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Grey

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[54] **APPARATUS FOR REMOVING CONTAMINANTS ENTRAINED IN A GAS STREAM**

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Related U.S. Application Data

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[52] **U.S. Cl.**..... **55/118,** 23/260, 23/277 C, 23/284, 23/285, 55/71, 55/73, 55/122, 55/126, 55/127, 55/130, 55/138, 55/145, 55/152, 55/155, 55/228, 55/238, 55/257, 55/319, 55/347, 55/447, 110/8 R, 110/119, 261/79 A, 261/118, 261/DIG. 9, 423/235, 423/240, 423/242

[51] **Int. Cl.**..... **B03c 3/78,** B01d 47/06, F23g 5/00

[58] **Field of Search** ..... 55/6, 7, 10, 12, 55/13, 117, 118, 119, 120, 122, 127, 124, 125, 126, 136, 137, 138, 143, 145, 146, 150, 152, 154, 155, 156, 130, 71, 73, 228, 238, 257, 319, 347, 447; 23/260, 277 C, 284, 285; 110/8 R, 119; 261/79 A, 118, DIG. 9; 423/235, 240, 242

[56] **References Cited**

UNITED STATES PATENTS

1,250,088	12/1917	Burns	55/118 X
1,549,753	8/1925	Edler	55/130
2,740,493	4/1956	Wintermute	55/127 X
2,841,240	7/1958	Wintermute	55/127
2,989,144	6/1961	Styrie	204/322 X
3,443,362	5/1969	Ebert	55/117
3,492,790	2/1970	Ebert	310/5 X
3,503,348	3/1970	Dvirka	110/8 R
3,592,541	7/1971	Gourdine	96/1 R X

FOREIGN PATENTS OR APPLICATIONS

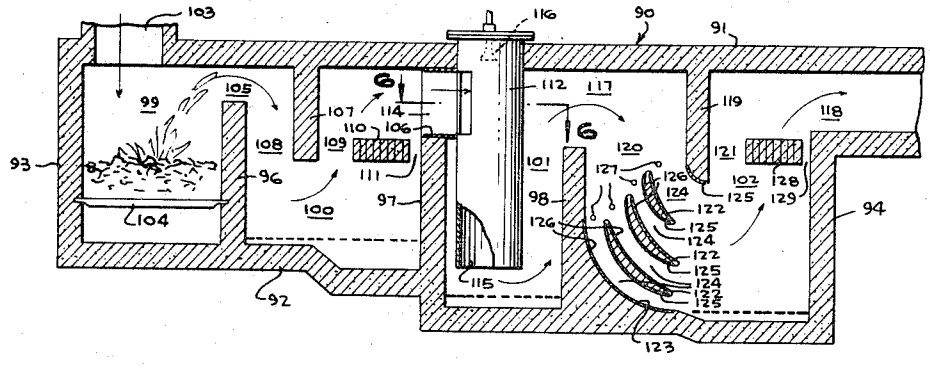
730,960	5/1932	France	55/127
913,708	6/1946	France	55/396
849,928	9/1960	Great Britain	55/127

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[57] **ABSTRACT**

An incinerator generally including a combustion chamber, a flue, means for conducting combustion gases emanating from the combustion chamber to the flue, the conducting means including passage means for imparting a curved motion to the combustion gases, means disposed in the passage means for producing a plurality of electrostatic fields including a plurality of sets of spaced electrodes, each set of electrodes producing an electrostatic field through which a portion of the gases traverse, and means disposed either upstream relative to the means for producing a plurality of electrostatic fields, or in conjunction therewith, for ionizing the combustion gases, whereby contaminants including solids and gaseous molecules entrained in the combustion gases will be ionized by the ionizing means and subjected to cooperating centrifugal, electrostatic and gravitational forces as the gases traverse through the passage means to remove the contaminants from the combustion gases.

9 Claims, 6 Drawing Figures



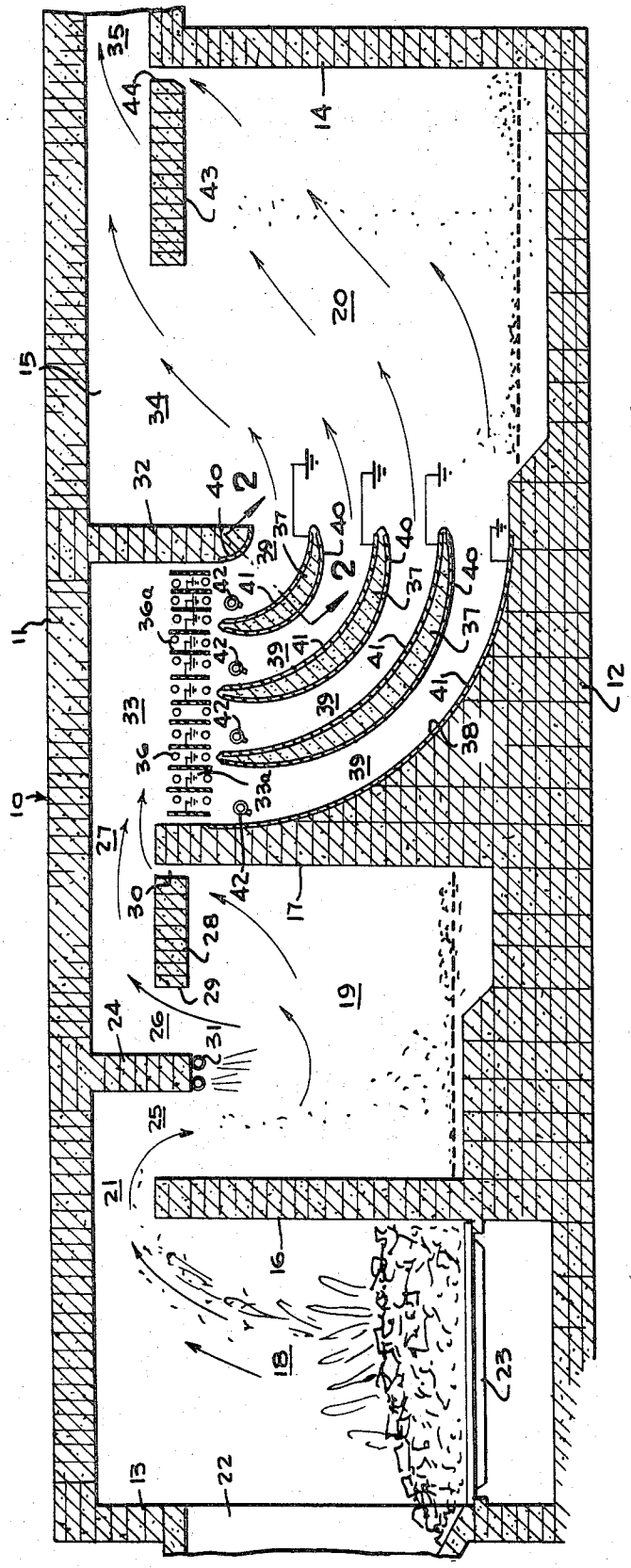


FIG-1

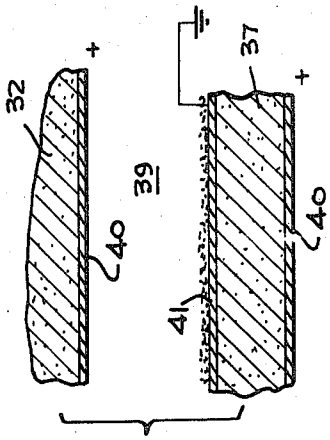


FIG-2

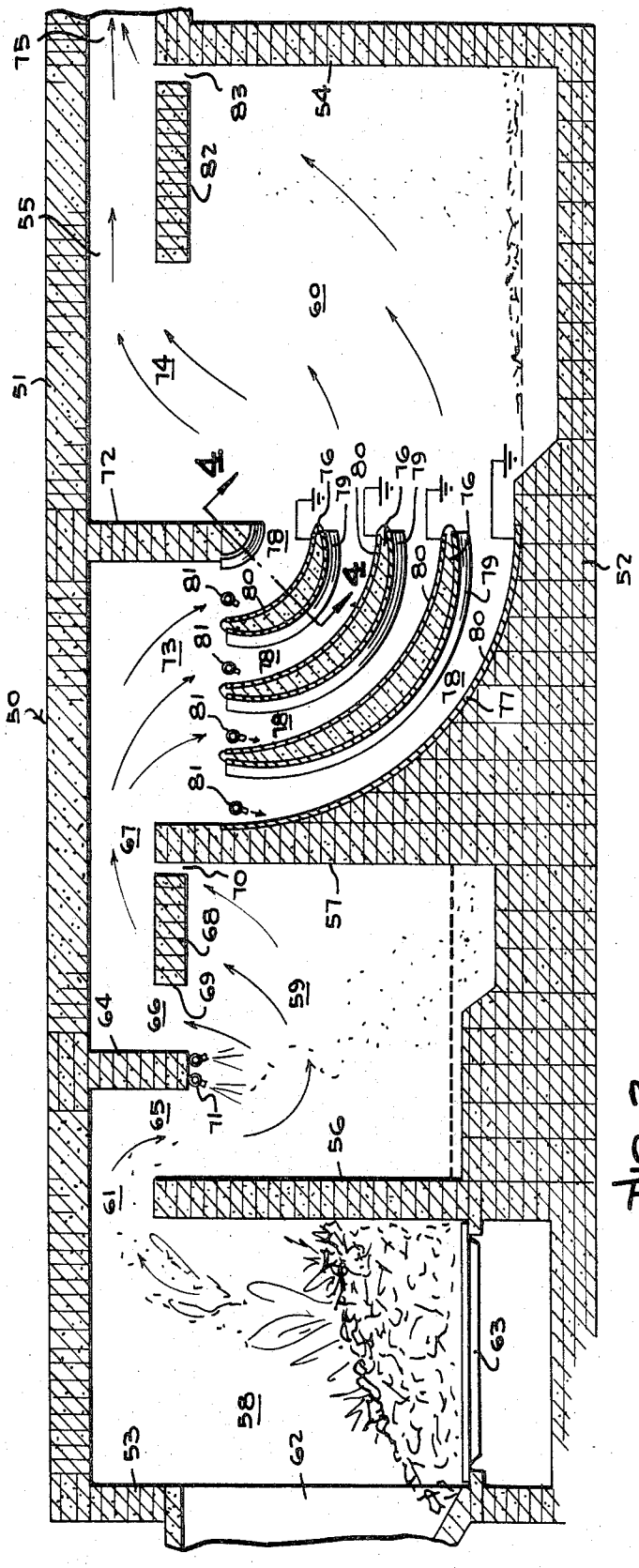

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FIG-3

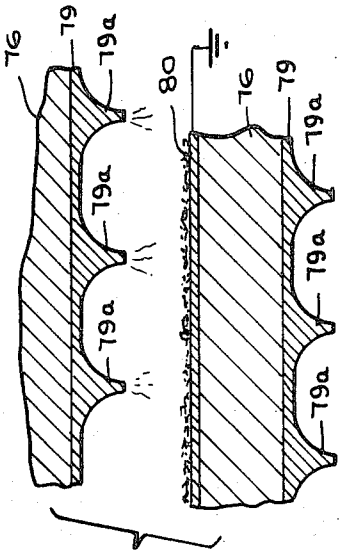

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FIG-4

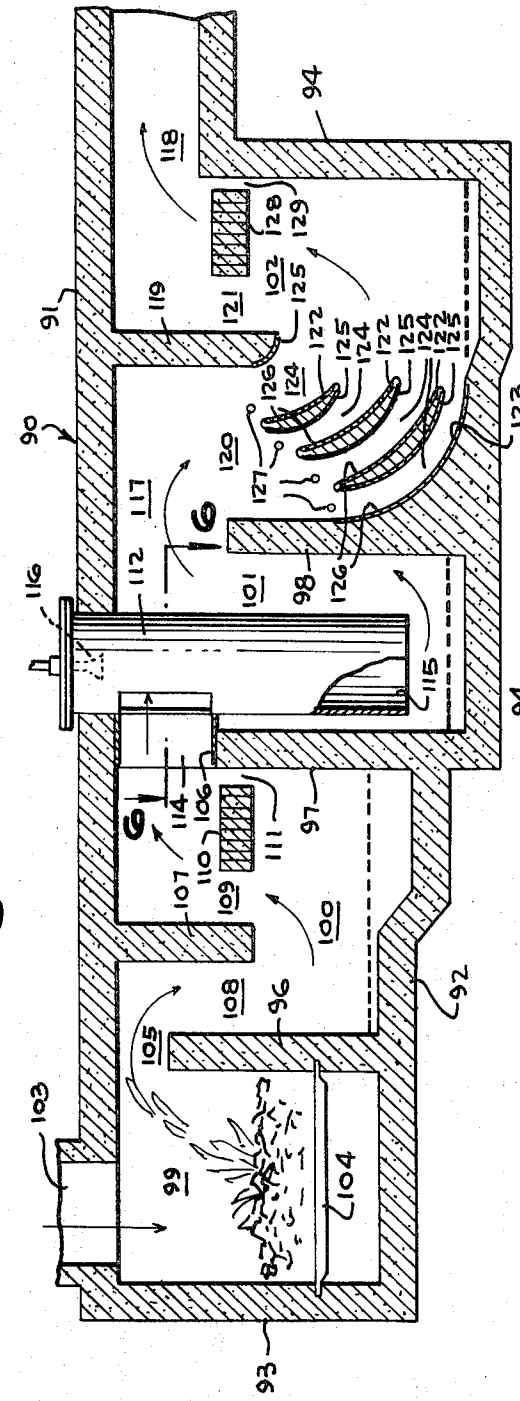


FIG-5

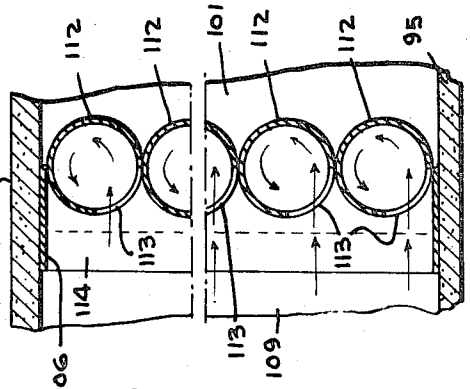


FIG-6

APPARATUS FOR REMOVING CONTAMINANTS ENTRAINED IN A GAS STREAM

This is a division of application, Ser. No. 83,711 filed Oct. 26, 1970, now U.S. Pat. No. 3,656,440.

This invention relates to a novel incinerator and more particularly to an incinerator capable of producing a low particulate content and reduced concentrations of gaseous contaminants in the effluent emitted therefrom. This invention further contemplates a novel apparatus for removing solid and gaseous contaminants from a stream of gases, suitable for use in incinerators and other effluent emitting devices wherein it is desired to remove solid and gaseous contaminants from the effluent.

In the past, the most practical and economical method of solid waste disposal has been incineration. In view of this, many municipal, industrial, commercial and residential types of incinerators have been designed, erected and operated over a period of decades. With the increased use of such incinerators and other sources of effluent emissions into the atmosphere, such as automotive exhaust emissions and industrial and power plant emissions, the pollution of the atmosphere has approached critical levels potentially hazardous to human and animal life.

As a result of the increased pollution of the atmosphere federal, state, county and municipal governments have enacted legislation establishing more stringent code requirements with respect to effluent emissions of municipal, industrial and residential incinerators. Many government codes require the particulate loading of effluent emission not to exceed 0.10 to 0.20 grains per standard cubic foot. It has been found, however, that most existing incinerators and other installations emitting effluent into the atmosphere, are incapable of complying with such code requirements. Furthermore, it has been found that most new incinerator designs which have been proposed, perhaps may be capable of complying with such code requirements but are economically unfeasible to erect and operate.

Accordingly, it is the principal object of the present invention to provide a novel apparatus for removing particulate entrained in a stream of gas.

Another object of the present invention is to provide a novel apparatus suitable for use with a device emitting effluent into the atmosphere to remove particulate entrained in such effluent.

A further object of the present invention is to provide a novel apparatus suitable for use with a device emitting particulate laden effluent into the atmosphere, for removing said particulate so that the particulate loading of the effluent will approach the particulate loading of the ambient atmosphere.

A still further object of the present invention is to provide a novel apparatus for removing particulate entrained in a stream of gas which is relatively simple in construction and comparatively inexpensive to operate.

Another object of the present invention is to provide a novel incinerator.

A further object of the present invention is to provide a novel incinerator operable to produce an effluent emission having a low particulate content.

A still further object of the present invention is to provide a novel incinerator capable of producing an effluent emission having a particulate loading approaching the particulate loading of the ambient atmosphere.

Another object of the present invention is to provide a novel incinerator capable of producing an effluent emission of low particulate loading, thus minimizing the particulate pollution of the atmosphere in the operation of the incinerator.

Another object of the present invention is to provide a novel incinerator capable of meeting governmental code requirements pertaining to pollution of the atmosphere.

A further object of the present invention is to provide a novel incinerator capable of producing an effluent emission having a particulate loading approaching the particulate loading of the ambient atmosphere, which is simple in construction and comparatively inexpensive to erect, operate and service.

Another object of the invention is to provide a novel apparatus and method for reducing the concentration of gaseous contaminant of a stream of gas.

A further object of the invention is to provide a novel apparatus and method for reducing both the solid and gaseous contaminant of a stream of gas, and particularly a stream of combustion gases.

Other objects and advantages of the present invention will become more apparent to those persons having ordinary skill in the art to which the invention pertains, from the following description taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a vertical cross-sectional view of an embodiment of the invention;

FIG. 2 is an enlarged cross-sectional view taken along line 2—2 in FIG. 1;

FIG. 3 is a vertical cross-sectional view of another embodiment of the invention;

FIG. 4 is an enlarged cross-sectional view taken along line 4—4 in FIG. 3;

FIG. 5 is a vertical cross-sectional view of a third embodiment of the invention; and

FIG. 6 is a cross-sectional view taken along line 6—6 in FIG. 5.

Briefly described, according to one embodiment, the present invention relates to an incinerator generally including a combustion chamber, a flue, means for conducting combustion gases emanating from the combustion chamber to the flue, the conducting means including passage means for imparting a curved motion to the combustion gases, means disposed in the passage means for producing a plurality of electrostatic fields including a plurality of sets of spaced electrodes, each set of electrodes producing an electrostatic field through which a portion of the combustion gases traverse, and means disposed upstream relative to the means for producing the plurality of electrostatic fields, for ionizing the combustion gases whereby particulate entrained in the combustion gases will be ionized by the ionizing means and subjected to cooperating centrifugal, electrostatic and gravitational forces as the combustion gases traverse through the passage means to remove the particulate from the combustion gases. Preferably, the incinerator further includes a secondary combustion chamber and means for removing particulate larger than a predetermined size, in the order of 3 to 5 microns, from the combustion gases emanating from the combustion chambers, disposed between the primary chamber and the gas conducting means, and a settling chamber disposed between the gas conducting means and the flue, having means upon which particu-

late diverted from the main stream of gases and not previously collected, may impinge.

In the embodiment as described, the ionization and electrostatic precipitation of the particulate entrained in the stream of combustion gases occur in separate stages. The combustion gases are first ionized and then subsequently caused to pass through a plurality of electrostatic fields which function to precipitate the ionized particles. In another embodiment of the invention, the electrostatic precipitation of the particulate in the gas stream is accomplished in a single stage wherein the plurality of electrostatic fields are of sufficient strength to produce corona discharges which function to ionize particulate entrained in the gas stream, which are precipitatd by the same electrostatic fields producing the corona discharges.

In both embodiments as broadly described, it is contemplated that a combination of centrifugal, electrostatic and gravitational forces will be applied to particulate entrained in the stream of combustion gases emanating from the combustion chamber and flowing to the flue of the incinerator, to remove such particulate from the main stream of the gases. Simultaneously, electrostatic forces are applied to ionize molecules of gaseous contaminants, to further remove such contaminants from the gas stream. To increase the overall efficiency of the incinerator, it further is contemplated to utilize a secondary combustion chamber disposed upstream of the combined separator, to prolong combustion, thus reducing the particulate content of the combustion gases, and also to utilize an upstream scrubber chamber which is effective in removing particulate of five microns or larger in size, and cooling the gases, thus reducing the power requirements and increasing the effectiveness of the electrostatic precipitators.

Referring to FIGS. **1** and **2** of the drawings, there is illustrated the first embodiment of the invention utilizing a two stage electrostatic precipitator. The embodiment includes a housing structure **10** having an upper wall **11**, a lower wall **12**, a front end wall **13**, a rear end wall **14**, and a pair of side walls **15, 15**. The various walls of the housing structure are either constructed of or lined on the interior sides thereof with a fire resistent material such as firebrick and the like. Disposed within the housing structure is a partition wall **16** consisting of firebrick, which is spaced from the front end wall **13**, and a partition wall **17** spaced from the rear end wall **14**, providing a combustion chamber **18**, a gas washer or scrubber chamber **19** and a settling chamber **20**. The upper end of the partition wall **16** terminates below the upper wall **11** to provide a horizontal passageway **21**. The front end wall **13** is provided with a charging opening **22** communicating with the combustion chamber **18** through which refuse may be charged into the combustion chamber onto a grate **23** mounted in the lower end of the combustion chamber and spaced from the lower wall **12**. Conventional openings are provided in at least one of the side walls below the grate **23** for removing ash deposited in the bottom of the combustion chamber below the grate **23**. Although a simple combustion chamber having a grate for supporting refuse and an opening for charging refuse into the combustion chamber are shown in FIG. **1**, it is to be understood that any suitable type of combustion chamber utilizing any type of charging system and grate assembly or stoker may be used within the scope of the invention.

Depending from the upper wall **11** and extending into the scrubber chamber **19**, is a curtain wall **24**. The lower end of the curtain wall projects below the upper level of the partition walls **16** and **17**, and is spaced from the lower wall **12**. In addition, the curtain wall **24** is spaced from the partition walls **16** and **17**, to provide vertical passageways **25** and **26** on opposite sides of the curtain wall. The vertical passageway **25** intercommunicates the horizontal passageway **21** and the scrubber chamber **19**, and the vertical passageway **26** intercommunicates the settling chamber **20** with a horizontal passageway **27** formed by the termination of the upper end of the partition wall **17** below the upper wall **11**.

Supported on the side walls **15,15**, and disposed in the vertical passageway **26** is a horizontal baffle **28** having the front end **29** spaced from the curtain wall **24** to provide a restricted passageway between the front end of the baffle and the curtain wall. Preferably, the lower end of the baffle **28** is elevated relative to the lower end of the curtain wall **26**, and the cross-sectional areas of the vertical passageway **25** and the restricted passageway between the baffle and the curtain wall are substantially equal. In addition, the rear end of the baffle wall **28** is provided with a relief passageway **30** which functions to eliminate any high pressure zone produced in the scrubber chamber below the baffle.

In the particular construction of the settling chamber **19** as described, it will be seen that combustion gases emanating from the combustion chamber will rise and pass through the horizontal passage **21**, downwardly through the vertical passageway **25**, around the lower end of the curtain wall **24** in the scrubber chamber, describing a curved path, upwardly through the restricted portion of the vertical passageway **26** and horizontally through the passageway **27** into the settling chamber. As the stream of gases flow along such a path through the scrubber chamber, fly ash particulate having a particle size in the order of five microns and larger will be removed from the stream of combustion gases primarily by sprinklers **31** mounted on the lower end of curtain wall **24**, which direct a spray of water downwardly across the path of gases flowing through the scrubber chamber. The sprinklers may be of any suitable type capable of removing large particulate from the stream of combustion gases flowing through the scrubber chamber. It will be appreciated that either the contact of the water spray with the particulate or the combination of the force of the water spray and the centrifugal forces acting on the particulate, will cause the particulate either to precipitate and fall to the bottom of the scrubber chamber, or to be diverted tangentially from the main stream of gases flowing through the scrubber chamber and impinge upon either the partition wall **17** or the baffle **28** which causes them to lose their kinetic energy and fall to the bottom of the scrubber chamber. The sprinklers further function to reduce the temperature of the gas from the order of 1,600°F to the order of 600°F. The relief passageway **30** in the baffle **28** is provided to prevent the formation of a high pressure zone below the baffle **28** which would function to deter fly ash particulate from being diverted from the main stream of the combustion gases flowing through the scrubber chamber.

Depending from the upper wall **11** and extending into the settling chamber **20** is a curtain wall **32**. The lower end of the curtain wall **32** projects below the upper level of the partition wall **17** and is space above the

lower wall **12**. The curtain wall is spaced from the partition wall **17** and the rear end wall **14**, to provide vertical passageways **33** and **34** on opposite sides thereof. The vertical passageway **33** intercommunicates the horizontal passageway **27** and the settling chamber **20**, and the vertical passageway **34** intercommunicates the settling chamber **20**, and a flue opening **35** provided in the upper end of the rear end wall **14**. With such an arrangement of components, a stream of combustion gases introduced through the horizontal passageway **27** will be caused to flow downwardly through vertical passageway **33**, around the lower end of the curtain wall **32**, and upwardly through the vertical passageway **28**, describing a curved path having the center of curvature thereof disposed in the lower end of the curtain wall **32**, and horizontally through the flue opening **35** to be discharged into the atmosphere.

Extending across the passageway **33** and supported on the end walls **15,15** is a plurality of ionizing electrodes consisting of one or more electrically conducting wires disposed transversely to the flow of gases, inside of passageway **33** provided by a plurality of short grounded plates **36***a* disposed transversely in passageway **33** and extending in the direction of the flow of gases. A high direct current voltage in the order of 4 to 10 kv is applied to the electrodes **36** to produce electrostatic fields of sufficient strength to provide corona discharges in passageways **33***a*, which function to produce an ionizing zone through which combustion gases introduced through the horizontal passageway **27** are caused to flow. Disposed downstream from the ionization zone provided by the electrode **36**, is a plurality of curved, electrode supporting plates **37** which are spaced betweeen the lower end of the curtain wall **32** and a curved wall **38** merging at the extremities thereof with the interior wall surfaces of the partition wall **17** and a portion of lower wall **17** and a portion of lower wall **12** defining the settling chamber, thus providing a plurality of curved passageways **39**. Preferably, the support members **37** are constructed of a nonelectrically conducting material, extend across the entire length of the settling chamber, are provided with a center of curvature similar or in the vicinity of the center of curvature of the path of gases traversing through the settling chamber and are provided with an airfoil configuration to a) minimize the resistance of the support members to the streams of gases flowing through the settling chamber, b) maintain an unbroken water film for the removal of collected particles and gaseous contaminants, and c) vary the passage area so as to reduce the gas velocity at the exit, thereby reducing the probability for re-entrainment of collected particles. Mounted on the lower end of the curtain wall **32** and the undersides of the support members **37** are curved, negatively charged plates **40**. Spaced from the negatively charged plates **40** and mounted on the support members **37** and the curved wall **38** of the housing structure is a plurality of grounded collector plates **41** which cooperate with the negatively charged plates **40** when a high direct current voltage is applied, to produce electrostatic fields between the sets of electrodes in the passageways **39**.

In the operation of the embodiment illustrated in FIGS. **1** and **2**, when refuse is burned in the combustion chamber **18**, a certain amount of fly ash particulate and gaseous contaminants such as sulfur oxides, nitrogen oxides, and combined and uncombined halogens including fluorines, chlorines, etc., will be entrained in the combustion gases emanating from the combustion chamber and will flow through passageways **21** and **25**, around the lower end of the curtain wall **24** in the scrubber chamber, and upwardly through the restricted portion of the passageway **26** into the horizontal passageway **27**. As the stream of combustion gases flows around the lower end of the curtain wall **24**, most of the fly ash particulate having a particle size in the order of five microns and larger will be removed from the stream of gases flowing upwardly through the restricted portion of the passageway **26** either by means of the water spray provided by the sprinklers **31** or a combination of the force applied by the water spray and the centrifugal forces produced by the curved motion of the stream of gases, whereby the large fly ash particulate will either be precipitated or caused to divert and impinge upon the horizontal baffle **28** or the partition wall **17** causing the particulate to lose its kinetic energy and fall to the bottom of the scrubber chamber. The relief passageway **30** in the rear end of the horizontal baffle eliminates the formation of any high pressure zone below the baffle which would tend to inhibit the removal of large fly ash particulate so that the stream of combustion gases flowing through the horizontal passageway **27** and introduced into the settling chamber substantially will contain particulate having a particle size of less than 5 microns.

As the stream of combustion gases continues to flow downwardly through the ionization zone of passageway **33**, particulate entrained in the stream of gases will be ionized by the corona discharges produced between the electrodes **36** and **36***a*. The ionized particulate is then caused to flow through arcuate passageways **39** and upwardly through passageway **34** into the flue opening **35**. In doing so, the ionized particulate will be caused to be diverted from the main stream of gases flowing through the settling chamber by centrifugal forces produced by the motion of the gas stream, electrostatic forces produced by the electrostatic fields in the curved passageways **39**, and gravitational forces. The combination of such forces functions to remove the residual particles entrained in the stream of gases flowing through the settling chamber.

The electrostatic fields provided between the plates **40** and **41** in the passageways **39**, will cause a substantial portion of the ionized particles passing through such passageways to be collected on the collector plates **41**. Particulate deposited on the plates **41** is removed and deposited at the bottom of the settling chamber by means of washer units **42** which spray a film of water on the collector plates **41** to wash precipitated particulate from the surfaces thereof.

Gas molecules which also have been ionized will be forced to the collector plates **41** whereby those molecules which either dissolve in or react with the water flowing along the collector plates, effectively will be removed from the gas stream. Since many of the undesirable contaminants, particularly sulfur oxides, nitrogen oxides and combined and uncombined halogens such as chlorine, fluorine, etc. behave in this manner, the device constitutes an effective means for the removal of such undersirable gaseous contaminants from the effluent emitted into the atmosphere by the incinerator.

It further is contemplated, that certain additives be introduced into the water used for washing the collector plates, which will adsorb or chemically react with

the contaminants to render the contaminants harmless and, preferably, produce a form of the contaminants which would facilitate their removal from the liquid medium. In addition, it is contemplated that any suitable liquid medium such as water, with or without an adsorbing or chemically reactive additive, may be used to wash the collector plates of precipitated contaminant. Alternatively, the additive may be introduced into the liquid medium subsequent to the washing of the collector plates, depending on the nature of the contaminants and the product of the physical or chemical combination of the contaminants with the liquid medium.

Since many of the contaminants would chemically react with water used as a washing medium, it specifically is contemplated that an additive be introduced into the water which will neutralize any acid that may be formed by the reaction of the contaminants with the water, thereby preventing corrosion of the collector plates. Under such circumstances, an alkaline solution including an alkali metal hydroxide such as sodium hydroxide or potassium hydroxide or an alkaline earth metal hydroxide such as calcium hydroxide or magnesium hydroxide, in solutions ranging from 0.05 percent to 50 percent by weight, would be added to the water utilized as a liquid washing medium to neutralize the acids formed by the contaminants.

It is to be understood that the invention contemplates the use of any suitable liquid washing medium either alone or in physical or chemical combination with a contaminant treating agent introduced into the liquid medium either prior or subsequent to the washing operation, which in any manner, either physically or chemically, will react with the precipitated molecules of gaseous contaminants and possibly even with the precipitated particulate, to render the discharge fluid from the collector plates harmless, thus enhancing the contaminant removal and protecting the various components of the incinerator and auxiliary equipment from any corrosive or deteriorative effects of the discharge liquid.

The curved motion of the various stream of gases flowing through passageways **39** will cause particulate which has not been deposited on the plates **41** to be diverted from the recombined stream of gases flowing upwardly through vertical passageway **34** by means of the centrifugal, electrostatic and gravitational forces acting on such particulate. Such particulate along with water droplets entrained in the recombined gas streams will move along tangential or involute paths at diminshing velocities until they either fall to the bottom of the settling chamber or impinge upon the rear end wall **14** or a horizontal baffle **43** provided in the vertical passageway **34**, causing them to lose their kinetic energy, fall to the bottom of the settling chamber, and be entrapped in the water basin provided therein. The front end of the horizontal baffle **43** is spaced from the curtain wall **32** to provide a restricted portion of the passageway **34** through which the clean gases flow, to be discharged through the flue into the atmosphere. The formation of a high pressure zone below the horizontal baffle **43**, tending to deter the separation of particulate from the main stream of gases flowing upwardly through the restricted portion of passageway **34**, is prevented by means of a relief passageway **44**.

Although the settling chamber with its particular configuration and the electrostatic precipitator, providing a combination of centrifugal, electrostatic and gravitational forces for removing solid and gaseous contaminants from the stream of combustion gases flowing through the settling chamber, would be sufficient to reduce materially the amount of contaminants emitted into the atmosphere, it is preferred that fly ash particulate having a particle size in the order of five microns and larger be removed from the combustion gases prior to introducing the gases into the settling chamber. The removal of larger particulate enhances the effectiveness of the settling chamber as described. Furthermore, it is preferred that primary and secondary combustion chambers be utilized so as to prolong the resident time of the gases, thus providing maximum incineration of the refuse and the production of a smaller amount of fly ash particulate entrained in the combustion gases introduced into either the scrubber chamber or directly into the settling chamber. Such an embodiment subsequently will be described.

Referring to FIGS. **3** and **4** of the drawings, there is illustrated a second embodiment of the invention utilizing a one stage electrostatic precipitator. The embodiment includes a housing structure **50** having an upper wall **51**, a lower wall **52**, a front end wall **53**, a rear end wall **54**, and a pair of side walls **55,55**. The walls of the housing structure are either constructed of or lined on the interior sides thereof with a fire resistant material such as firebrick and the like. Disposed within the housing structure is a partition wall **56** consisting of firebrick which is spaced from the front end wall **53**, and a partition wall **57** which is spaced between the partition wall **56** and the rear end wall **54** to provide a combustion chamber **58**, a gas washer or a scrubber chamber **59** and a settling chamber **60**. The upper end of the partition wall **56** terminates below the upper wall **51** to provide a horizontal passageway **61**.

The front end wall **53**, is provided with an opening **62** through which refuse may be changed into the combustion chamber onto a grate **63** mounted in the lower end of the combustion chamber and spaced from the lower wall **52**. Conventional access openings are provided in the side walls below the grate **63** for removing ash deposited in the bottom of the combustion chamber. Although a simple combustion chamber having a grate for supporting refuse and an opening for charging refuse in the combustion chamber are shown in FIG. **3**, it is to be understood that any suitable type of combustion chamber utilizing any type of charging system and grate assembly or stoker may be used within the scope of the present invention.

Depending from the upper wall **51** and extending into the scrubber chamber **59**, is a curtain wall **64**. The lower end of the curtain wall **64** projects below the upper level of the partition walls **56** and **57**, and is spaced from the lower wall **52** to provide vertical passageways **65** and **66** on opposite sides thereof. The vertical passageway **65** intercommunicates the horizontal passageway **61** and the scrubber chamber **59**, and the vertical passageway **66** intercommunicates the settling chamber **59** with a horizontal passageway **67** provided by the termination of the upper end of the partition wall **57** below the upper wall **51**.

Disposed in the vertical passageway **66** and supported on the side walls **55,55** is a horizontal baffle **68** having the front end **69** thereof spaced from the curtain wall **64** to provide a restricted passageway between the front end of the baffle and the curtain wall **64**. Preferably, the lower end of the baffle **68** is elevated relative

to the lower end of the curtain wall 64, and the cross-sectional areas of the vertical passageway 65 and the restricted passageway between the baffle and the curtain wall are substantially equal. In addition, the rear end of the baffle wall 68 is provided with a relief passageway 70 to eliminate any high pressure zone produced in the scrubber chamber below the baffle.

Combustion gases emanating from the burning refuse on the grate 63 in the combustion chamber, will be caused to rise and pass through the horizontal passageway 61, downwardly through the vertical passageway 65, around the lower end of the curtain wall 64, describing a curved path, upwardly through the restricted portion of the vertical passageway 66, and horizontally through the passageway 67 into the settling chamber. As the stream of gases flows along such a curved path through the scrubber chamber, fly ash particulate having a particle size in the order of 5 microns and larger will be removed from the stream of combusiton gases primarily by sprinklers 71 mounted on the lower end of the curtain wall 64 or in the vicinity thereof which direct a spray or curtain of water downwardly across the path of gases flowing through the scrubber chamber. The sprinklers may be of any suitable type capable of removing large particulate from the stream of combustion gases flowing through the scrubber chamber. It will be noted that either the force of the water spray or a combination of the force of the water spray and the centrifugal forces acting on the particulate as it traverses through the scrubber chamber, will cause the particulate either to precipitate and fall to the bottom of the scrubber chamber as it passes around the lower end of the curtain wall, or impinge upon either the partition wall 57 or the lower side of the baffle 68. The sprinklers also function to reduce the temperature of the gases from the order of 1500°F to 1700°F to the order of 400°F to 600°F. The relief passageway 70 in the baffle 68 is provided to prevent the formation of a high pressure zone below the baffle 68 which otherwise would function to deter fly ash particulate from being diverted from the main stream of the combustion gases flowing through the scrubber chamber.

Depending from the upper wall 51 and extending into the settling chamber 60 is a curtain wall 72. The lower end of the curtain wall 72 projects below the upper level of the partition wall 57 and is spaced above the lower wall 52. The curtain wall 72 also is spaced from the partition wall 57 and the rear end wall 54, providing vertical passageways 73 and 74 on opposite sides thereof. The vertical passageway 73 intercommunicates the horizontal passageway 67 and the settling chamber 60, and the vertical passageway 74 intercommunicates the settling chamber 60 and a flue opening 75 provided in the upper end of the rear end wall 54. It will be appreciated that with such an arrangement of components, a stream of combustion gases introduced through horizontal passageway 67 will be caused to flow downwardly through vertical passageway 73, around the lower end of the curtain wall 72, and upwardly through the vertical passageway 74, describing a curved path having a center of curvature disposed in the lower end of the curtain wall 72, and horizontally through the flue opening 75 to be discharged into the atmosphere.

Disposed in the lower end of the vertical passageway 73 and in the main body of the settling chamber 60 is a plurality of curved support members 76 which are spaced between the lower end of the curtain wall 72 and a curved wall 77 which merges at the extremities thereof with the partition wall 57 and a portion of lower wall 52, thus providing a plurality of curved passageways 78. Preferably, the support members 76 are constructed of a nonelectrically conducting material, extend across the entire width of the settling chamber, are provided with a center of curvature similar or adjacent to the center of curvature of the path of gases traversing through the settling chamber, and are provided with an airfoil configuration to minimize resistance to the gases flowing through the settling chamber. Mounted on the lower end of the curtain wall 72 and the undersides of the support members 76, are curved, negatively charged plates 79. Spaced from the negatively charged plates 79 and mounted on the upper sides of the support members 76 and on the curved surface 77, is a plurality of grounded collector plates 80 which cooperate with the negatively charged plates 79 when a high direct current voltage is applied to each of the sets of plates, to produce electrostatic fields between the sets of electrodes in the passageways 78.

Each of the negatively charged plates 79 is provided with a plurality of transversely spaced, longitudinally disposed projecting portions 79*a* which extend toward the adjacent collector plate 80. As best illustrated in FIG. 4, each of the projecting portions 79*a* has a tapered cross-sectional configuration and a terminal portion of a relatively small diameter. When a sufficient voltage is applied to a set of plates 79 and 80, an electrostatic field of sufficient strength is produced in the passageway 78 between the plates to produce a corona discharge between the tapered projecting portions 79*a* of the plate 79 and the collector plate 80. As hereinafter will be described, the corona discharges produced across the passageways 78 function to ionize the combustion gases traversing therethrough, whereupon the ionized solid contaminants entrained in the gases along with some molecules of gaseous contaminants will be caused to be precipitated by the electrostatic fields and deposited on the collector plates 80.

In the operation of the embodiment as illustrated in FIGS. 3 and 4, when refuse is burned in the combustion chamber 38, a certain amount of fly ash particulate will be entrained in the combustion gases emanating from the combustion chamber and will flow through the passageways 61 and 65, around the lower end of the curtain wall 64 in the scrubber chamber, and upwardly through the restricted portion of passageway 66 into the horizontal passageway 67. As the stream of gases flows around the lower end of the curtain wall 64, large fly ash particulate having a particle size in the order of five microns and larger will be precipitated from the main stream of gases flowing upwardly through the restricted portion of passageway 66 either by means of the force of the water spray provided by the sprinklers 71, or a combination of the force of the water spray and the centrifugal force created by the curved motion of the stream of gases flowing through the scrubber chamber, whereby large fly ash particulate will either be precipitated or caused to be diverted and impinge upon the baffle 68 or the partition wall 57. The relief passageway 70 in the rear end of the baffle 68 functions to eliminate the formation of any high pressure zone below the baffle which would tend to inhibit the removal of large fly ash particulate, so that the stream of combustion gases flowing through the horizontal pas-

sageway 67 and introduced into the settling chamber, substantially will contain particulate having a particle size of less than 5 microns.

The stream of combustion gases entering the vertical passageway 73 is caused to flow downwardly through the curved passageways 78 and then upwardly through the passageway 74 into the flue opening 75. In doing so, the particulate entrained in the stream of gases passing through the passageways 78 will be ionized by the corona discharges, and will be caused to be diverted from the main stream of gases flowing through the settling chamber by centrifugal forces created by the motion of the gas stream, electrostatic forces produced by the electrostatic fields in the curved passageways 78, and gravitational forces. The combination of such forces functions to remove the residual particles entrained in the stream of gases flowing through the settling chamber and discharged into the flue opening.

The electrostatic forces provided between the plates 79 and 80 and the centrifugal forces produced by the motion of the gas stream will cause a substantial portion of the ionized particles passing through the passageways 78 to be collected on the collector plates 80. Particulate deposited on the collector plates is removed therefrom and deposited at the bottom of the settling chamber by means of washer units 81 which spray a film of water on the collector plates to wash precipitated particulate from the surfaces thereof. The washer units 81 are supported by the side walls 55,55, and are disposed in the leading ends of the curved passageways 78 adjacent to the collector plates 80. Ordinarily, the washer units will consist of water pipes having discharge openings or nozzles directed toward the collector plates 80. It is to be understood, however, that any suitable device may be utilized for washing particulate deposited on the collector plates.

In addition to solid contaminants being ionized and electrostatically precipitated from the gas stream as it flows through passageways 78, molecules of gaseous contaminants also will be ionized by the corona discharge produced in the passageways 78, which are electrostatically precipitated. Similar to the action of the electrostatically precipitated gaseous molecules described in connection with the embodiment illustrated in FIGS. 1 and 2 of the drawings, such gaseous molecules will be collected by the liquid washing medium and carried off therewith. In this embodiment of the invention, as in the aforementioned embodiment, it is contemplated to utilize a liquid-washing medium with or without an appropriate additive which will render nonreactive the collected gaseous and/or solid contaminants or the product of the gaseous and/or solid contaminants either physically or chemically combined with the liquid-washing medium.

The curved motion of the various streams of gases flowing through the passageways 78 will cause particulate which has not been electrostatically precipitated, to be diverted from the recombined main stream of gases flowing upwardly through the vertical passageway 74, by means of centrifugal, electrostatic and gravitational forces acting on the particulate. Such particulate along with droplets of the washing medium will be caused to move along tangential or involute paths at diminishing velocities until the particles either fall to the bottom of the settling chamber or impinge upon the rear end wall 54 or a horizontal baffle 82 provided in a vertical passageway 74, causing them to lose their kinetic energy and fall to the bottom of the settling chamber. The front end of the horizontal baffle 82 is spaced from the curtain wall 72 to provide a restricted portion in the passageway 74 through which the clean gases flow to be discharged through the flue into the atmosphere. The formation of a high pressure zone below the baffle 82, tending to inhibit the separation of particulate from the main stream of gases flowing through the restricted portion of passageway 74, is prevented by means of a relief passageway 83 provided in the rear end of the baffle.

As previously mentioned in connection with the embodiment illustrated in FIGS. 1 and 2, although the settling chamber with its particular configuration and the electrostatic precipitator, providing a combination of centrifugal, electrostatic, and gravitational forces for removing solid and gaseous contaminants from the stream of combustion gases flowing through the settling chamber, would be sufficient in the embodiment illustrated in FIGS. 3 and 4 to materially reduce the solid and gaseous contaminant loading of gases emitted into the atmosphere, it is preferred that fly ash particulate having a particle size in the order of 5 microns and larger be removed from the combustion gases prior to introducing such gases into the settling chamber. The removal of larger particulate enhances the effectiveness of the settling chamber as previously described. Furthermore, it is preferred that primary and secondary combustion chambers be utilized so as to prolong the residence time and thus provide maximum incineration of the refuse and the production of a smaller amount of fly ash particulate entrained in the combustion gases introduced into either the scrubber chamber or directly into the settling chamber.

Referring to FIGS. 5 and 6, there is illustrated a third embodiment of the invention. Such embodiment consists of an incinerator including a housing structure 90 having an upper wall 91, a lower wall 92, a front end wall 93, a rear end wall 94 and a pair of side walls 95,95. Similar to the aforementioned embodiments, the various walls of the housing structure 90 are either constructed of or lined on the interior side thereof with a fire resistant material such as firebrick and the like. Disposed within the housing structure are partition walls 96, 97 and 98 consisting of firebrick, providing a primary combustion chamber 99, a secondary combustion chamber 100, a gas washer or scrubber chamber 101 and a settling chamber 102. The upper wall of the primary combustion chamber 99 is provided with an opening 103 through which refuse may be charged into the primary combustion chamber onto a grate 104 mounted in the lower end of the chamber and spaced from the lower wall thereof. Conventional openings are provided in at least one of the side walls below the grate 104 for removing ash deposited in the bottom of the primary combustion chamber below the grate. Although a simple primary combustion chamber having a grate for supporting refuse and an opening for charging refuse into the chamber are shown in FIG. 5, it is to be understood that any suitable type of combustion chamber utilizing any type of charging system and grate assembly or stoker may be used within the scope of the invention.

The partition walls 96 and 97 defining the front and rear walls of the secondary combustion chamber, terminate below the upper wall 91 to provide horizontal passageways 105 and 106 communicating with the pri-

mary combustion chamber and the scrubber chamber, respectively. Depending from the upper wall **91** and extending into the secondary combustion chamber, is a curtain wall **107**, the lower end of which projects below the upper levels of the partition walls **96** and **97**. In addition, the curtain wall **107** is spaced from the partition walls **96** and **97** to provide vertical passageways **108** and **109** on opposite sides thereof communicating with the horizontal passageways **105** and **106**, respectively.

Supported on the side walls **95,95** and disposed in the vertical passageway **109** is a horizontal baffle **110** having the front end thereof spaced from the curtain wall **107** to provide a restricted passageway between the front end of the baffle and the curtain wall. Preferably, the lower end of the baffle **110** is elevated relative to the lower end of the curtain wall **107**, and the cross-sectional areas of the vertical passageway **108** and the restricted passageway between the baffle and the curtain wall are substantially equal. In addition, the rear end of the baffle wall **110** is provided with a relief passageway **111** which functions to eliminate any high pressure zone produced in the secondary combustion chamber below the baffle.

Mounted within the scrubber chamber **101** is a plurality of vertical cylindrical conduits disposed in side-by-side relation across the width of the scrubber chamber, as best illustrated in FIG. **6**. The conduits **112** may be secured to the upper wall **91** of the incinerator housing and extend downwardly into the scrubber chamber, having the lower ends thereof spaced from the lower wall **92** of the incinerator housing. The upper ends of each of the conduits **112** are provided with vertical, elongated openings **113** which are offset relative to the vertical axes of the conduits, communicate with the secondary combustion chamber through a duct **114** disposed in horizontal passageway **106** and the vertical passageway **109**, and permit the entry of combustion gases tangentially into the cylindrical chambers of the conduits. The lower ends of the conduits **112** are provided with outlet openings **115** which are axially spaced relative to the inlet openings **113**, and which communicate with the scrubber chamber. In addition to being located at the lower ends of the conduits **112**, the outlet openings **115** also may be disposed on the lower sides of the conduits. It will be noted that gases introduced into the conduits **112** tangentially, will be caused to traverse the lengths of the conduits in a helical or swirling motion, and be ejected through the outlet openings **115** into the lower end of the scrubber chamber **101**.

Disposed in the upper end of each conduit **112** is a sprinkler or spray unit **116** which functions to spray or sprinkle water downwardly along the interior sides of the conduits **112**. Each of the spray units **116** is connected to a fluid supply line, and is provided with a shut-off valve so that selected spray units may be placed into or removed from service as desired. Water discharged through the lower ends of the conduits **112** is collected at the lower end of the scrubber chamber which functions as a trough, which may be returned to the sprinkler units for recirculation through the system. Additional means may be provided for adding fresh make-up water to the sprinkler system and to drain the lower end of the settling chamber for repairs or routine maintenance.

The partition wall **98** and the rear end wall **94** form the front and rear walls of the settling chamber **102**. The upper end of the partition wall **98** terminates below the upper wall **91** to provide a horizontal passageway **117** communicating with the scrubber chamber **101**. The rear end wall **94** is provided with an opening **118** communicating with the flue of the incinerator.

Depending from the upper wall **91** and extending into the settling chamber **102** is a curtain wall **119**. The lower end of the curtain wall projects below the upper level of the partition wall **98** and is spaced above the lower wall **92** of the incinerator. The curtain wall **119** is spaced from the partition wall **98** and the rear end wall **94** to provide vertical passageways **120** and **121** on opposite sides thereof. The vertical passageway intercommunicates the horizontal passageway **117** and the settling chamber **102** and the vertical passageway **121** intercommunicates the settling chamber with the flue opening **118**. With such an arrangement of components, a stream of combustion gases introduced through the horizontal passageway **117** will be caused to flow downwardly through vertical passageway **120**, around the lower end of the curtain wall **119**, and upwardly through the vertical passageway **120**, describing a curved path having the center of curvature thereof disposed in the lower end of the curtain wall **119**, and horizontally through the flue opening **118** to be discharged into the atmosphere.

Disposed in the lower end of the vertical passageway **118** and in the main body of the settling chamber **102** is a plurality of curved support members **122** which are spaced between the lower end of the curtain wall **119** and a curved wall **123** which merges at the extremities thereof with the partition wall **98** and a portion of the lower wall **92**, thus providing a plurality of curved passageways **124**. Preferably, the support members **122** are constructed of a nonelectrically conducting material, extend across the entire width of the settling chamber, are provided with a center of curvature similar or adjacent to the center of curvature of the path of gases traversing through the settling chamber, and are provided with an airfoil configuration to minimize resistance to the gases flowing through the settling chamber. Mounted on the lower end of the curtain wall and the undersides of the support members **122**, are curved, negatively charged plates **125**. Spaced from the negatively charged plates **125** and mounted on the upper sides of the support members **122** and on the curved surface **123**, is a plurality of grounded collector plates **126** which cooperate with the negatively charged plates **125** when a high direct current voltage is applied to each of the sets of plates, to produce electrostatic fields between the sets of electrodes and the passageways **124**.

Similar to the construction of the negatively charged plates **79** described in connection with the embodiment illustrated in FIGS. **3** and **4**, each of the negatively charged plates **125** is provided with a plurality of transversely spaced, longitudinally disposed projecting portions which extend toward the adjacent collector plate. The projecting portions have tapered cross-sectional configurations and terminal portions of a relatively small diameter. As previously described in connection with the embodiment illustrated in FIGS. **3** and **4**, when a sufficient voltage is applied to a set of plates **125** and **126**, an electrostatic field of sufficient strength is produced in each passageway **124** between the plates to produce a corona discharge between the tapered projecting portions of the negatively charged plates **125** and the collector plates **126**. The corona discharges

produced across the passageways **124** function to ionize the combustion gases traversing therethrough, whereupon ionized fly ash particles entrained in the gases along with some molecules of gaseous contaminants will be caused to be precipitated by the electrostatic fields and deposited on the collector plates **126.**

In the operation of the embodiment illustrated in FIGS. **5** and **6**, when refuse is burned in the primary combustion chamber **99**, the gaseous products of combustion at least to some extend will continue to burn as they flow through horizontal passageway **105**, and downwardly through vertical passageway **108** and around the lower end of the curtain wall **107** in the secondary combustion chamber. As the burning gases flow around the lower end of the curtain wall **107** and through the restricted passageway between the front end of the baffle **110** and the curtain wall **107**, centrifugal forces acting on fly ash particles entrained in the gases will cause the fly ash particles to be diverted from the main stream of gases, and follow tangential or involute paths toward either the partition wall **97** or the horizontal baffle **110.** Fly ash particles thus diverted from the main stream of the combustion gases and impinging upon the partition wall **97** or the baffle **110** will be caused to lose their kinetic energy and fall to the bottom of the secondary combustion chamber to be removed by conventional means. The relief passageway **111** in the rear end of the horizontal baffle **110** prevents the formation of any high pressure zone in the secondary combustion chamber below the baffle **110** which possibly would result in re-entrainment of fly ash particles previously diverted from the main stream of gases traversing through the secondary combustion chamber. The secondary combustion chamber thus functions to prolong the burning of fly ash particles and, through the use of centrifugal and gravitational forces, to remove fly ash particles having a size in the order of 50 microns and greater, prior to introducing the combustion gases into the scrubber chamber.

The gases tangentially entering the conduits **112** through inlet openings **113** will be caused to traverse through the conduits in a helical or swirling motion. As the gases traverse through the conduits **112** with such a motion, to be ejected through the outlet opening **115**, they will contact the stream of water injected into the conduits by the spray units **116.** The contact of such gases with the film of water flowing downwardly along the inner sides of the conduits will cause fly ash particles having a size in the order of five microns and greater to become separated from the combustion gases and be carried by the water downwardly into the trough at the lower end of the scrubber chamber. The conduits **112** further function to reduce the temperature of the gases from the order of 1600°F to the order of 600°F.

The stream of combustion gases flowing upwardly in the scrubber chamber **101**, through horizontal passageway **117** and downwardly through vertical passageway **120**, is caused to flow downwardly through the curved passageways **124** and then upwardly through the passageway **121** into the flue opening **118.** In so doing, particulate and some of the gaseous contaminants entrained in the stream of gases passing through the passageways **124** will be ionized by the corona discharges, and will be caused to be diverted from the main stream of gases flowing through the settling chamber by the centrifugal forces created by the motion of the gas stream, electrostatic forces produced by the electrostatic fields in the curved passageway **124**, and gravitational forces. The combination of such forces functions to remove the residual particles and some of the gaseous contaminants entrained in the stream of gases flowing through the settling chamber and discharged into the flue opening.

The electrostatic forces acting in passageways **124** and the centrifugal forces produced by the motion of the gas stream, will cause a substantial portion of the ionized particles passing through the passageways **124** to be collected on the collector plates **126.** Particulate deposited on the collector plates is removed therefrom and deposited at the bottom of the settling chamber by means of washer units **127** which spray or sprinkle a film of water on the collector plates to wash precipitated particulate and molecules of gaseous contaminants from the surfaces thereof. The washer units **127** are supported by the side walls **95,95** and are disposed in the leading ends of the curved passageways **124** adjacent the collector plates **126.**

In addition to particulate being ionized and electrostatically precipitated from the gas stream as it flows through the passageways **124**, molecules of gaseous contaminants also will be ionized by the corona discharge produced in the passageways **124**, which will be electrostatically precipitated. As described with the aforementioned embodiments, such gaseous molecules will be collected by liquid washing medium and carried off therewith. It further is contemplated to utilize a liquid medium with or without an appropriate additive which will render nonreactive the collected solid and/or gaseous contaminants or the product of the solid and/or gaseous contaminants either physically or chemically combined with the liquid washing medium.

The curved motion of the various streams of gases flowing through the passageways **124** will cause particulate which has not been electrostatically precipitated, to be diverted from the recombined main stream of gases flowing upwardly through the vertical passageway **121** by means of centrifugal, electrostatic and gravitational forces acting on such particulate. Such particulate along with droplets of the washing medium, will be caused to move along tangential or involute paths at diminishing velocities until the particles and droplets either fall to the bottom of the settling chamber or impinge upon the rear end wall **94** or a horizontal baffle **128** provided in the vertical passageway **121**, causing them to lose their kinetic energy and fall or flow to the bottom of the settling chamber. The front end of the horizontal baffle **128** is spaced from the curtain wall **119** to provide a restricted portion of the passageway **121** through which the clean gases flow, to be discharged through the flue into the atmosphere. The formation of a high pressure zone below the baffle **128**, tending to cause diverted particulate to become reentrained in the main stream of gases flowing through the restricted portion of the passageway **121**, is prevented by means of a relief passageway **129** provided in the rear end of the baffle.

In the embodiment illustrated in FIGS. **5** and **6** of the drawings, it will be noted that a series of combinations of forces are applied to the solid and gaseous contaminants entrained in the products of combustion emanating from the primary combustion chamber to reduce the solid and gaseous contaminant loading of the effluent emitted into the atmosphere to a loading approach-

ing that of the ambient atmosphere. It specifically is to be noted that the secondary combustion chamber functions to increase the resident time of the gases to produce complete combustion and apply a combination of centrifugal and gravitational forces to remove solid particles having a particle size of 50 microns and greater, the scrubber chamber utilizes centrifugal and gravitational forces in conjunction with the physical and chemical combination of a film of water with the contaminants to remove particulate having a particle size of 5 microns and greater and to reduce the concentration of gaseous contaminants of the gas, and the settling chamber applies a combination of centrifugal, electrostatic and gravitational forces to reduce the solid and gaseous contaminants of the effluent emitted into the atmosphere.

In the various embodiments of the invention as described it has been mentioned that particulate deposited on the collector plates of the electrostatic precipitator may be removed by washing the collector plates with a film of water. In this respect, it is contemplated that the particulate deposited on the collector plates also may be removed by other suitable means including vibrating the collector plates. It further is contemplated that alternate configurations of the electrodes of the electrostatic precipitator may be utilized including a plurality of rectilinear plates and a plurality of curved plates having tangential trailing ends which in either instance would still cooperate with other designed features of the housing structure to impart a curved motion on the stream of combustion gases passing through the settling chamber. Although in the aforementioned embodiments the electrodes have been described as being negatively charged, it is within the scope of this invention to utilize either negatively or positively charged electrodes. It further is contemplated that each of the chambers wherein contaminants are precipitated, optionally be provided with wet bottom basins for entrapping precipitated contaminants.

There are several advantages which accrue from the plurality of curved passageways utilized in each of the aforementioned embodiments, wherein solid and gaseous contaminants are subjected to combined centrifugal, electrostatic and gravitational forces. The centrifugal force produced by the curved motion of the gases traversing the passageways positively maintains the films of liquid washing medium on the collector plates. This considerably reduces the tendency of the various films of liquid washing medium to break up due to both electrostatic forces resulting from high collecting fields and air flow shear forces caused by high gas stream velocities. This feature alone offers the possibility of exceeding by a significant degree the usual 20 to 25 ft/sec maximum gas velocities used in conventional electrostatic precipitator systems, thereby enhancing the liklihood for eliminating the necessity of any mechanical cleaning of the electrodes. Further, since the centrifugal field maintains smooth films of liquid washing medium over the curved collector plates and also keeps larger particles off the repeller plats, it is likely that considerably high collector-section fields can be maintained; e. g., possibly as high as 7 kv/cm.

A further advantage of the plurality of curved passageways is that the variable flow passageway area through which the gases are conducted permits a substantial reduction in gas velocity near the trailing ends of the passageways thus reducing the tendency for reentrainment of the water dripping off of the collector plates. Pressure drop through the system also is provided by the aerodynamic shaping which produces favorable boundry-layer pressure gradients over half the plate area, as well as low-loss inlet and exit flow configurations and smooth surfaces on the collector plates, i.e., the films of liquid washing medium, to reduce friction-factor losses.

In the reduction of solid wastes by incineration, ideally it has been sought to provide an incinerator design which is effective in reducing solid wastes to a minimum volume with minimum power consumption and without unduly impairing the structural integrity of the incinerator, and emitting an effluent into the atmosphere having a solid and gaseous contaminant loading approaching the loading of the ambient atmosphere. It is contemplated that the aforementioned invention is operable to both economically reduce refuse to a minimum volume and, to produce an effluent emission of a sufficient quality to minimize both solid and gaseous contamination of the atmosphere.

From the foregoing detailed description, it will be evident that there are a number of changes, adaptations and modifications of the present invention which come within the province of those skilled in the art. However, it is intended that all such variations not departing from the spirit of the invention be considered as within the scope thereof as limited solely by the dependent claims.

I claim:

1. An apparatus for removing contaminants entrained in a stream of gas comprising means for imparting a curved motion to said stream of gas, means for producing a plurality of electrostatic fields including a plurality of sets of spaced electrodes, each set of electrodes producing an electrostatic field through which a portion of said gases traverse, means disposed upstream relative to said means for producing a plurality of electrostatic fields, for ionizing said gases whereby contaminants entrained in said combustion gases will be ionized by said ionizing means and subjected to cooperating centrifugal, electrostatic and gravitational forces as said stream of gases flows through said apparatus, and means for collecting said contaminants.

2. An apparatus for removing contaminants entrained in a stream of gas according to Claim 1 including means for removing contaminants deposited on said electrodes.

3. An apparatus for removing contaminants entrained in a stream of gas according to claim 2 wherein said means for removing contaminants deposited on said electrodes comprises means for injecting a fluid on said electrodes to wash the deposited contaminants therefrom.

4. An apparatus for removing contaminants entrained in a stream of gas according to claim 1 wherein the electrodes of each of said set of electrodes comprise elongated plates disposed sufficiently adjacent along the lengths thereof to provide an electrostatic field having sufficient strength to precipitate ionized contaminants entrained in said gas stream traversing therethrough.

5. An apparatus for removing contaminants entrained in a stream of gas according to claim 1 wherein said electrodes consist of spaced, rectilinear plates.

6. An apparatus for removing contaminants entrained in a stream of gases according to claim 1

wherein said electrodes consist of spaced, curved plates.

7. An apparatus for removing contaminants entrained in a stream of gas according to claim 1 wherein said electrodes consist of spaced, curved plates having substantially tangential trailing end portions.

8. An apparatus for removing contaminants entrained in a stream of gas according to claim 1 wherein said means for imparting a curved motion to said stream of gases functions to cause said stream of gases to follow a curved path about a horizontal axis.

9. An apparatus for removing contaminants entrained in a stream of gas according to claim 1 wherein said means for imparting a curved motion to said stream of gases comprises a curved passageway having a horizontal axis of curvature, said electrodes are curved and substantially parallel having a substantially horizontal axis of curvature, said electrodes are mounted on traversely disposed support members secured to opposite sidewalls of said passageway, having adjacent electrodes of opposite polarity insulated from each other, and means for injecting a washing fluid on the electrodes on which contaminants are deposited.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,765,153 Dated October 16, 1973

Inventor(s) Jerry Grey

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 13, " 28" should be -- 34--;

Column 8, line 12, "resident" should be --residence--;

Column 14, line 21 " 120" should be -- 121--;

Column 14, lines 26 and 27, " 118" should be -- 120--;

Column 17, line 3, "resident" should be --residence--;

Column 17, line 55, "liklihood" should be --likelihood--.

Insert below "Inventor":

--[73] Assignee: Morse Boulger, Inc., Corona, New York--.

Signed and sealed this 3rd day of June 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
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