United States Patent [19]

Kelly

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[45] **Nov. 13, 1973**

[54] **WASTE DISPOSAL**

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[52] **U.S. Cl.** .... **110/8 C,** 110/11, 110/15

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

[58] **Field of Search** .... 110/8 R, 8 C, 11, 110/12, 15, 18 R, 18 C; 34/172

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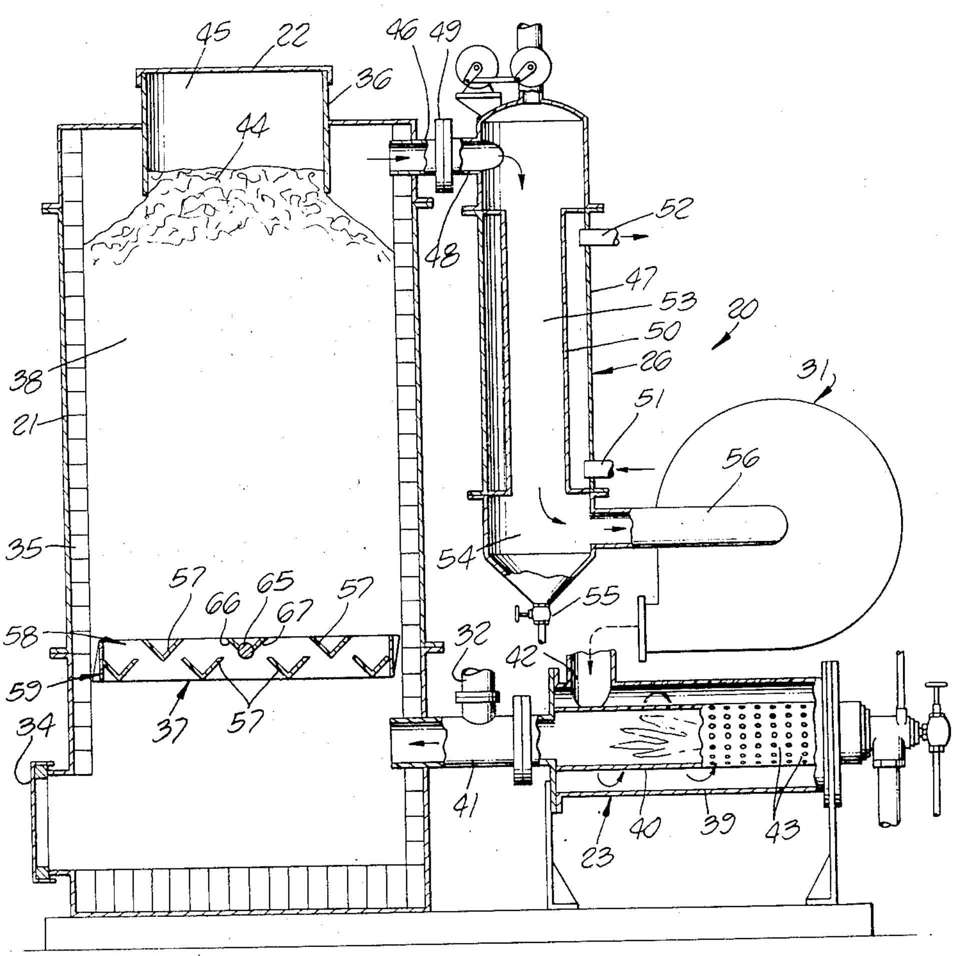
Primary Examiner—Kenneth W. Sprague
Attorney—George J. Netter et al.

[57] **ABSTRACT**

Waste materials to be disposed of are fed into a feed hopper, the outlet of which is directed into a rotary vane feeder to automatically control the feed rate and act as an airlock. Shredded waste material is stacked in a pyrolyzing chamber or column through which hot gases, initially containing no oxygen pass upwardly, driving off volatile material. A condenser reclaims the condensable materials, and the non-condensable gases are recirculated through the combustor and pyrolyzing chamber carbonizing the pyrolyzed waste in the lower reaches of the chamber. After pyrolyzing is completed in the lower portions of the waste material, excess air is admitted into the recirculating hot gas stream. Contact of the oxygen in the excess air with the carbonized material causes substantially immediate combustion. Ash from the combustion zone is then dumped into a discharge chute, or, optionally, removed by traveling scraper bars.

Loading of waste into the described disposal system may be on a batch basis, or, alternatively, by a conveyor as a continuous process, and, in the latter case, a steady state operation is achieved where destructive distillation occurs, in the central regions, while distillation is substantially complete and carbonizing and combustion takes place at the lowermost levels.

18 Claims, 12 Drawing Figures



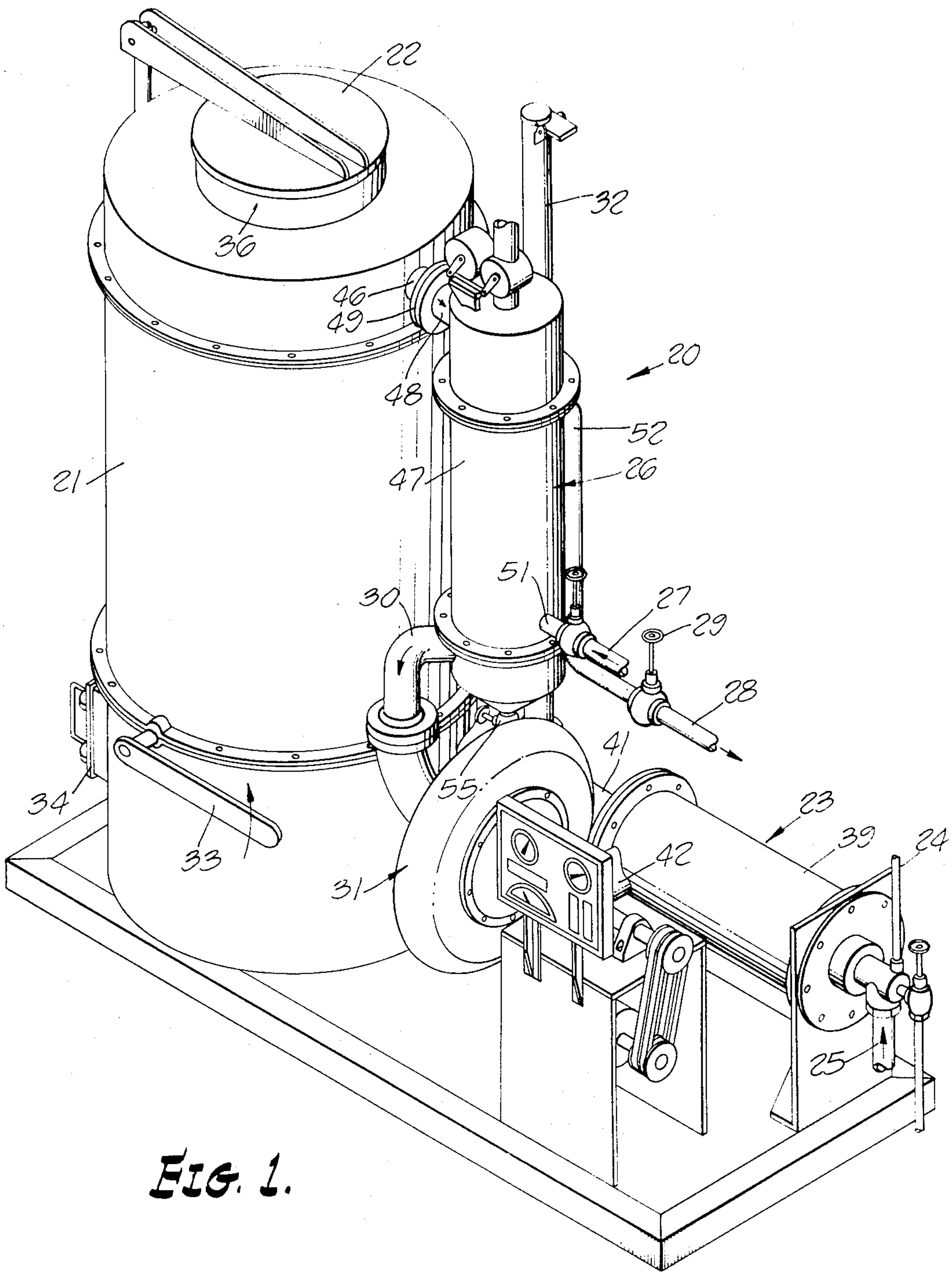

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FIG. 1.

FIG. 2.

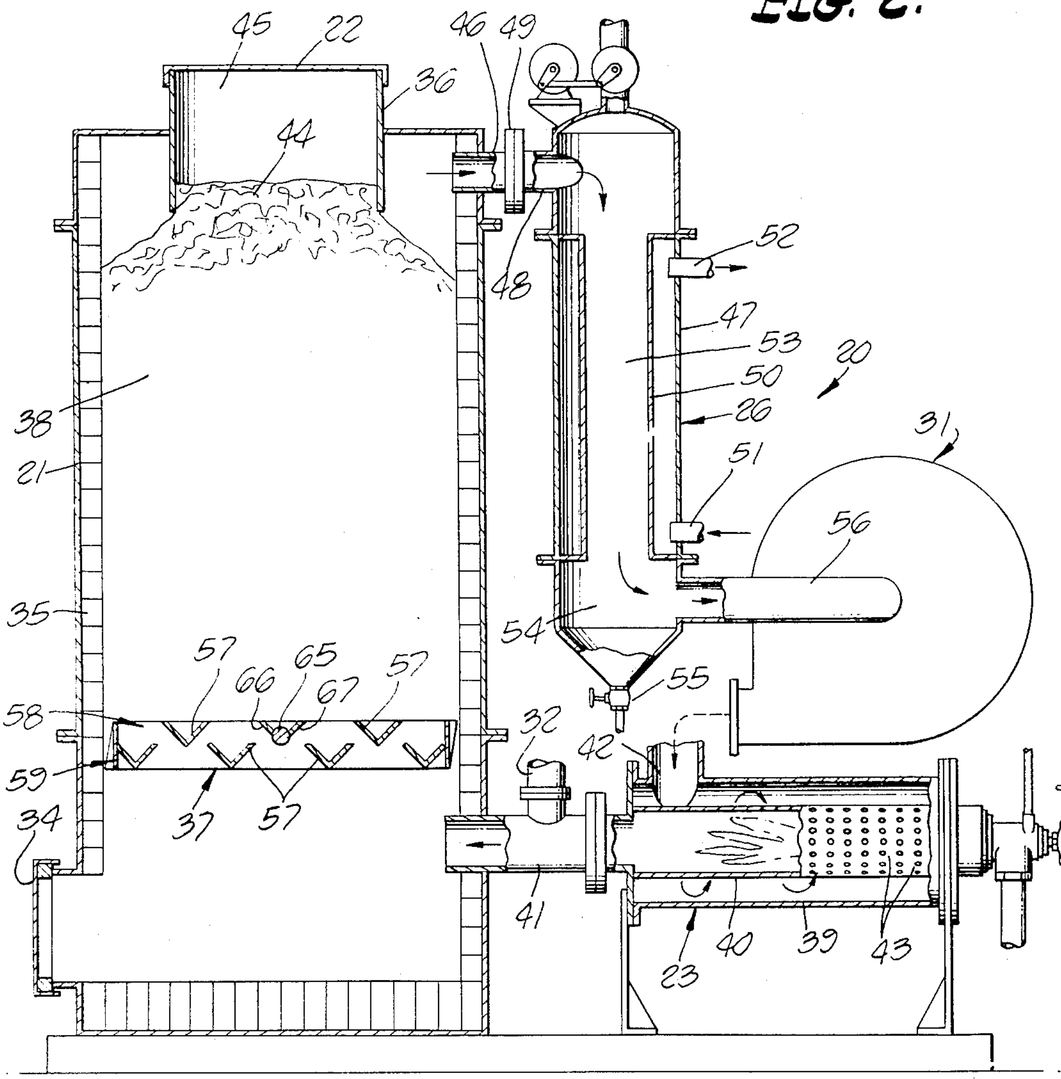
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FIG. 4.

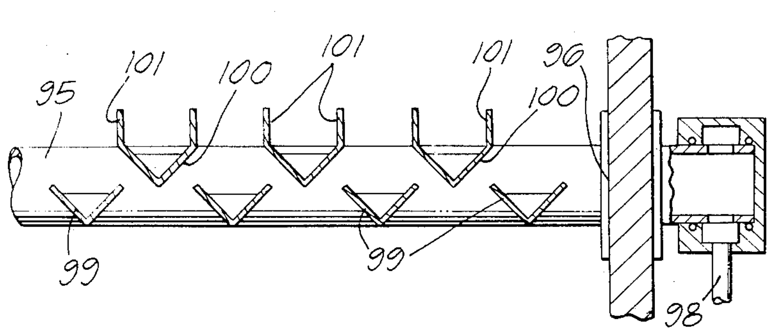
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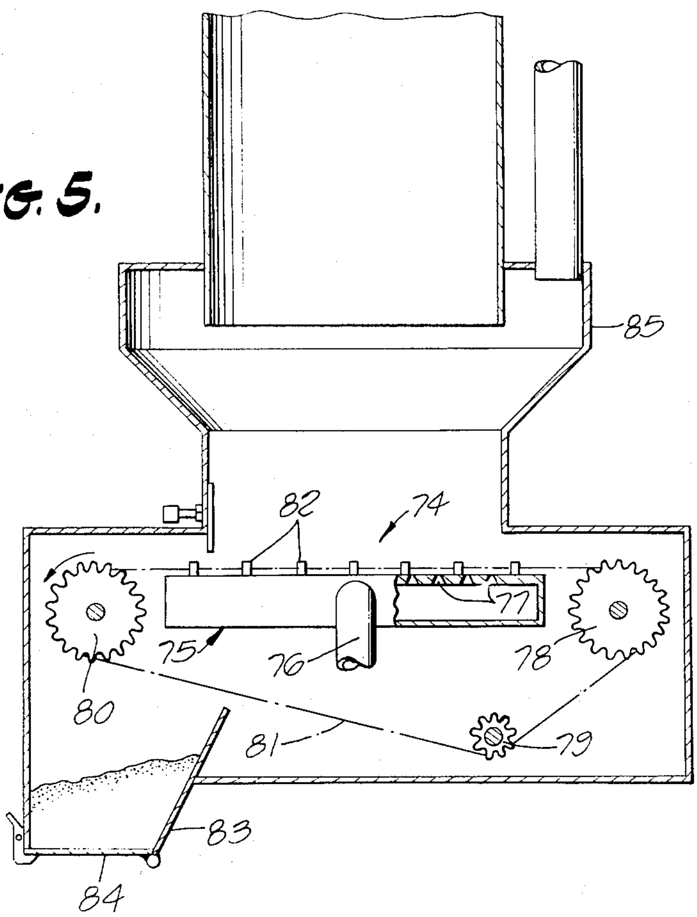
FIG. 5.



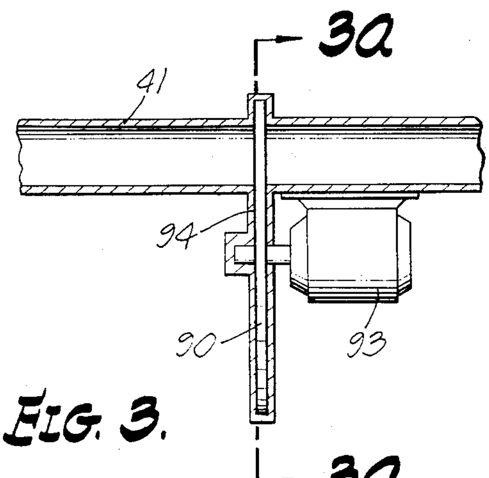


FIG. 3.

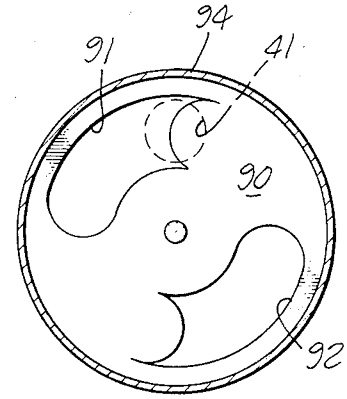


FIG. 3a.

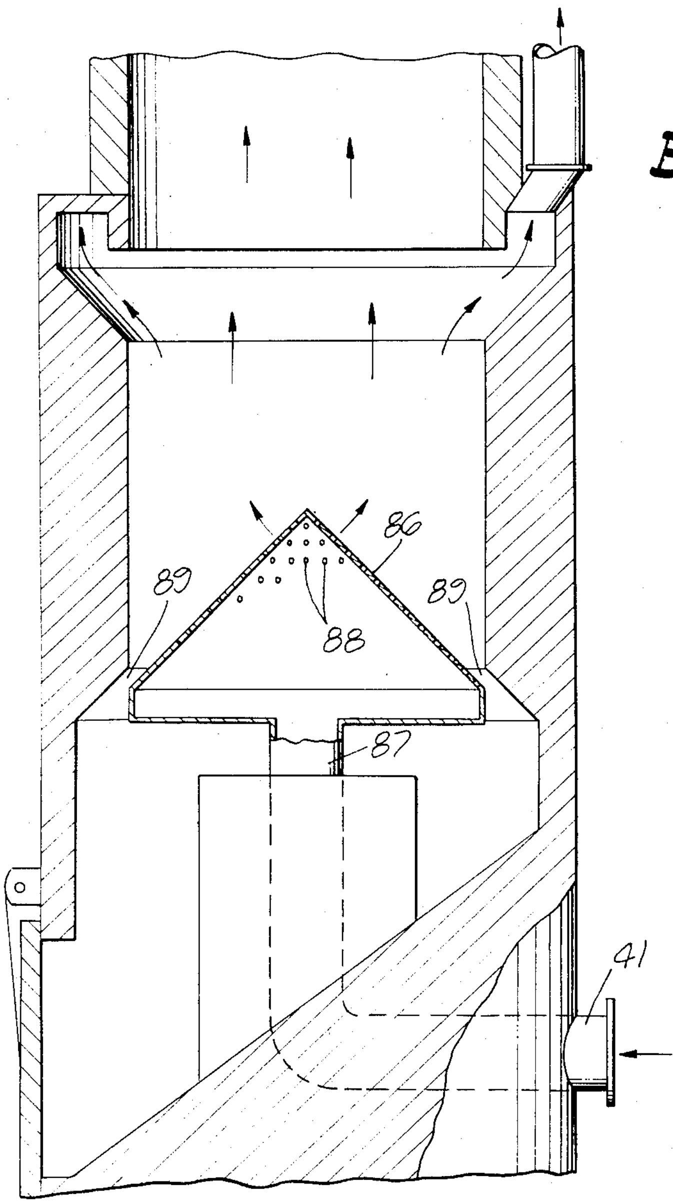


FIG. 6.

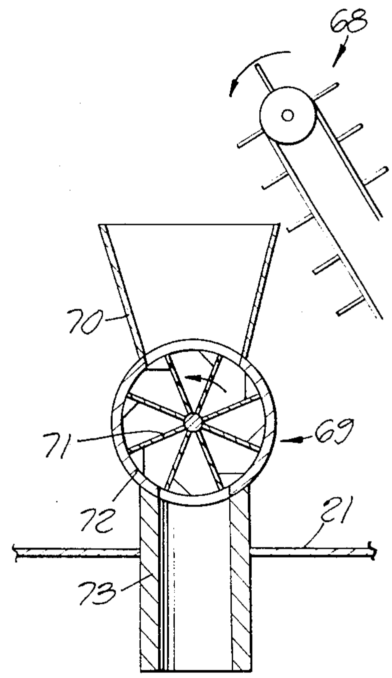


FIG. 8.

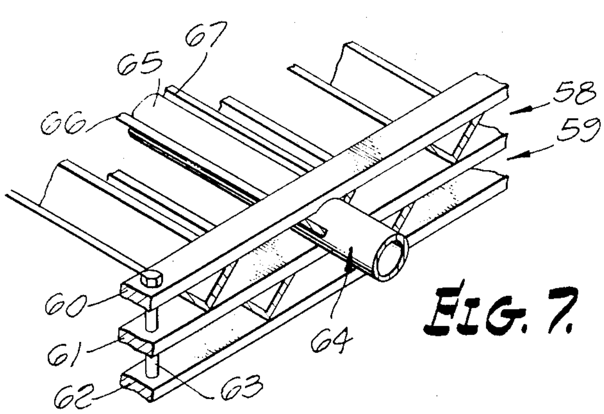


FIG. 7.

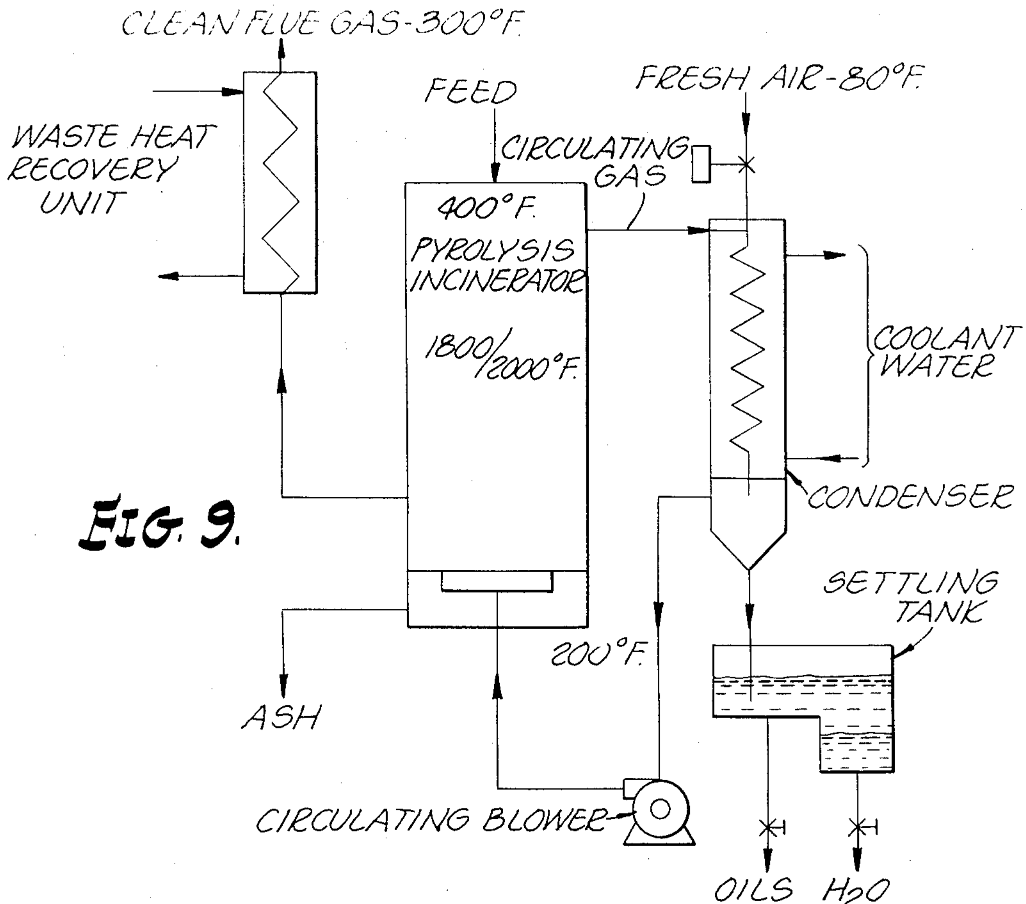

CLEAN FLUE GAS-300°F.
WASTE HEAT RECOVERY UNIT
FEED
CIRCULATING GAS
FRESH AIR-80°F.
400°F.
PYROLYSIS INCINERATOR
1800/2000°F.
COOLANT WATER
CONDENSER
SETTLING TANK
200°F.
ASH
CIRCULATING BLOWER
OILS
H_2O

FIG. 9.

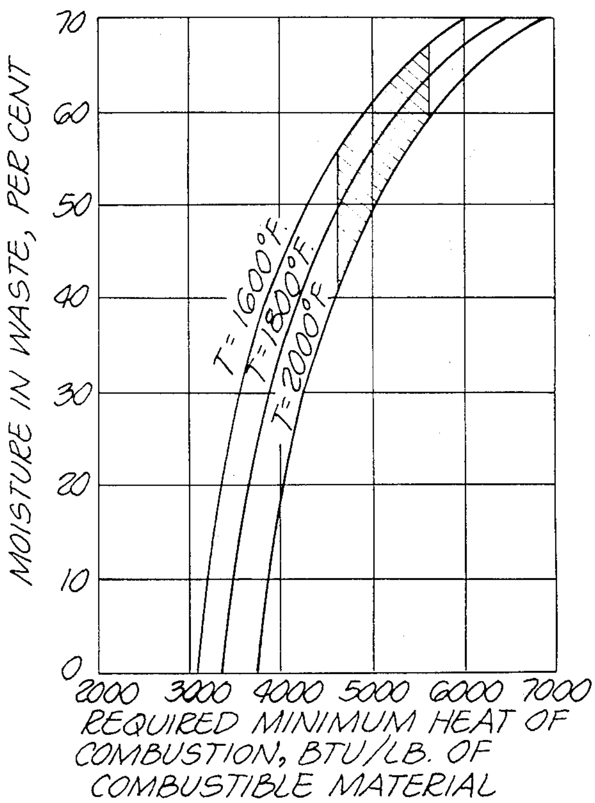
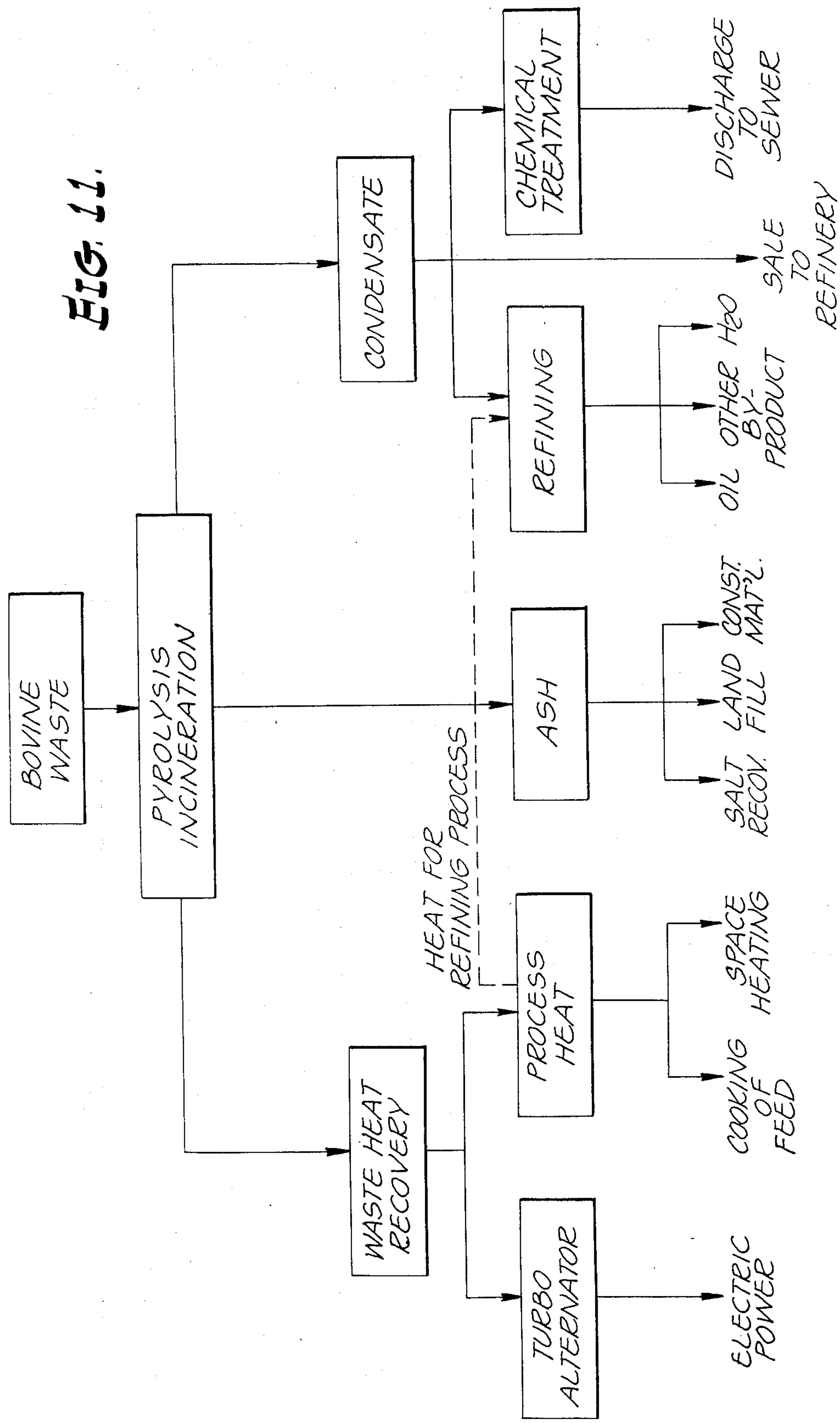

MOISTURE IN WASTE, PER CENT
0
10
20
30
40
50
60
70
T=1600°F.
T=1800°F.
T=2000°F.
2000 3000 4000 5000 6000 7000
REQUIRED MINIMUM HEAT OF COMBUSTION, BTU/LB. OF COMBUSTIBLE MATERIAL

FIG. 10.

FIG. 11.


BOVINE WASTE
PYROLYSIS INCINERATION
CONDENSATE
CHEMICAL TREATMENT
DISCHARGE TO SEWER
SALE TO REFINERY
REFINING
H2O
OTHER BY-PRODUCT
OIL
ASH
CONST. MAT'L.
LAND FILL
SALT RECOV.
HEAT FOR REFINING PROCESS
PROCESS HEAT
SPACE HEATING
COOKING OF FEED
WASTE HEAT RECOVERY
TURBO ALTERNATOR
ELECTRIC POWER

WASTE DISPOSAL

The present invention pertains generally to the disposal of waste materials, and, more particularly, to a system for disposing of waste materials employing both pyrolytic and incineration techniques which provides useful by-products as well as a non-polluting residue.

BACKGROUND OF THE INVENTION

The disposal of waste materials is a matter of ever increasing importance. Not only is the quantity of such materials to be disposed of steadily increasing, but the variety of materials which must be gotten rid of is also increasing at a great rate. Exemplary of homogeneous solid waste materials which occur in large quantities are such things as animal manure, sawdust and tree bark in the lumber industry, and hulls, stalks and other such agricultural wastes. Still other examples of materials which can be easily reduced to a homogeneous mixture are hospital and other institution wastes, and industrial waste materials such as paper, cardboard and plastics. In the system described herein, all of these homogeneous solid wastes can be disposed of with equal effectivity and facility however, as the system is described it will be particularly directed toward the disposal of animal dross and specifically bovine waste.

It is desirable in waste disposal to be able to recycle or obtain useful by-products that may be present in the waste, and produce from the non-usable remainder materials an inert solid material and/or an exhaust gas, neither of which is polluting or contaminating.

The quantity and possible polluting effect of animal wastes presents a particularly difficult problem throughout the world. For example, it is estimated that at this time domestic cattle, sheep, hogs and chickens in the United States annually produce approximately 2 billion tons of waste. Such waste, if not properly handled, treated, or properly disposed of, provides a breeding place for vermin in dusty and dry weather and, in rainy weather, produces a run-off which is polluting. In the past, farming and dairying areas have used manure as fertilizer by spreading it on crop lands and pastures, which still is an excellent recycling step. But this merely transfers the pollution problem from the feedlot to the cropland since, at best, the wastes are only used periodically during the planting cycle, and, of course, the animal waste is being produced continually. In any event, this procedure is no longer practical in most cases primarily because commercial fertilizers have been found to be cheaper and easier to apply.

In addition, where large quantities of, say, live-stock wastes are collected prior to treating or disposal, there is the problem of the unpleasant odor which makes it necessary to only pile up livestock waste in large quantities at a distance from anyone who may be adversely affected.

Open air offensive odor of animal waste materials is not satisfactory in most situations because of the fact that the combustion produces gaseous materials which pollute the atmosphere and also may have an offensiveodor to persons in the area. Also, incineration destroys many useful by-products that could otherwise be obtained.

OBJECTS AND SUMMARY OF THE INVENTION

It is therefore a primary object and aim of this invention to provide a system for disposal of waste material which achieves improved conversion of the waste material into useful by-products, a relatively inert, non-polluting solid residue, and clean exhaust gas.

A further object of the invention is the provision of a waste disposal system particularly adaptable for disposal of animal manure, relying upon an initial pyrolysis followed by incineration.

Another object of the invention is the provision of an animal waste disposal system which is operable on waste materials supplied in a batch or continuously.

Yet another object is the provision of a waste disposal system which can be fabricated at one location and readily transported in sections for assembly on site.

A still further object is the provision of a system as in the above objects which can be operated with a varying feed rate of waste materials.

Another object is the provision of a waste disposal system in which a quantity of pyrolized waste is further reduced to an inert ash by incineration.

A further object is the provision of a waste disposal system as described in the above objects in which the gaseous result of pyrolyzing the waste is condensed and the non-condensable gas portion is recirculated through combustion section where it is reheated, after which a portion is vented to the atmosphere and the remainder passed through the waste to pyrolyze it.

In accordance with the practice of the present invention, waste materials to be disposed of are fed into a feed hopper, the outlet of which is directed into a rotary vane feeder which automatically controls the feed rate and acts as an airlock. Shredded waste material is stacked in a pyrolyzing chamber or column through which hot gas from a combustor, initially containing no oxygen, passes upwardly driving off water vapor and some volatile oils. A condenser reclaims all the condensable materials, and the non-condensable gases are recirculated through the combustor and pyrolyzing chamber carbonizing the pyrolyzed waste in the lower reaches of the chamber.

After initial pyrolyzing to a carbonized material has been completed in the lower portions of the waste material, excess air is admitted into the recirculating hot gas stream. Contact of the oxygen in the excess air with the carbonized material causes substantially immediate combustion to occur. Ash from the combustion zone is then dumped into a discharge chute, or, optionally, removed by traveling scraper bars.

Loading of waste into the described disposal system may be on a batch basis, or, alternatively, by a conveyor as a continuous process. In the latter case, a steady state operation is achieved where destructive distillation of hydrocarbons occurs and oils are driven off in the central regions of the pyrolyzing chamber, while distillation is substantially complete and carbonizing and combustion takes place at the lowermost levels.

Special grate assemblies are used to retain the waste materials in the pyrolyzing zone and in the carbonizing zone the requisite time. In one form for batch operation, the grate assembly includes a number of elongated members having upwardly directed portions which can be rotated as a unit to empty the solid residue. Another version of grate assembly for a continuous process unit includes a foraminous conical body which is, optionally, rotated, reciprocated or pulsed with air through its foramina to maintain movement of the solid residue.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is an overall view of the system of the present invention, illustrating its major parts in cooperative connection.

FIG. 2 is an elevational, sectional view of the apparatus of FIG. 1.

FIG. 3 is a sectional, elevational view of a recirculating gas flow pulsing device for use with a conical grate.

FIG. 3a is a sectional view taken along the line 3a–3a of FIG. 3.

FIG. 4 is a sectional, elevational view of a first embodiment of grate for use in the pyrolyzing chamber of FIGS. 1 and 2.

FIG. 5 is a sectional, elevational view of a traveling scraper bar for removing the solid residue in a continuous manner.

FIG. 6 is a sectional, elevational view of a further form of grate.

FIG. 7 is a perspective, elevational, partially fragmentary view of one end of the grate shown in FIG. 2.

FIG. 8 is a sectional, elevational, partially fragmentary view of a rotary vane feeder for use in the apparatus of the invention.

FIG. 9 is a schematic flow diagram of the pyrolysis/incineration system of the present invention.

FIG. 10 is a graph of the moisture in waste versus required minimum heat of combustion of carbonized waste for the continuous process unit to be self-sustaining at certain specified temperatures of operation.

FIG. 11 is a schematic depiction of operational process flow of this invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

With reference now to the drawings and particularly FIG. 1, the system of the present invention is enumerated generally as at 20 and is seen to include a cylindrical upstanding chamber or column 21, within which pyrolysis, carbonization and incineration takes place, as will be described. Waste material to be disposed of may be added in a batch via a feed door 22 at the upper end of the chamber 21. A combustor 23 initially converts a gas and air mixture supplied by gas line 24 and air line 25 into an oxygen-free hot gas which is supplied to the lower end of the chamber 21 for effecting pyrolysis of the waste materials.

Gases emitted during pyrolysis are taken from the upper end of the chamber 21 and cooled to condense those gases present which can be condensed out in condenser 26 by coolant water supplied via pipe 27. The liquid condensate is provided externally through pipe 28 under the control of a valve 29. Non-condensable gases from the chamber are recirculated through piping 30 and directed to blower 31 and then to the combustor 23 for burning and emission via the flue gas chimney 32.

A crank arm 33 may be provided for manual shaking of the included grate assembly in the chamber 21 to transfer the solid residue to the lowermost regions thereof. Access door 34 serves as a means through which the incinerated ash may be taken from the chamber.

Generally as to operation of the system described to this point, a gas and air mixture on combustion initially produces a high temperature, oxygen-free gas that is directed into the lower end of the chamber or column 21 which has been provided with a quantity of waste material. The high temperature in the absence of oxygen breaks down the waste materials, giving off, in part, a condensable gas which is treated in the condenser 26 to provide a usable by-product distillate. Also, a certain percentage of the gaseous materials will not be condensable and they will be recirculated via piping 30 and the blower 31 for reburning in the combustor 23 to produce a substantially pollutant free flue gas which is emitted into the atmosphere through the chimney means 32.

In addition to the pyrolysis described immediately above, air containing oxygen is drawn into the recirculating gas stream on the suction (low pressure) side of the blower. This excess air is passed through the combustor to the lower reaches of the chamber 21 which institutes incineration or combustion in the already pyrolyzed materials. The pyrolysis and incineration are not accomplished as separate steps, but simultaneously, the different operations being performed on different parts of the enclosed mass 17 of waste materials. That is, on steady state operation being achieved, oxygen-rich hot gases applied to the lower end of the chamber passes through the waste materials incinerating them. There hot gases having lost their oxygen now move upwardly through the added waste materials continuing the pyrolyzing process to drive out condensable (and non-condensable) gases. In this way, a solid residue (ash) will be available in the grate assembly which is shaken into the lower regions for subsequent removal at the access door 34.

Turning now to FIG. 2 which is a side elevational, sectional view of the apparatus of FIG. 1, the pyrolysis chamber 21 is seen to include a generally cylindrical, upstanding hollow structure, the internal walls of which are lined with a suitable heat insulator such as firebrick 35, for example. The upper end of the column, for a batch unit, includes the feed door 22 which is pivotally affixed to the upper end of a feed chute 36 that extends downwardly into the upper end of the chamber 21 a limited extent, forming a recirculating gas collection manifold at the top of the pyrolyzing section. A set of grates 37, to be more particularly described later herein, is located in the lower portion of the chamber and onto which the quantity of waste materials 38 being disposed of rests. The access door 34 is located in the lowermost side wall of the chamber, just below the grates.

The combustor 23 includes an outer cylindrical enclosing wall 39 with a concentrically arranged foraminous tube 40 therewithin. Gas and air are provided to the interior of the tube 40 and burned in conventional manner. The hot gases from the combustor are emitted through the pipe 41 into the chamber 21 immediately below the grate assembly. Recirculated non-condensed gases are added to the interior of the combustor as at 42 in a tangential flow pattern allowing residence time for preheating as they pass to the combustion end of the tube. The openings or foramina 43 of the inner tube 40 are located to maintain a swirling action increasing the residence time of the recirculating gas and thereby insuring mixing, heating, ignition of combustible gases and combustion of smoke and odor causing gases.

The feed chute 36 generally comprises a hollow cylindrical member the lower end of which extends a definite, but limited, amount into the chamber 21. Waste material is fed into the chamber through the feed door

22 for batch operation in such manner as to maintain the upper level 44 thereof above the lower chute end. With this feed arrangement an air space 45 forms above the waste material which serves as an exhaust manifold collecting and directing gases produced during pyrolysis to outlet conduit 46 interconnected with the condenser 26.

The condenser 26 includes an elongated, hollow housing 47 disposed in a generally vertical position. The conduit 46 communicates with the condenser interior via a pipe 48 coupled therewith as at 49. An elongated annular jacket 50 secured to the inner wall surface of housing 47 is provided with circulating cooling water which enters the jacket at 51 and exits therefrom at 52.

Gases from the chamber 21 move into the condenser through pipes 46 and 48 and down the jacket central cavity 53. Liquid condensate collects in the lower part 54 and is removed at the drain fitting 55. Non-condensed gases are taken out the lower side wall of housing 47 through conduit 46 for recirculating by the blower 31 for burning in the combustor 23 and eventual emission into the air from chimney means 32.

The grate assembly 37 according to a first form of the invention includes a plurality of elongated members 57 having a V-shaped cross-section. As shown in FIG. 2 and 7, the members 57 are arranged in two layers 58 and 59, one above the other, where the members of each layer are laterally spaced and the members of one layer are out of registry with the members of the other layer. More particularly, the members 57 are arranged parallel to one another with their common ends unitarily clamped between bars 60, 61 and 62 secured together by threaded member 63, for example.

One of the centrally located V-shaped members enumerated as 64 includes a cylindrical rod 65 with wall members 66 and 67 affixed thereto forming the requisite V-shape. The outer ends of the rod 65 are journaled in the wall of chamber 21 and one end of which is connected to the crank arm 33 for shaking the ash residue into the lower chamber regions for removal.

By virtue of the V-shaped construction of the grate members 57 the waste material is maintained in the central and upper regions of the chamber during operation. In particular, any molten materials produced during operation are entrapped in the V-shaped troughs and held there a sufficient time to complete pyrolysis and incineration. Also, since the members are spaced from one another the hot gases from the combustor can pass therethrough for application onto the waste material batch 38. For batch operation, dumping of the ash residue into the ash removal area is accomplished by shaking or rotating the grate assembly through an angle of 180° or less.

As described to this point, operation has been considered to be on a batch basis, that is, a certain quantity of waste material is treated in the manner of the invention, after which a further quantity or batch of waste material is loaded into the chamber 21 and processed. It is contemplated, however, that operation can be accomplished on a continuous basis and reference is now made to FIG. 8 in this regard. As shown there a traveling conveyor 68 of conventional design carries waste material to be disposed of to a point above the chamber 21 where it is dumped into a rotary-vane feeder 69. The feeder includes an open-ended hopper 70 in to which waste materials from the conveyor 68 are dumped, while the hopper lower end opens onto a power driven rotary vane 71. The housing 72 enclosing the vane 71 also includes a cylindrical conduit 73 which extends downwardly into the chamber 21 similarly to the cylinder 36 of FIG. 2. In operation, the conveyor 68 supplies waste materials to the rotary vane feeder at a sufficient rate to keep the hopper 70 substantially filled which, in turn, insures that there is a substantial air seal through the rotating vane 71.

In addition, for continuous, as opposed to batch operation, it is necessary to remove the solid waste residue or ash continuously. Accordingly, in order to utilize the apparatus of FIGS. 1 and 2 in a continuous manner, the air box in the lower part of the chamber 21 includes combined grate and ash conveying apparatus 74, shown best in FIG. 5. More particularly, an enclosed air box 75 is provided with recirculating gases and feeder air from the blower through fitting 76.

When operated on a continuous basis with certain combustible waste materials of high enough heat value, sufficient heat is produced during incineration of carbonized materials in the lowermost portions of the waste material mass in the chamber 21 to produce an equilibrium, self-sustaining condition. The initial heat source (not shown) could be an externally located combustor similar to 23 (also similarly located in the recirculating gas duct), a combustor incorporated within the air box, or simply ordinary charcoal ignited briquets arranged in a uniform layer on top of the air box to bring the chamber heat up to the requisite value to achieve self-sustaining operation.

If the heat value of the waste material is too low, or has a high moisture content, an external heat source such as the combustor 23 will be required for continuous operation.

The upper surface of the air box 75 includes a plurality of orifices 77 which distribute the hot gases uniformly up through the waste materials for the purposes already described. Each of these orifices are conical shaped, opening out into the air box interior, serving to make the orifices self-cleaning.

Gears 78, 79 and 80 are interconnected with a continuous belt 81 which includes a plurality of transversely arranged, parallel, spaced scraper bars 82 on its outer surface. The gears are driven by a power source (not shown) moving the scraper bars across the upper surface of the air box 75 to scrape or shave off a layer of ash deposited thereon of substantially the thickness of the scraper bars. With the direction of movement shown by the arrow in FIG. 5, the ash layers so removed are deposited in a receptacle portion 83 which can be emptied in any convenient manner such as by unlatching a door 84 and removing manually, or by a conventional rotary vane feeder similar to that used in the waste feed section 71 and 72. The amount of ash removed as each scraper bar passes over the air box is also controlled by a manually positioned baffle plate located at the dumping end of the traveling grate.

It is also important to note that the ash formation at the ends and sides of the air box and lower chamber walls forms an air seal which enhances overall operation.

An exhaust manifold 85 located part way up the column 21 side collects the exhaust gases. Temperature sensors (not shown) may be located in the different zones or sections of the column 21 and used to control the traveling grate speed, and thus the thickness of carbonized material and ash collected between the exhaust manifold and the air box, which, in turn, maintains proper incineration temperature within the waste materials. Only carbonized waste material is incinerated in this part of the column **21** since all smoke and gas producing volatiles have been driven off during pyrolysis. In a very real sense, the external combustor **23** of the batch system has been replaced here by a carbon burning incineration section at the bottom of the mass of waste materials.

As a further example of a grate assembly particularly useful for continuous operation is that shown in FIG. **6**, comprising a hollow, conical member **86** facing upwardly within the chamber **21** and upon which the mass of waste material **38** rests. The lower portion of the conical member **86** includes a vertically extending conduit **87** which is interconnected with the conduit **41** such that the recirculating gases and fresh air from the blower are received within the interior of the conical member and make their way out into the waste materials via a plurality of self-cleaning orifices **88** for the same purposes and operation described in connection with the first described embodiment. Ash flow may be promoted and controlled by rotating the entire grate and air box assembly, producing a grinding action between the outer surface of the conical member **86** and the interior wall of the chamber **21**, thereby causing ash to pass downwardly via the edge openings **89**, for example, into a collection receptacle. Also, of course, the incoming hot gases from the combustor will tend to promote movement of the ash on the surface of the conical member **86**.

To increase the movement of ash induced by gas flow through the conical orifices **88**, this flow may be cyclically interrupted to produce a corresponding pressure pulsing of the waste materials on the grate which promotes ash movement. As shown in FIGS. **3** and **3*a***, pulsing of the gases is accomplished by rotating a valve plate **90**, having a pair of openings **91** and **92** in its edge margin, that is located transversely of and in blocking relation to gas flow in the tube **41**. More particularly, a drive motor **93** revolves the plate **90**, the edge margin of which is received within a suitably dimensioned slotted housing **94** to alternately block and allow transmission of gas flow through the pipe **41**.

As a slightly different mode of operation, the entire grate apparatus of FIG. **6** may be reciprocated vertically either while the grate is rotating as described above, or the reciprocating and rotating may be alternated.

A still further form of grate assembly having particular utility for reprocessing thermal plastics from industrial waste, is that illustrated in FIG. **4**. That is, the depicted system is for batch operation use with thermal plastic wastes or other waste materials which pass through a molten or fluid state during pyrolysis as described. The assembly shown there includes a cylindrical shaker bar tube **95** rotatably journaled in the chamber wall as at **96**. An outer end of the bar extends through the journal and is joined to a swivel end-cap (not shown) by a screw-on collar with appropriate high temperature seals of suitable conventional design. A lever arm **98** is secured to the tube **95** outside the pyrolysis and incineration chamber. The lever is used to shake or rotate the grate assembly as a unit on completion of an incineration to dump the remaining ash into the lower portion of the chamber for removal. A plurality of elongated members **99** of V-shaped cross-section are affixed to the bar **95** at spaced intervals forming a planar arrangement thereof with the V-shaped concavities of each facing upwardly when in the at rest position for supporting the waste materials. A further set of V-shaped elongated members **100** are also affixed to the bar **95** to extend transversely of the bar similarly to members **99** and form a second plane of these members generally parallel to the first plane with each member **100** being located between a pair of members **99**. The members **100** are of similar construction to **99** except that they have further upstanding walls **101** enlarging the concavity volume encompassed thereby. As in the case of the grate assembly of FIG. **2**, the mutually spaced arrangement of the members **100** and **99** permits hot gases to pass therebetween and be uniformly distributed upwardly through the waste materials. At the point where the V-shaped members **100** are affixed to the cylindrical shaker tube **95**, the V-shaped openings conforming to the inner dimensions of members **100** are cut through the tube wall.

During operation, the waste materials rest on the concavities presented by the different V-shaped members to retain the molten or liquefied materials and direct their flow via the V-shaped openings into the shaker tube **95** which, in turn, directs the liquid out of the pyrolyzing chamber into a collection tank or other receptacle. Rotation of the tube **95** by its lever arm dumps ash residue for removal as described in connection with the other emobidments.

With reference now to a flow schematic of the pyrolysis/incineration accomplished by the present invention shown in FIG. **9**, materials fed into the pyrolysis/incinerator are exposed to hot gases from the combustor which brings them, at least in the lower half of the quantity **38**, to a temperature in the range of 1,800° F. to 2,000° F. which converts certain of the solids and all of the liquids contained therein to water vapor and volatile oils for subsequent distillation out in the condenser and separation in a conventional settling tank, for example. The non-condensed gases are then circulated by a blower through the combustor from which a part equal in mass to the combustor fuel gas and air supply is exhausted as clean flue gas while the remainder is circulated again into the pyrolyzing/incinerating chamber. Means of conventional construction may be provided for recovering heat from the flue gas for uses to be described later herein. It is also contemplated that fresh air at approximately room temperature or slightly above (80° F.) may be mixed with the gases coming from the pyrolysis/incineration chamber (approximately 400° F.) and directed through the condenser to assist in cooling the gas to the required lower temperature at which condensation can take place. The excess air admitted into the recirculating gas stream at this point is circulated in the manner already described and thereby supplies the necessary oxygen for incineration of carbonized waste.

FIG. **11** depicts an operational process flow schematic of this invention specific for bovine waste. The excess heat on recovery from the flue gas may be used to drive a turbo alternator, for example, producing electric power, or may also be used for cooking of the cattle feed material, or, if used on a farm, space heating of the barn. The solid residue can be used for land fill, as construction material and has a sufficient salt content such that the recovery thereof may be feasible. As to the liquid condensate, where further refining is required, the recovered heat can be useful in refining the condensate to produce the final by-product. Where refining is not required, the condensate material may be sold to others, as is. Moreover, in the event that the quantities produced are not such as to make utilization of the distilled by-products feasible or desirable, they may be discharged into a sewer, for example.

In accordance with the practice of the present invention, two separate and distinct operations are accomplished in the disposal of waste materials. First, the application of high heat in the absence of oxygen to the waste materials produces destructive distillation followed by combustion of non-condensable gases. Second, the charred waste material is then incinerated, effecting a final reduction of the carbonized waste to relatively inert ash.

The overall principal combustion reaction for animal manure can be expressed generally in the following form:

$$C_6H_{10}O_5 + 6O_2 \rightarrow 6CO_2 + 5H_2O$$

$$\text{By weight: } 1.00 + 1.19 \rightarrow 1.64 + 0.55$$

Based on this equation, with no solid residue remaining, it is indicated that 5.32 pounds of air would be required per pound of dry combustible manure for disposal of dross by the described system.

As brought out earlier, an important advantage of the invention is the provision of clean flue gas which is neither harmful to the ecology nor has an offensive odor. Analysis of flue gas from an actual construction of the invention establishes the following content where water vapor has been condensed out:

Components	Chemical Analysis Percent by Weight
N_2	72.8
CO_2	24.2
Ar	1.7
Misc.	1.3
	100 percent

With the practice of the techniques and use of the apparatus described herein, reduction of animal waste materials into an inert ash residue and clean flue gas of inoffensive odor with condensable products of sufficient value to warrant recovery are provided. No elaborate precipitator or other apparatus are necessary to treat the flue gas. Moreover, the flue gas has a low particulate matter content which is at the present time far lower than that figure published by known government agencies involved in controlling the emission of pollutants into the air. Useful work may also be accomplished through recovery of heat from the flue gas either for performing collateral services or for direct involvement in refining certain condensate by-products of the same waste disposal operation. A high efficient incineration or combustion is achieved since the material is initially dried and charred during the initial pyrolysis. The described apparatus may be easily prefabricated and transported in sections for assembly at a site for use, and may then be broken down again for transmittal to a further use site.

What is claimed is:

1. A method of converting animal waste materials to a non-polluting form, comprising:

forming a single quantity of the waste material into a vertical stack within a chamber;

initially passing hot gases in the absence of oxygen upwardly through the waste material stack for producing progressive pyrolysis of said waste material from the bottom up;

adding oxygen to the hot gases for inducing combustion in at least the lower portions of the waste material stack;

stopping passage of the hot gases through the waste material stack while maintaining the addition of oxygen; and

adding further waste materials to the top of the stack and removing ash residue from the bottom of the stack at respective rates as to maintain a substantially constant quantity of waste materials in said stack and where self-sustaining pyrolysis and combustion of said waste material is obtained.

2. A method as in claim **1**, in which the waste material has its temperature raised to above about 1,800° F.

3. A method as in claim **1**, in which the waste material temperature is raised to within the range of about 1,800°–2,000° F.

4. A method of converting animal dross to an inert non-polluting ash and clean effluent gas, comprising:

supporting a single quantity of said dross formed into a vertical stack in a confined chamber;

heating said supported dross in the absense of oxygen sufficiently to carbonize said dross;

continued heating of the carbonized dross in the presence of oxygen to produce combustion thereof; and

conduiting gaseous material produced during carbonizing and combustion to the external atmosphere from a single point above the stack.

5. A method as in claim **4**, in which there are further provided the steps of cooling the gaseous material given off during carbonizing and combustion of the animal dross to liquefy the condensable gas components, and recirculating the non-condensed gases through the confined chamber where they are heated with the dross and condensed again prior to exhausting to the atmosphere.

6. A method as in claim **4**, in which the quantity of animal dross is supported on a single foraminous surface, and heating is accomplished by passing hot gases upwardly through the foramina and thence through the animal dross.

7. A method as in claim **6**, in which there are provided the further steps of cooling the gaseous material to liquefy the condensable components, intermittently interrupting the non-condensed gaseous material to form a pulsing stream, and recirculating said pulsing stream with said hot gases through the foramina and animal dross.

8. A method as in claim **4**, including the further steps of continuously adding animal dross to the supported quantity and continuously removing ash residue after combustion of said dross at such respective rates as to maintain a relatively constant quantity of dross within the chamber.

9. A system for converting waste materials to a relatively inert, non-polluting form, comprising:

a generally vertically elongate container including a single integral quantity of waste materials in continuous contacting relationship with the container walls, said container having an inlet in the lower portion below the materials and an outlet in the upper portion above the materials;

combustor means providing substantially oxygen-free heated gases connected to the container inlet for heating the waste materials sufficiently to break down the same into gaseous components and a combustible solid remainder;
condenser means connected with the container outlet for liquefying the condensable gaseous components; and
means selectively actuatable to subsequently provide an oxygen containing atmosphere with the heated gases for incinerating the combustible solid remainder.

10. A system as in claim **9**, in which the waste materials rest on a supporting means mounted within the container above the container inlet, said supporting means including a plurality of mutually spaced elongated elements arranged on a common frame, said elements having concave portions upwardly directed for supporting the waste materials, and means connected to the frame and extending outwardly of the container for rotating the frame a limited angular extent to dump solid ash residue into the container lower reaches for removal.

11. A system as in claim **10**, in which said elongated elements are generally V-shaped in transverse cross-section and arranged in at least two layers.

12. A system as in claim **10**, in which the rotating means turns the elements about an axis generally parallel to the elements long dimension.

13. A system as in claim **10**, in which the rotating means turns the elements about an axis transverse to the elements long dimension.

14. A system as in claim **9**, in which the waste materials rest upon a foraminous surface mounted within said container, the heated gases passing upwardly through the foramina to the waste materials.

15. A system as in claim **9**, in which the waste materials are supported by tablelike means mounted within the container across an upper surface of which scraper means are driven to force solid ash therefrom into the container lower reaches for removal.

16. A system as in claim **9**, in which conduit means interconnect the condenser means and container inlet for recirculating non-condensed gaseous components with the heated gases, and means having parts located within the conduit means for pulsing the recirculated non-condensed gaseous components.

17. A process for converting manure to non-polluting ash and gases, which comprises the steps of:
forming a vertically extending column of manure, the entire periphery of which is confined;
passing hot gases up through the full column length which progressively carbonizes the manure, gaseous materials produced thereby passing through all the manure lying above;
collecting the hot gases and gaseous materials from a single region above the column;
condensing the collected gases and gaseous materials to remove condensables;
mixing the noncondensed gases and gaseous materials with air;
passing the mixture of air, gases and gaseous materials upwardly through the manure column to progressively incinerate the carbonized manure;
venting to the atmosphere from the same region above the manure column all gases and gaseous materials remaining after incinerating; and
removing ash from the lowermost part of the column as it becomes fully incinerated, whereby manure located above moves along a gravity path down the column for further progressive carbonizing and incineration.

18. A process as in claim **17**, wherein manure is continuously added to the top of the column and ash is continuously removed from the lowermost parts of the column, producing a continuously downwardly moving column of manure increasingly carbonized and incinerated.

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