Sept. 6, 1932. G. H. HORNE ET AL 1,875,341

GAS CLEANING AND HEAT TRANSFER APPARATUS

Filed July 28, 1931 3 Sheets-Sheet 1

Fig. 1.

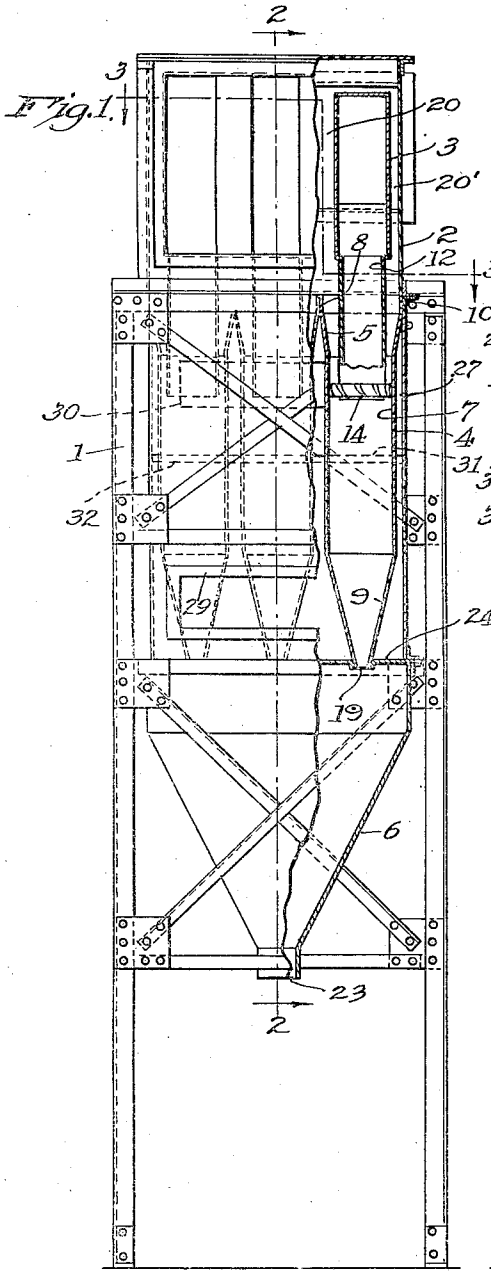
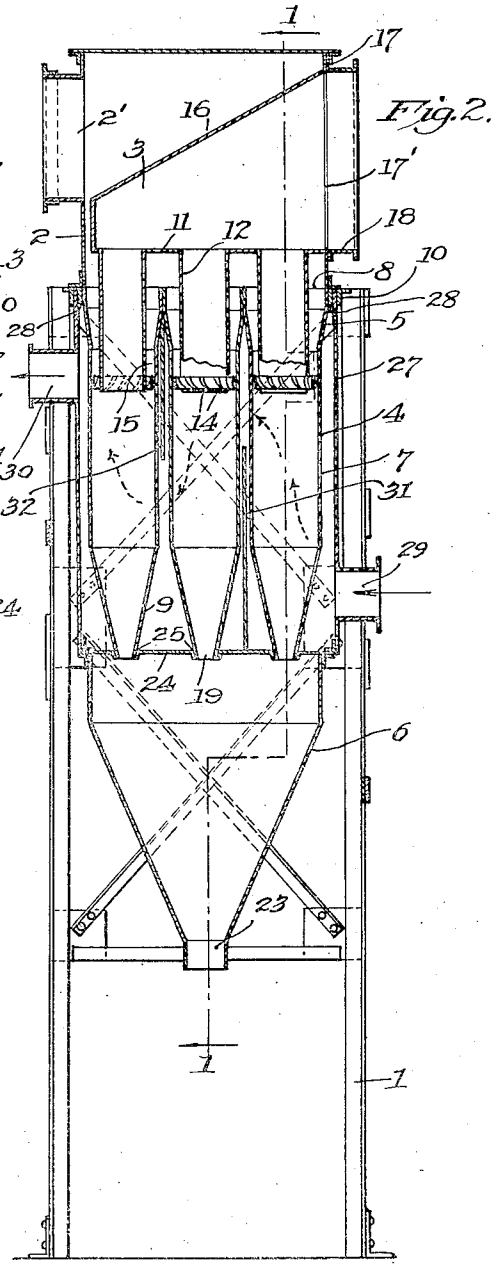


Fig. 2.



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GAS CLEANING AND HEAT TRANSFER APPARATUS

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Fig. 3.

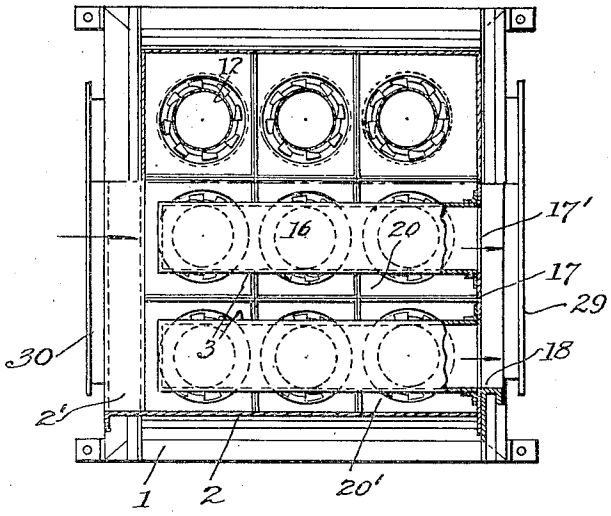
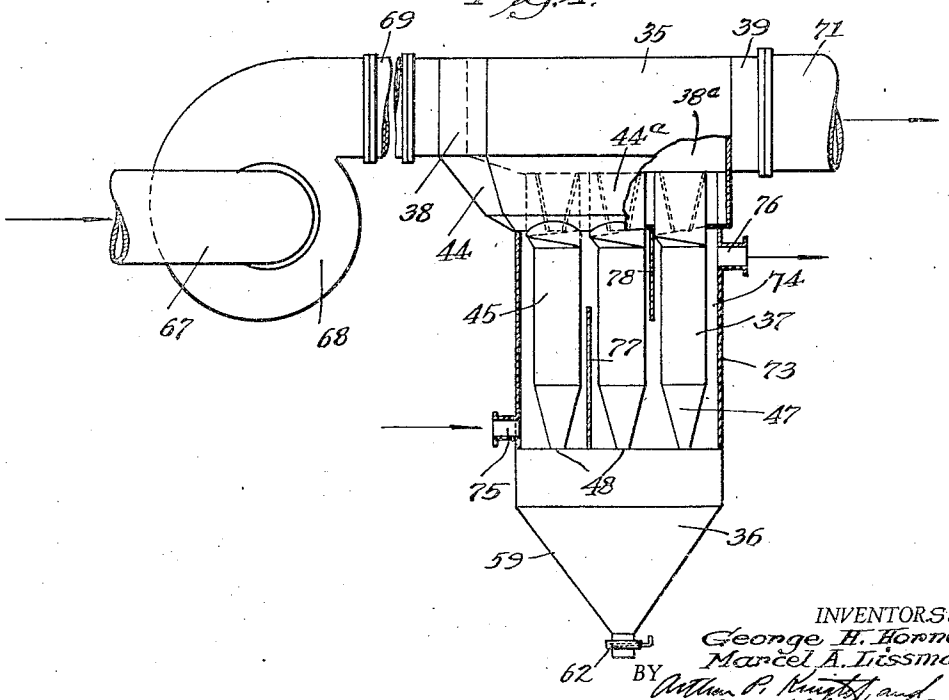


Fig. 4.



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GAS CLEANING AND HEAT TRANSFER APPARATUS

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Fig. 5.

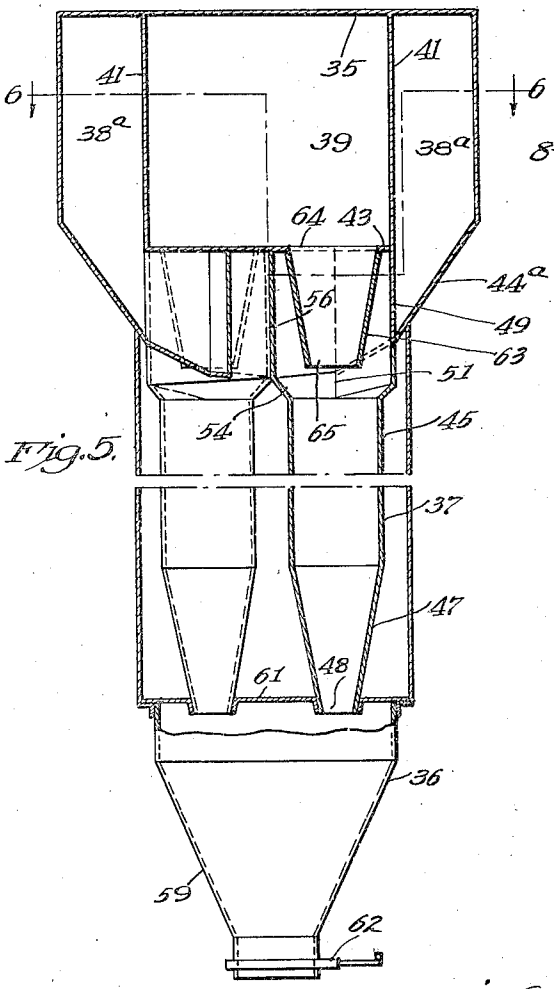


Fig. 7.

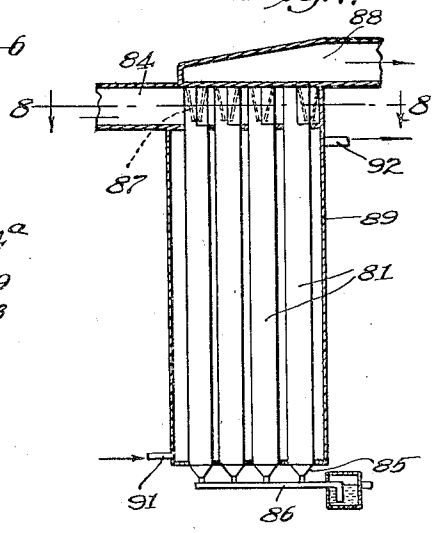


Fig. 8.

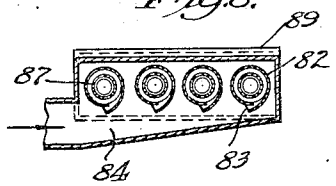
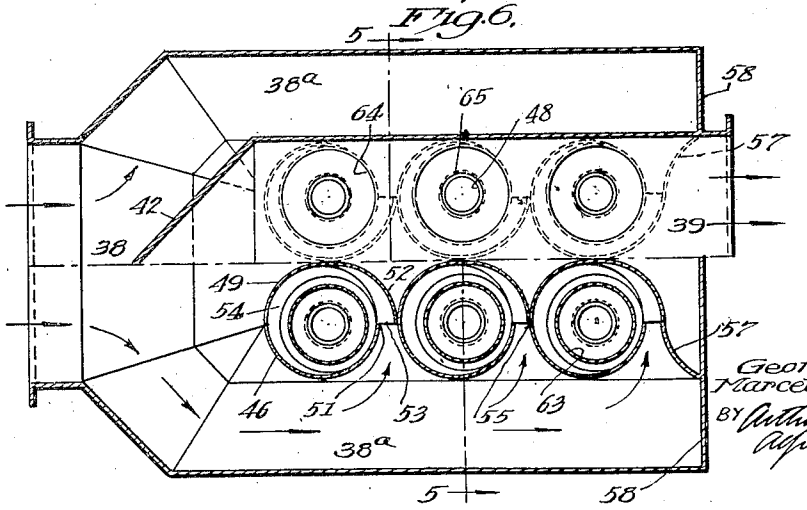


Fig. 6.



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UNITED STATES PATENT OFFICE

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GAS CLEANING AND HEAT TRANSFER APPARATUS

Application filed July 28, 1931. Serial No. 553,540.

This invention relates to apparatus for removing suspended material from gases and for effecting transfer of heat to or from such gases, and particularly to apparatus in which the cleaning and heat transfer operations are conducted simultaneously in a single piece of apparatus.

The principal object of this invention is to provide apparatus in which both the removal of suspended materials from the gas and the transfer of heat to or from the gas may be effected simultaneously and with a high degree of efficiency, in an apparatus of mimimum size and cost, and with a minimum requirement for power expenditure.

A particular object of the invention is to provide an apparatus in which a high velocity vortical or cyclonic gas movement is utilized not only for centrifugally separating suspended material from the gas but also for promoting efficient transfer of heat between the gas and the walls of the apparatus through which such heat transfer is effected.

A further object of the invention is to provide in certain instances for separation from the gas, not only of suspended material already present therein but also of suspended material formed therein by condensation resulting from cooling of the gas in its passage through the apparatus.

This application is filed as a continuation in part of our applications Serial No. 356,921, filed April 22, 1929, and Serial No. 403,003, filed October 28, 1929.

The apparatus of the present invention comprises essentially a plurality of tubular separating elements connected in parallel between common inlet header means at one end thereof and a common receptacle for separated material at the other end thereof and each provided with gas outlet means adjacent the end connected to said inlet header means, together with a common housing surrounding said tubular separating elements and means for passing through said housing a fluid medium at a temperature materially different than the temperature of the gas passed through the tubular separating elements, so as to provide for either heating or cooling of said gas. Each of the tubular separating elements communicates with the common inlet header through inlet means adapted to produce whirling, vortical or cyclonic motion of gas within said separating elements and is provided with an elongated separating chamber of circular cross-section and with a restricted outlet opening at the end connected to the common material receptacle, while the gas outlet means of each separating element communicates with the separating chamber thereof substantially centrally of said chamber and adjacent the inlet end. The apparatus also preferably comprises baffle means extending across said housing between the separating elements and transverse to the direction of flow of fluid medium through said housing so as to increase the length of path of said fluid medium to said housing and provide increased efficiency of heat transfer between said fluid medium and the walls of said separating elements. The fluid medium passed through the housing and around the separating elements may be either a liquid medium or a gaseous medium.

The accompanying drawings illustrate certain forms of apparatus embodying our invention, and referring thereto:

Fig. 1 is an end elevation of one form of such apparatus, partially in section on line 1—1 in Fig. 2.

Fig. 2 is a vertical section on line 2—2 in Fig. 1.

Fig. 3 is a horizontal section on line 3—3 in Fig. 1.

Fig. 4 is a partly sectional side elevation of another form of apparatus.

Fig. 5 is a transverse section on line 5—5 in Fig. 6.

Fig. 6 is a horizontal section on line 6—6 in Fig. 5.

Fig. 7 is a vertical section of another form of apparatus adapted particularly for condensation and separation of liquid materials from gases.

Fig. 8 is a horizontal section on line 8—8 in Fig. 7.

The apparatus shown in Figs. 1 to 3 comprises a suitable supporting structure 1 on the upper portion of which is mounted an in-

let header 2, a plurality of outlet headers 3 mounted within said inlet header, a plurality of tubular separating elements 4 having their upper ends connected to said inlet header to receive gas therefrom and provided at their lower ends with restricted outlet openings 19, and a common receptacle 6 for receiving separated material discharged through said outlet openings.

The inlet header 2 may be formed as a rectangular housing of sheet metal or other suitable material and is provided at one end with an inlet opening 2′ adapted for connection of an inlet flue or conduit therethrough. Each of the tubular separating elements 4 preferably comprises a cylindrical portion 7, an upwardly flared or expanded upper end portion 5 whose lower end is circular and whose upper end 8 is of rectangular shape, and a downwardly and inwardly tapered lower end portion 9 providing an outlet cone leading to the restricted opening 19 of said element. In assembling said separating elements the rectangular upper end portions 8 thereof are arranged contiguously and are electrically welded or otherwise firmly secured together so as to unite all of the separating elements at their upper ends, and the assemblage of separating elements thus formed is mounted on the supporting frame 1, as by means of supporting members 10, and the inlet header 2 is then mounted thereon so that the open upper ends of the flared portions 5 are in communication with the interior of said inlet header.

The separating elements 4 are preferably arranged in a plurality of rows extending side by side, each of said rows preferably comprising a plurality of said elements, and a separating outlet header 3 is provided for the separating elements of each row. Each of said outlet headers extends across the top of the separating elements of the corresponding row and said outlet headers are spaced apart from one another and from the side walls of the inlet header so as to provide spaces 20 therebetween and spaces 20′ between said outlet headers and the side walls of the inlet header, for permitting free passage of gas through the inlet header from the inlet opening 2′ to the open upper ends of the respective separating elements.

From the bottom plate 11 of each outlet header 3 a plurality of gas outlet tubes 12 extend downwardly within the upper portion of the respective separating elements of that row, each of said outlet tubes opening at its upper end to said bottom plate into said outlet header and opening at its lower end into the interior of the corresponding separating element. A series of vanes or blades 14 are provided around the lower portion of each outlet tube 12, said vanes or blades being inclined helically and being arranged within an annular inlet passage 15 provided between the upper portion of the cylindrical separating chamber 7 and the lower portion of said outlet tube, so as to cause the gas passing through said inlet passage to be deflected spirally as hereinafter described. The deflector vanes 14 may be secured to the respective outlet tubes 12 and preferably extend into close sliding contact with the cylindrical members 7 so as to properly center said outlet tubes within said cylindrical members.

In order to minimize turbulance and facilitate passage of gas from the inlet opening 2′ through the inlet header to the inlet openings of the respective tubular separating elements, each outlet header 3 is preferably formed with an inclined top wall 16 extending upwardly from the end adjacent inlet opening 2′ toward the other end. At the last-mentioned end the several outlet headers 3 are secured to a plate 17 having openings 17′ registering with the respective outlet headers and provided with common outlet means 18 into which all of said outlet headers discharge, said outlet means 18 being adapted for connection to an outlet flue or conduit or being, if desired, open to the atmosphere.

The receptacle 6 for separated material may consist of a hopper of conical or other suitable shape mounted on the supporting frame 1 before the assemblage of separating elements and provided with a top plate 24 formed with openings 25 which fit around and are secured to the lower end portions of the conical outlet members 9. Said receptacle 6 may be provided at its lower end with a discharge opening 23 through which the separated material may be removed continuously or from time to time under the control of any suitable gate or conveyor means.

The apparatus as so far described is adapted to function as a mechanical dust collector of high efficiency, and as such is claimed in the application of Marcel A. Lissman No. 500,753, filed December 8, 1930. Our present invention, however, contemplates the provision of housing means surrounding the separating elements of such apparatus and means for passage of a fluid medium through the interior of said housing means and around said separating elements. Said housing means is shown as comprising a rectangular housing 27 of such dimensions as to inclose all of the separating elements 4 and extending throughout substantially the entire height of said separating elements. The upper end of the space within said housing is closed by engagement of the side walls thereof with the upper ends of the assemblage of separating elements, either directly or through filler strips indicated at 28, while the lower end of said space is closed by the top plate 24 of the material receptacle. Said housing is also provided with inlet means 29 and outlet means 30 opening into the interior

thereof at opposite sides of the housing so as to provide for flow of fluid medium thorugh said housing, for example, in a direction from right to left in Fig. 2, and alternate upwardly and downwardly extending baffle plates 31 and 32 are preferably also provided, extending across said housing between the separating elements in planes transverse to the direction of flow of fluid medium, so as to cause the fluid to follow a tortuous or zig-zag path through said housing, passing alternately upwardly and downwardly around the separating elements in the successive rows, as indicated by the arrows.

The operation of the above described apparatus is as follows: The air or gas to be treated, which is assumed to contain dust fume or other suspended solid or liquid material, is supplied through any suitable inlet flue to the inlet header 2, and passes downward through the spaces 20 between the several outlet headers 3 to the respective inlet openings at the upper ends of the separating elements 4, being conducted from such inlet openings downwardly through the annular inlet passages between the expanded portions 5 and the outlet tubes 12. From the lower end of the expanded portion of each separating element, the gas passes into the upper end of the cylindrical portion 7 of such element and between such upper portion and the lower end portion of the outlet tube 12, and at this point the gas is subjected to the action of the vanes 14 which deflect the gas so as to impart a swirling or vortical motion thereto, so that as the gas passes downwardly in the tubular member 4 it has a tangential as well as a vertical component of motion. This results in a pressure head representing an excess of pressure at the peripheral portion or zone of the vortically moving body of gas and a deficiency of pressure in the central portion or core of such body. As the gas descends in the cylindrical portion 7, the tangential velocity is gradually decreased by reason of the friction against the wall of the separating element so that when the gas reaches the tapered outlet cone at the bottom of the cylindrical portion 7 the radial pressure head thereon is sufficiently decreased to enable the longitudinal pressure head originally imposed upon the gas to force the gas inwardly as it descends in the outlet cone.

The proportion of the parts are preferably such that the pressure at the periphery of the outlet opening 19 is somewhat greater than the pressure at the gas outlet tube 12, so that there is a positive ejecting action on the suspended particles at the peripheral portion of the outlet opening, it being understood that due to the vortical motion the suspended particles being heavier than the gas are thrown outwardly into the peripheral zone adjacent the wall of the separating element and descend along or adjacent such wall until they reach the outlet opening. Concurrently with the above described operation, there is an inward flow of relatively clean gas toward the center of the separating element and upwardly to the outlet opening 12, and the streams of relatively clean gas passing upwardly through the several outlet openings 12 are collected in the corresponding headers 3 and eventually delivered to the outlet means 18.

Concurrently with the above described operation, a fluid medium at a suitable temperature different from the temperature of the gas passing through the separating elements, is delivered through inlet means 29 and caused to pass as above described through the housing 27 to the outlet means 30. Due to the difference in temperature of the medium inside and outside the separating elements a transfer of heat is effected from one medium to the other, through the walls of said separating elements. In this connection, a particular advantage of the apparatus is that the inner surfaces of said walls are at all times kept substantially clean and free from deposits of separated material which frequently build up in the tubes or other elements of heat transfer apparatus of other types, and which materially reduce the rate of heat transfer from the gas inside said elements to said walls. In the apparatus of our invention the walls are kept clean due to the high velocity of whirling movement of the gas in contact therewith, which serves to carry all separated material down to the lower ends of the separating elements and out through the openings 19 into the material receptacle 6.

The transfer of heat to or from the gas passing through the separating elements may, in practice, be utilized for various purposes. For example, it may be desired to cool such gas simultaneously with the removal of suspended material thereon, in which case the fluid medium passed through the housing 27 may consist of a gas or other fluid at a temperature lower than that of said first-named gas. In certain cases, the resultant cooling of the gas during passage through the separating elements may result in condensation of certain constituents thereof and formation of a mist or fume of fine suspended particles, and part or all of the particles thus formed may be mechanically separated from the gas by centrifugal action as above described.

In other cases, it may be desired to heat the gas passing through the separating elements, and in that event a gas or other fluid at higher temperature than said first-mentioned gas is passed through the housing 27, resulting in transfer of heat from said last-mentioned gas or fluid to said first-mentioned gas. The passage of a gas or other fluid

medium through housing 27 at a temperature higher than that of the gas within the separating elements may also be employed in cases where the primary object thereof is not to effect a material increase in temperature of the gas inside the separating elements, but merely to prevent undue cooling of such gas, as for example when it is desired to prevent condensation of moisture in said gas which would tend to moisten or wet solid particles separated from the gas and cause the same to stick together and to adhere to the walls of the separating elements. This is particularly true with certain classes of solid materials such as for example powdered milk, which has a marked tendency to become sticky in the presence of only a small amount of condensed moisture.

Another form of apparatus in accordance with this invention is shown in Figs. 4 to 6 inclusive, comprising common upper header means 35, a common material receptacle or settling chamber 36, and a plurality of vertically disposed tubular separating elements 37 connected between said upper header means and said material receptacle. The upper header means 35 is so constructed as to provide an inlet flue 38 and an outlet flue 39, said inlet flue having two branches 38*a* leading therefrom and extending alongside the outlet flue at opposite sides thereof. The outlet flue 39 extends directly across the upper ends of the tubular separating elements 3 and is completely separated from the inlet flue means by side walls 41, end wall 42, and bottom plate 43. As shown in Figs. 4 and 5, the bottom walls 44 and 44*a* of the inlet flue 38 and branch flues 38*a* are sloped downwardly and inwardly toward the inlet openings of the tubular separating element so as to conduct toward said inlet openings any material which may settle upon such bottom walls from the gas entering such apparatus.

Each tubular separating element is shown as comprising a cylindrical portion 45 whose height is preferably several times as great as its diameter, tangential gas inlet means 46 at the upper end of said cylindrical portion and a conical bottom portion 47 tapering downwardly and inwardly toward a restricted material outlet opening 48. The tangential inlet means is shown as comprising a curved deflector plate 49 which is substantially tangential to the cylindrical portion at its inner end 51 and which extends outwardly from this point in the form of a spiral whose outer end 52 is spaced from the inner end 51, so as to provide a gas inlet opening 53 therebetween. The lower edge of the deflector plate 49 is connected to the upper edge of the cylindrical portion 45 by means of a suitably shaped inclined shoulder 54. The outer ends 52 of the deflector plates are tightly secured to the deflector plates of the adjacent elements as shown at 55, while the deflector plates of the elements in the two rows are also in close contact as indicated at 56. Curved plates 57 extend from the deflector plates of the last element of each row to the end wall 58 of the inlet header, so as to complete the inclosure of the branch flues 38*a* and direct all of the gas from said flues into the inlet openings 53 of the several separating elements.

The constricted lower ends of the conical bottom portions 47 of the several separating elements open at 48 into the common material receptacle 36 which is shown as provided with downwardly and inwardly sloping side walls 59, top plate 61, and with suitable means at its lower end such as discharge gate 62 for removal of collected material therefrom.

Each separating element is also provided with a frusto-conical gas outlet pipe 63 disposed within the inlet header means 46 and coaxial with the cylindrical portion 45. Said outlet pipes are shown as secured to the bottom plate 43 of the outlet flue and depending therefrom within and spaced from the spiral deflector plates 49. Said plate 43 entirely closes the upper end of the space between the deflector plates 49 and outlet pipes 63 of the several separating elements, but is provided with openings 64 through which said outlet pipes open at their upper ends into the outlet flue 39. The outlet pipes 63 may, as shown, be substantially coextensive vertically with the inlet openings 33, and each of said outlet pipes is of smaller diameter at its lower end than at its upper end, and is provided at its lower end with an opening 65.

Any suitable means may be used for delivering dust-laden gas to the apparatus and for causing the desired velocity of gas flow therethrough. For example, as shown in Fig. 4, such gas may be delivered through a flue 67 to a fan or blower 68 and thence through flue 69 to the inlet flue 38 of the separating apparatus. The outlet flue 39 may be connected to a flue 71 for conducting the treated gas to any desired point. It will be understood, of course, that if desired the fan or blower may be placed in the outlet flue instead of in the inlet flue.

Apparatus of the type described immediately above, adapted to function primarily for the separation of suspended material, is claimed in our above mentioned pending application Serial No. 403,003. In accordance with the present invention such apparatus is provided with housing means 73 surrounding all of the tubular separating elements 37 and extending from the top plate 61 of the material receptacle upwardly to the bottom walls 44*a* of the inlet flue means, so as to completely inclose a space 74 around said separating elements. Said housing is also provided with inlet means 75 and outlet

means 76 whereby a gas or other fluid medium may be passed through said chamber, and with alternate upwardly and downwardly extending baffle plates 77 and 78 extending transversely across said chamber so as to cause such gas or fluid medium to follow a tortuous path therethrough.

In the operation of this form of apparatus the gas passes from the inlet flue branches 38*a* through the inlet openings 53 of the several separating elements and is deflected by deflector plates 49 and by outlet pipes 63 and caused to pass downwardly with a rapid whirling motion within the cylindrical portion 45 of said separating elements. Centrifugal separation of the suspended material from such gas, the discharge of such material into the material receptacle 36, and the outflow of clean gas through the outlet pipes 63 takes place in substantially the same manner as above described, and the apparatus is also adapted to function in substantially the same manner as above described to effect cooling or heating of the gas being treated, upon passage of a gas or other fluid medium at relatively lower or relatively higher temperature through the housing 73.

The apparatus shown in Figs. 7 and 8, which is of a type shown in our above-mentioned pending application Ser. No. 356,921, is particularly adapted for the separation of liquid particles from gas and is intended especially for use as a combined condenser and collector, for the purpose of cooling a gas to cause condensation of one or more constituents thereof in the form of liquid particles, and separating such particles from the remaining gas. Such apparatus comprises a plurality of cylindrical condensing and separating tubes 81 provided at their upper ends with tangential inlet means 82 which may, for example, be similar to the tangential inlet means 46 shown in Figs. 4 to 6 inclusive, communicating at 83 with an inlet flue 84 and being also provided at their lower ends with conical bottom portions 85 connected to a discharge pipe 86 for condensed liquid. Said condensing and separating tubes are also provided at their upper ends with centrally disposed gas outlet pipes 87 which may be similar to the outlet pipes 68 above described with reference to Figs. 4 to 6 inclusive, and which communicate with outlet flue 88. A casing 89 surrounds the tubes 81 and extends from the bottom of the inlet flue 84 down to substantially the lower ends of said tubes, and is provided with means such as inlet pipe 91 and outlet pipe 92 for maintaining a flow of water or other fluid medium therethrough.

In the operation of this form of apparatus a gas or vapor comprising one or more condensible constituents is supplied to inlet flue 84 and passed through the apparatus under sufficient pressure head to cause it to enter tubes 81 with a high velocity vortical movement and to pass downwardly adjacent the outer walls of said tubes and thence upwardly along the axes thereof to the outlet flue. In this operation the rapid movement of the gas or vapor in contact with the inner surfaces of the walls of said tubes insures effective transfer of heat therefrom to said walls and thence to the cooling medium around the tubes, with correspondingly rapid condensation of condensible material therein, such condensation occurring partially in the form of finely divided liquid particles in suspension in the gas or vapor. Such particles are immediately subjected to centrifugal separating action as above described and are thus separated from the gas or vapor, and the material thus condensed and separated flows down inside the tubes and is drawn off through discharge pipe 86.

We claim:

1. A gas cleaning and heat transfer apparatus comprising a plurality of tubular separating elements disposed in spaced parallel relation and provided at their upper ends with inlet means adapted to impart whirling motion to gas entering therethrough, and with centrally disposed gas outlet means and provided at their lower ends with restricted outlet openings, housing means surrounding all of said separating elements and provided with means for passing a fluid medium therethrough at a temperature different than the temperature of the gas within said separating elements, means connected to said inlet means of all of said separating elements for delivering thereto a gas carrying suspended material, and means connected to said restricted outlet openings of all of said separating elements for removing material collected in said separating elements.

2. A gas cleaning and heat transfer apparatus comprising a plurality of tubular separating elements connected in parallel between common inlet header means at one end thereof and a common receptacle for separated material at the other end thereof, and each provided with gas outlet means adjacent the end connected to said inlet header means, each of said tubular separating elements communicating with said inlet header means through inlet means adapted to produce vortical motion of gas within said separating elements and being provided at the end opposite said inlet means with a restricted outlet opening communicating with said common receptacle for separated material, a common housing surrounding said tubular separating elements and means for passing fluid medium through said housing.

3. A gas cleaning and heat transfer apparatus comprising a plurality of tubular separating elements each comprising an elongated chamber of circular cross-section having inlet means at its upper end adapted to produce whirling motion of gas entering there-

through and a restricted outlet opening for separated material at its lower end and centrally disposed gas outlet means at the end adjacent said inlet means, said tubular separating elements being disposed parallel to one another and having the elongated chambers thereof spaced somewhat apart, common inlet header means communicating with the inlet means of all of said separating elements, a common receptacle for separated material communicating with the restricted outlet openings at the lower ends of all of said separating elements, a common housing disposed between said common inlet header means and said common receptacle and surrounding all of said separating elements, and means for passing a fluid medium through said housing and around said separating elements.

4. An apparatus as set forth in claim 2 and also comprising baffle means extending across said common housing between said separating elements and transverse to the direction of flow of fluid medium through said housing so as to cause said fluid medium to follow a tortuous path through said housing.

5. A condensing and collecting apparatus comprising a plurality of tubular separating elements provided at their upper ends with inlet means adapted to impart whirling motion to gas entering therethrough and with centrally disposed gas outlet means and provided at their lower ends with restricted outlet openings for separated material, housing means surrounding all of said tubular separating elements and provided with means for passage through said housing and around said separating elements of a fluid medium at a temperature lower than that of the gas within said separating elements, means for delivering to said inlet means for said separating elements a gas containing a condensible constituent, and means connected to said restricted outlet openings at the lower ends of said separating elements for removing material condensed and collected in said separating elements.

In testimony whereof we have hereunto subscribed our names this 17th day of July, 1931.

GEORGE H. HORNE.
MARCEL A. LISSMAN.