

[54] **GASEOUS FLOW SEPARATOR AND HEAT EXCHANGER**

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[51] Int. Cl. **B01d 45/00**

[58] Field of Search 55/442, 443, 444, 445, 55/446, 461, 462, 463, 464, 465, 267, 268, 269, 447; 165/177, 178, 179, 183, 111; 62/288, 290

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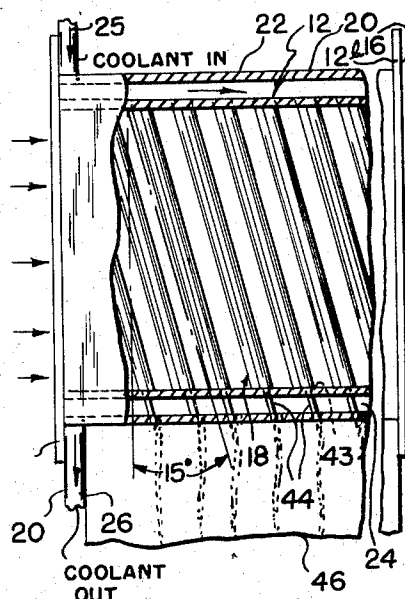
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[57] **ABSTRACT**

A gaseous flow separator and heat exchanger which has a plurality of laterally spaced filter elements extending across the gas flow, for entrapping particulate matter in the flow, and conducting the matter downwardly out of the flow path as well as conducting heat out of the gas flow, and wherein the filter elements are of a configuration which prevents the buildup of particulate material and dust on the filter elements by utilizing laterally disposed wings on the filter elements defining pockets or cavities which form vortexes in the cavities entrapping particulate material therein and moving it downwardly. Each filter element has a forwardly projecting nose portion extending forwardly of the cavities and causing gas flow to be diverged from the wing pockets.

9 Claims, 10 Drawing Figures



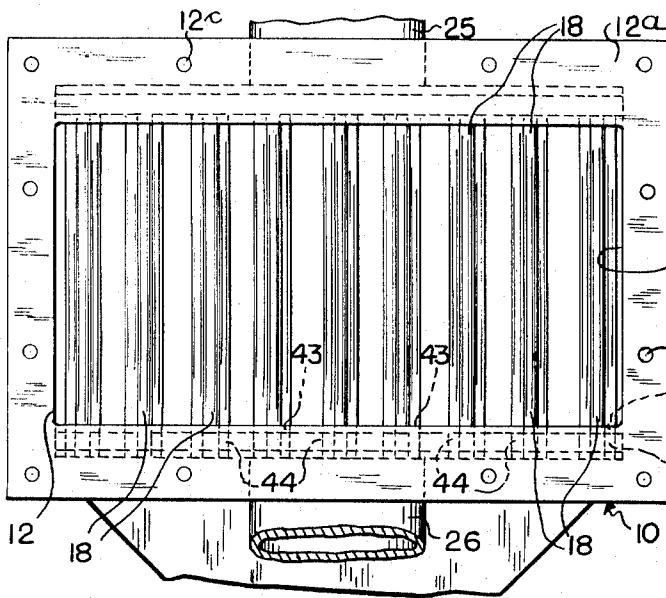


FIG. 1

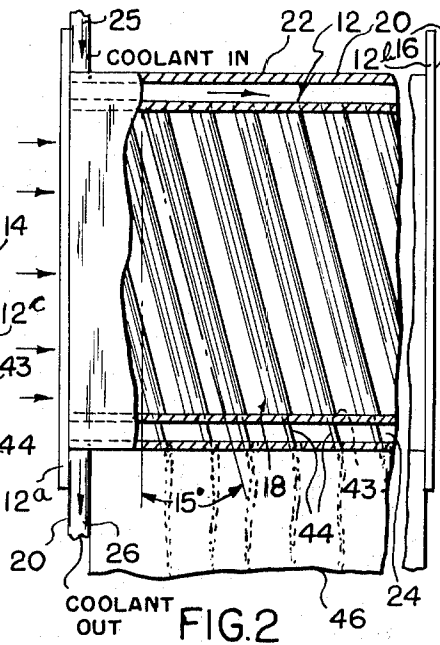


FIG. 2

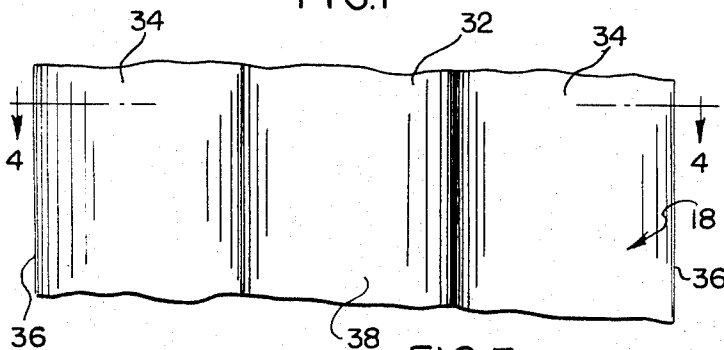


FIG. 3

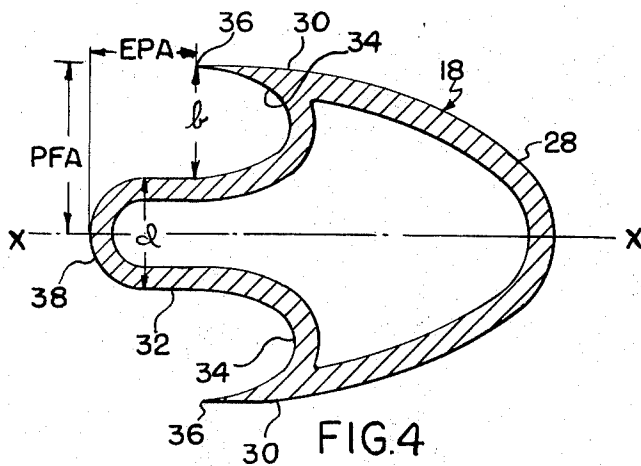


FIG. 4

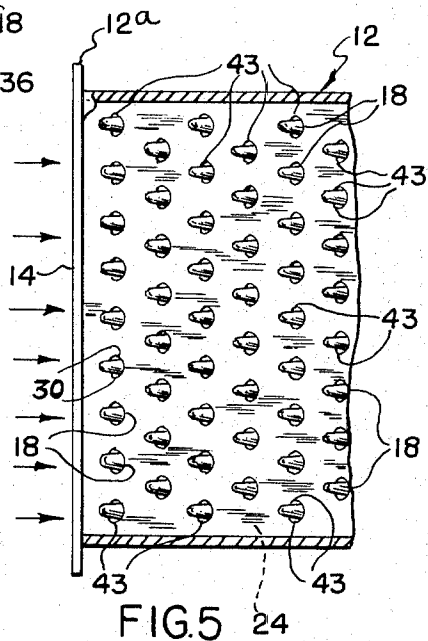


FIG. 5

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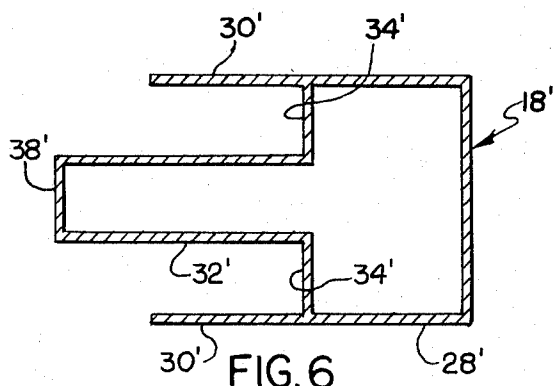


FIG. 6

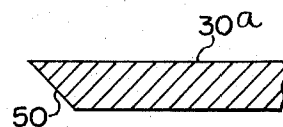


FIG. 8

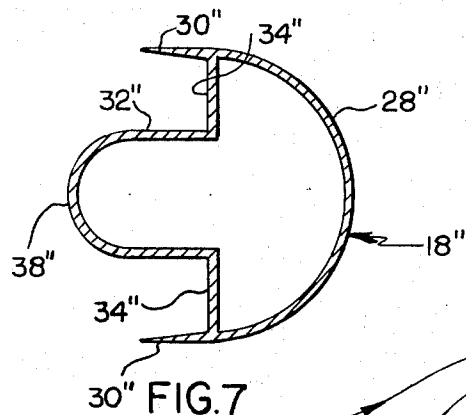


FIG. 7

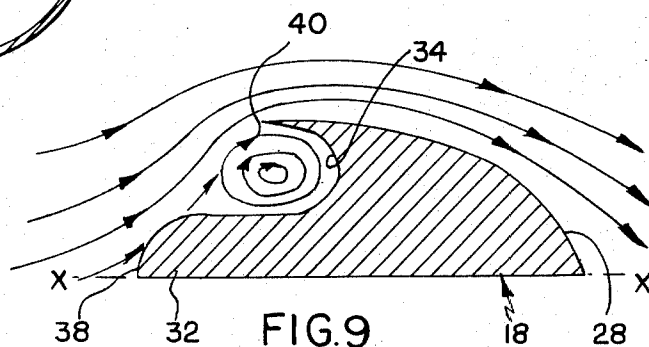


FIG. 9

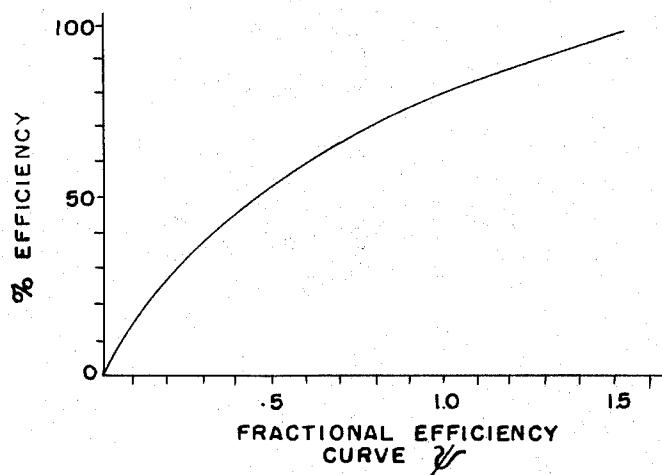


FIG. 10

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GASEOUS FLOW SEPARATOR AND HEAT EXCHANGER

This invention relates in general to a combined gaseous separator and heat exchanger, for removing foreign particulate matter from gaseous flow and removing heat from the gaseous flow, and more particularly to a novel arrangement of filter elements for the combined separator and heat exchanger, for collecting and removing particulate matter from the gaseous flow and preventing retention of such matter and dust on the filter elements, thereby aiding in maintaining the efficiency of the heat exchanging function.

BACKGROUND OF THE INVENTION

Many separators for removing particulate matter from gaseous flow are known in the art. However, many of these separators are unduly complex and thus are not economically feasible, or else they do not operate in an effective manner to remove particulate matter from the gaseous flow, or they are of such nature that particulate matter is deposited thereon from the gaseous flow and inhibits heat exchange from the gaseous flow to the filter elements.

An example of a prior art arrangement of separator or gas filter element is shown in U.S. Pat. No. 2,831,550, issued Apr. 22, 1958 to R. A. Bub and entitled "Gas Filter Element."

SUMMARY OF THE INVENTION

The present invention provides a combined gaseous flow separator and heat exchanger which is effective to remove particulate matter carried in the gaseous flow as well as heat, and which includes a series of laterally disposed filter elements, each of which comprises an elongated member having laterally disposed wing portions which define pockets for forming vortexes therein during interception of gas flow, and a forwardly extending nose portion disposed intermediate the wing portions.

An object of the present invention is to provide a novel combined gaseous flow separator and heat exchanger.

Another object of the present invention is to provide a novel gaseous flow separator and heat exchanger combination which includes a plurality of laterally spaced, generally vertically arranged, filter elements which have laterally disposed wing portions defining generally elliptically shaped, in plan view, pockets, adapted to form vortexes for entrapping particulate matter carried in the gaseous flow, and wherein each filter element includes a forwardly projecting portion disposed intermediate the wing portions and providing a surface at its leading end disposed generally transverse to the direction of gaseous flow, for deflecting gas flow.

A further object of the invention is to provide the combination aforesaid wherein the filter elements are elongated members of hollow construction, and which may carry cooling fluid interiorly thereof for cooling the filter elements during gaseous flow thereby providing highly effective heat exchange between the gas flow and the filter elements.

A further object of the present invention is to provide a novel combination gaseous flow separator and heat exchanger which includes filter elements each of which comprise two para-axial cavities separated by a projec-

tion which on its leading end includes a surface disposed generally transverse to the direction of flow.

Other objects and advantages of the invention will be apparent from the following description taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a fragmentary, generally diagrammatic front elevational view of a combined gaseous flow separator and heat exchanger in accordance with the invention;

FIG. 2 is a broken, side elevational view of the FIG. 1 arrangement;

FIG. 3 is an enlarged, fragmentary, front elevational view of one of the filter elements of the mechanism illustrated in FIGS. 1 and 2;

FIG. 4 is a reduced size, sectional view taken generally along the plane of line 4—4 of FIG. 3, looking in the direction of the arrows;

FIG. 5 is a fragmentary, sectional, diagrammatic plan view illustrating the rows of filter elements, and the staggered relationship of the filter elements in adjacent rows;

FIG. 6 is a diagrammatic, sectional view generally similar to that of FIG. 4, but illustrating a modified form of filter element for a gaseous flow separator and heat exchanger;

FIG. 7 is a view similar to FIG. 6, but showing a further modified form of filter element;

FIG. 8 is an enlarged, fragmentary, view of one of the wing portions of a filter element, showing a further modification of such wing portion;

FIG. 9 is a diagrammatic illustration illustrating the formation of the vortex in one of the laterally disposed pockets of the filter element, and also illustrating the deflection of the gaseous flow past the filter element, which flow in connection with the aforementioned vortex, maintain the filter element clean of deposited particles and dust; and

FIG. 10 is an illustration of a curve showing the particulate collection efficiency of the gaseous flow separator as a function of the scaling parameter (ψ).

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The gaseous flow separator and heat exchanger is adapted for use for removing particulate material and heat from a gaseous flow, such as, for instance, may be encountered in a power unit wherein the stack gas is adapted to be treated to remove therefrom the foreign particulate material prior to its being discharged into the atmosphere. The mechanism of the present invention is particularly effective in removing particulate matter in the range of larger than 5 microns in size and in a gaseous flow having a velocity of from approximately 10 feet per second up to 80 feet per second, although it will be understood that it may also be expeditiously utilized in other environmental situations.

The gaseous flow may be at an average inlet temperature of between, for instance 400° to 500° F but can be at substantially any temperature, limited of course by the melting temperature of the structural components of the arrangement. However, inlet temperatures of up to 1,000° F have been experienced with test mechanism embodying the invention and have been found to have no adverse effects whatsoever upon the operation thereof.

Referring now again to the drawings, and particularly to FIGS. 1 and 2, there is shown a gaseous flow separa-

tor and heat exchanger 10 defining an enclosure 12 which may include flange portions 12a, 12b having openings 12c therein, for attaching the separator into the emission stack system of, for instance, a combustion unit such as a power unit. The housing enclosure may include a gaseous flow inlet opening 14 and a gaseous flow outlet opening 16.

Disposed in the enclosure 12 are a plurality of laterally spaced elongated filter elements 18 which are adapted for trapping particulate material disposed in the gaseous flow and removing it therefrom. Heat exchanger means 20 (FIGS. 1 and 2) coact with the enclosure and with the filter elements for removing heat from the gaseous flow. When the mechanism is utilized in conjunction with an exhaust stack of a power unit such as aforementioned, the mechanism will remove the heavier particulate materials from the gaseous flow and permit the more efficient operation of other separators, such as electrostatic precipitators, conventionally utilized with power unit emission stacks.

The aforementioned heat exchange mechanism 20 comprises chambers 22, 24 which coact with the elongated filter elements 18, for transmitting heat via the filter elements to the chambers 22 and 24, and in which a coolant, such as water or air or the like is maintained in flowing condition. For instance, coolant may enter upper chamber 22 via entry duct 25 and may leave lower chamber 24 via exit duct 26. The filter elements 18 may be of hollow construction as best shown in FIG. 4, and may communicate at their ends with the respective upper and lower chambers 22, 24, and thus may transmit coolant therethrough. Such an arrangement will of course materially increase the heat transfer characteristics of the mechanism.

The enclosure 12 and associated heat exchange chambers 22, 24, and heat exchanging filter elements 18 are preferably formed of metal, such as steel or aluminum, which has good heat transfer characteristics, for facilitating the transfer of heat from the gas flow entering the enclosure inlet 14, the heat being passed from the gas to the filter elements 18 and the chambers 22, 24 and heat exchange coolant flowing there-through.

Each of the filtering and heat exchange elements 18 comprises a body portion 28 (FIG. 4) which has paraxial wing portions 30 extending in the general direction of the gas inlet 14, and a nose portion 32 projecting forwardly from the wing portions 30, and in conjunction with the wing portions defining laterally spaced pockets or recesses 34 on opposite sides of the longitudinal vertical center plane X—X of the respective filter element. Pocket portions 34 define a partial elliptical configuration in horizontal cross section as can be best seen in FIG. 4, and the leading end of each of the wing portions 30 preferably terminates in a sharpened edge, as at 36, in this embodiment of filter and heat transfer element 18.

The nose portion 32 at its leading end, includes a frontal bluff surface 38 which extends generally transverse of the direction of the gas flow, and is operative in conjunction with the hereinafter described vortexes to deflect gas flow, as will be hereinafter discussed in greater detail. The leading end of nose portion 32 is a semi-circular in configuration in horizontal section, as can be seen in FIG. 4, and then the nose portion extends rearwardly or downstream to merge smoothly

with and partially define the aforementioned pocket portions 34.

Gas flow impacting the filter elements 18 produces a vortex 40 (FIG. 9) in each respective pocket portion 34, with particulate matter in the gas flow being entrapped in the vortex and moved downwardly along the lengthwise extent of the respective filter element. In this connection and as can be best seen in FIG. 2, each filter element is disposed obliquely in a direction longitudinally of the enclosure, and preferably at an angle of approximately 15° with respect to the vertical, so that the particulate matter and dust entrapped by the filter elements 18 are moved downwardly along the respective filter element. When the entrapped particulate matter arrives at the top defining wall of the lower heat exchanger chamber 24, it enters openings 43 (FIG. 5) in such top wall into which the particulate matter and dust flow. Such openings are provided with coaxing tubular conduits 44 associated with each of the wing portions (FIG. 2) of each element 18, for transmitting the particulate matter and dust through the coolant chamber 24 without permitting direct contact of the coolant with the particulate matter, and then the tubes 44 empty into lower hopper 46 disposed below the chamber 24, wherein the particulate matter is collected for subsequent disposal. It will be seen that the discharge tubes 44 interact with the coolant flowing in the lower chamber 24, and are cooled thereby, but that the coolant is separated from direct contact with the particulate matter removed from the gas flow via the discharge tubes.

The vortexes 40 move generally rotatably in the respective pocket in the direction of said nose portion (in other words clockwise in the half of the filter element shown in FIG. 9 — counterclockwise in the opposite pocket) but in both instances in a direction toward the nose portion with respect to the defining surface of the respective pocket.

The aforementioned vortexes 40 maintain the pockets 34 clean of particulate material by scrubbing the surfaces of the pockets during gas flow through the mechanism. The bluff nose portion 32 of each filter element in conjunction with the vortexes 40 deflects a portion of the associated gas flow around the wings and body portion of the respective filter element (FIG. 9), and maintains the external wing and body surfaces of the filter element clear and clean of dust and particulate material due to the gas flow movement, thus insuring that good heat transfer characteristics exist between the gas flow passing through the mechanism and the filter elements 18.

As can be best seen in FIG. 4, the diameter d of the semi-circular nose portion 32 at the leading end thereof is preferably approximately the same as the minor axis dimension b of the each elliptical-like pocket portion 34. Each pocket portion may have an eccentricity in a range between just slightly greater than 0 (a semi-circle) and 0.9.

Referring now in particular to FIG. 5, the filter elements 18 are preferably arranged in rows extending transversely of the enclosure 12, with the elements in one row being staggered with respect to the elements in the adjacent row or rows, so that substantially the entire cross-sectional area of gas flow is intercepted by the filter elements 18 and yet in a manner not materially restricting the flow through and around the filter elements to the gas outlet 16.

Referring now to FIG. 10, there is illustrated a fractional collection efficiency curve for mechanism embodying the FIG. 4 arrangement of filter elements, with the efficiency being a function of a quantity identified as scaling parameter (ψ), which in turn is a function of the particle density (ρp), the approach flow velocity (μo), the fluid flow viscosity (dynamic) (μ), the particle diameter (D_p) and the characteristic collector diameter (D_c). In other words, $\psi = (\rho p \mu o / 18 \mu)^{1/2} (D_p / \sqrt{D_c})$.

The characteristic collector diameter (D_c) has been determined as a first approximation to be equal to the ratio of the extension projected area EPA (FIG. 4) with respect to the frontal projected area PFA of the filter element, times the sum of the total projection. In other words, above identified D_c is the ratio of the extension projected area (EPA) to the projected frontal area (PFA) times the sum of the extension projected area and the projected frontal area $D_c = (EPA/PFA) (EPA + PFA)$. It will be seen that determining D_c for a particular filter element configuration and solving for the scaling parameter (ψ) will indicate what type of collection efficiency should be expected with a particular arrangement of filter and heat exchanger of the FIG. 4 configuration. It will be seen that as the particle size (D_p) increases, the value of the scaling parameter ψ increases and the collection efficiency increases. Similarly, it will be seen that if the characteristic collector diameter (D_c) decreases, the overall collection efficiency should be expected to increase.

Referring now to FIG. 6, there is shown another embodiment of filter and heat exchanger element 18' wherein the body portion 28' is of polygonal or rectangular configuration in horizontal cross section, as opposed to the elliptical-like configuration of the preferred FIG. 4 embodiment. The wing portions 30' extend forwardly from the body portion generally parallel to the defining surface of the nose portion 32' and with the surface 38' on the leading end of the bluff nose portion being planar and extending perpendicular to the direction of gas inlet flow. The deflection of gas flow with surface 38' is somewhat greater than with the surface 38 of the first described embodiment, but collection efficiency is substantially the same, with vortexes being formed in the pocket portions 34' in a similar manner as aforescribed in connection with the preferred embodiment. Member 18' can likewise be hollow for transmission therethrough of coolant for transferring heat from the gas flow to the heat exchanging mechanism 20 of the apparatus.

FIG. 7 disclosed a further embodiment of filter element and heat exchanger 18'' wherein the body portion 28'' is of semi-circular configuration in horizontal cross section, and with the bluff nose portion 32'' having a deflecting surface 38'' at its leading end, which is of semi-circular configuration in cross section, similar to that of the preferred embodiment. The nose portion 32'' extends forwardly of the wing portions 30'' which partially define generally rectangular shaped pockets 34''. During gas flow, vortexes are produced in the pockets and particulate material is removed from the gas flow. The deflected gas flow about the body maintains the body portion 28'' clean of dust and particulate material, thus maintaining optimum heat transfer characteristics for the filter elements 18''.

Referring now to FIG. 8, there is shown a further modification of wing portion 30a which has an oblique

abutment surface 50 at its leading end rather than the transverse abutment surface of the FIG. 6 embodiment or the sharpened edge abutment surface of the FIGS. 4 and 7 embodiments.

From the foregoing description and accompanying drawings it will be seen that the invention provides a novel gaseous flow separator and heat exchanger combination which is effective in removing particulate material from the gas flow and removing heat from the gas flow, and which utilizes filter and heat exchange elements comprising laterally spaced pocket portions and a forwardly extending nose portion disposed intermediate the pocket portions with the pocket portions forming vortexes during the gas flow and entrapping particulate material from the gas flow therein and moving it downwardly away from the filter elements. Moreover, the nose portion provides a deflecting surface at its leading end which extends generally transverse to the direction of gas flow, which aids in maintaining the filter elements clear of deposits of dust and particulate material, thereby maintaining the efficiency of the heat exchange operation of the filter element.

The terms and expressions which have been used are used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of any of the features shown or described, or portions thereof, and it is recognized that various modifications are possible within the scope of the invention claimed.

What is claimed is:

1. In combination, a gaseous flow separator comprising an enclosure, said enclosure having a gas inlet and a gas outlet, a plurality of laterally spaced substantially vertical filter elements mounted in said enclosure, said filter elements extending transversely of said enclosure, heat transfer means coacting with said enclosure for removing heat from said gaseous flow in said enclosure, each of said filter elements comprising, an elongated member formed generally symmetrically on opposite sides of the longitudinal vertical center plane thereof, and having laterally disposed wing portions defining a pair of open pockets facing in the direction of said gas inlet and a forwardly extending bluff nose portion disposed intermediate said wing portions, the leading end of said nose portion being of generally semi-circular configuration, the outermost extremities of said wing portions defining the outermost lateral extremities of said member, the configuration of each of said pockets in plan being partial ellipsoid-like and comprising a major and a minor axis, the major axis extending generally in the longitudinal direction of extension of said center plane, and said minor axis extending in a direction generally transverse to the longitudinal direction of said extension of said center plane, said minor axis defining the open extent of the respective of said pockets facing in the direction of said gas inlet, as well as the respective generally outermost lateral extremity of said member whereby the outer end of each of said wing portions is relatively narrow in width, the ellipsoid-like interior surface of each of said pockets merging smoothly with the respective side surface of said nose portion; the diameter of said leading end of said nose portion being generally the same magnitude as the length of said minor axis of each of said pockets, said pockets being disposed downstream of the distal end of said nose portion, said nose portion and said pockets of said wing portions being operable to cause formation of

vortexes in said gaseous flow moving generally rotatively in said pockets in the general direction of said nose portion with respect to said interior surface of the respective of said pockets, and adapted to entrap in said pockets particulate material carried in the gaseous flow.

2. The combination in accordance with claim 1 wherein each of said filter elements is disposed obliquely longitudinally of said enclosure, and means coacting with the lower end of each of said filter elements for draining particulate material downwardly relative to the respective filter element and away from said enclosure.

3. The combination in accordance with claim 2 wherein said means coacting with each of said filter elements comprises a tube coacting with the respective pocket of each of said wing portions, said heat transfer means including fluid flow for removing heat from said filter elements, each said tube extending through an associated of said heat transfer means and isolating the particulate material therein collected from the pockets of said wings from the fluid flow in said heat transfer means.

4. The combination in accordance with claim 1 including means coacting with said enclosure and with said filter elements for receiving therein particulate material removed from the gas flow by said filter elements.

5. The combination in accordance with claim 1 wherein each of said wing portions merges into a single generally vertical leading edge in the direction of said gas inlet.

6. The combination in accordance with claim 1 wherein each filter element includes a body portion defining a partial elliptical configuration in horizontal cross section, and projecting rearwardly of the nose portion of the respective filter element in the direction of gaseous flow, the major axis of the partial elliptical configuration of said body portion being generally coplanar with the longitudinal vertical center plane of the filter element, and the exterior defining surface of said body portion merging smoothly with the respective wing portion.

7. The combination in accordance with claim 6 wherein each filter element is of a hollow metallic construction.

8. The combination in accordance with claim 1 wherein said filter elements are arranged in at least two rows extending across the cross section of said enclosure, the filter elements of one row being staggered with respect to the filter elements of the other row, for intercepting substantially the entire cross-sectional area of the gaseous flow.

9. In combination, a gaseous flow separator and heat exchanger comprising, an enclosure, said enclosure having a gas inlet and a gas outlet, a plurality of laterally spaced substantially vertical filter elements mounted in said enclosure, said filter elements extending transversely of said enclosure, said filter elements being arranged in at least two spaced rows extending across said enclosure, the filter elements of one row

being staggered with respect to the filter elements of the other row for intercepting substantially the entire cross sectional area of the gaseous flow, heat transfer means including upper and lower chambers adapted for containing coolant, coacting with said enclosure for removing heat from said gaseous flow in said enclosure, each of said filter elements comprising an elongated member formed generally symmetrically on opposite sides of the longitudinal vertical center plane thereof and having laterally spaced wing portions each defining an open pocket facing in the direction of said gas inlet and a forwardly extending bluff nose portion disposed intermediate said wing portions, each of said pockets defining in plan a partial elliptical configuration comprising a major and a minor axis with the minor axis thereof being generally perpendicular to the longitudinal vertical center plane of the filter element, said major axis extending generally in the direction of longitudinal extension of said center plane, said minor axis defining the open extent of the respective of said pockets facing in the direction of said gas inlet, as well as the respective generally outermost lateral extremity of said member whereby the outer end of each of said wing portions is relatively narrow in width, the partial elliptical-like interior surface of each of said pockets merging smoothly with the respective side surface of said nose portion, the leading end of said nose portion being of generally semi-circular configuration in horizontal cross section with the diameter of said semi-circular portion being approximately the same dimension as said minor axis of each of said partial elliptical configurations of said pockets, said pockets being disposed downstream of the leading end of said nose portion, each filter element being of hollow construction communicating with said upper and lower chambers for passage therethrough of coolant of said heat transfer means, means coacting with each of said filter elements for receiving therein material removed from the gaseous flow by said pockets, the last mentioned means comprising a tube coacting with the pocket of each said wing portion, said tube extending to said lower chamber of said heat transfer means and isolating the material collected from said wings from coolant flow in said lower chamber, each said filter element including a body portion defining a partial elliptical configuration in horizontal cross section projecting rearwardly of the nose portion of the respective filter element in the direction of gaseous flow, the major axis of the partial elliptical configuration of said body portion being coplanar with the longitudinal vertical center plane of the filter element, the exterior defining surface of said body portion merging smoothly with said wing portions, said nose portion and said pockets of said wing portions being operable to cause formation of vortexes in said gaseous flow moving generally rotatively in said pockets in the general direction of said nose portion with respect to said interior surface of the respective of said pockets, and adapted to entrap in said pockets matter carried in the gaseous flow.

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