Dec. 18, 1962 W. C. L. HEMEON 3,068,812

METHOD AND APPARATUS FOR INCINERATING COMBUSTIBLE WASTES

Filed May 7, 1959 4 Sheets-Sheet 1

Fig. 1.

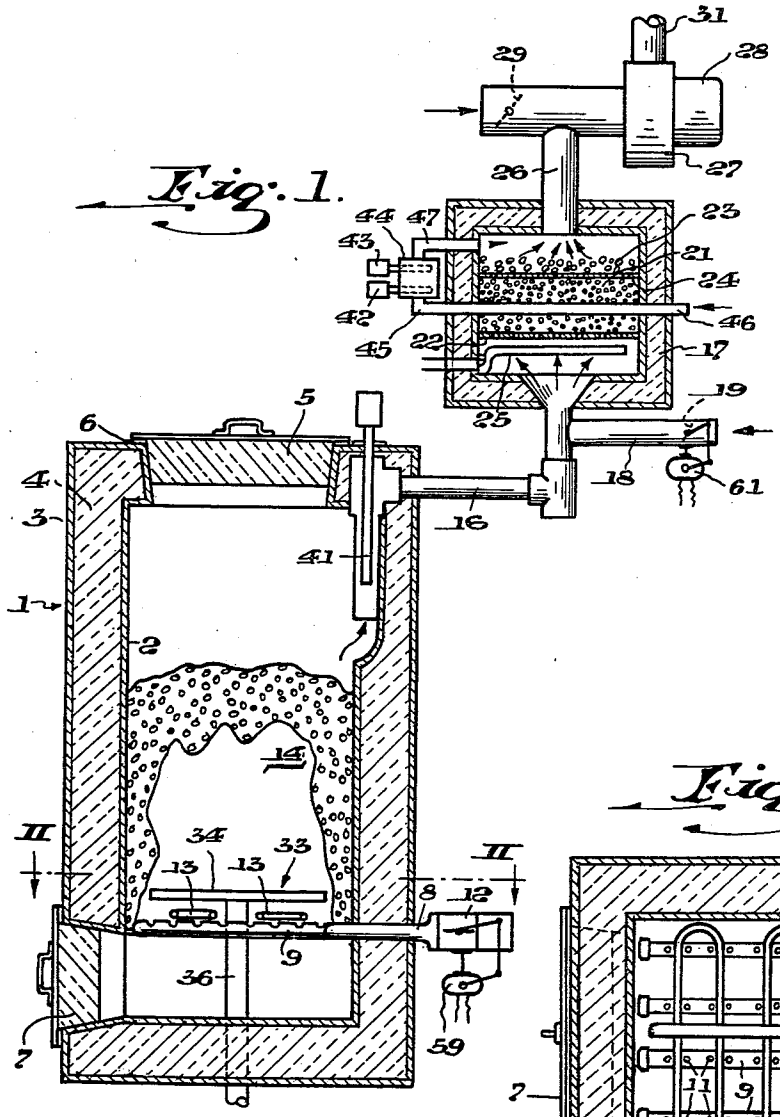
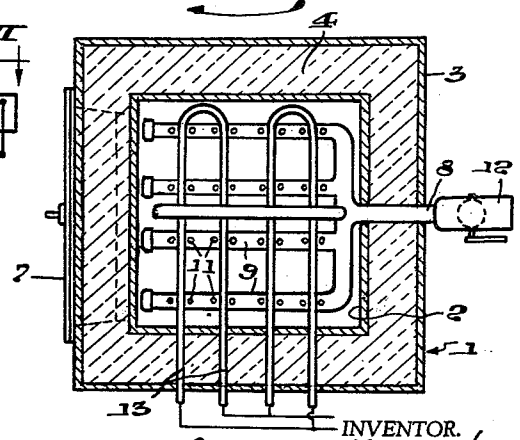


Fig. 2.



INVENTOR.
WESLEY C. L. HEMEON

BY
Brown, Critchlow, Flick & Peckham
his
ATTORNEYS

Dec. 18, 1962 W. C. L. HEMEON 3,068,812

METHOD AND APPARATUS FOR INCINERATING COMBUSTIBLE WASTES

Filed May 7, 1959 4 Sheets-Sheet 2

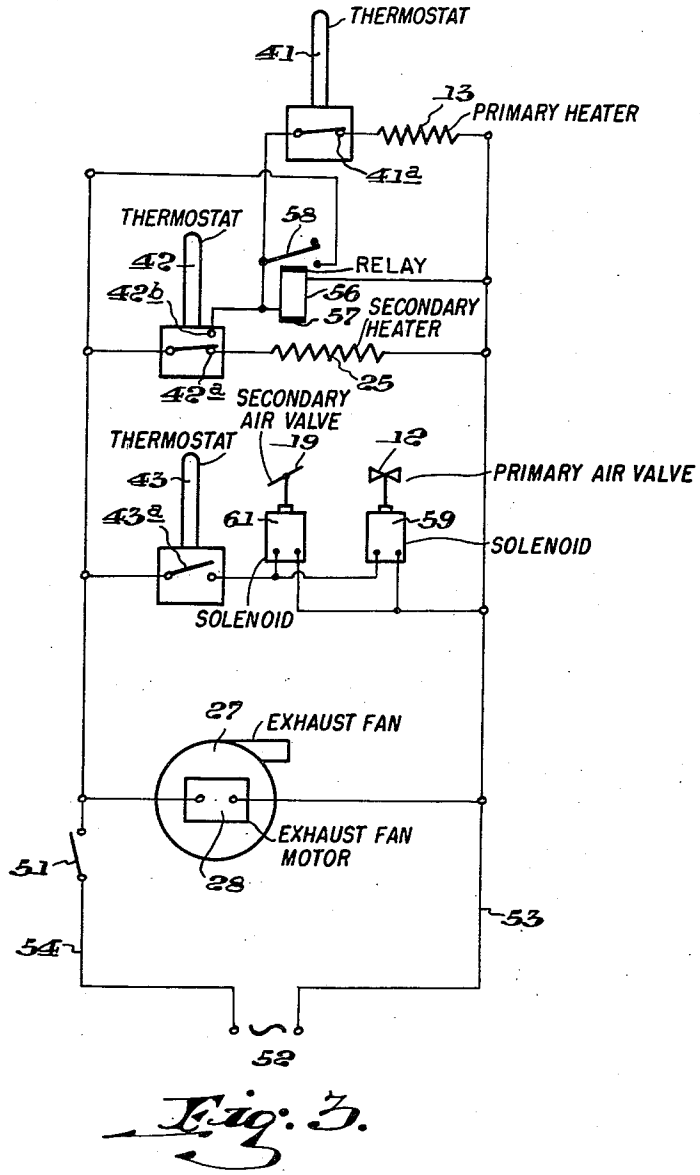


Fig. 3.

INVENTOR.
WESLEY C. L. HEMEON.

BY
Browns, Critchlow, Dick & Peckham
ATTORNEYS.

Dec. 18, 1962 W. C. L. HEMEON 3,068,812

METHOD AND APPARATUS FOR INCINERATING COMBUSTIBLE WASTES

Filed May 7, 1959 4 Sheets-Sheet 3

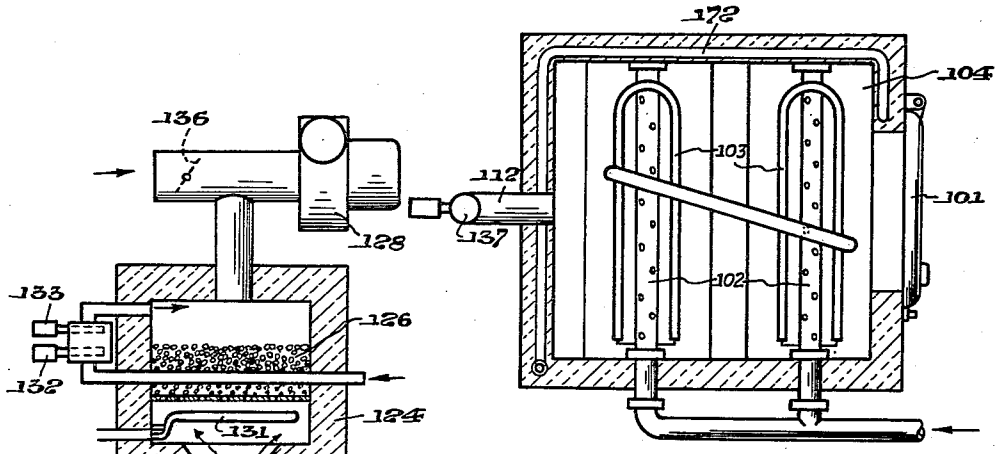


Fig. 5.

Fig. 4.

INVENTOR.
WESLEY C.L. HEMEON.

BY

Brown, Critchlow, Flick & Peckham
his
ATTORNEYS.

Dec. 18, 1962 W. C. L. HEMEON 3,068,812

METHOD AND APPARATUS FOR INCINERATING COMBUSTIBLE WASTES

Filed May 7, 1959 4 Sheets-Sheet 4

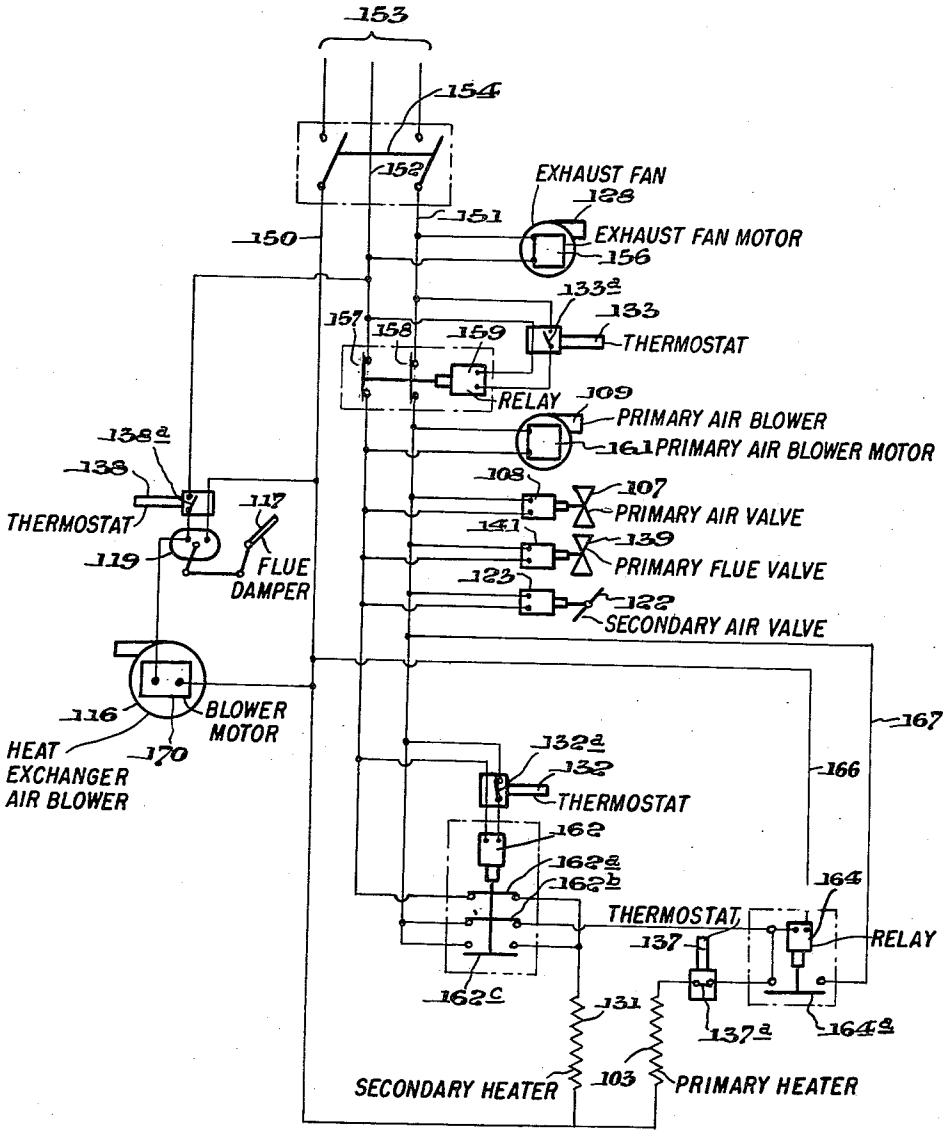


Fig. 6.

INVENTOR.
WESLEY C. L. HEMEON.

BY
Brown, Critchlow, Flick & Peckham
his ATTORNEYS

United States Patent Office

3,068,812
Patented Dec. 18, 1962

3,068,812

METHOD AND APPARATUS FOR INCINERATING COMBUSTIBLE WASTES

Wesley C. L. Hemeon, 5618 Northumberland St., Pittsburgh 17, Pa.

Filed May 7, 1959, Ser. No. 811,616
6 Claims. (Cl. 110—8)

This invention relates to a method and apparatus for incinerating combustible wates, in which gasification and combustion of the waste material occur simultaneously in a primary combustion chamber and subsequent oxidation of unburned gases and smoke occurs in a bed of catalyst in a secondary combustion chamber.

Among the objects of this invention is the economical destruction of combustible material without liberating obnoxious gases or smoke from the apparatus into the ambient space or from the ultimately vented flue gases into the atmosphere.

A further object is to provide a method and apparatus of the foregoing type, in which incineration will proceed automatically at a maximum rate consistent with the most economical and efficient use of the catalyst in the secondary combustion chamber.

Other objects will be apparent from the following description of the invention in connection with the attached drawings, in which

FIG. 1 represents a partly schematic, vertical section of an incinerator embodying this invention for use in the home;

FIG. 2 is a sectional plan view of the primary combustion chamber along the line II—II of FIG. 1;

FIG. 3 is a schematic wiring diagram of the electrical controls for automatically regulating the auxiliary heat input and air supply to the incinerator shown in FIG. 1;

FIG. 4 is a modified form of an incinerator, particularly suited to commercial installation, showing a partly schematic vertical section thereof;

FIG. 5 is a sectional plan view along the line V—V of FIG. 4; and

FIG. 6 is a schematic wiring diagram of the electrical controls used in the modified incinerator.

In accordance with this invention, the waste material is placed in an airtight primary combustion chamber, where it is initially heated, and if necessary intermittently heated thereafter, to ignition temperature by auxiliary heating means. A control valve regulates the amount of air admitted to the chamber, and the air is preferably discharged therein adjacent the auxiliary heating means. The volatile components of the waste material and the products of its combustion are then completely oxidized by passing them through a permeable bed of suitable catalyst in a secondary combustion chamber, which is provided with a separate controllable secondary air supply to assure complete oxidation of those gases. To maintain the temperature of the catalyst above the minimum temperature at which it is activated, in the absence of sufficient sensible and potential heat in the gases from the primary combustion chamber, auxiliary heat is supplied to the catalyst bed directly or indirectly. To prevent the catalyst from becoming overheated, the temperature of the gases entering the secondary chamber may be cooled either by extracting heat therefrom, by increasing the supply of secondary air, or by decreasing the primary air supply to slow down or stop combustion in the primary chamber. The regulation of the air supply to each of the chambers and of the amount of auxiliary heat introduced therein is controlled automatically in accordance with the temperature of the gases leaving the primary combustion chamber, or the temperature of the catalyst bed, or a combination of those temperatures.

The foregoing arrangement results in a predetermined flow of primary air to selected locations in the primary combustion chamber that will result in optimum gasification and combustion of the waste therein. In addition, the auxiliary heating means in the primary combustion chamber not only ignite the combustible waste but also dry it out if wet and at the same time generate volatile gases for subsequent oxidation in the catalyst bed. The auxiliary heating means in the secondary combustion chamber assure that the catalyst bed will always be kept at a sufficiently elevated temperature to activate the catalyst, so that the products of primary gasification and combustion never pass through the catalyst bed when the temperature is lower than that required for effective use of the catalyst.

Referring to the drawings, the primary combustion chamber is indicated generally by the numeral 1. It includes an inner jacket 2, preferably of steel, an outer jacket 3, and insulating material 4 between the two jackets. A removable charging lid 5, provided with a sealing gasket 6, at the top of the chamber permits the introduction of waste material to be incinerated. An ash door 7, also provided with a sealing gasket, gives access to the bottom of the chamber for the removal of ashes. An air supply duct 8 extends through the wall of the primary combustion chamber and may connect to hollow grate bars 9, which discharge the air into the chamber through one or more openings 11. An adjustable, solenoid-operated valve 12 in the inlet of the air duct controls the amount of primary air passing into the chamber. Heating means, in the form of a heating element 13, preferably of the electrical resistance type, rests on the grate bars. A combustible charge 14 is supported by both the heating element and the grate bars. Alternatively, the grate bars may be solid, serving only to support the charge; and the air duct is then provided with a single outlet (preferably located adjacent to heater 13.

Volatile components of the combustible waste and gases resulting from its combustion pass out of the primary combustion chamber through a flue 16 to the lower end of a secondary combustion chamber 17, having a wall structure similar to that described for the primary combustion chamber. A secondary air duct 18, with an adjustable, solenoid-operated valve 19 and its inlet end, permits room air to be mixed with the flue gases before the latter are introduced into the secondary combustion chamber. That chamber contains a permeable bed of suitable catalyst material 21 resting on a grating 22. The catalyst may be of any suitable type that is effective at relatively low temperatures to oxidize the flue gases coming from the primary combustion chamber; for example, the catalyst may be in the form of a coating of platinum on the surface of a suitable carrier, such as ceramic pellets, or it may consist of pellets of vanadium pentoxide. A bed of inert refractory granules 23 may be supported on a grating 24 on top of the catalyst bed to contain the latter in place. Immediately below the catalyst bed is an auxiliary heating element 25, preferably of the electrical resistance type. A venting flue 26 leads the ultimate products of combustion that have passed through the catalyst bed to an exhaust fan 27, driven by an electric motor 28. An adjustable damper 29 may be provided in the vent flue to admit cold air for cooling the flue gases before they reach the fan and to help con-

trol the degree of negative pressure in the system, and thereby the flow of primary and secondary air. The fan discharges the gases through a vent pipe 31, which leads them to the open air.

Except for the air supply ducts 8 and 18, the damper 29, and the vent pipe 31, the system described is airtight when the charging lid 5 and the ash door 7 are closed. The term "airtight," as used herein, means that degree of sealing between the inside and outside of the system that will not only prevent any substantial amount of air from entering the system (except through the air ducts expressly provided for that purpose) when the chamber is subjected to negative pressure during its normal operation, but also prevent any perceptible escape of smoke or gas from the system at the end of an incinerating cycle when the exhaust fan is turned off and there exists a positive thermal pressure in the upper part of the primary combustion chamber due to the temperature gradient therein. These considerations are particularly applicable where the charging door is located, as shown in FIG. 1, near the top of the primary chamber, i.e., above the level of atmospheric pressure. On the other hand, if the charging door is located below said level, no problem of leakage out of the chamber will be encountered. It will generally be more convenient, however, to provide a charging door in the upper part of small, domestic type incinerators and to limit the lower placed charging doors to commercial installations as described later herein with reference to FIG. 4.

In large installations, and also in some cases in small ones, it may be desirable to provide a rabble 33 in the primary combustion chamber for stirring the waste material to increase the rate of combustion. Such a rabble may take the form of a rotatable rod 34, mounted on a vertical shaft 36 that extends through the bottom of the primary combustion chamber. The shaft may be rotated slowly by any suitable means (not shown).

The electrical control elements include a thermostat 41 responsive to the temperature of the flue gases leaving the primary chamber. The temperature of the catalyst bed is controlled within a predetermined range by a pair of thermostats 42 and 43. The temperature responsive elements of these thermostats are positioned in an air flow chamber 44, which is connected to one end of an air inlet tube 45. The latter has an inlet 46 open to the atmosphere and a portion of the tube is embedded in the layers of the catalyst bed. An outlet tube 47 has one end also connected to chamber 44 and its other end to the vent flue 26 on the inlet side of the exhaust fan. A continuous flow of air accordingly passes through chamber 44, the temperature of this air being proportional to but lower than the temperature of the catalyst bed. This arrangement permits the use of a relatively cheap, low temperature thermostat. Of course, high temperature thermostats may be used, in which case their sensing elements are preferably inserted directly in the catalyst bed.

The operation of the apparatus will be described in connection with FIG. 3, showing the electrical circuit connections between the various control elements. After the primary chamber has been charged with waste material and the charge opening is closed, switch 51 in the main electrical circuit is closed. This switch may be a manual off-and-on switch or a time switch that remains closed for a predetermined period, corresponding to the length of the desired incinerating cycle. Current then flows from a suitable source 52 through conductors 53 and 54 to start the fan motor 28, putting the system under negative pressure. Initially, valve 19 controlling the secondary air supply is in its normal, partly opened position; and valve 12 controlling the primary air supply is in its normal open position. Current also flows to heating element 25 through normally closed contact 42*a* of thermostat 42, which is responsive to the temperature of the catalyst bed. When the temperature of the lower layers of the catalyst have been raised by heater 25 to the level where the catalyst become active (usually between 600° and 900° F.), thermostat 42 opens contact 42*a* to turn off heater 25 and at the same time closes contact 42*b* to energize coil 56 of a holding relay 57. Switch arm 58 of that relay then closes to complete an independent circuit to the coil through conductors 53 and 54, so that relay 57 thereafter remains energized until switch 51 is opened at the end of the incinerating cycle. The closing of switch arm 58 also completes a circuit to heating element 13 in the primary chamber through normally closed contact 41*a* of thermostat 41, which is responsive to the temperature of the gases in the flue between the two chambers. In other words, the primary heater 13 is not turned on until the lower layers of the catalyst have been raised to the temperature at which they are activated, so that any volatile gases given off by the combustible waste and the products of its combustion will be completely oxidized in the catalyst bed. When the temperature of the flue gases leaving the primary chamber has risen to a predetermined level, normally indicating that the charge has been ignited and that its combustion is self-sustaining, thermostat 41 opens contact 41*a* to open the circuit to heater 13. In case the charge in the primary chamber is not in a condition for combustion to be self-sustaining, as for example, if the charge or a portion of it is wet, heater 13 will be turned on again when the temperature of the flue gases between the chambers falls low enough to close contact 41*a* of thermostat 41. Once holding relay 57 has been initially energized, the current to heater 13 is controlled solely by thermostat 41. It has been found generally desirable to maintain the temperature of the flue gases leaving the primary chamber between 200° and 500° F., but higher temperatures can be maintained if desired.

The temperature of the catalyst bed is maintained within a predetermined range by thermostats 42 and 43. A satisfactory range for the type of catalyst referred to was found to be between 900° and 1500° F. As already indicated, thermostat 42 controls the initial operation of the primary heater 13 and also the operation of heating element 25 beneath the catalyst bed, closing the latter heating circuit whenever the temperature of the bed falls below the predetermined minimum and opening that circuit when the temperature rises above that minimum. If desired, the heat from heating element 25 may be supplemented by adding to the flue gases entering the secondary chamber an auxiliary stream of fuel gas, or other oxidizable gas, which will give up its potential heat on oxidation to the catalyst bed. The supply of this gas would be regulated by a valve (not shown) controlled by thermostat 42. To prevent an excessive rise in the catalyst temperature, for example, above 1500° F., thermostat 43 controls the amount of primary and secondary air admitted to the system. If the temperature of the catalyst rises above a predetermined maximum, normally open contact 43*a* of that thermostat is closed, supplying current to solenoids 59 and 61. Solenoid 59 when energized actuates valve 12 in the primary air duct to decrease or entirely shut off the flow of primary air. Solenoid 61 when energized opens valve 19 to its fully open position in the secondary air duct. Those valves return to their normal positions under the urging of springs (not shown) when the solenoids are deenergized. The combined effect of their operation is to slow down or completely halt further combustion in the primary chamber, thereby lowering the temperature of the flue gases, and at the same time to dilute those gases with additional air before they reach the catalyst bed in the secondary combustion chamber. Simultaneous operation of both valves, accordingly, quickly brings the temperature of the catalyst bed back within the desired range, whereupon thermostat 43 returns to its normal position to deenergize solenoids 59 and 61. Under some circumstances, the maximum temperature of the catalyst can be effectively controlled if thermostat 43 actuates only one of the air valves 12 or 19. Of course, the normal position of each of those valves may be inde-

pendently adjusted to give the right amount of primary and secondary air to maintain normal combustion and catalytic oxidation at an optimum level.

Oxidation of gases in the catalyst bed will depend upon the nature and amount of the catalyst used, and on the dimensions and temperature of the bed. Each layer of catalyst that is at or above the minimum activation temperature contributes to the oxidation reaction. Initially, when the temperature of the lowermost layers of catalyst has been raised by heater **25** to above the minimum activation temperature, oxidation of the flue gases occurs primarily in that preheated zone at the entrance to the bed. After heater **25** is turned off, this zone tends gradually to cool to the temperature of the entering gas mixture, which in the early stages of the incineration process may be relatively low. Accordingly, in this initial period there may be an absence of temperature equilibrium in the catalyst bed, and as a result the activated oxidation zone tends to migrate through the bed in the direction of gas flow. This is due to the fact that the entering gases cool, and thereby inactivate, the bottom layers of catalyst but at the same time are preheated to promote catalytic oxidation in the upper portions of the bed. However, whenever the lower layers of the bed are inactivated by this cooling process, heater **25** is turned on by thermostat **42**, and equilibrium is restored. Of course, the heat given off by oxidation of the unoxidized flue gases in the catalyst bed also contribute to raising the temperature of that bed to or above the minimum temperature at which the catalyst is activated.

An incinerator constructed in accordance with this disclosure had a primary chamber of approximately 2 cubic feet capacity. The heater for drying and igniting the waste had a capacity of 1800 watts, which was found adequate to dry out wet garbage and rubbish and to ignite it in a reasonable period of time. The primary air flow was about one cubic foot per minute (ranging usually between ½ and 1½ c.f.m.). The secondary or catalyst-containing chamber was a cylindrical space, about 6 inches in diameter and about 8 inches high. The heater near the bottom had a capacity of 1500 watts. The catalyst was in granular form, composed of, approximately, 1/16-inch diameter fragments, 1½ pounds of which was found suitable for the purpose in hand. This provided a bed of catalyst about 1¾ inches in depth. Secondary air was admitted to the system at a normal rate of 1 to 3 cubic feed per minute, and averaging about 2½ c.f.m., which was found to be a good value in relation to the rates of combustion normally obtained with this particular assembly and in relation to the dimensions of the catalyst bed. Thus, the total flow of the mixture of primary flue gas and secondary air approximated 3½ c.f.m. through the catalyst bed during normal operation. At this rate, the secondary air inlet was only partly open, so that the flow of secondary air could be increased if the catalyst bed became overheated. The pressure drop through the system under the above conditions amounted to about ½ inch of water. The exhaust fan used had sufficient capacity to permit bleeding in room air just ahead of the fan at a rate of approximately 50 c.f.m., to mix with and cool the hot stream of flue gases before they entered the fan, and so avoid any mechanical problems that might otherwise be encountered due to excessive gas temperatures passing through the fan.

The rate of combustion was measured by analysis of flue gases from the primary chamber and from the secondary chamber. The accompanying table presents calculated results from one run, in which the combustion rate is arbitrarily expressed in terms of cellulose, calculated from CO_2 analyses. Of particular interest are the figures in the last column indicating that two-thirds of the total combustion occurs in the catalyst bed. This illustrates the fundamental importance of the secondary combustion process.

Rate of Combustion in Primary and Secondary Combustion Chambers in Terms of Cellulose ($C_6H_{10}O_5$) *Calculated from* CO_2 *Gas Analyses*

CHARGE—3 LBS. DRY LOOSE NEWSPAPER

[Primary air 1 c.f.m.; secondary air 2.5 c.f.m.]

Time Period, Mins. from Start	Overall Combustion Rate, lbs./hr.	Percent of Total Combustion in Secondary Chamber
1–3	0.68	71
4–9	1.72	66
10–13	1.61	69
14–19	1.72	55
20–26	2.54	71
27–30	2.58	65
31–40	2.39	62
41–46	1.83	62
65–70	1.05	46
78–84	0.90	12
88–92	0.82	40

In FIGS. 4–6 are shown a modification of the apparatus described above, which will be found most useful in commercial installations, where it is necessary to handle a large volume of refuse with maximum economy and efficiency.

The modified apparatus is in general similar to that already described. The primary combustion chamber **100** is provided with a charging door **101** in its side. The charge is supported within the chamber on hollow perforated grate bars **102**, on which rest electric heating elements **103**. The ashes of combustion are discharged below the grate bars into hoppers **104**, which can be emptied when required. The primary air supply is provided by an inlet pipe **106** connected to the hollow grate bars; and a valve **107**, activated by a solenoid **108**, is adapted to assume a fully opened or closed position to control the supply of primary air. As an alternative to the arrangement shown in FIG. 1, in which the primary air was drawn into the chamber by the negative pressure induced therein by an exhaust fan, one can use a blower **109** at the primary air inlet in conjunction with an exhaust fan, to decrease the negative pressure, and the attendant chance of air leakage, without decreasing the amount of air flowing through the chamber. In such case, it is desirable to provide an auxiliary valve **110** in the air inlet pipe that is responsive to the pressure inside the primary chamber, for example, to increase the flow of air whenever the negative pressure in the chamber exceeds a given amount, or to decrease the supply of primary air whenever the pressure in the chamber rises above a predetermined maximum that might cause outward leakage. The pressure responsive valve **110** should preferably be adjusted to balance the negative pressure induced by the exhaust fan and the positive pressure produced by blower to maintain a small net negative pressure (e.g. 0.01 inch of water) in the primary chamber. Such an arrangement will minimize any leakage into the chamber; but, if desired, some leakage of outside air around the charging door **101** can be permitted because this door is in the lower part of the chamber below the level of neutral pressure therein and there will be no tendency, for the reasons stated earlier herein, for outward leakage of gases due to thermal pressure. Accordingly, 5 to 10% of the primary air may be allowed to enter the chamber around this door, the balance being supplied by blower **109**. The air entering around the door will be delivered reasonably adjacent to the heating elements **103**.

At the back of the primary chamber is a baffle **111**, over which the flue gases pass to an outlet flue **112**, at the top of which the flue gases pass either through a flue throat **113** or through a heat exchanger **114**. The latter is provided with pipes **115**, through which passes cooling air from a blower **116**, in heat exchange relation to the flue gases entering the heat exchanger. The path followed by the flue gases is determined by the position of

a damper valve 117, pivotally mounted above a partition member 118 separating the flue throat and the heat exchanger. This movable damper is normally in the position shown in solid lines in FIG. 4, so as to direct the gases through the flue throat. It may be moved to the position shown in broken lines by a solenoid 119, to direct those gases through the heat exchanger. In either case, the flue gases pass through the damper opening to a flue 120, where they are mixed with secondary air from inlet pipe 121, which is provided with a valve 122 activated by a solenoid 123 to assume a partly open (normal) or a fully opened position. The mixture of flue gases and secondary air then passes through the secondary combustion chamber 124 with its catalyst bed 126 and the fully oxidized gases are vented to the atmosphere by an exhaust fan 128. The secondary combustion chamber is in all respects, except size, similar to that described in FIG. 1, with a heating element 131 and thermostatic controls 132 and 133, the latter being responsive to the temperature of the catalyst bed. A damper 136 permits the addition of outside air to the flue gases leaving the secondary combustion chamber before they enter the exhaust fan.

A thermostat 137 in flue 120 performs the same function as thermostat 41 in FIG. 1, i.e., controls the heating elements 103 in the primary chamber. In addition, thermostat 138, also in flue 120, controls the operation of damper valve 117 through solenoid 119. In flue 112 is provided a damper 139, actuated by a solenoid 141, to assume a fully open or fully closed position, to prevent in the latter position an inflow of air to the primary chamber around the charging door 101 when the control system dictates that the primary combustion process be interrupted.

The various controls that have been referred to are interconnected in an electrical circuit shown in FIG. 6. This circuit, for convenience, is shown as a three-wire, 220 volt system, with line conductors 150 and 151 and a neutral or ground conductor 152. The line conductors are connected to a three-wire current source 153 by a switch 154. The various thermostatically operated switches and relay switches are shown in FIG. 6 in their non-energized positions. At the beginning of the incinerating cycle, main switch 154 is closed and current flows through conductors 151 and 152 to the exhaust fan motor 156. It also passes through normally closed switches 157 and 158 of a relay 159 to energize motor 161 of the primary air blower 109. Current from conductors 151 and 152 energizes solenoids 108 and 141 to fully open primary air valve 107 and damper 139 in flue 112, and also energize solenoid 123 to partially open secondary air valve 122. Current also passes through normally closed switch 132*a* of thermostat 132 adjacent the catalyst bed in the secondary combustion chamber to energize a relay 162. Switch 132*a* is closed whenever the temperature in the catalyst bed is below a predetermined figure, such as 900° F. When relay 162 is energized, its contacts 162*a*, *b*, and *c* move from the positions shown in the drawings to their energized positions, in which a 220 volt circuit is completed to the catalyst heater 131 through contact 162*c* and line conductors 150 and 151. When this heater has raised the temperature of the catalyst bed to its minimum activated temperature, switch 132*a* opens to deenergize relay 162, the contacts of which return to the positions shown in FIG. 6. The catalyst heater 131 is now connected in a 110 volt circuit provided by conductors 151 and 152 through contact 162*a*. In other words, the catalyst heater continues to operate at half the previous voltage. When relay 162 is deenergized, current also flows through closed contact 162*b* from line conductor 151 through the coil of a holding relay 164 and then through a conductor 166 back to line 150. The resulting energization of relay 164 closes its contact 164*a*, which locks the relay into an energizing circuit through conductor 167 that is connected to line 151, so that the relay will remain energized regardless of the later opening of contact 162*b*. While relay 164 is energized, the heating element 103 in the primary combustion chamber will be connected in a 220 volt circuit through switch 137*a* of thermostat 137, switch 137*a* being closed so long as the temperature of the flue gases in flue 120 is below some predetermined figure, such as 300° F. As current passes through heating element 103, the charge in the primary combustion chamber is heated until it is finally ignited. Combustion will then ordinarily go on a self-sustaining basis until the charge is consumed. However, additional heat will be supplied to the catalyst bed and to the charge whenever thermostats 132 and 137 call for additional heat. In the event that combustion proceeds sufficiently rapidly to elevate the temperature of the catalyst bed above some predetermined figure, such as 1500° F., further controls operate to lower the temperature therein. Those controls include thermostat 133, which is responsive to temperatures in the catalyst bed. When the temperature therein rises above 1500° F., switch 133*a* closes to energize relay 159 and open its contacts 157 and 158. The opening of those contacts stops the primary air blower 109; it also deenergizes solenoids 108, 141, and 123 to close respectively primary air valve 107 and flue damper 139 to fully open secondary air valve 122. The opening of contacts 157 and 158 also opens the circuits to relays 162 and 164, and cuts off current to heaters 103 and 131.

The operation of the pivoted damper 117 is controlled by solenoid 119, which is in turn controlled by thermostat 138 in flue 120. Thermostat 138 can be selected to close its switch 138*a* whenever the temperature in flue 120 rises above a predetermined amount, such as 400° F. Upon the closing of this switch, solenoid 119 is energized to move the damper 117 to its broken line position shown in FIG. 4, and to energize motor 170 of blower 116. This diverts the gases leaving flue 112 into the heat exchanger 114, where they are substantially cooled by the air supplied by blower 116 flowing through pipes 115 in heat exchange relation to the flue gases.

In addition, or as an alternative, to extracting heat from the primary flue gases by means of the flue heat exchanger 114, heat can also be extracted therefrom by circulating a cooling fluid, such as air or water, through conduits 172 in heat exchange relation to the inner jacket 173 of the chamber. Such cooling means have the further advantage of making it unnecessary to use fire brick or some other insulated lining in the primary chamber.

As previously stated, one of the principal objects of the present invention is to incinerate combustible wastes at a maximum rate consistent with the optimum use of a given quantity of catalyst. Optimum use signifies maximum operating capacity of the catalyst mass and this in turn means (1) low temperature of the primary flue gases during stages when their gaseous fuel content is high; (2) maximum rate of gas flow through the catalyst bed; and (3) highest permissible exit temperature from that bed. The significance of maintaining a low primary flue gas temperature, i.e., minimum sensible heat content, is in the fact that, other factors being fixed, it permits the generation of maximum potential heat by catalytic oxidation and the removal of that heat from the catalyst mass as sensible heat in the secondary flue gases, within the limits imposed by the maximum allowable temperature specified to protect the catalyst against deterioration.

The primary flue gases are kept at a low temperature in three ways. First, when the combustible charge is one that can be consumed only slowly, e.g., where it has a high moisture content, the auxiliary heat supplied to the primary chamber is interrupted whenever the temperature of the primary flue gases rises above a predetermined level. Second, if the character of the waste material or the operating conditions in the primary chamber is such that the primary flue gas temperature continues to rise in the absence of auxiliary heating in the primary chamber, then heat may be extracted from those flue gases at a controlled rate, as by the heat exchanger

of FIG. 4. Third, the primary flue gases are led from the point of ignition of the waste material (i.e., adjacent the auxiliary heating elements in the primary chamber) through the relatively cooler mass of unconsumed waste before being discharged from the primary chamber. This latter operation serves both to cool the flue gases and helps to gasify unignited portions of the waste material.

Accordingly, the optimum temperature level selected for the primary flue gases is a compromise between two objectives: that of maintaining primary combustion at a high rate to decrease the time of the incinerating cycle, which tends to raise the flue gas temperature, and that of maintaining the flue gas temperature relatively low for maximum economy in the use of a given quantity of catalyst, particularly when the oxidizable constituents of the primary flue gases are high. As a result, during the incinerating stages when the application of auxiliary heat is required in the primary chamber, this heat is supplied in such a way that the sum of the heat generated by the primary combustion and that added from the auxiliary source is substantially constant within the ranges heretofore given, thereby maintaining primary combustion at a maximum rate consistent with the avoidance of high temperatures in the primary flue gases.

It is a feature of this invention that the secondary combustion phase is dominant in the production of heat, while primary combustion is utilized principally to convert a large proportion of the waste material into combustible gases that are oxidized in the secondary combustion chamber, as exemplified in the tubular data given above on the rate and percentage of combustion in that chamber. The apparatus and process herein described permit the operation of the primary combustion chamber in such a way as to gasify the waste material, thereby keeping the gas stream entering the catalyst bed at a low temperature without at any time impairing catalytic oxidation. In this connection, it will generally be found desirable to keep the primary air supply at the minimum necessary to sustain combustion.

By means of controls heretofore described, combustion and volatilization (carbonization) in the primary combustion chamber and combustion in the catalyst bed operate mutually to supplement each other, assisted by the external heat supplied to each at appropriate times and appropriate locations. More particularly, incineration in the primary combustion chamber will at times proceed (*a*) as a process of drying out damp rubbish by supplying auxiliary heat, (*b*) as combustion of a portion of the dried-out charge, or (*c*) carbonization and coincident volatilization or destructive distillation of organic material. Thus when conditions in the primary chamber are favorable for combustion of dried-out waste, destruction will proceed by that mechanism. When conditions in that space are unfavorable for such effective combustion, the carbonization process will prevail and the unconsumed gases therefrom will be destroyed by oxidation in the catalyst bed. In practice the two processes co-exist, one or the other dominating according to conditions respecting space, type of charge, and stage of the incineration cycle.

It will be apparent from the foregoing description that the present invention provides an incinerator and an incinerating process that are ideally suited for domestic and commercial use, in that gasification and combustion, of waste material proceeds efficiently and economically under automatic controls that assure the most effective use of the catalyst and the complete oxidation of the gaseous products of incineration.

According to the provisions of the patent statutes, I have explained the principle of my invention and have illustrated and described what I now consider to represent its best embodiment. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. In an incinerator having a primary combustion chamber for volatalizing and burning waste material and having a secondary combustion chamber provided with a catalyst bed for oxidizing combustible gaseous products issuing from the primary chamber and having separate primary and secondary electrical resistance heaters positioned respectively in the primary and secondary chambers and adapted to be connected to a source of electric power, the improvement comprising a pair of temperature responsive switch means, the first of said switch means being responsive to the temperature of the catalyst bed and assuming a first operative position when that temperature is below a predetermined minimum to connect the secondary heater to the power source for heating the catalyst bed to the desired minimum operating temperature and assuming a second operative position when said temperature is above said minimum to disconnect the secondary heater from said source and at the same time initially connect the primary heater through the second of said switch means to said source, the second switch means being responsive to the temperature of the gases leaving the primary combustion chamber and assuming a closed position so long as the temperature of those gases is below a predetermined maximum, and means operative after the first switch means has initially assumed its second operative position at the beginning of an incinerating cycle to connect the primary heater through the second switch means directly to the power source without passing through the first switch means.

2. Apparatus according to claim 1, in which the first temperature responsive switch means includes a temperature responsive element that is located in a tube having an inlet at one end open to the atmosphere and an outlet at the other end, a portion of the tube being positioned inside the secondary chamber in heat exchange relation to the catalyst bed, means for drawing air through the tube in heat exchange relation to the temperature responsive element within the tube, whereby said element will be directly responsive to the temperature of the air in the tube and the temperature of the latter will be responsive to, but substantially lower than, the temperature of the catalyst bed.

3. Apparatus according to claim 1 that includes the following additional elements: means forming an inlet to the primary chamber for normally admitting thereto an amount of primary air that will promote limited combustion and extensive volatilization of waste material therein, and means for decreasing the amount of air admitted through the inlet when the temperature of the catalyst bed rises above a predetermined maximum to decrease the rate of combustion in the primary chamber and so decrease the aggregate total of sensible heat in the gaseous products and the latent heat of the combustible constituents therein issuing from the primary chamber, thereby to cool the catalyst bed to a desired operating temperature.

4. Apparatus according to claim 1 that includes the following additional elements: means forming an inlet to the secondary chamber for normally admitting thereto an amount of secondary air more than sufficient to oxidize compeltely the combustible constituents in the gaseous products issuing from the primary chamber, and means for increasing the amount of air admitted through the inlet when the temperature of the catalyst bed rises above a predetermined maximum, thereby to cool the catalyst bed to a desired operating temperature.

5. A method of incinerating combustible waste material in an incinerator having a primary chamber for receiving the waste material and a secondary chamber provided with a catalyst bed for oxidizing combustible gaseous products issuing from the primary chamber, said method comprising the following steps: initially electrically heating the catalyst bed to the desired operating temperature, then electrically heating a portion of the

waste material in the primary chamber in the presence of a limited amount of air to promote limited combustion of the waste material, passing the resulting heated gaseous products of combustion through cooler unburned portions of the waste material to volatilize those portions, regulating the amount of electrical heating and the amount of air supplied to the waste material in the primary chamber so that the total sensible heat of the gaseous products issuing from the primary chamber will remain substantially constant at an elevated temperature that is lower than the temperature at which oxidization of its combustible constituents can occur, adding to the gaseous products issuing from the primary chamber a secondary stream of air in an amount more than sufficient to oxidize completely the combustible constituents therein, passing the resulting gaseous mixture in contact with the catalyst bed to promote complete oxidation of its combustible constituents, and decreasing the amount of air supplied to the primary chamber when the temperature of the catalyst bed rises above a predetermined maximum.

6. The method according to claim 5 that also includes the step of extracting suitable heat from the gaseous products issuing from the primary chamber by passing those products in indirect heat exchange relation with a cooling fluid before those products are brought into contact with the catalyst bed.

References Cited in the file of this patent

UNITED STATES PATENTS

1,681,421	McCabe	Aug. 21, 1928
1,891,100	Lauterbur et al.	Dec. 13, 1932
1,995,723	Van Denburg	Mar. 26, 1935
2,121,733	Cottrell	June 21, 1938
2,130,491	Gilliland	Sept. 20, 1938
2,377,356	Miller	June 5, 1945
2,549,517	Persons	Apr. 17, 1951
2,598,067	O'Brien	May 27, 1952
2,625,121	Vanderwerf	Jan. 13, 1953
2,845,882	Bratton	Aug. 5, 1958
2,858,778	Gleasman	Nov. 4, 1958

FOREIGN PATENTS

771,919	Great Britain	Apr. 10, 1957