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Woods

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[54] **INCINERATOR WITH AFTERBURNER**

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[52] **U.S. Cl.** .... **110/8 R,** 110/8 A, 110/119

[51] **Int. Cl.** **F23g 5/12**

[58] **Field of Search** 110/8 R, 8 A, 8 C, 18 R, 18 C, 110/119

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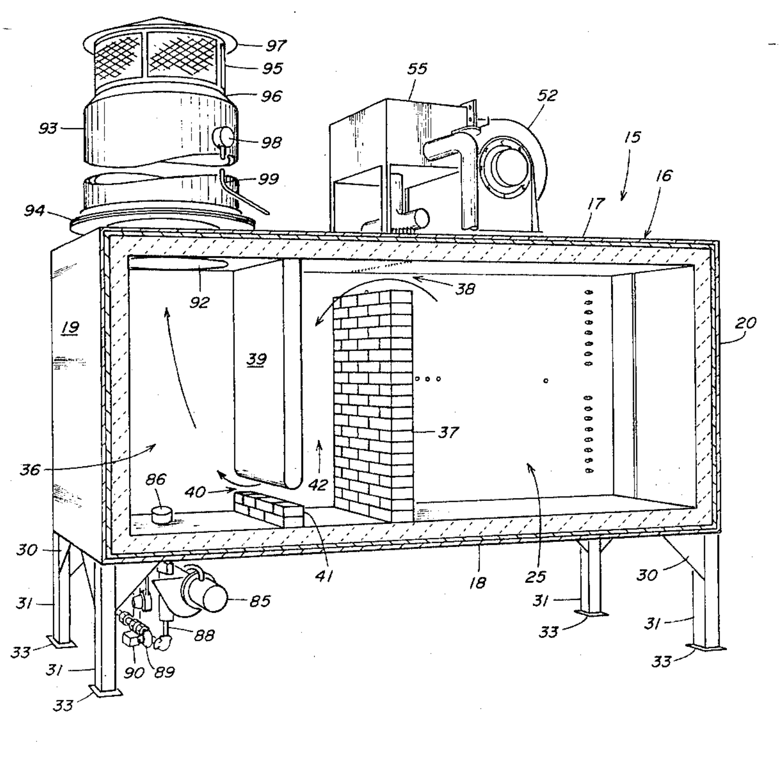
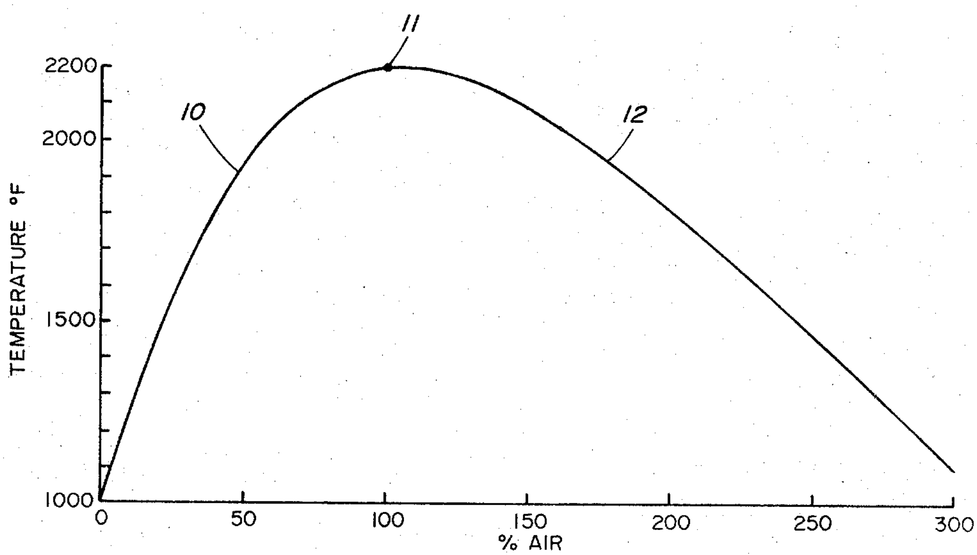
Primary Examiner—Kenneth W. Sprague

[57] **ABSTRACT**

A method and apparatus for the complete thermal conversion of waste solids such as paper and cardboard to essentially pollution free products of combustion is disclosed. The incinerator apparatus includes a housing having a primary burning chamber supplied with combustion air by a blower discharging into the chamber through a series of selectively arranged and oriented nozzles in the chamber top and side walls. Two vertical baffle walls in the housing define a vertical flow passage from the top of the primary chamber to the bottom of an afterburner chamber supplied with fuel and air through a burner. The rate of the fuel supplied from the burner is controlled to maintain a constant temperature in the afterburner exhaust chamber as sensed by a thermocouple. The method includes maintaining an excess air environment in the primary chamber and introducing the product off-gases or effluent into the afterburner chamber at a velocity and direction with respect to the burner nozzle to achieve complete mixing. The air/fuel ratio is controlled to utilize the excess air in the off-gas to maintain a predetermined constant temperature in the afterburner to effect complete combustion.

49 Claims, 6 Drawing Figures

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% AIR

FIG. 1

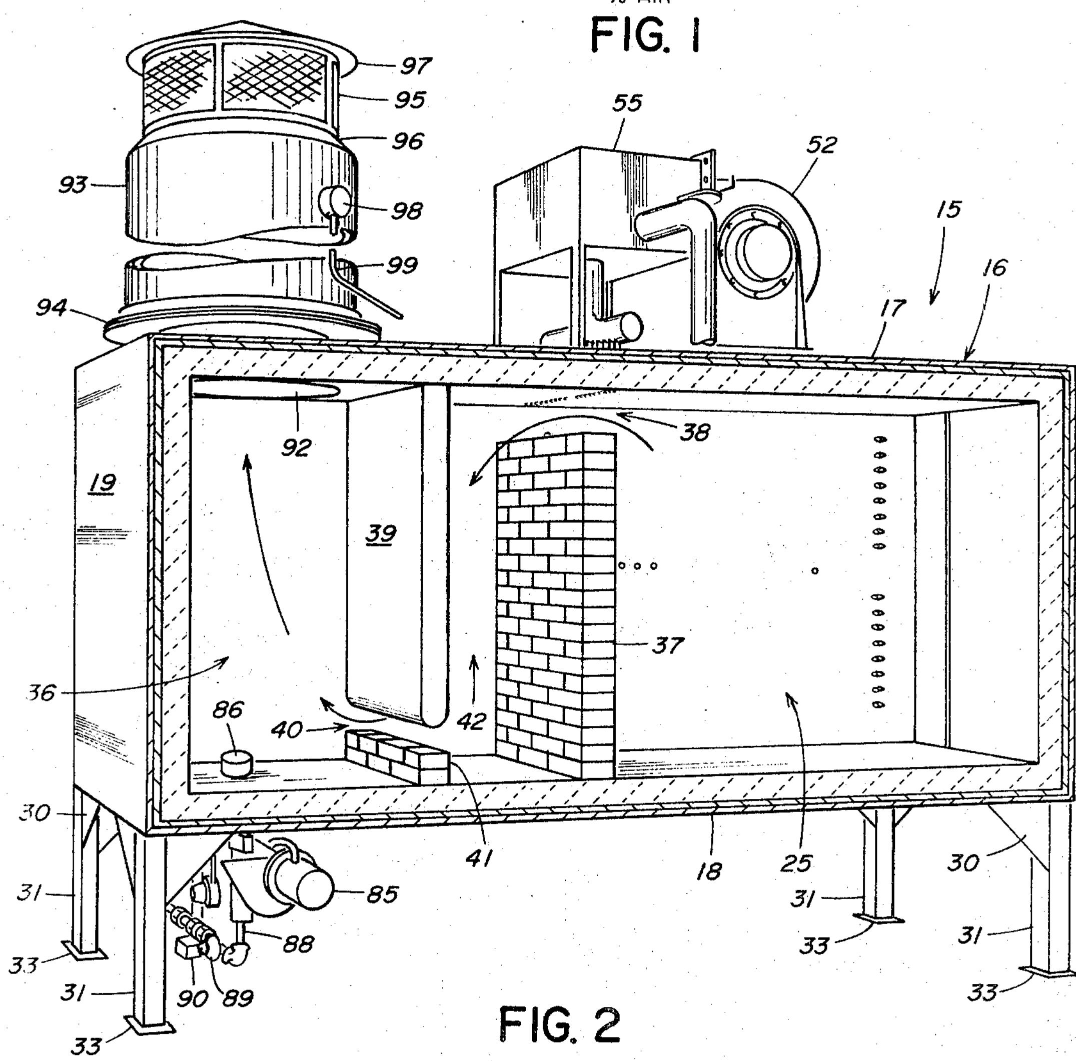
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FIG. 2

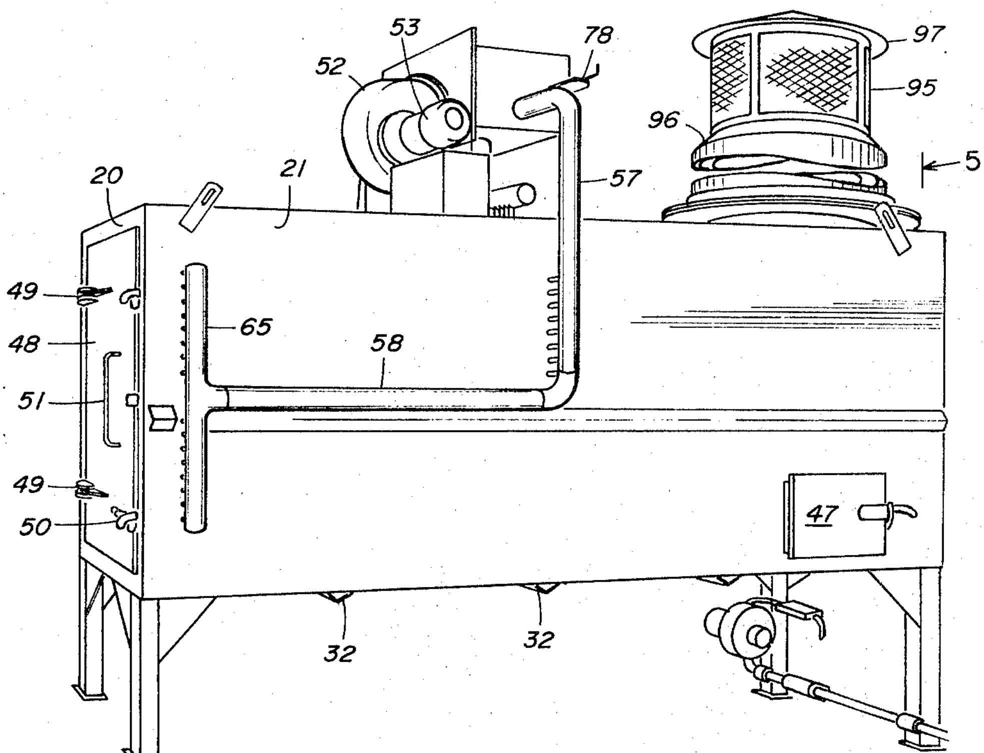
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FIG. 3

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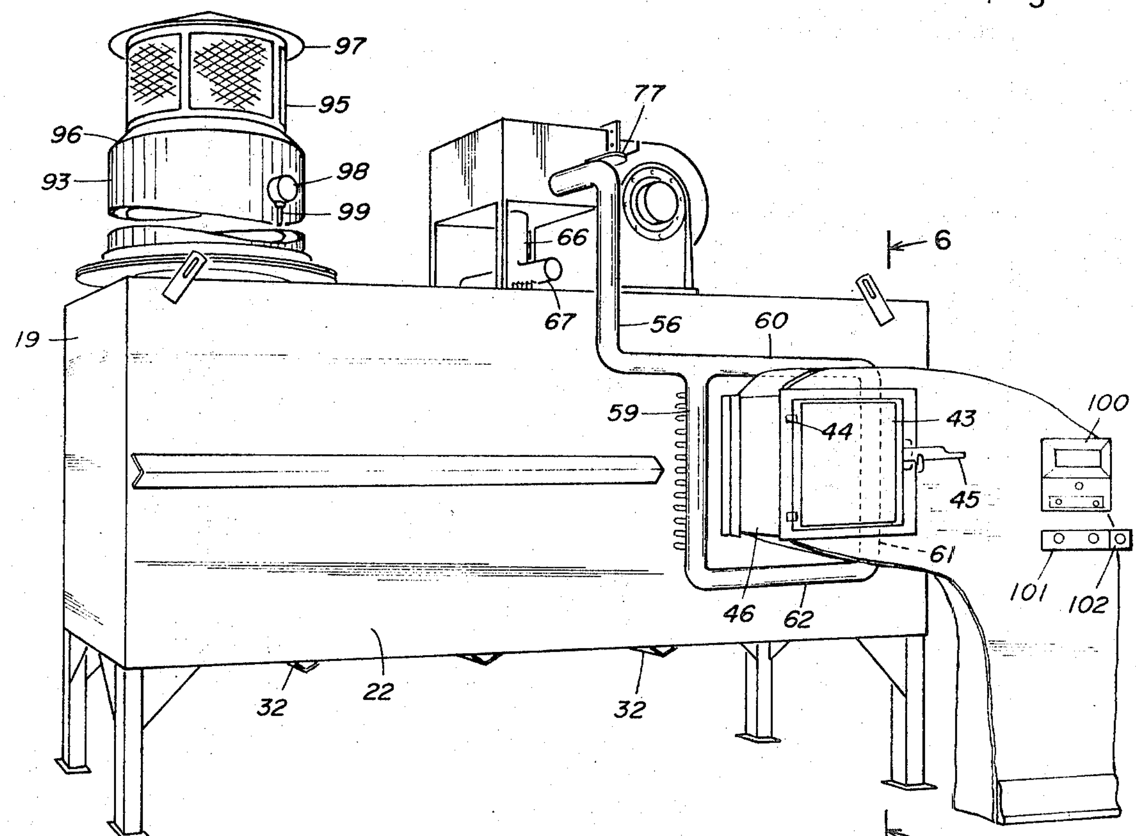
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FIG. 4

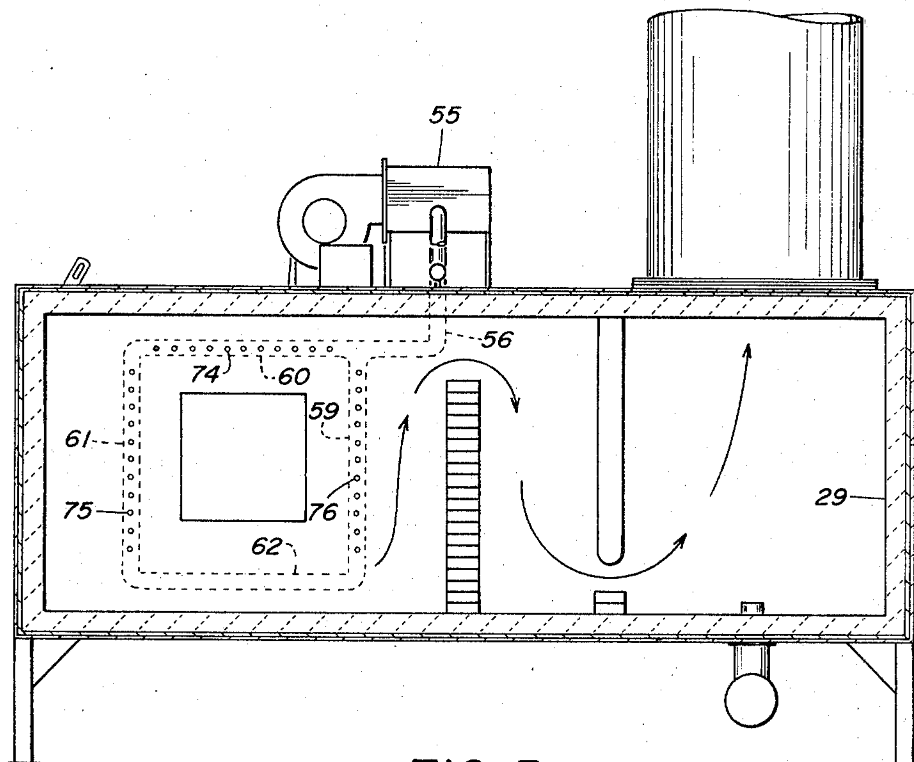

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FIG. 5

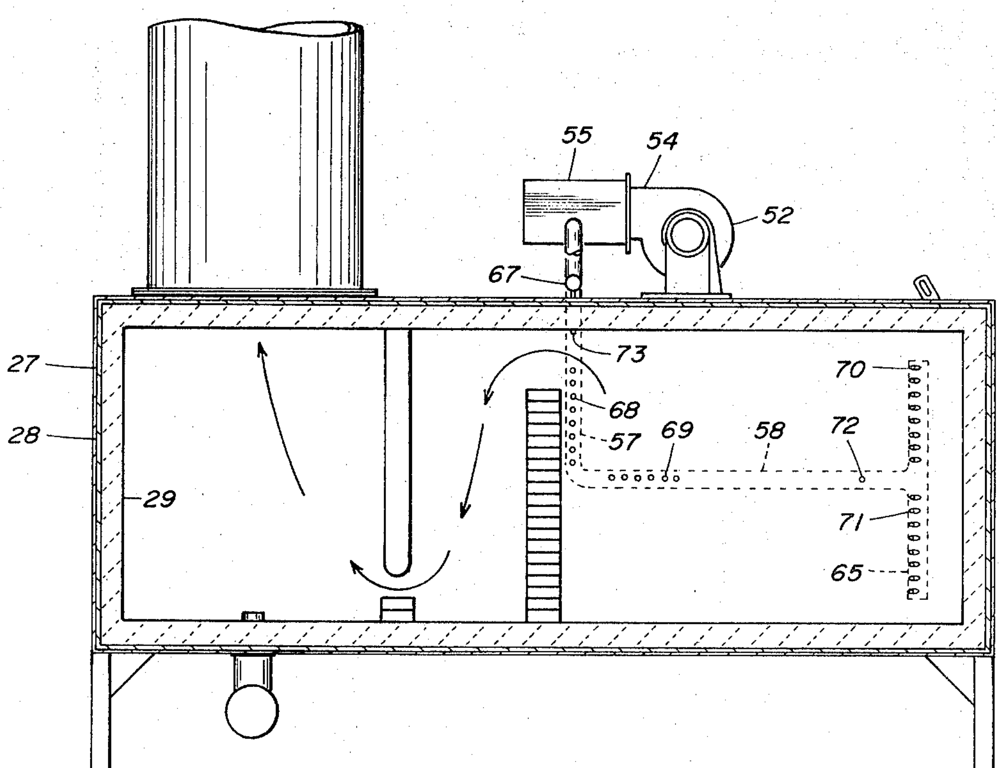

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FIG. 6

INCINERATOR WITH AFTERBURNER

The present invention relates to a combustion apparatus and method and more particularly relates to a method and apparatus for incinerating solid waste refuse to achieve essentially complete thermal combustion so that unacceptable contaminants are not released into the atmosphere.

The disposal of solid waste has become an increasing problem in today's society which generates large volumes of paper, cardboard, plastic and other similar discarded materials. In the case of combustible solid waste products, incineration has proven to be a convenient way of disposing of these products. Incineration units can be installed at industrial plants, apartment complexes, shopping centers or waste collection centers for the thermal destruction of such solid waste matter. Combustion of waste products of the character mentioned is a convenient solution in that large volumes of solid waste material can be reduced into a relatively small amount of residue. Transportation and handling of the large quantities of solid waste is minimized to the disposal of a relatively small amount of ash and other residue at a suitable location. Land fills, which often consume large valuable tracts of urban land and which are expensive to maintain as well as often being unsanitary and unsightly, can be eliminated or at least utilized more efficiently.

Nevertheless, burning of waste materials presents other problems as today, with increasing emphasis on environmental quality, incineration apparatus and methods have come under strict surveillance and regulation. Federal and local legislation in this area no longer permits uncontrolled emissions from solid waste incinerators. Clean air legislation regulates the acceptable amount of particulate matter and the constituency of off-gases from incineration units. Failure to abide by the regulatory acts in this area can result in severe monetary penalties being levied against the owners and operators as well as imposition of permanent injunctions against operation.

Therefore, there exists a need for an efficient, effective method and apparatus by which industries, shopping centers, apartment complexes, and businesses can dispose of their combustible solid waste products in accordance with existing environmental regulations. Incinerators in which the combustion is incomplete and products of incomplete combustion such as carbon particles, carbon monoxide, nitrous oxide, and sulfur are released into the air will no longer be tolerated. In accordance with this need, the present invention provides an incinerating method and apparatus which completely oxidizes waste material and effectively eliminates discharge of carbon, carbon monoxide, and similar pollutants into the atmosphere. With the method and apparatus of the present invention, combustion of hydrocarbons is essentially complete and flyash is settled out so that exhaust from the incinerator contains primarily only carbon dioxide, nitrogen, oxygen, and water vapor. The apparatus and method of the present invention are economical and efficient and, as such, are adapted for use in present shopping centers, industrial sites and waste collection centers.

The incinerator of the present invention has a main or primary burning chamber in which air at some pressure higher than atmospheric is directed over the combustible waste products charged into the chamber to burn the contents of the chamber. A sufficient quantity of air is introduced to maintain an excess air condition in the primary combustion chamber. The combustion air is introduced into the primary combustion chamber at a constant rate from a blower through a series of nozzles in the side and top walls of the combustion chamber. The location and disposition of the nozzles are such that air is directed toward the combustible fuel and flame rather than into the ash that collects at the bottom of the chamber. In this way, thorough mixing of the air and products of combustion are obtained and agitation and entrainment of settled flyash in the off-gases is avoided.

The products of off-gases from the primary chamber are directed through a vertical baffle arrangement to a secondary afterburner chamber. The baffle arrangement serves to control the velocity of the off-gases so that proper back pressure is maintained in the main chamber and so that flyash and the like and other particulate matter will settle out from the off-gases. An auxiliary gas burner in the afterburner chamber controlled by monitoring exhaust stack temperature utilizes the excess air in the off-gases from the primary chamber to thermally oxidize any remaining combustibles in the off-gases and produce an acceptable effluent from the unit.

A more complete understanding of the objects of the method and apparatus of the present invention will become apparent from a reading of the following specification and drawings in which:

FIG. **1** is a graph representing a combustion curve for a typical solid waste paper product;

FIG. **2** is a perspective view from the front side of the incinerator, partly broken away to expose the interior details;

FIG. **3** is a perspective view from the rear side of the incinerator of the present invention;

FIG. **4** is a perspective view from the front side showing a typical installation;

FIG. **5** is a sectional view looking toward the front interior wall of the incineration unit; and

FIG. **6** is a sectional view looking toward the rear interior wall of the unit.

Referring to FIG. **1**, a curve representing the stoichiometric combustion of a typical combustible waste material such as cardboard is shown. Temperature in degrees Fahrenheit is represented on the vertical coordinate and the amount of air available for combustion is represented on the horizontal coordinate. The exact quantity of air necessary to completely react to complete combustion with the material is known as 100 percent theoretical air. Any volume of air beyond this minimum quantity of air required for combustion is known as excess air. Looking at the graph of FIG. **1**, the portion of the curve designated by the numeral **10** is representative of the temperature of combustion when insufficient air for complete combustion is available. The lower the percentage of air available, the lower the temperature of combustion because of the insufficient amount of air. Point **11** represents 100 percent theoretical air, that is, the point at which the exact minimum amount of air for complete combustion is available. It is at this point that the temperature of combustion is the highest. As indicated by the portion **12** of the curve, the temperature of combustion decreases because in the excess air region the excess air serves to cool or reduce the temperature of combustion. Along curve **10** to the left of point **11** combustion is incomplete and black smoke, in the form of carbon dioxide, carbon monoxide and solid carbon particles would be emitted. Obviously, the ideal operating condition coincides exactly at point **11** on the curve. However, in practice it is extremely difficult, if not impossible, to maintain an incineration operation exactly at 100 percent theoretical air. Because of uneven loading or charging of the incinerator, incineration is not a steady state process. Further, it is difficult to accurately monitor the parameters of the process such as temperature because of the effects of radiation and to make operational adjustments because of the slow response time of most units.

With the present invention a blower is provided which is sized to maintain an excess air condition in the primary chamber where the fuel such as a cardboard or other solid waste is incinerated. Generally the excess air is maintained in the range of from 100 to 300 percent theoretical air. The effluent or off-gas from the primary chamber is conducted to a secondary or afterburner chamber in which a burner is throttled to compensate for the fluctuations that may occur in the primary chamber. The afterburner operates to maintain an essentially constant temperature in the afterburner chamber and, therefore, if the incoming effluent from the primary chamber is incompletely combusted and contains a large volume of excess air, the afterburner will serve to provide supplementary combustion and oxidize any incompletely burned materials in the effluent from the primary chamber. Conversely, if the volume of excess air is slight, the temperature will remain high, and the heat supplied by the afterburner can be reduced. Since combustion is complete, only carbon dioxide, nitrogen, water vapor, and oxygen are emitted from the afterburner into the atmosphere.

FIGS. 2 to 6 show in detail the incinerating apparatus of the present invention. The apparatus, generally designated by the numeral **15,** includes a generally rectangular body or compartment **16.** The compartment has elongated top and bottom walls **17** and **18** and is enclosed by end walls **19** and **20** and at opposite sides by rear wall **21** and front wall **22.** The compartment walls have an outer carbon steel shell **27** internally covered with a lining of asbestos, fiberglass, or similar heat resistant insulation **28.** Within the layer of insulation **28,** a thick lining of refractory **29** completes the interior of the incinerator. Incinerator body **16** is supported at legs **31** vertically located at the four corners of the body **16.** The legs are shown in the form of angle irons welded to the exterior of shell **27** and reinforced at gusset plates **30.** Ground pads **33** serve to distribute the weight of the unit over a larger area. Angle irons **32** are welded to the exterior of incinerator shell **27** at various locations to provide stiffening and add strength to the body.

The interior of the incinerator compartment is subdivided into a main burning chamber **25** and an afterburner chamber **36** by internal baffling. The baffling arrangement includes bridge wall **37** which extends vertically from the floor **18** and terminates below the interior of top wall **17.** Rectangular passage **38** is defined in the incinerator between the top of bridge **37** and the interior of top wall **17.** Longitudinally spaced from bridge wall **37** is drop arch **39** which extends downwardly from top **17,** terminating above the floor of the incinerator. Abutment member **41** extends across the floor of the chamber aligned with baffle member **39.** A lower passageway in the form of a rectangular opening **40** is defined between the lower end of baffle **39** and abutment **41.** The vertical space **42** between wall **37** and baffle **39** provides the flow passage between the main burning chamber **25** and the afterburning chamber **36** for the effluent products of combustion. The velocity of the effluent gases flowing through this passage is maintained by virtue of the restrictions at **38** and **40** so that subsidence of entrained particulate matter will occur. Further, lower opening **40** conveys to direct the effluent gases into afterburner chamber **36** with sufficient velocity to effect a good mixing. The rapid expansion of the gases upon entrance to chamber **36** also contributes to good mixing. The net result is that thorough combustion is obtained and radiant heat transfer to the afterburner chamber walls is reduced.

Rectangular charging door **43** pivots at hinges **44** to open into the main burning chamber from side **22.** A latch **45** secures the door in a closed position and prevents it from being opened due to the internal pressure generated in the combustion chamber. As seen in FIG. **4,** door **43** may be extended laterally from side wall **22** by extension section **46.** In this way, the incinerator may be located at the rear of the building with door **43** flush mounted on the interior of a building to permit charging of waste materials from within, making it unnecessary for the attendant to leave the building. A large cleanout door **48** is provided in end wall **20** for access to the main burning chamber for cleaning and maintenance operations. Door **48** is hinged at **49** for operation at handle **51** and may be secured or locked in a closed position at latches **50.** A smaller cleanout door **47** opens into the afterburner chamber **36** for access to that chamber.

Air to support combustion in main burning chamber **25** is provided by constant speed blower **52** mounted on the exterior of upper surface **17** of the incinerator. Blower **52** would, for example, be of the centrifugal type and driven by electric motor **53** to produce a sufficient volume of air. The outlet **54** of blower **52** is connected to rectangular plenum chamber or box **55** also mounted on the upper surface of the incinerator. An air distribution system communicates box **55** with the main burner chamber **25** and includes delivery duct **56** which extends along side **22** of the incinerator to connect with distribution ducts **59, 60, 61,** and **62,** which are arranged in a rectangular configuration. Similarly, delivery duct **57** extends vertically along side **21** and connects with horizontal distribution pipe **58** which is at an elevation approximately corresponding to the middle of the unit. Pipe **58** terminates in vertical duct **65** in a general T configuration. Short duct **66** extends from the bottom of plenum **55** and connects with horizontal distribution duct **67** extending across the top of the main burning chamber.

The air distribution system connects to the main burning chamber through a series of nozzles extending through the wall of the incinerator oriented to promote combustion and minimize particle entrainment and infiltration of atmospheric air. Looking at FIG. **6,** a vertical row of nozzles **68** located in duct **57** extend through wall **21** adjacent the bridge wall and are directed to discharge into the chamber **36** at approximately 90° from the side wall. Similarly, horizontal row of nozzles **69** are directed at a 90° angle from side wall **21.** Upper vertical row of nozzles **70** located in duct **65** at the end of distribution pipe **64** are horizontal and are directed toward the bridge wall 37 at a suitable angle, as for example, 45°. Similarly, lower row of vertical nozzles 71 are directed at an angle toward the bridge wall as does single nozzle 72. A row of nozzles 73, located in the top wall 17 and connected to duct 67 are disposed at right angles to top wall 17 and discharge adjacent interior baffle wall 37. At the front side 22 of the main combustion chamber, as seen in FIG. 5, horizontal row of nozzles 74 in duct 60 and vertical rows 75 and 76 in ducts 61 and 59, respectively, are adjacent the charging door and are arranged to introduce air in a stream at 90° to the side wall. With the above-described air distribution system, it will be seen that the nozzle arrangement serves to selectively direct air into the main burning chamber 25 at selected locations so that the jets of air impinge in the flame or combustion area in the chamber, rather than the lower area of the chamber occupied by the ash and residue. Impingement of the air into the combustion area serves to promote mixing of the air and the combustion products as well as minimizes fluidization and agitation of the ash bed in the lower portion of chamber 25. Agitation of the ash that accumulates in the bottom of chamber 25 is undesirable in that entrainment and carry-over of the ash with the combustion effluent will result.

As well as being disposed within chamber 25 to avoid impinging air into the ash bed, the air nozzles are arranged to avoid directing jets of air at the space occupied by charging door 43 so that escape of ash and heat and flame are avoided when the door is opened. For example, rows of nozzles 70 and 71 opposite the door are directed to discharge toward the bridge wall to create a flow of air across the charging door opening. Gate valves 77 and 78 are provided to control the volume of air flow into the distribution systems from the distribution box 55.

The afterburner chamber 36 is maintained at a predetermined temperature by variable burner unit 85 mounted on the underside of the incinerator. Burner 85 discharges a mixture of fuel and air into chamber 36 through discharge nozzle 86 centrally located in the bottom of chamber 36. Gas is supplied to nozzle 86 by gas supply line 88 which contains butterfly valve 89 which is variable through operator 90 to throttle the supply of gas to nozzle 86. Burner 85 supplies a continual constant volume of air through nozzle 86 while valve 89 regulates the supply of fuel to afterburner chamber 36 at a variable rate to maintain a predetermined constant temperature in chamber 36.

Control panel 101, located adjacent the temperature control panel, contains buttons operating switches in the motor circuits to connect the blower and burner motors to a source of power. The schematic details of the motor circuit are not shown as such circuits are well known and conventional and further description is not deemed necessary to a complete understanding of the present invention. The blower and burner circuit would preferably include a timer 102 since in most installations the burning procedure will be periodic. For example, in a shopping center or supermarket, waste cartons and packaging will usually be burned at the end of the business day with the incinerator being inactive most of the day. Therefore, to conserve energy a suitable process time would be chosen and set on the timer, the time being sufficient for combustion of the charged waste materials. At the end of the chosen time, the blower and burner would be shut off and the incinerator would be automatically shut down. In this way, the incinerator would not be operating throughout a period after combustion has been completed, thereby reducing the danger of accident while the incinerator is unattended as well as reducing the consumption of fuel energy by the incinerator.

The exhaust or emission from afterburner chamber 36 is directed through afterburner stack 93 which is a steel cylinder chamber secured to the upper surface of incinerator 15 at flange 94. The interior of stack 93 is lined with a thickness of suitable refractory. Circular flue 92 in the upper surface of chamber 36 communicates with stack 93. The flue is sized to maintain the required residence time within the afterburner chamber. A spark arrester 95, in the form of a cylindrical wire mesh screen, is located at the upper truncated end 96 of stack 93 and serves to confine any sparks or glowing embers within the incinerator. A rain shield 97 affixed to the top of spark arrester 95 encloses the upper end of the stack.

The temperature in the afterburner stack is measured by a thermocouple employing a hot junction 98 inserted into stack 93 near the upper end. Lead wires 99 run to the temperature controller 100 which would be located in a convenient location for the operator to observe as for example, within a building. The temperature to be maintained, the set point, is placed on the controller and the valve operator 90 responds automatically to maintain this setting by adjusting the opening at valve 89 to admit more or less fuel into chamber 36.

The apparatus of the present invention and the method carried out thereby will be better understood from the following description of operation of the invention. The incinerator apparatus 15 would be located and installed at a convenient site such as a waste collection center for cardboard and paper products within a shopping center. Incinerator 15 would preferably be located immediately adjacent the rear wall of a collection building with front side 22 abutting the rear wall of the collection building. Charging door 43 opens within the interior of the building, thereby facilitating loading the main burning chamber 25. Similarly, temperature controller 100 would be located within the building for observation and control by the operator.

To begin a burning cycle, the operator would depress the start button at control panel 101 which would energize the blower 52 and the burner 85 causing air to be forced into main burning chamber 25 and a mixture of gas and air would be discharged under pressure into afterburner chamber 36. Once the operator has started up the blowers, an initial charge of waste material such as discarded cardboard boxes and other packaging are placed into main burning chamber 25 through charging door 43. The combustion cycle will be begun by the operator manually kindling the waste material. As mentioned above, the blower and burner are both operative. The set point on the controller is at a temperature to insure complete combustion of the products from the main combustion chamber. In practice, the temperature setting of the control should be in the range of from 1,400° F. to 2,200° F. with the typical average setting being 1,550° F. As burning continues, the unit heats up until full operating temperature is reached. The operator will continue to charge materials into the main burning chamber through the charging door. The main blower 52 is sized to provide an excess of from

100 percent to 300 percent theoretical air in the primary chamber. As the cardboard or other combustible fuel burns, the amount of percent of excess air will increase because the available fuel to oxidize with the air will decrease. Therefore, as seen in FIG. **1**, the excess air rate will increase and the temperature is forced down. When this occurs, the decrease in temperature is sensed by the thermocouple and the throttling valve **89** on burner **85** is automatically regulated to increase the flow of gas into afterburner chamber **36.** The increased volume of fuel in chamber **36** will react with tbe excess air from chamber **25** to thermally oxidize any carbon or carbon monoxide in the effluent or off-gases from chamber **25.** This oxidiation converts the carbon and carbon monoxide and other products to carbon dioxide, nitrogen, water vapor and oxygen, as well as suppressing the formation of dangerous products of combustion such as nitrous oxide. The discharge into the atmosphere from the top of the afterburner stack at screen **95** is essentially nonpolluting and free of particulate matter.

Conversely, if the volume of cardboard or fuel from the main chamber is increased, the amount of excess air will be caused to decrease and the temperature of the products of combustion admitted into the afterburner from chamber **25** will increase. This increased temperature will be reflected in a decrease in amount of fuel introduced into chamber **36** by burner **85.**

The vertical baffle arrangement between the chambers serves several important functions in the incineration process. The opening **38** in wall **37** serves to restrict flow of the products of combustion from chamber **25** so that sufficient back pressure is maintained in chamber **25** to provide adequate residence time in chamber **25** to effect combustion as completely as possible. The restricted opening **38** in channel **37** and lower opening **40** in baffle **39** imposes a pressure drop that restricts the velocity of the gases flowing from chamber **25** to chamber **36** to settle out particulate material contained in the off-gases. The velocity should be regulated on the order of six to nine feet per second so that there is minimum entrainment and carry-over of ash in the flow from the main burning chamber to the afterburning chamber. Lower abutment **41** serves as a barrier to prevent settled ash from being carried into the afterburning chamber **36** as some of the settled ash tends to be lifted by the deflection of the flow of gases off the bottom of the passageway.

Restriction **41** further directs the flow into the afterburner chamber toward the jet emitting from the burner at approximately right angles to the jet. The velocity of the discharge into the afterburner is at a sufficiently high velocity to obtain good mixing and turbulence in the chamber which is also enhanced by the sudden expansion occurring as the off-gases exit from lower opening **40** into chamber **36.** The air forced into the primary chamber of the incinerator has the effect of increasing the volume and velocity of the air introduced perpendicularly into the afterburner both as a result of the increased volume of air forced into the incinerator and also as a result of the higher temperature reached as a result of more complete combustion and corresponding greater expansion of air due to heating. As combustion progresses in the afterburner chamber, the gases mix and move turbulently upwardly through afterburner stack **93.** The upward turbulent movement also serves as a barrier to at least provide some protection to the afterburner walls from the radiant heat effect generated at burner nozzle **86.**

It will be noted that the cross-sectional area of the stack of the afterburner chamber is less than the area of the afterburning chamber. This contributes to maintain the proper residence time in the afterburning chamber to effect complete thermal oxidation of unburned particles entering this chamber.

In summary, the present invention provides an apparatus and process for incinerating solid waste which is essentially non-polluting. The conversion of hydrocarbons into carbon dioxide and water vapor is complete so that no harmful emissions are introduced into the atmosphere. Maintenance of an excess air environment in the main burning chamber coupled with afterburning of the products of combustion from the main chamber in which the heat is controlled assures that clean air criteria are met.

It will be obvious to those skilled in the art to make various changes, modifications, and alterations to the present invention without departing from the spirit and scope of the invention thereof.

I claim:

1. An incinerator comprising:

a primary combustion chamber,

blower means adapted to direct a supply of air in excess of that required for combustion into said primary chamber,

a secondary combustion chamber,

burner means for supplying fuel into said secondary chamber,

regulator means for controlling the rate of operation of said burner means, said regulator means adapted to regulate the rate of fuel supply to the secondary chamber to maintain a predetermined temperature in said secondary chamber,

a passageway interconnecting said primary and secondary chambers and adapted to conduct the off-gases from said primary chamber to the burner zone in said secondary chamber, and

means associated with said passageway adapted to control the said velocity of said gases therein within predetermined limits to effect settling of particulate matter in the gases and to maintain proper combustion.

2. An incinerator comprising:

a primary combustion chamber,

blower means adapted to direct a supply of air in excess of that required for combustion into said primary chamber,

a secondary combustion chamber,

burner means for supplying fuel into said secondary chamber,

regulator means for controlling the rate of operation of said burner means, said regulator means adapted to regulate the rate of fuel supply to the secondary chamber to maintain a predetermined temperature therein, discharge means directing the discharge of gases into said secondary chamber with sufficient velocity and direction to induce turbulent upflow of combustion products in said secondary chamber, a passageway interconnecting said primary and secondary chambers and adapted to conduct the off-gases from said primary chamber to the burner zone in said secondary chamber, and

means associated with said passageway adapted to control the said velocity of said gases therein within predetermined limits to effect settling of particulate matter in the gases and to maintain proper combustion.

3. The incinerator of claim 2 wherein said discharge means direct the off-gases into said second chamber perpendicularly with respect to the burner discharge into said secondary chamber.

4. The incinerator of claim 1 wherein said blower communicates with the primary chamber through a distributor system including a series of nozzles located in the primary chamber walls.

5. The incinerator of claim 4 wherein said nozzles are adapted to direct a flow of air with substantially even distribution into the flame area of the primary chamber.

6. An incinerator comprising:

a primary combustion chamber having access means therein for charging the primary chamber with a quantity of fuel,

blower means adapted to discharge a positive supply of air in excess of the amount of air required for complete combustion to said primary chamber,

air distributing means communicating the discharge from said blower with said primary combustion chamber,

an afterburner chamber located adjacent said primary chamber,

regulatable burner means adapted to supply air and fuel into said afterburner chamber,

exhaust means communicating with said afterburning chamber and adapted to exhaust effluent gases therefrom,

passageway means interconnecting said primary chamber with said afterburner chamber to direct the off-gases from said primary chamber to said afterburner chamber, said passageway means including restriction means associated therewith to control the velocity of the off-gases through said passageway whereby substantially all of the particulate material is caused to settle from said off-gases prior to entry in said afterburner chamber, and

control means adapted to regulate said burner means to maintain a predetermined temperature in said afterburner chamber whereby essentially complete combustion of combustibles remaining in said off-gases occurs in said afterburner chamber.

7. The incinerator of claim 6 wherein said air distribution system includes a plurality of air nozzles communicating with said primary chamber.

8. The incinerator of claim 6 wherein said passageway includes abutment means in the flow path of the off-gases to reduce the carryover of entrained particulate material into said afterburner chamber.

9. An incinerator comprising:

a primary combustion chamber having access means therein for charging the primary chamber with a quantity of fuel,

blower means adapted to discharge a positive supply of air in excess of the amount of air required for complete combustion to said primary chamber,

air distributing means comprising a plurality of nozzles communicating the discharge from said blower with said primary combustion chamber, said nozzles are oriented to direct air into the flame area of the combustion chamber and substantially away from the area occupied by the access means,

an afterburner chamber located adjacent said primary chamber,

regulatable burner means adapted to supply air and fuel into said afterburner chamber,

exhaust means communicating with said afterburning chamber and adapted to exhaust effluent gases therefrom,

passageway means interconnecting the upper portion of said primary chamber with the lower portion of said afterburner chamber to direct the off-gases from said primary chamber to said afterburner chamber, said passageway means including restriction means associated therewith to control the velocity of the off-gases through said passageway whereby substantially all of the particulate material is caused to settle from said off-gases prior to entry in said afterburner chamber, and control means adapted to regulate said burner means to maintain a predetermined temperature in said afterburner chamber whereby essentially complete combustion of combustibles remaining in said off-gases occurs in said afterburner chamber.

10. The incinerator of claim 6 wherein said restriction means are sized to control the residence time in said passageway.

11. A refuse incinerator to effect substantially complete combustion of solid waste materials, said incinerator comprising:

a substantially rectangular burning compartment having top, bottom, side and end walls,

a first vertical wall extending in said compartment between said side walls and terminating below said top wall and defining with one end wall a primary chamber,

an access door in said compartment for charging waste fuel materials in said main burning chamber,

a blower,

an air distributor system for introducing air into said main burning chamber connected to said blower, said air distribution system including air nozzles directed into the flame area within said primary chamber,

a second vertical wall in said compartment spaced apart from said first wall and defining a passageway therebetween, said second wall extending between the side walls from the top of the chamber and terminating above the compartment bottom and defining with said other end wall an afterburner chamber whereby effluent gases from said main chamber are introduced near the bottom of said afterburner chamber,

exhaust stack means communicating with the top of said afterburner chamber and adapted to carry away the exhaust gases from said afterburner chamber,

burner means adapted to introduce fuel and air into said afterburner chamber through discharge nozzle means located in the bottom of said afterburner, and

regulator means adapted to regulate said burner to vary the air/fuel ratio to maintain the temperature in the afterburner in a predetermined range,

whereby off-gases from said main chamber are introduced perpendicularly to the burner discharge in said afterburner and said burner effects substantially complete combustion of combustibles in said off-gases.

12. The apparatus of claim 11 wherein said burner nozzle discharge is directed upwardly and is adapted to induce an up-flow of gases in said afterburner chamber.

13. The apparatus of claim 11 wherein an abutment is provided on the compartment bottom subjacent the terminal end of said second wall adapted to reduce entrainment of particulate matter to said afterburning chamber.

14. The apparatus of claim 11 wherein said burner is a gas burner and said air/fuel ratio is varied by varying the amount of gas supplied to the afterburner chamber.

15. A refuse incinerator for the substantially complete combustion of solid waste fuels, said incinerator comprising:
- a substantially rectangular burning compartment having top, bottom, side and end walls,
- a first vertical wall extending upwardly in said compartment between said side walls and terminating below said top walls and defining with one end wall a primary burning chamber,
- an access door in said compartment opening into said primary burning chamber for charging waste fuel into said primary chamber,
- a blower discharging into an air distribution box,
- an air distribution system connecting with said air distribution box, said distribution system having ducts extending to the top and opposite side walls of said primary chamber,
- nozzle arrangement means connecting with said duct means and adapted to discharge air into the flame area of the primary chamber to support combustion therein, said nozzle arrangement means including a first bank arranged in the top wall, a second bank in one side wall extending around three sides of said access door, and a third bank in said other side wall arranged with a horizontally and a vertically extending row, said third bank having preselected nozzles directed to discharge away from the opposite access door opening,
- a second vertical wall in said compartment spaced apart from said first wall and defining a flow passageway therebetween, said second wall extending between the compartment side walls from the top of the chamber and terminating above the compartment bottom and defining an afterburner chamber with the other end wall,
- abutment means located subjacent the terminal end of said second wall,
- an exhaust stack communicating with the top of said afterburning chamber and adapted to carry away the exhaust gases from said chamber,
- gas burner means having a nozzle means in the bottom discharging vertically upwardly into the afterburner chamber to support combustion therein,
- valve means associated with said burner adapted to regulate the ratio of fuel and air discharged into said afterburner chamber,
- regulator means controlling said valve means in response to the temperature in afterburner chamber to maintain said temperature in a predetermined range whereby off-gases from said main chamber are caused to flow through said passageway and are introduced perpendicularly to the burner in said afterburner to effect substantially complete combustion of combustibles in said off-gases.

16. The incinerator of claim 15 wherein said incineration compartment is a refractory lined steel shell.

17. The incinerator of claim 15 wherein the blower and air distribution box are located on the exterior of the compartment top wall.

18. The incinerator of claim 15 wherein said exhaust stack is provided with spark emission control means.

19. A method of incineration of waste materials comprising:
- incinerating the waste materials in a primary combustion zone which is maintained in an excess air condition to support combustion therein,
- conducting the off-gases from the primary zone through a restricted opening to a passageway to promote subsidence of particulate matter in said passageway and maintain adequate combustion in said first zone,
- introducing said off-gases into a secondary incineration zone,
- introducing a mixture of fuel and air into said secondary zone, and
- regulating the air/fuel supply to said secondary zone to maintain a predetermined temperature in said secondary zone whereby substantially complete thermal oxidation of combustibles in said off-gases is obtained.

20. A method of incineration of waste materials comprising:
- incinerating the waste material in a primary combustion zone which is maintained in an excess air condition to support combustion therein,
- conducting the off-gases from the primary zone through a restricted opening to a passageway to promote subsidence of particulate matter in said passageway and maintain adequate combustion in said first zone,
- introducing said off-gases into a secondary incineration zone,
- introducing a mixture of fuel and air into said secondary zone, and
- regulating the air/fuel supply to said secondary zone to maintain a predetermined temperature in said secondary zone whereby substantially complete thermal oxidation of combustibles in said off-gases is obtained, said off-gases are discharged from said passageway into said secondary burning zone substantially perpendicular with respect to the introduction of air and fuel from said burner.

21. The method of claim 20 wherein said air volume flow and fuel and said off-gases flow is turbulent in said second zone thereby enhancing mixing and reducing the radiation effects to the chamber walls.

22. The method of claim 19 wherein the air rate to said primary zone is constant and is directed therein by a plurality of nozzles discharging into the flame zone.

23. The method of claim 20 wherein said air fuel supply is regulated by altering the rate of gas flow inversely in response to the exhaust gas temperature to maintain the temperature in a predetermined range.

24. The method of claim 23 wherein said predetermined temperature range is from 1,400° F. to 2,200° F.

25. The method of claim 24 wherein the velocity of the off-gases in said passageway is regulated to about from 6 to 9 fps.

26. A method of incineration of waste material comprising:

incinerating the waste material in a primary combustion zone which is maintained in an excess air condition to support combustion therein, said excess air is maintained at from 100 to 300 percent of theoretical air required for combustion,

conducting the off-gases from the primary zone through a restricted opening to a passageway to promote subsidence of particulate matter in said passageway and maintain adequate combustion in said first zone,

introducing said off-gases into a secondary incineration zone,

introducing a mixture of fuel and air into said scondary zone, and

regulating the air/fuel supply to said secondary zone to maintain a predetermined temperature in said secondary zone whereby substantially complete thermal oxidation of combustibles in said off-gases is obtained.

27. An incinerator comprising:

a primary combustion chamber,

blower means adapted to direct a supply of air in excess of that required for combustion into said primary chamber,

a secondary combustion chamber,

burner means for supplying fuel into said secondary chamber,

temperature sensor means in said secondary chamber, regulator means connected to said sensor means for controlling the rate of operation of said burner means in response to the temperature in said secondary chamber, said regulator means adapted to regulate the rate of fuel supply to the secondary chamber to maintain a predetermined temperature in said secondary chamber, and

a passageway interconnecting said primary and secondary chambers and adapted to conduct the off-gases from said primary chamber to the burner zone in said secondary chamber.

28. In combination, an incinerator having a primary combustion chamber, blower means adapted to direct a supply of air in excess of that required for combustion into said primary chamber, a secondary combustion chamber, burner means for supplying fuel into said secondary chamber, a passageway interconnecting said primary and secondary chambers and adapted to conduct the off-gases from said primary chamber to the burner zone to said secondary chamber,

the improvement which comprises:

temperature sensor means in said secondary chamber, and

regulator means connected to said sensor means for controlling the rate of operation of said burner means in response to the temperature in said secondary chamber, said regulator means adapted to regulate the rate of fuel supply to the secondary chamber to maintain a predetermined temperature in said second chamber.

29. An incinerator comprising:

a primary combustion chamber,

blower means adapted to direct a supply of air in excess of that required for combustion into said primary chamber,

a secondary combustion chamber,

burner means for supplying fuel into said secondary chamber,

a passageway interconnecting said primary and secondary chambers and adapted to conduct the off-gases in a vertically downward direction from said primary chamber to the burner zone in said secondary chamber, and

means associated with said passageway adapted to control the said velocity of said gases in said passageway within predetermined limits to effect settling in said passageway of particulate matter from the gases.

30. An incinerator as defined in claim 29 additionally comprising abutment means located in said passageway to reduce entrainment of particulate matter to said secondary chamber.

31. An incinerator as defined in claim 29 wherein the flow of off-gases in said secondary chamber is vertically upward.

32. An incinerator as defined in claim 29 wherein said means associated with said passageway is a restricted flow path in said gas flow between said primary chamber and said passageway.

33. An incinerator as defined in claim 32 wherein said means associated with said passageway additionally comprises a restricted flow path in said gas flow between said passageway and said secondary chamber.

34. In combination with an incinerator having a primary combustion chamber, blower means adapted to direct a supply of air in excess of that required for combustion into said primary chamber, a secondary combustion chamber, burner means for supplying fuel into said secondary chamber,

the improvement which comprises a passageway interconnecting said primary and secondary chambers and adapted to conduct the off-gases in a vertically downward direction from said primary chamber to the burner zone in said secondary chamber, and

means associated with said passageway adapted to control the said velocity of said gases in said passageway within predetermined limits to effect settling in said passageway of particulate matter from the gases.

35. An incinerator as defined in claim 34 additionally comprising abutment means located in said passageway to reduce entrainment of particulate matter to said secondary chamber.

36. An incinerator as defined in claim 34 wherein the flow of off-gases in said secondary chamber is vertically upward.

37. An incinerator as defined in claim 34 wherein said means associated with said passageway is a restricted flow path in said gas flow between said primary chamber and said passageway.

38. An incinerator as defined in claim 37 wherein said means associated with said passageway additionally comprises a restricted flow path in said gas flow between said passageway and said secondary chamber.

39. An incinerator comprising:

a primary combustion chamber,

a secondary combustion chamber,

burner means for supplying fuel into said secondary chamber,

a passageway interconnecting said primary and secondary chambers and adapted to conduct the off-gases from said primary chamber to the burner zone in said secondary chamber, blower means adapted to direct a supply of air in excess of that required for combustion into said primary chamber, and

a plurality of nozzles communicating with said blower means, said nozzles adapted to direct a flow of air at the exit from said primary chamber substantially perpendicular to flow of off-gases.

40. In combination with an incinerator having a primary combustion chamber, a secondary combustion chamber, burner means for supplying fuel into said secondary chamber, a passageway interconnecting said primary and secondary chambers and adapted to conduct the off-gases from said first chamber to the burner zone in said second chamber, blower means adapted to direct a supply of air in excess of that required for combustion into said primary chamber,

the improvement which comprises a plurality of nozzles communicating with said blower means, said nozzles adapted to direct a flow of air at the exit from said primary chamber substantially perpendicular to flow of off-gases.

41. An incinerator comprising:

a primary combustion chamber,

blower means adapted to direct a supply of air in excess of that required for combustion into said primary chamber,

a secondary combustion chamber,

burner means for supplying fuel into said secondary chamber,

a passageway interconnecting said primary and secondary chambers and adapted to conduct the off-gases from said primary chamber to the burner zone in said secondary chamber, and

means associated with said passageway adapted to mix said gases in said passageway whereby proper combustion is maintained.

42. An incinerator as defined in claim **41** wherein said means associated with said passageway is a restricted flow path in said gas flow between said primary chamber and said passageway.

43. In combination with an incinerator having a primary combustion chamber, blower means adapted to direct a supply of air in excess of that required for combustion into said primary chamber, a secondary combustion chamber, burner means for supplying fuel into said secondary chamber, a passageway interconnecting said primary and secondary chambers and adapted to conduct the off-gases from said primary chamber to the burner zone in said secondary chamber,

the improvement which comprises means associated with said passageway adapted to mix said gases in said passageway whereby proper combustion is maintained.

44. An incinerator as defined in claim **43** wherein said means associated with said passageway is a restricted flow path in said gas flow between said primary chamber and said passageway.

45. An incinerator comprising:

a primary combustion chamber,

blower means adapted to direct a supply of air in excess of that required for combustion into said primary chamber,

a secondary combustion chamber,

burner means for supplying fuel into said secondary chamber,

a passageway interconnecting said primary and secondary chambers and adapted to conduct the off-gases from said primary chamber to the burner zone in said secondary chamber, and

means associated with said passageway and said secondary chamber adapted to mix said gases entering said secondary chamber as said gases leave said passageway whereby proper combustion is maintained.

46. An incinerator as defined in claim **45** wherein said means associated with said passageway comprises a restricted flow path in said gas flow between said passageway and said secondary chamber.

47. In combination with an incinerator having a primary combustion chamber, blower means adapted to direct a supply of air in excess of that required for combustion into said primary chamber, a secondary combustion chamber, burner means for supplying fuel into said secondary chamber, a passageway interconnecting said primary and secondary chambers and adapted to conduct the off-gases from said primary chamber to the burner zone in said secondary chamber,

the improvement which comprises means associated with said passageway and said secondary chamber adapted to mix said gases entering said secondary chamber as said gases leave said passageway whereby proper combustion is maintained.

48. An incinerator as defined in claim **47** wherein said means associated with said passageway comprises a restricted flow path in said gas flow between said passageway and said secondary chamber.

49. An incinerator comprising:

a primary combustion chamber,

blower means adapted to direct a supply of air in excess of that required for combustion into said primary chamber,

a secondary combustion chamber,

burner means for supplying fuel into said secondary chamber,

temperature sensor means for measuring the temperature in said secondary chamber, regulator means connected to said temperature sensor means for controlling the rate of operation of said burner means in response to the temperature in said secondary chamber, said regulator means adapted to regulate the rate of fuel supply to the secondary chamber to maintain a predetermined temperature in said secondary chamber,

a passageway interconnecting said primary and secondary chambers and adapted to conduct the off-gases in a vertically downward direction from said first chamber to the burner zone in said second chamber, and

means associated with said passageway adapted to control the said velocity of said gases in said passageway within predetermined limits to effect settling of particulate matter from the gases.

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