shells. Secured to the outer shell 29 in the lower portion thereof, is the intake conduit 21 through which the dirt-laden gas enters tangentially into the manifold chamber 19.

Between the middle shell 31 and inner shell 33 are disposed the individual scrubber tubes 11 (Figs. 1 to 5 inclusive), twelve in number in the particular apparatus illustrated, the tubes being secured to the adjacent shells 31 and 33 or to the top plate 35 by any desired means. The tubes are closed at their top ends and open at their bottom ends, the latter being preferably truncated at an angle to the longitudinal axis of the tube, and with the shorter side of each tube adjacent to, and preferably co-extensive with the innermost shell 33. The intake scoop 17 adjacent the upper end of each tube 11 may be formed of curved plate, and extends tangentially into the annular intake chamber 19, adjacent the middle shell 31 and having its mouth facing in the same rotative direction in which the intake conduit 21 extends from the outer shell 29 (Fig. 2), that is, presented to the generally spiral flow of the gas upwardly through the intake manifold chamber. The intake scoops 17 merge tangentially with the cylindrical walls of the scrubber tubes 11 (Fig. 5) and, in the operation of the device, "skin" the inner layer of gas spiralling on a large radius through the intake chamber 19 and rapidly accelerate it to a high rotational velocity inside the scrubber tubes.

The spray nozzles 23 are distributed circumferentially about the interior of the intake manifold chamber 19 below the level of the intake scoops 17 of the scrubber tubes, and are connected by means of conduits 42 extending upwardly through the top plate 35 to a source of pressure liquid (not shown). The nozzles 25 located within the tubes 11 above the level of the intake scoops 17 are similarly connected by means of conduits 43 to the source of pressure liquid. It will be understood, of course, that the liquid supply system would include any suitable manifold for distributing the liquid under pressure to the nozzles, and one or more regulating valves for controlling the pressure of the liquid at the nozzle.

The effluent from the several scrubber tubes 11 is combined in the discharge manifold chamber 15 into a single stream of gas and discharged from the apparatus through the stack 13, which includes the inner shell 33 and a central discharge conduit 44 secured in the top plate 35 of the apparatus above the inner shell. Disposed within the inner shell 33 and connected therewith at its lower end by means of a suitable annular plate 45, is a short tube 47 (Figs. 1 and 6) having secured in its lower portion the curved guide vanes 27 which are disposed in the path of the entering gas to impart to the gas stream a twisting motion. In the embodiment shown, the upper and lower edges of each guide vane or plate are displaced 90 degrees from one another (Fig. 8), and to prevent the formation of a "core" in the gas stream, the guide vanes extend to the center of the tube 47 and are there joined to an upright re-enforcing member 49 which is positioned centrally of the tube and provided at each of its ends with a spider 51 to which the edges of the guide vanes 27 may be secured by any suitable means.

The rotary motion imparted to the stream of gas flowing upwardly through the inner tube 47 throws any liquid entrained in droplet form against the walls of the tube, and in order to remove this liquid, a series of vertical louvres 50 are provided to permit the liquid to pass outwardly into the annular space between the inner tube and the shell 33. It has been found that the removal of liquid in this manner is more effective if a portion of the gas is also permitted to escape through the louvres so as to sweep the liquid with it, and for this purpose the inner tube preferably terminates short of the top plate 35 of the apparatus (Fig. 1) so that the main stream of gas passing outwardly through the discharge conduit 44 exerts an aspirator effect tending to reduce the pressure within the annular space surrounding the louvred inner tube. To further assure that liquid entering the annular space about the inner tube is not again carried in the main gas streams, a plurality of radially extending vanes or "spoilers" 52 (Figs. 6 and 7) may be provided on the inner surface of the

inner shell 33 to intercept the liquid and convey it down to the bottom of the chamber.

The liquid and entrained particulate matter is collected at the bottom of the annular chamber surrounding the inner tube 47 and drained therefrom in any suitable manner as, for example, by a drain 53 discharging directly into the discharge manifold chamber 15 from whence it is conveyed outwardly through the drain 39.

The apparatus operates as follows:

A suitable liquid is supplied under pressure to the nozzles 25 in each of the scrubber tubes 11 and to the nozzles 23 in the annular intake manifold chamber 19, to direct a film of liquid downwardly along the walls of said tubes and chamber, and to create in the latter a spray curtain. A pressure head is created across the apparatus in any suitable manner so as to cause the dirt-laden gas to enter the intake conduit 21, from which it spirals upwardly through the annular manifolding chamber 19 and through the spray curtain, into the upper regions of the chamber.

It will be apparent that a certain amount of cleaning action takes place within this annular intake chamber. First of all the heavier, denser particles are immediately thrown by centrifugal force against the outer wall of the chamber where they become entrained in the downwardly flowing film of liquid, and are carried to the floor of the chamber. A further amount of particulate matter collides with droplets of liquid as the gas passes upwardly through the spray curtain, and is carried with the liquid to the walls of the chamber and down. Furthermore, the introduction of the gas at substantial velocity from the relatively restricted intake conduit 21 into the relatively unrestricted space within the annular manifolding chamber 19, reduces the velocity of flow and permits a certain amount of the entrained solid particles to settle out of the gas by gravity, as is well understood. The solid matter removed from the gas in the chamber 19 forms a sludge with liquid and is removed from the apparatus through the drain 41.

In the upper part of the intake manifold chamber 19, the layer of relatively cleaner gas circling along the inner wall 31 of the chamber is caught by the intake scoops 17 of the scrubber tubes 11, the radius of which may be of the order of ⅕ or less of the inner radius of the chamber 19, whereupon the gas entering the scrubber tubes is instantaneously accelerated to high rotational velocities, substantially increasing the centrifugal force and causing the smaller, lighter particles to impinge upon the walls of the scrubber tubes where they become entrained in the descending film of liquid supplied from the spray nozzles 25. The spray nozzles 25, as previously indicated, are positioned above the intake scoops 17 so that the film of liquid is supplied at a high enough level to have a lubricating effect in the scoop 17 and adjacent tube walls and to reduce the abrasive effect of the solid particles impinging thereupon.

The whirling gas spirals downwardly through the tubes 11 to enter the discharge manifold chamber 15, in which the individual streams of gas issuing from the scrubber tubes are combined and conveyed upwardly into the discharge stack 13. It will be noted that the gas, in passing through the discharge manifold chamber 15 is reversed in direction, this sudden change of direction being effective to remove from the gas by centrifugal force a major portion of any of the liquid in droplet form which may have become entrained by the gas in the intake manifold chamber 19 and in the scrubber tubes 11. The liquid and entrained particulate matter flowing downwardly along the inner surfaces of the scrubber tubes is conveyed by the truncated lower edges of the tubes over to the shell 31, thus minimizing the opportunity for further liquid entrainment, and flows downwardly therealong to collect in the discharge manifold chamber from which it is removed as a slurry or sludge by the drain 39.

The gas then passes upwardly through the inner tube 47 in which any remaining liquid in droplet form is centrifuged, passing out of the tube through the louvres 50, in its side walls, and being collected in the annular space around the tube 47 and conveyed by means of the drain 53 to the discharge manifold chamber 15 where it is co-mingled with the sludge and removed through the drain 39.

In the foregoing, there has been described an improved gas cleaner device employing known physical principles in a more effective manner, and in which higher cleaning efficiencies are attained than have previously been known in existing types of gas cleaners employing those principles. It has been found, furthermore, that the device of the invention is capable of handling substantial quantities of gas at relatively high velocities with minimum liquid entrainment, and that it requires the expenditure of only reasonable amounts of power.

Various features of the invention believed to be new and patentable are set forth in the appended claims.

I claim:

1. An apparatus for removing particulate matter from a moving stream of gas, comprising means including a pair of upright concentric shells connected together at their ends to define an annular intake chamber having an intake opening for admitting gas generally tangentially to said chamber a plurality of upright scrubber tubes disposed about the interior of the inner one of said shells, each scrubber tube being closed at its upper end and having near its upper end an intake conduit connecting said tube and said chamber and having its ends presented tangentially to said inner shell and to said tube respectively, means for directing a film of liquid downwardly along the inner walls of said chamber and said tubes for entraining the particulate matter impinging upon said walls, means defining a manifold chamber connected to the lower ends of said tubes, venting means for said manifold chamber comprising a vertical stack located centrally of said plurality of tubes and having within its lower portion an inner concentric shell connected with the lower end of the stack to define an annular chamber about said shell, said inner stack shell having interior guide vanes for imparting a whirling motion to the stream of gas entering said shell thereby to remove liquid and particulate matter from said gas by centrifugal action, said inner stack shell being perforated above said vanes to permit said liquid and particulate matter and a portion of said gas to enter said annular stack chamber, and means for removing the spent liquid and particulate matter from said intake chamber, said manifold chamber and said stack chamber.

2. An apparatus for removing particulate matter from a moving stream of gas comprising means including a pair of upright concentric cylindrical shells, top and bottom cover members secured to the ends of said shells and defining

therewith a central inner chamber and an annular outer chamber; an intake conduit for said apparatus connected to said outer shell to admit the gas to be cleaned tangentially to said annular chamber, a plurality of upright scrubber tubes within and disposed about the periphery of said inner chamber, each scrubber tube being closed at its upper end and having near its upper end an intake conduit connecting said tube and said outer chamber, said tube intake conduit having its ends presented tangentially to the inner one of said shells and to said tube respectively, means for directing a film of liquid downwardly along the walls of said outer chamber and said tubes for entraining the particulate matter impinging upon said walls; said tubes being open at their bottom ends and terminating short of said bottom cover member so as to discharge into said inner chamber, an exhaust conduit connected to the upper end of said inner chamber for discharging the gas from said apparatus, said inner chamber serving to manifold and reverse the direction of flow of the gas discharging from said plurality of tubes, and means for removing the spent liquid and its entrained particulate matter collecting in the bottoms of said chambers.

3. An apparatus for removing particulate matter from a moving stream of gas comprising means including a pair of upright concentric cylindrical shells, top and bottom cover members secured to the ends of said shells and defining therewith a central inner chamber and an annular outer chamber, an intake conduit for said apparatus connected to said outer shell to admit the gas to be cleaned tangentially to said annular chamber, a plurality of upright scrubber tubes within and disposed about the periphery of said inner chamber, each scrubber tube being closed at its upper end and having near its upper end an intake conduit connecting said tube and said outer chamber, said tube intake conduit having its ends presented tangentially to the inner one of said shells and to said tube respectively, means for directing a film of liquid downwardly along the walls of said outer chamber and said tubes for entraining the particulate matter impinging upon said walls, said tubes being open at their bottom ends and terminating short of said bottom cover so as to discharge into said inner chamber, means defining an exhaust stack extending downwardly through said top cover member centrally of said plurality of tubes and into said inner chamber for discharging the gas from said apparatus, said inner chamber servicing to manifold and reverse the direction of flow of the gas discharging from said plurality of tubes and to convey same to said stack, liquid eliminator means in the lower portion of said stack for removing entrained liquid from said gas, and means for removing the spent liquid and its entrained particulate matter from the bottoms of said chambers and from said eliminator means.

4. Apparatus for removing entrained liquid from a moving stream of gas comprising a cylindrical conduit for receiving said gas stream, a plurality of curved guide vanes disposed within said conduit to impart a whirling motion to said gas stream, said conduit being perforated downstream from said vanes, a shell surrounding said conduit and being connected thereto so as to form an annular chamber about the perforated portion of said conduit, a second conduit spaced from the downstream end of the first mentioned conduit, said chamber being connected to said second conduit downstream from said first mentioned conduit to return to said second conduit the gas escaping from said first mentioned conduit through said perforations, and means for removing liquid collecting in said chamber.

5. Apparatus for removing entrained liquid from a moving stream of gas comprising a cylindrical conduit having disposed therein a plurality of curved guide vanes for imparting a whirling motion to a stream of gas passing therethrough, said conduit having formed therein a plurality of longitudinally extending slot openings downstream from said vanes and terminating downstream from said slot openings, a shell surrounding said conduit and being connected thereto so as to form an annular chamber about the slotted portion of said conduit, said shell extending downstream beyond the discharge end of said conduit and being connected by means of an annular ring to a second conduit of lesser cross-sectional area than said shell, said second conduit receiving the discharge of the first-mentioned conduit and the portion of the gas escaping said first-mentioned conduit through said slot openings, and means for removing the liquid collecting in said chamber.

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