United States Patent

Hobbs et al.

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[54] INCINERATOR

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[52] **U.S. Cl.** ....**110/8 E,** 110/18 E

[51] **Int. Cl.** **F23g 5/10**

[58] **Field of Search** ....110/7, 8, 8 E, 15, 18, 18 E

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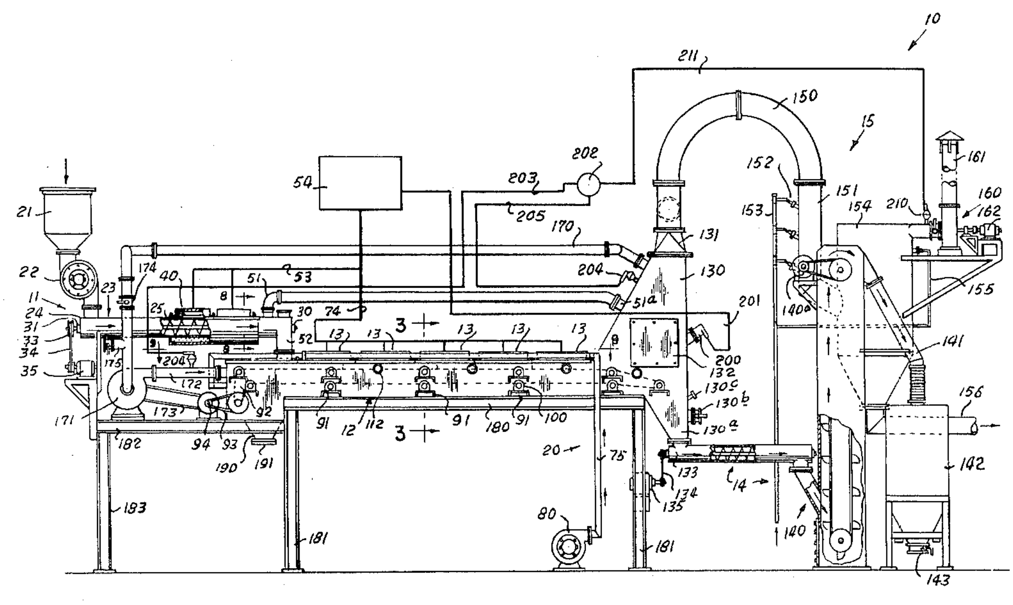
[57] **ABSTRACT**

A continuous-type incinerator for burning sludge from wastewater treating plants and similar refuse including a feed system having an infrared heating unit for refuse fragmentation, an elongated combustion chamber housing a continuous conveyor belt for moving refuse along the chamber, infrared heating units for applying intense heat to burn the refuse on the conveyor belt, a combustion gas recirculating system for returning combustion gases from the discharge end of the chamber to the inlet end to supplement the infrared heat, a cooling and combustion air system for forcing air over the infrared heating units and directing the air into the inlet end of the chamber to support combustion of the refuse, an ash removal system connected with the discharge end of the combustion chamber, a gas scrubber system connected with the discharge end of the combustion chamber, and a control system for manipulating the recirculation of combustion gases and controlling the temperature of the infrared heating units over the combustion chamber. Sludge is fed into the incinerator through the feed system in which infrared heat at about 2,500° F. breaks it into small particles for improved combustion. The sludge is moved on the conveyor belt along the chamber where recirculated combustion gases and infrared heat at a temperature in the range of 1,200° o 1,500° F. drives off all moisture and completely burns all volatile components of the sludge. The chamber is operated under a vacuum to prevent escape of noxious odors. At the discharge end of the chamber and conveyor belt, ash is dumped into the removal system and the combustion gases are directed into the scrubber which cools them, vents them to the atmosphere, and removes solid entrained particles.

25 Claims, 9 Drawing Figures



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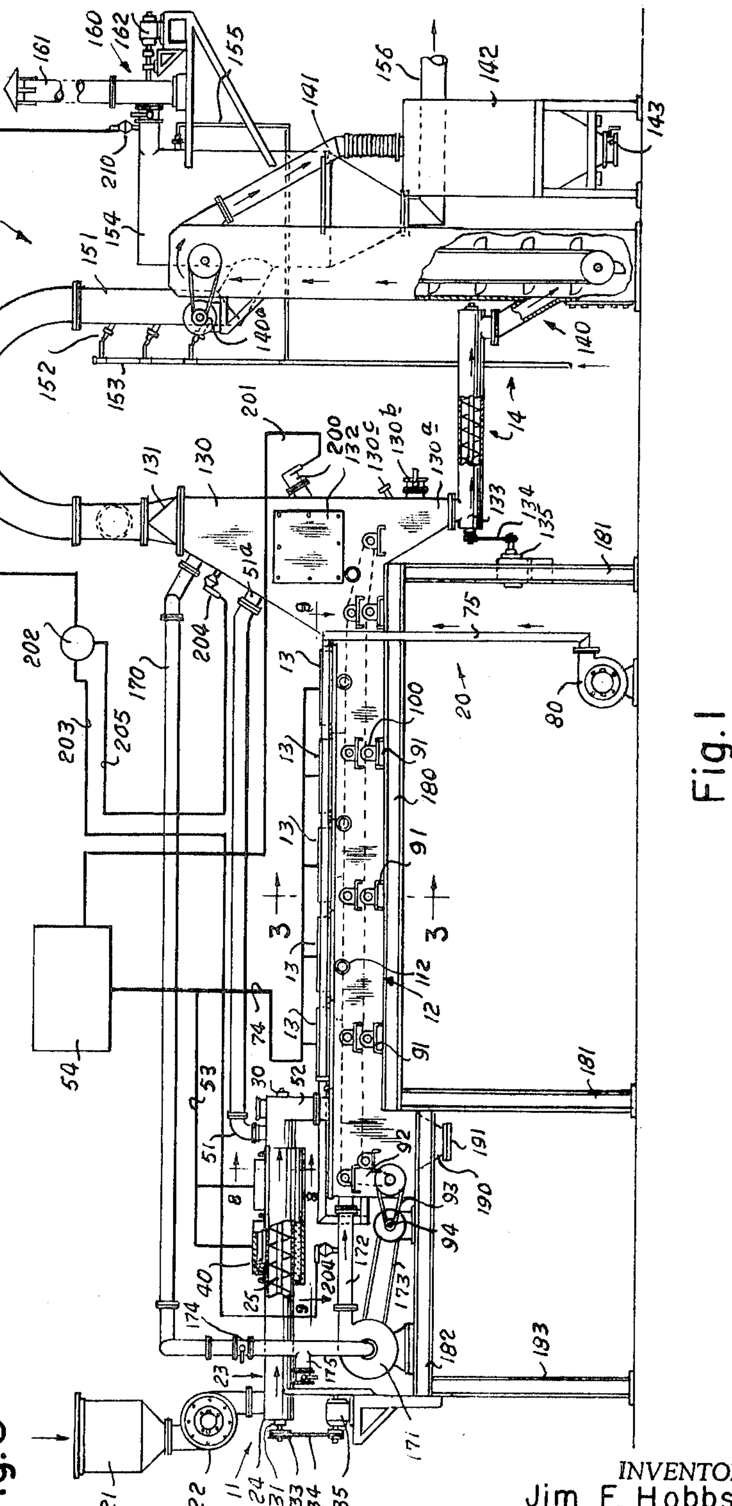

Fig.1

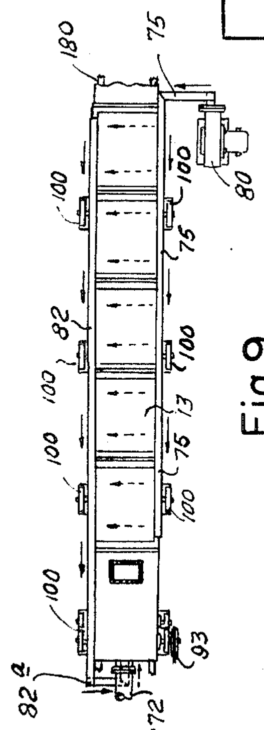

Fig.9

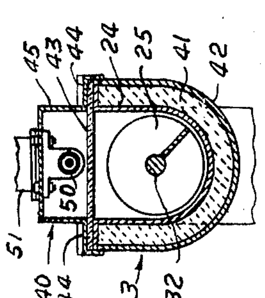

Fig.8

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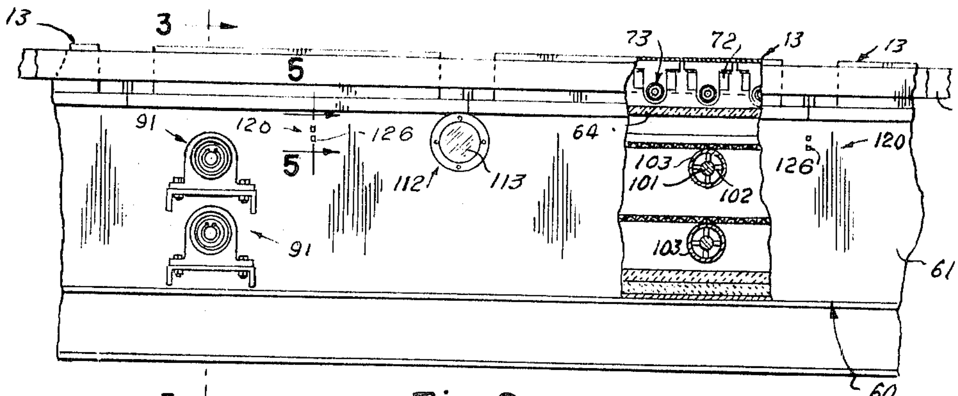

Fig. 2

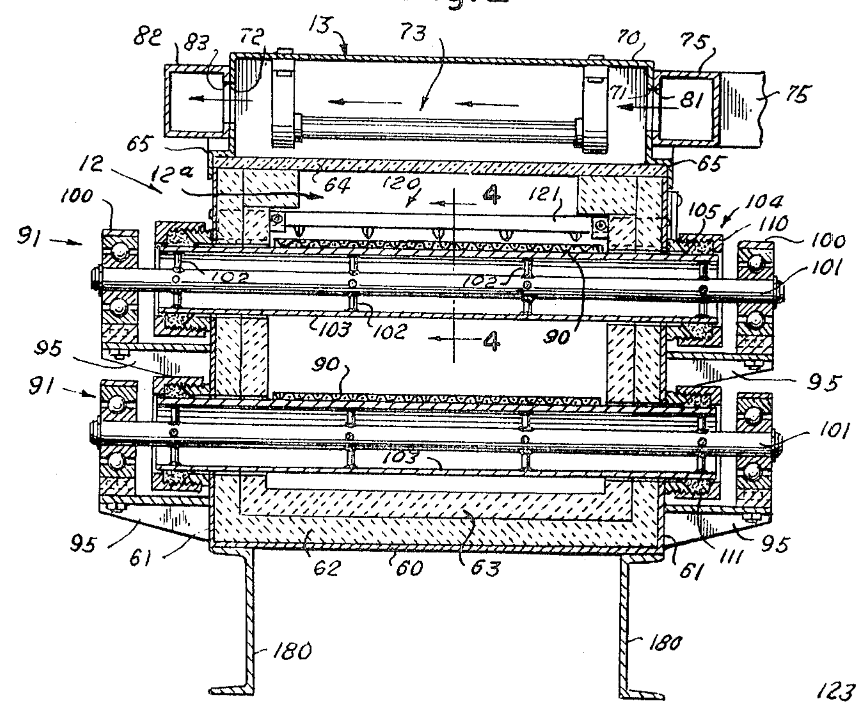

Fig. 3

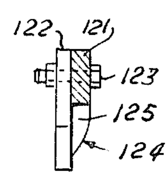

Fig. 6

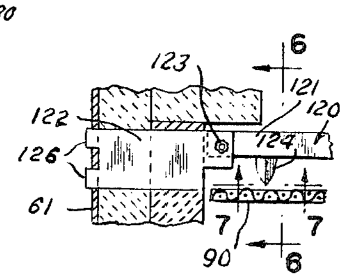

Fig. 5

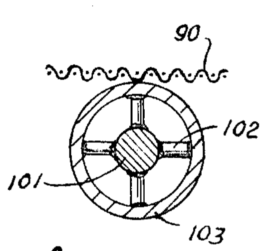

Fig. 4

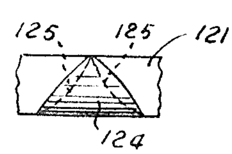

Fig. 7

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This invention relates to refuse treatment and particularly relates to apparatus and method for the incineration of refuse such as sewage sludge and the like.

Problems in the handling, treatment, and disposal of refuse, especially in areas of concentrated refuse collection, are becoming increasingly acute. Such refuse may be sewage sludge, industrial wastes of various kinds, and other waste products which require some form of treatment and disposal such as cattle dung which is produced in substantial volume in the large feed lot operations particularly prevalent in certain areas. In some instances the refuse is presently being disposed of by burying it in earth pits, though the location of suitable land for such disposal is becoming increasingly difficult, together with transportation and sanitation problems inherent in this approach to the problem. Other forms of disposition of such refuse have included burning in incinerators, which, however, have generally been large and expensive and functioned at a low efficiency. Thus, it has become increasingly urgent that more practical, efficient, and compact systems and methods be devised for the handling of the increasing volumes of various types of refuse being produced by municipal and industrial functions.

In accordance with the invention, an incineration system and method is provided utilizing a combustion chamber which is long and narrow in the nature of a conduit in which a belt-type conveyor is disposed for continuous movement and treatment of the refuse material, obviating many of the shortcomings of batch-type treatment so that a steady supply of refuse may be fed through the system. Heating units having infrared lamps providing highly concentrated, intense heat are disposed along the combustion chamber for supplying heat to the refuse moving on the conveyor, thereby providing a highly efficient, concentrated, accurately controllable heat source for the rapid reduction of the refuse being treated. The combustion chamber is maintained under a vacuum to prevent the escape of objectionable fumes during the combustion process. The refuse being treated is fed through a surge tank on a continuous basis into a first end of the combustion chamber where it is deposited on the upper moving face of the conveyor. The feed system includes infrared heat means for breaking the refuse into smaller, more readily burned particles. From the discharge end of the combustion chamber gaseous products of combustion are recirculated to the first inlet end of the combustion chamber where they are supplied to the chamber along with fresh makeup air for tempering and combustion supporting purposes. An air supply system is connected through the combustion chamber infrared units to the inlet end of the combustion chamber to cool the heat units and supply heated combustion supporting air to the refuse. The recirculation of the gaseous combustion products minimizes the infrared heat added to the system to support continuous combustion. Properly located temperature sensing devices along the combustion chamber and at the discharge end of the chamber supply the necessary data to the control system for most efficiently maintaining the combustion process, including the control of the infrared heat units so that the system may be fully automated to maintain peak efficiency of incineration. The refuse being treated is rapidly reduced along the continuous conveyor to a low-volume ash which is continuously removed from the discharge end of the combustion chamber for subsequent disposition. Conventional gas scrubbing devices are included at the discharge end of the incinerator for treating the exhaust gases by cooling them, venting them to the atmosphere, and separating the fly ash and the like. The continuous, highly efficient, compact system allows high volumes of refuse to be rapidly reduced to minimum quantities of nonobjectionable, much more readily disposable products. The invention has special application in its continuous incineration of sludge from wastewater treatment plants, both municipal and industrial. This sludge comprises a wide range of ratios of combustible solids and moisture. In the system and process of the invention the sludge is initially broken up by infrared heat and dried to remove all of the moisture, followed by incineration for destruction of all the volatiles remaining in the sludge after driving the moisture off, leaving the only solid as a minimum volume ash residue. The system provides a high volume, rapid reduction by oxidation method of treating sewage sludge and similar refuse in a compact, relatively low-cost apparatus.

A more thorough understanding of both the apparatus and method of the invention, together with its objects and advantages, will be understood from the following description taken in conjunction with the drawings wherein:

FIG. 1 is a side view in elevation, partially schematic, showing an incineration system embodying the invention;

FIG. 2 is an enlarged, fragmentary side view in elevation and section of a portion of the combustion chamber housing and the infrared heating units;

FIG. 3 is an enlarged view in section along the line 3—3 of FIG. 1, showing a portion of one of the heating units and a pair of the rollers in the conveyor system;

FIG. 4 is an enlarged view in section along the line 4—4 of FIG. 3, showing one of the rollers and a fragment of the conveyor belt;

FIG. 5 is an enlarged fragmentary view in section and elevation showing one end of one of the sludge rotation bars;

FIG. 6 is an enlarged view in section and elevation along the line 6—6 of FIG. 5;

FIG. 7 is a further enlarged bottom view along the line 7—7 of FIG. 5 showing one of the teeth on the sludge rotation bar;

FIG. 8 is a view in section along the line 8—8 of FIG. 1 showing a portion of the feed screw and a heater unit supported thereon for initial fragmentation of the sludge; and

FIG. 9 is a fragmentary top view in elevation illustrating the arrangement of the heating unit cooling and combustion air supply system used for feeding hot combustion supporting air into the combustion chamber of the system and cooling the infrared heat units.

Referring to the drawings, a refuse incineration system **10** embodying the invention includes a feed system **11**, an elongated housing **12** defining a combustion chamber **12*a***, infrared heat units **13**, an ash removal system **14**, and a gas scrubber **15**. Refuse to be treated is fed in through the system **11** which continuously supplies the combustion chamber with refuse which has been fragmented by intense infrared heat. Within the combustion chamber the fragmented refuse is moved continuously beneath the infrared units supplying intense infrared heat which in combination with the heat generated by the actual combustion of the refuse effects essentially complete reduction by combustion of the refuse within the combustion chamber. At the discharge end of the combustion chamber the ash residue is deposited into the system **14**, while the gaseous products of combustion discharge upwardly into the scrubber **15**. A portion of the discharged gases are recirculated to the combustion chamber along with fresh combustion supporting and heater unit cooling air from a fresh air system **20**. In the scrubber the exhaust gases from the combustion chamber are cooled and vented, and solid particles carried over with the gases are removed. The combustion chamber is operated under a slight vacuum to prevent noxious fumes from escaping from the chamber during the combustion process.

The principal application of the incinerator is the treatment of sewage sludge which is the semisolid product of a wastewater treatment plant. A typical charge of such sludge may comprise 20 percent solids with the remaining 80 percent being liquid. In the 20 percent solids 75 percent may be volatile and thus combustible in the present system. Thus, of the original total quantity of the sewage sludge, the 80 percent liquids may be removed by vaporization with combustion then eliminating 75 percent of the remaining 20 percent solids so that of the initial total volume of sludge only 5 percent may remain in the form of an ash which requires further disposition.

The sludge feed system **11** includes a hopperlike surge tank **21** into which the sludge is fed from a supply source, not shown. The surge tank is mounted on a feed pump 22 the discharge of which is connected with a screw conveyor 23 which has a shell-like housing 24 in which a feed screw 25 is rotatably supported between flange mounted bearings 30 and 31 secured at opposite ends of the housing. One end of a shaft 32 supporting the feed screw extends from the bearing 31 and supports a pulley 33 which is driven by a belt 34 from a motor 35.

A particularly unique feature of the feed system 11 is the fragmentation of the sludge by intense heat application from a pair of infrared heat units 40 mounted on the feed screw housing toward the discharge end thereof. Referring particularly to FIG. 8, the section of the feed screw over which the heat units are mounted is insulated by a layer of moldable refractory 41 extending along the sides and bottom surfaces of the housing 24 of the feed screw slightly longer than the combined length of the two units 40. The refractory layer is within an outer housing shell 42. As particularly evident in FIG. 8, the insulated portion of the feed screw housing is U-shaped in cross section and open at the top the length of the heat units. The top of the insulated portion is covered by a quartz pane 43 which provides a window or lens between the feed screw compartment and the heat unit. The quartz pane rests on the top edges of the feed screw housing clamped in place by flanges 44 connected with the heater unit housing 45, in which is suspended infrared heat lamps 50. The lamps 50 are suitable infrared lamps capable of rapidly raising the temperature of the sludge moved by the feed screw beneath the heat unit to a temperature of about 2,500° F. The quartz pane 43 effectively shields the lamp 50 from the dirt and moisture of the sludge while permitting the full intensity of the heat units to be focused on the sludge for its fragmentation. Downstream from the heater units conduit 51 is connected into the feed screw housing between the discharge end of the housing and the heater units to carry off vapors generated during the sludge fragmentation step. The feed screw discharges downwardly into the combustion chamber 12*a* through a vertical conduit 52.

The combustion chamber 12*a* is defined in the elongated housing 12 which, as shown in FIG. 3, is generally rectangular in cross section. The housing has a bottom panel 60 connected with vertical, spaced side panels 61, both of which are a suitable metal material. Within the side and bottom panels the combustion chamber is lined with a double layer of refractory material formed by an outer insulating refractory layer 62 and an inner refractory layer which comprises a low-erosion-type castable refractory 63. The outer layer of insulation 62 must provide a major portion of the needed heat insulation qualities and thus is formed of a suitable insulating refractory, which, however, generally is not capable of standing up under the severe stress conditions imposed by the drastic temperature changes inherent in direct exposure to the heat within the combustion chamber. The inner layer of insulation 63 is formed of a suitable material which is capable of performing under severe temperature changing conditions. Among the materials available for such service, the absolute insulating qualities are substantially less than those of materials which will suffice for the outer layer of insulation. The top of the housing 12, both upstream and downstream of the heater units 13, is of the same general construction as the sides and bottom as shown in FIG. 3. Along the portion of the combustion chamber supporting the heater units 13, the top of the housing comprises quartz panels 64 which permit the full intensity of the heater units to be focused into the combustion chamber while protecting the infrared lamps from the moisture and dirt within the chamber. The quartz panels are held in place by longitudinal flange sections 65 formed along the lower outer edges of and supporting the rectangular housings 70 of the heater units 13. The sidewalls of the housings 70 have air inlet openings 71 and outlet openings 72 for heater unit cooling air.

A plurality of transverse infrared heater units 73 are spaced along the length of the combustion chamber within the housings 70 supported from the roof panels of the housings. The heater units are infrared lamps of a suitable design to supply heat at a temperature of about 1,200° to 1,500° F. to supplement the heat generated by the combustion of the sludge within the chamber. Electric power is supplied to the infrared lamps through a lead 74 from the control panel 54. Cooling air for the heater units 13 enters through a supply duct 75 connected with an air pump or blower 80. A horizontal portion of the cooling duct 75 extends the length of the heater units 13, is secured along a sidewall of the heater unit housings 70, and is provided with outlet openings 81 which register with the openings 71 in the heater housings so that air supplied from the pump 80 is distributed laterally across each of the housings for cooling the lamps within the housings. A cooling air discharge duct 82 is similarly connected down the opposite sides of the heater units secured to the side panel of the unit housings 70 with openings 83 registering with the air outlet openings 72 of the housings so that a complete flow path is established between the inlet and outlet ducts across and through each of the heater unit housings. The cooling air discharge duct 82 has a U or a return end section 82*a* at the inlet end of the combustion chamber housing connected into the end panel of the housing for supplying heated combustion supporting air to the chamber. Thus, the cooling and combustion supporting air system 20 including the pump 80, the supply duct 75, and the discharge duct 82 performs the dual function of cooling the infrared lamps and supplying hot combustion supporting air to the combustion chamber.

The sludge is moved along the combustion chamber on a conveyor belt 90 supported on a plurality of spaced roller units 91 for moving the sludge from the discharge 52 of the supply system to the scrubber and ash disposal end of the combustion chamber. The conveyor belt is constructed of a suitable chain linkage arrangement of material capable of continuous operation at extremely high temperatures in the range of 1,500° F. and higher. In the particular conveyor system shown, a roller unit is disposed at opposite ends of the combustion chamber with three pairs of upper and lower roller units spaced along the length of the combustion chamber between the end rollers for supporting the continuous conveyor belt. The belt runs above both the upper and the lower rollers and around the opposite end rollers. The roller unit at the driven end of the belt is connected with a gear unit 92 driven by a belt 93 from a motor 94. The gear box arrangement includes means, not shown, for adjusting the tension in the belt.

Referring particularly to FIG. 3, each of the roller units 91 is supported on side brackets 95 secured to the side panels 61 on opposite sides of the combustion chamber housing. Bearing units 100 are bolted on the brackets 95 for supporting a roller shaft 101. Each of the roller shafts has spaced along its length sets of four radial spokes 102 which support a cylindrical roller 103. The opposite end portions of the rollers are disposed through stuffing boxes 104 formed by an annular flange 105 secured on the housing side panel and threaded into a cap 110. Asbestos rope 111 is confined in a ring within the cap against the outer end of the flange around the roller for sealing against heat losses from within the combustion chamber along the outer surface of each of the rollers. The opposite ends of the rollers are open to the atmosphere so that air may circulate throughout the length of each of the rollers along the annular space defined within the roller around the roller shaft 101. Observation ports 112 having removable covers 113 for visual inspection of the interior of the combustion chamber are formed along the length of the side panels of the housing.

Spaced along the combustion chamber above the top feed portion of the conveyor belt 90 are turning bar units 120 which stir up, turn, and generally agitate and mix the sludge being incinerated on the belt to better expose it to the combustion process. Each turning bar unit includes a crossbar 121 mounted at each end on a bracket 122 by bolts 123, FIGS. 5 and 6. The brackets are set through the two layers of refractory lining with cleats 126 projecting through the sidewall 61 of the combustion chamber housing. A plurality of plowlike teeth 124 are spaced along the length of the bar so that the tip ends of the teeth are closely spaced from the top surface of the conveyor belt 90. The teeth 124 each has concave turning faces 125 which enable the spaced teeth to plow the sludge on the top face of the conveyor belt in such a manner that it is thoroughly turned as it moves along the length of the belt within the combustion chamber. Several of the turning bar units are placed along the length of the belt with the teeth being so positioned that all of the sludge is turned as it moves along the length of the belt. The tooth spacing and position on the several turning bars are varied to insure maximum sludge agitation by the time the sludge has moved past all of the bars.

The discharge end of the combustion chamber is connected with a stack 130 which is secured at its upper end by a flanged coupling 131 to the scrubber 15 and at its lower end to the ash disposal system 14. A removable inspection door 132 is secured in the near side panel of the stack as shown in FIG. 1. The lower hopper portion 130*a* of the stack connects directly into the feed end of a screw conveyor 133 driven by a belt 134 from a motor 135. The screw conveyor discharges downwardly to a bucket elevator unit 140 driven by a motor 140*a*. The discharge of the elevator is connected through a conduit 141 into a hopper-type storage tank 142 which is unloadable through a bottom door 143 for removal of the ash.

The upper end of the connector 131 at the upper end of the stack connects with a U-shaped refractory lined conduit 150 of the scrubber. The conduit 150 connects into a spray section 151 having a plurality of vertically spaced sprays 152 connected through a pipe 153 to a water supply, not shown. The spray section discharges into a scrubber tank 154 of suitable standard design supplied with water through a line 155. Gas from the scrubber is removed to the atmosphere by an exhaust fan 160 through a stack 161. A motor 162 drives the exhaust fan.

The conduit 51 from the downstream discharge end of the screw conveyor of the feed system 11 is connected at 51*a* into the upper portion of the stack 130 for removal of the vaporized liquid and any products of combustion that may be generated in the feed screw conveyor by the heater units 40. The discharge portion of the stack 130 also is connected through a conductor 170 to the intake of a pump or a blower 171 which discharges through a conduit 172 into the inlet end of the combustion chamber 12a for furnishing hot combustion initiating gases to the combustion chamber along the length of and at the elevation of the upper sludge-carrying portion of the conveyor belt. The blower 171 is driven by a belt 173 from the motor 94. A fully adjustable valve 174 is connected in the combustion gas return line 170 for controlling the rate of the flow of the recirculation of combustion gases from the stack to the combustion chamber. A tempering air valve 175 is connected into the gas return line 170 to admit air for tempering or lowering the temperature of the combustion gases before their recirculation to the combustion chamber.

The combustion chamber housing 12 is supported on a pair of spaced parallel channel members 180 mounted on legs 181 while at a lower level the blower 171 along with the drive motor 94 and the related driving mechanism and inlet end of the combustion chamber housing are mounted on channel members 182 supported on one pair of the legs 181 and a spaced pair of similar legs 183. The inlet end of the combustion chamber is formed with a hopper section 190 having a cleanout door 191 for removal of ash and miscellaneous debris collecting at the inlet end of the chamber.

The control panel 54, in addition to being connected with the heater units 40 in the supply system 11 and the heater units 13 of the combustion chamber, is connected with various temperature sensing elements for determining the temperature of exhaust gases and supply air and the like to provide proper control of the incineration process. A temperature sensing element 200 is connected into the stack 130 to read or sense the temperature in the combustion chamber at the discharge end of the conveyor belt. The sensing element 200 is connected by a lead 201 to the control panel. A multiple pen recorder 202 is connected by a lead 203 to a temperature sensor 204 in the recirculation conduit 172 to the combustion chamber between the blower 171 and the inlet end of the chamber. Another temperature sensor 204 is located in the upper discharge portion of the stack 130 connected by lead 205 to the recorder. A further temperature sensor 210 at the discharge from the scrubber tank 154 is connected by a lead 211 to the recorder.

A manually controlled valve 130*b* for controlling communication between the atmosphere and the base end 130*a* of the stack is connected into the lower discharge portion of the stack above the screw conveyor 133. A capped thermoweld 130*c* is secured in the discharge portion of the stack 130 for insertion of a temperature sensor as desired. The functions of the recorder 202 sensing and recording critical operation temperature and the control panel 54 may be fully automated, fully manual, or arranged in various degrees between manual and automatic for controlling the operation of the incinerator to achieve maximum efficiency. While the principal control of the panel 54 in the arrangement of the system illustrated is the maintenance of a desired temperature at the heater units 13 and 40, other functions may be ascribed to the control panel as desired, depending upon the level of automation to be achieved in the system. For example, the exhaust gas recirculating control valve 174, the tempering air valve 175 for admission of air to aid in controlling the temperature of the recirculating combustion gases, and other controllable functions, such as the supply of cooling and combustion supporting air from the system 20, may be interconnected with the control panel as desired and required to fully adjust all of the variables existent within the system for optimum operation.

In the operation of the incinerator, sludge from a wastewater treatment plant, which may be either a municipal plant or industrial, is fed at a continuous rate, commensurate with the capacity of the incinerator, into the feed system 11 through the surge tank 21. The sludge is in the nature of a mudlike slurry combining solids and liquids in varying percentages depending upon the processes of the treatment plants. The solids may comprise a wide range of the total volume of the sludge. The sludge is deposited in the surge tank 21 from which it is delivered by the pump 22 into the screw conveyor 23 where the feed screw 25 moves the material along the conveyor to the combustion chamber. As the sludge is displaced along the conveyor housing by the feed screw, it passes along the portion of the conveyor heated by the infrared lamps 50. The intense heat of the lamps, which may be on the order of about 2,500° F., is focused through the quartz panels 43 on the sludge being moved by the feed screw. The intense, violent change to which the sludge is subjected in moving from the unheated input end of the feed conveyor into the extremely high temperature imposed on the unit by the lamps 50 instantaneously vaporizes a substantial portion of the moisture in the sludge with the explosionlike effect of the vaporization breaking the sludge down into particle sizes which are much more readily incinerated in the combustion chamber. The fundamental purpose of the application of the heat from the infrared lamps along the feed screw is not moisture removal but rather fragmentation of the sludge which most generally is tightly bonded together by the interlacing of hair and similar fibrous particles when it enters the conveyor. The zone along the conveyor at which the heat is focused will attain temperatures on the order of 2,000° to 2,500° F., which is necessary to produce the instantaneous explosivelike vaporization for severing the hair particles to break the bonds holding the especially larger pieces of sludge together. Additionally, there may be a minor degree of combustion occurring, and certainly there will be some melting of the hair and other fibrous particles. While at the focal point of the intense heat supplied by the infrared lamps the temperature is extremely high, the overall average temperature along the feed conveyor probably would be on the order of 500° to 600° F. The fragmented sludge is discharged by the feed screw to the connecting conduit 52 through which it drops into the combustion chamber **12a** on the top surface of the conveyor belt **90**. The moisture and other gaseous byproducts of the fragmentation heat at the discharge end of the feed conveyor is exhausted from the conveyor housing through the flow conductor **51** through which it moves to and is discharged into the upper portion of the stack **130**.

The conveyor belt **90** is driven by the motor **94** at a rate which is calculated to permit complete combustion of the sludge deposited on the belt between the point of deposit and the discharging zone of the belt at its end above the ash removal system at the base of the stack **130**. Obviously, there are a number of variables which will determine the rate at which the conveyor belt is driven. For example, the physical nature of the sludge, including the percentage of moisture and the combustible solids, affects the time required to fully drive the moisture from the sludge and completely incinerate the combustible portion of the solids. The actual process of incineration of the sludge as it is moved along by the conveyor belt is accomplished by the combination of the heat supplied by the infrared lamps in the heat units **13** and the heat generated by the combustion of the volatile contents of the sludge.

Obviously, in starting up the incinerator, no products of combustion, and thus byproduct heat for recirculation, is initially available, and thus the first heat applied to the sludge within the combustion chamber is supplied from the heat units **13** toward the inlet end of the chamber. The sludge is heated along the combustion chamber to a temperature in the range of 1,200° to 1,500° F. with the moisture in the sludge being initially driven off followed by incineration of the volatile portions of the sludge. The gaseous vapors from the vaporizing of the liquid in the sludge and the subsequent burning of the solid particles passes along the combustion chamber into the stack **130**. A forced draft is provided along the length of the combustion chamber by the combined force of fresh combustion supporting air supplied from the system **20** and the recirculated gases. The air is introduced into the system by the blower **80** which discharges through the supply duct **75** into each of the heater units **13** through the side duct and heater unit housing ports **81** and **71**. The air flows laterally across the heater unit housings as designated by the flow direction indicator arrows in FIGS. **3** and **9**. Within the heater unit housings the air functions to cool the infrared lamps which preheat the air, and it is discharged through the housing and duct ports **72** and **83** into the discharge duct **82**. The forced flow of heated combustion-supporting air flows through the duct **82** and the return portion **82a** of the duct into the inlet end of the combustion chamber where it is discharged into the chamber along the length of the combustion chamber upstream from the point of admission of the sludge on the conveyor belt from the sludge supply system. Additionally, the blower **171** discharges recirculated combustion gases through the conduit **172** into the inlet end of the combustion chamber in the general vicinity of the point of entry of the fresh combustion-supporting air. A portion of whatever gases are flowing upwardly in the stack **130** above the discharge end of the conveyor belt is withdrawn from the stack through the conduit **170** by the blower **171**. During the startup of the incinerator this recirculated gas portion will include fresh air in the system, some of the gaseous discharge from the supply feed screw which enters the stack through the conduit **51**, and such gaseous discharge as is generated during the initial vaporization and combustion processes in the chamber. The volume or rate of flow of the recirculation through the conduit **170** is controllable by the valve **174**.

During the initiation stage of the combustion process the conveyor belt is driven at a very slow rate as compared with the belt rate when the incinerator is operating at its full capability for a given sludge. Obviously, it will take longer initially to heat up the entire system and start moisture driveoff and combustion than to achieve complete combustion after the system is fully operative. When combustion is fully established, the process is controlled to maintain an approximate temperature of 1,500° F. at the discharge end of the conveyor belt as sensed by the temperature sensing means **200**. The desired temperature may be maintained by control of several variables including the power to the infrared lamps, the flow rate of recycled combustion gases through the conduit **170**, and the admission of tempering air to the conduit through the valve **175**. Once the combustion process is fully established in the combustion chamber, the recirculation of the combustion gases provides a substantial amount of heat which, when combined with the heat in the fresh combustion air entering through the duct **82**, provides a major portion of the heat necessary to sustain combustion of the volatile solids of the sludge along the conveyor belt. The entering hot gases at the inlet end of the combustion chamber flow along the top surface of the conveyor belt contacting the sludge being deposited on the belt through the conduit connection **52** from the screw supply conveyor starting the drying process by driving off the moisture from the sludge on the belt. Once full capacity combustion is established in the chamber, a minimum amount of supplemental heat from the infrared lamps will be necessary.

As the sludge deposited from the feed conveyor moves along with the conveyor belt, the teeth **124** on the turning bars break up the sludge which tends under the intense heat of the combustion chamber to crust as it moves along beneath the infrared lamps. The placement of the turning teeth of the several turning bars at different locations along the length of the bars insures maximum contact of the sludge on the belt by the teeth to agitate and improve the exposure of the sludge to the heat. The flow rate and pressures of the recirculated combustion gases, the air supplied by the system **20**, and the draft induced by the stack **130** are manipulated to maintain the combustion chamber operating under a vacuum or somewhat reduced pressure relative to the surrounding or ambient atmosphere to prevent noxious fumes from escaping from the chamber during the combustion of the sludge solids.

As the sludge reaches the discharge end of the conveyor belt, all of the volatile solids have been incinerated with the small quantity of ash remaining being deposited downwardly into the lower hopper portion **130a** of the stack. The ash falls into the discharge conveyor **130** in which a feed screw moves the ash to the elevator **140** in which it is lifted and deposited downwardly through the conduit **141** into the storage tank **142**. The ash is removable from the storage tank through the lower door **143**.

The combustion gases flowing into the stack **130** from the discharge end of the combustion chamber and through the conduit **51** from the feed system flow upwardly through the stack **130** into the conduit **150** to the spray portion **151** of scrubber **15**. Water from the nozzles **152** is injected into the combustion gases for cooling the gases and separating the solid particles or fly ash carried over by the gases from the discharge end of the combustion chamber. A portion of the water and fly ash are discharged from the conduit **156** at the bottom of scrubber tank **154**. The tank may include compartments for several passes of the combustion gases, during which additional water may be sprayed into the flowing gases for further cooling and fly ash separation. The cooled exhaust gases are discharged to the atmosphere through the exhaust stack **161** by the exhaust fan **160**.

The gases flowing along the length of the combustion chamber introduced through both the conduits **172** carrying the recirculated combustion gases and tempering air along with the fresh combustion supporting air entering through the duct **82a**, in addition to supporting the combustion, generally keep the conveyor belt relatively clean blowing debris dropping from the top surface of the belt down through the return bottom side of the belt along the chamber toward the ash removal portion of the stack. Any portions of the sludge which drop through the belt at the inlet end of the combustion chamber may be cleaned out from time to time through the removable door **191** in the cleanout hopper section **190**.

The apparatus and method of the invention provide for highly efficient, continuous sludge incineration which permits the handling of a maximum quantity of sludge in a minimum of time and space. The use of the infrared heat, both in starting up the combustion process and for sustaining the process, is a highly efficient manner of supplying a maximum quantity of heat at a minimum cost and in equipment which is highly compact. Thus, the principal source of heat generated in the combustion chamber is derived from the burning of the volatile solids of the sludge with the necessary supplement being supplied by the intense, compact, high temperature infrared lamps. Additionally, initial fragmenting of the sludge in preparation for the combustion process is also provided by the application of the intense heat from infrared lamps.

While the incinerator and incineration method have been discussed in terms of the processing of the sewage sludge, it will be recognized that other forms of refuse may be processed by the same method in the apparatus. Particularly, for example, the sludge byproduct of cattle feed lots in high-density cattle feed operations presents a particularly difficult disposal problem, which is solvable in the same manner provided above for the sewage sludge. The high concentration of heat obtainable with infrared lamps substantially reduces normal heat losses inherent in present incinerators.

What is claimed and desired to be secured by Letters Patent is:

1. An incinerator for burning refuse comprising: means defining a combustion chamber; refuse support means within said combustion chamber; means for depositing refuse on said support means in said combustion chamber; means for removal of ash residue from said combustion chamber; combustion gas exhaust means connected with said combustion chamber; an infrared heat source comprising at least one infrared lamp supported to direct high-intensity infrared heat rays on said refuse in said combustion chamber; and a protective pane secured between said infrared lamp and said combustion chamber, said pane being transparent to infrared rays.

2. An incinerator for burning refuse comprising: means defining a combustion chamber; refuse support means within said combustion chamber; means for depositing refuse on said support means in said combustion chamber; means for removal of ash residue from said combustion chamber; combustion gas exhaust means connected with said combustion chamber; an infrared heat source comprising at least one infrared lamp supported to direct high-intensity infrared rays on said refuse in said combustion chamber; and means for recirculating combustion gases from the discharge end of said combustion chamber to the inlet end of said chamber to supplement heat supplied from said infrared lamp for burning said refuse.

3. An incinerator in accordance with claim 2 including valve means for admission of tempering air to said combustion gas recirculating means.

4. An incinerator in accordance with claim 3 including means for supplying combustion-supporting air to said combustion chamber.

5. An incinerator in accordance with claim 4 wherein said combustion-supporting air is directed over said infrared lamp for cooling said lamp preliminary to introduction of said air into said combustion chamber.

6. An incinerator for burning refuse comprising: means defining a combustion chamber; refuse support means within said combustion chamber; means for depositing refuse on said support means in said combustion chamber; means for removal of ash residue from said combustion chamber; combustion gas exhaust means connected with said combustion chamber; an infrared heat source comprising at least one infrared lamp supported to direct high-intensity infrared rays on said refuse in said combustion chamber; and refuse feed means for introducing said refuse into said combustion chamber on said refuse support means, said refuse feed means including infrared heat means for applying high-intensity heat to said refuse preliminary to introducing said refuse into said combustion chamber for physically breaking said refuse into smaller particles to improve combustion of said refuse in said combustion chamber.

7. An incinerator in accordance with claim 6 including gas scrubbing means connected with the outlet end of said combustion chamber for cooling combustion gases exhausting from said chamber and removing entrained solid particles from said gases.

8. An incinerator in accordance with claim 6 wherein said infrared heat means associated with said combustion chamber is adapted to provide heat to said refuse in said chamber at a temperature within the range of about 1,200° to 1,500° F., and said heat means in said supply means adapted to supply heat at about 2,000° to 2,500° F.

9. An incinerator for burning refuse comprising: a housing defining an elongated combustion chamber having an inlet end and a discharge end; a conveyor belt supported for movement in said combustion chamber for moving refuse along said combustion chamber from said inlet end to said discharge end; infrared heat means supported on said housing and adapted to focus infrared rays on said refuse on said conveyor belt as said belt moves said refuse along said combustion chamber; refuse charging means connected with said housing at said inlet end of said combustion chamber for receiving refuse from a source and discharging said refuse on said conveyor belt in said chamber; stack means at the discharge end of said combustion chamber for receiving combustion gases discharged from said chamber produced by the combustion of said refuse on said conveyor belt; means for removing ash residue from said combustion chamber at said discharge end of said chamber; combustion gas conduit means connected from said combustion gas discharge means to said inlet end of said combustion chamber for recirculating combustion gases from said discharge end of said combustion chamber to said inlet end of said chamber for providing a portion of the heat required for combustion of said refuse on said conveyor belt; and temperature control means for controlling the temperature of said recirculating combustion gases admitted to said inlet end of said combustion chamber and said infrared heat means.

10. An incinerator in accordance with claim 9 including combustion-supporting air supply means for supplying air along said infrared heat means for cooling said heat means and into said inlet end of said combustion chamber for supplying combustion supporting air to said chamber.

11. An incinerator in accordance with claim 9 including infrared heat means connected with said refuse-charging means for focusing high-intensity heat on said refuse in said charging means for breaking said refuse into smaller, more readily combustible particles preliminary to introducing said refuse into said combustion chamber on said combustion chamber on said conveyor belt.

12. An incinerator in accordance with claim 11 wherein said infrared heat means on said housing is adapted to supply concentrated heat within the range of about 1,200° to 1,500° F., and said infrared heat means connected with said refuse-charging means is adapted to supply concentrated heat in the range of about 2,000° to 2,500° F. for breaking up said refuse.

13. An incinerator in accordance with claim 12 including gas-scrubbing means connected with said discharge end of said combustion chamber for cooling combustion gases discharged from the said chamber and venting said gases to the atmosphere while removing solid particles from said gases, and ash residue handling means connected with the said discharge end of said combustion chamber for removal and temporary storage of ash residue.

14. An incinerator for burning refuse comprising: a housing providing an elongated combustion chamber; an insulating refractory lining within said housing around said chamber for retaining heat therein; a conveyor belt movably supported on rollers disposed transversely of said combustion chamber and connected with opposite sidewalls of said housing supporting said conveyor belt with an upper portion moving along said housing within said chamber for supporting refuse during

combustion within said chamber and a return portion of said belt below said supporting upper portion of said belt, said rollers being disposed to provide opposite end tension rollers and intermediate belt-supporting rollers for supporting both the upper and lower sections of said belt, said rollers having open passages therethrough opening through opposite sides of said housing for cooling said rollers; said housing and said combustion chamber having a first inlet end and an opposite second discharge end; a combustion gas stack connected with said housing at said discharge end of said combustion chamber; a plurality of infrared heat lamps supported along said housing over said combustion chamber for focusing high-intensity heat in said chamber on refuse on said upper portion of said conveyor belt; protective pane means supported on said housing between said infrared heat lamps and said combustion chamber, said pane means being transparent to infrared rays for permitting maximum heat transmission to said refuse while protecting said lamps from moisture and dirt in said combustion chamber; a combustion gas recirculating conduit connected from said stack to the inlet end of said housing into said combustion chamber for recirculating combustion gases from said stack into said chamber along said upper conveyor belt portion to provide a portion of the heat required for burning said refuse on said conveyor belt; heat sensing and control means for controlling the temperature of said recirculating combustion gases introduced into said inlet end of said combustion chamber and the intensity of said infrared lamps; and refuse supply means connected with said housing for introducing refuse into said combustion chamber at the inlet end thereof on said upper portion of said conveyor belt; infrared lamp means connected with said refuse supply means for supplying intense heat to said refuse moving through said supply means for breaking up said refuse into smaller particles for maximum exposure to heat in said combustion chamber on said conveyor belt.

15. An incinerator in accordance with claim **14** wherein said infrared heat lamp on said housing are adapted to supply infrared heat to refuse on said upper portion of said conveyor belt at a temperature in the range of 1,200° to 1,500° F., and said infrared lamp means on said supply means is adapted to supply infrared heat to refuse moving through said supply means at a temperature within the range of about 2,000° to 2,500° F. for breaking up said refuse.

16. An incinerator in accordance with claim **15** including a gas scrubber system connected with said combustion gas stack for treating combustion gases and discharge of said gases to the atmosphere, and ash removal and storage means connected with said housing at the discharge end of said combustion chamber and said conveyor belt.

17. An incinerator in accordance with claim **15** including a fresh-air combustion supporting system having a supply duct connected from blower means to one side of said infrared lamp units and a discharge duct connected from the other side of said infrared lamp units to the inlet end of said combustion chamber for cooling said lamp units and supplying heated combustion-supporting air to said combustion chamber.

18. An incinerator in accordance with claim **17** including heat sensing means connected in said stack for sensing the temperature at the discharge end of said combustion chamber, a tempering air inlet valve connected into said combustion gas recirculating conduit, and means for controlling the intensity of said lamp units and said tempering valve for maintaining a predetermined temperature in said combustion chamber along said conveyor belt.

19. A method of incineration of refuse comprising the steps of: supporting a charge of refuse in a combustion chamber; applying infrared heat to said refuse until all the moisture in said refuse is driven off and all combustible matter in said refuse is incinerated; and recirculating combustion gases generated by incineration of said combustible portion of said refuse to said combustion chamber for supplying heat for supplementing said infrared heat for incinerating said refuse.

20. A method of incinerating refuse in accordance with claim **19** including the step of flowing air over the source of said infrared heat for cooling said source and thereafter directing said air into said combustion chamber to provide combustion supporting air for incineration of said refuse in said chamber.

21. A method of incinerating refuse in accordance with claim **20** including the step of breaking up said refuse preliminary to introduction into said combustion chamber to improve the efficiency of combustion therein including applying intense heat to said refuse from an infrared heat source before said refuse is introduced into said combustion chamber.

22. A method of continuous incineration of refuse comprising the steps of: heating said refuse by intense application of infrared rays from an infrared heat source to a temperature in the range of about 2,500° F. for breaking said refuse into smaller particle sizes for improved combustion; introducing said refuse into a combustion chamber; moving said refuse along said combustion chamber from an inlet end to an outlet end thereof; applying heat to said refuse from an infrared heat source to maintain the temperature of said refuse within the range of about 1,200° to 1,500° F. as said refuse moves through said combustion chamber for driving moisture from said refuse and for incinerating combustible portions of said refuse; recirculating combustion gases generated by incineration of the said refuse in said combustion chamber from the discharge end of said combustion chamber back into the inlet end of said chamber along the line of the direction of movement of said refuse in said chamber for supplying a portion of the heat for combustion of said refuse; controlling the temperature in said combustion chamber at the discharge end thereof at a level of about 1,500° F. by controlling the admission of tempering air and the rate of flow of said recirculating combustion gases upstream from said inlet end of said combustion chamber; and discharging ash residue and combustion gases from said discharge end of said combustion chamber.

23. The method of claim **22** including the steps of flowing air over said infrared heat source for said combustion chamber for cooling said heat source, and directing said air from said heat source into said inlet end of said combustion chamber along the line of direction of movement of said refuse in said chamber to aid in supporting combustion in said chamber and to supply heat to said chamber for said combustion.

24. The method of claim **23** including the steps of discharging combustion gases from said discharge end of said combustion chamber into gas scrubbing means for cooling said gases and discharging said cooled gases to the atmosphere while removing entrained solid particles from said combustion gases, and discharging ash residue of said incinerated refuse from said discharge end of said chamber into ash handling means.

25. The method of claim **22** including the step of maintaining the pressure within said combustion chamber at a value less than the ambient pressure to prevent escape of noxious odors during the incineration of said refuse within said chamber.

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