

[54] **METHOD AND APPARATUS FOR THE THERMAL REDUCTION OF RUBBER OR PLASTIC MATERIAL**

[76] Inventor: **Kenneth W. Stookey**, 780 Maple Rd., Williamsville, N.Y. 14221

[22] Filed: **Mar. 13, 1972**

[21] Appl. No.: **234,003**

[52] U.S. Cl. **110/8 R, 110/10, 110/118**

[51] Int. Cl. **F23g 7/00**

[58] Field of Search **110/8 R, 8 C, 8 A, 110/18 R, 10, 118**

[56] **References Cited**

UNITED STATES PATENTS

3,495,555	2/1970	Boyd et al.	110/8
3,561,378	2/1971	Fabry	110/8
3,589,313	6/1971	Smith et al.	110/8
2,167,653	8/1939	Holbrook et al.	110/118
3,397,657	8/1968	Tada	110/8

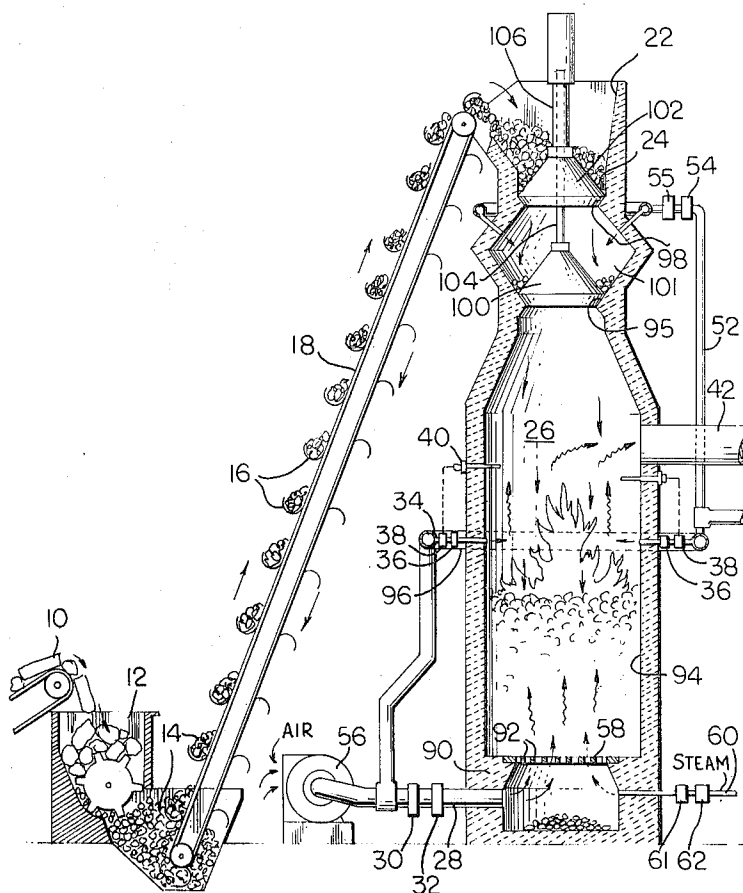
Primary Examiner—Kenneth W. Sprague

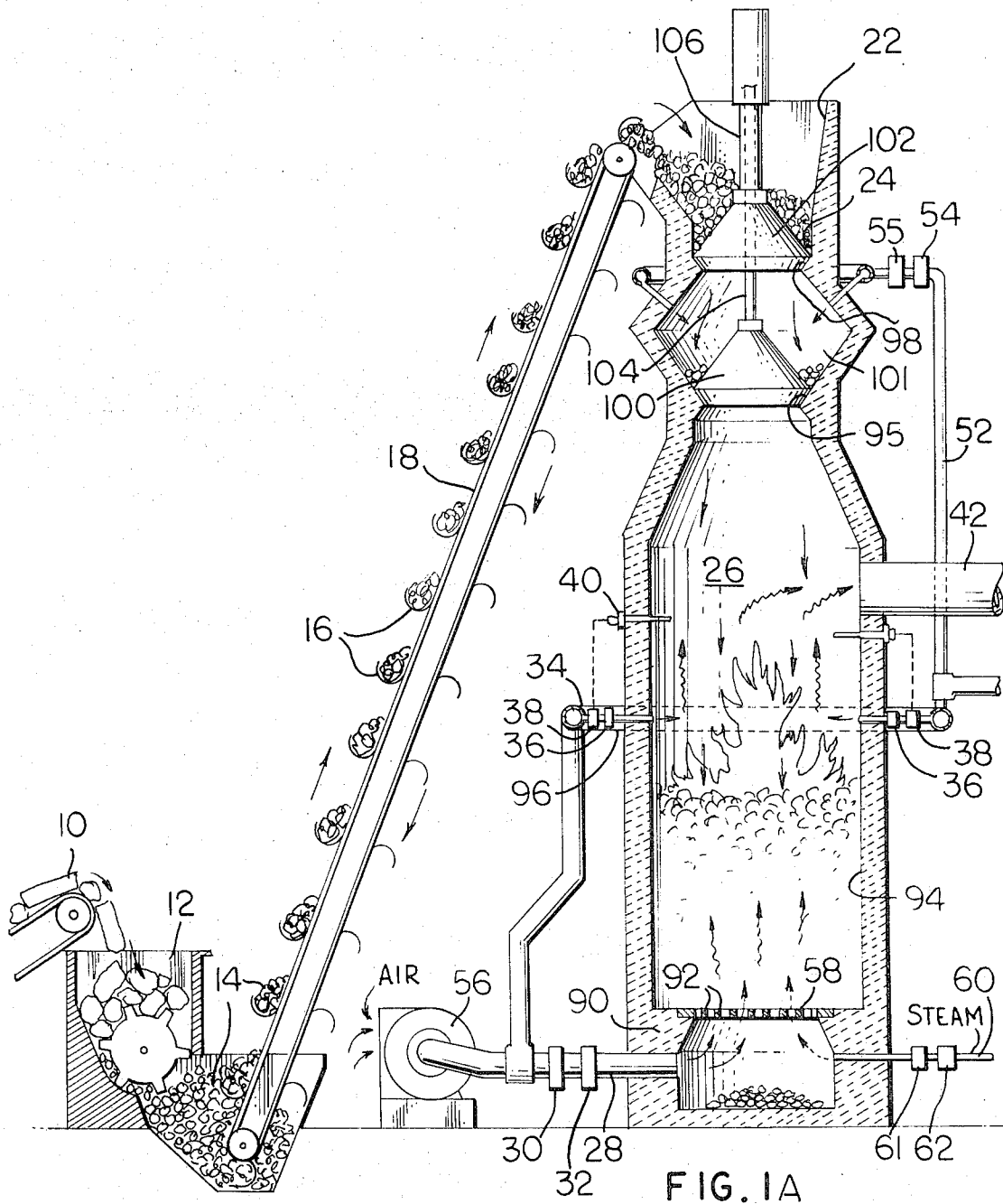
Attorney—Albert L. Jeffers et al.

[57] **ABSTRACT**

A method and apparatus for thermally reducing rubber or plastic materials in which the rubber or plastic material is comminuted to a predetermined size and it is then subjected to primary combustion in the lower portion of a first chamber with the gases and distilled combustible vapors in the upper portion of the first chamber being subjected to secondary combustion and with the still only partially oxidized gases then being conducted to a second chamber and admixed with further air for tertiary combustion and the combustion thereof completed and with these last hot gases being used as the heat input for a boiler, such as a waste heat boiler. Automatic controls are provided to control the temperature in the upper portion of the first mentioned chamber to within predetermined limits and a further control is provided to insure substantially complete combustion in the second mentioned chamber, and with a bare minimum of excess air. This method and apparatus is not suitable for generally municipal waste disposal.

26 Claims, 3 Drawing Figures





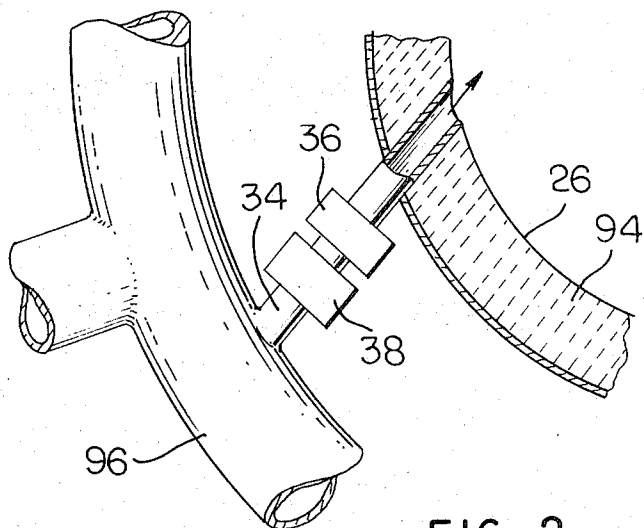


FIG. 2

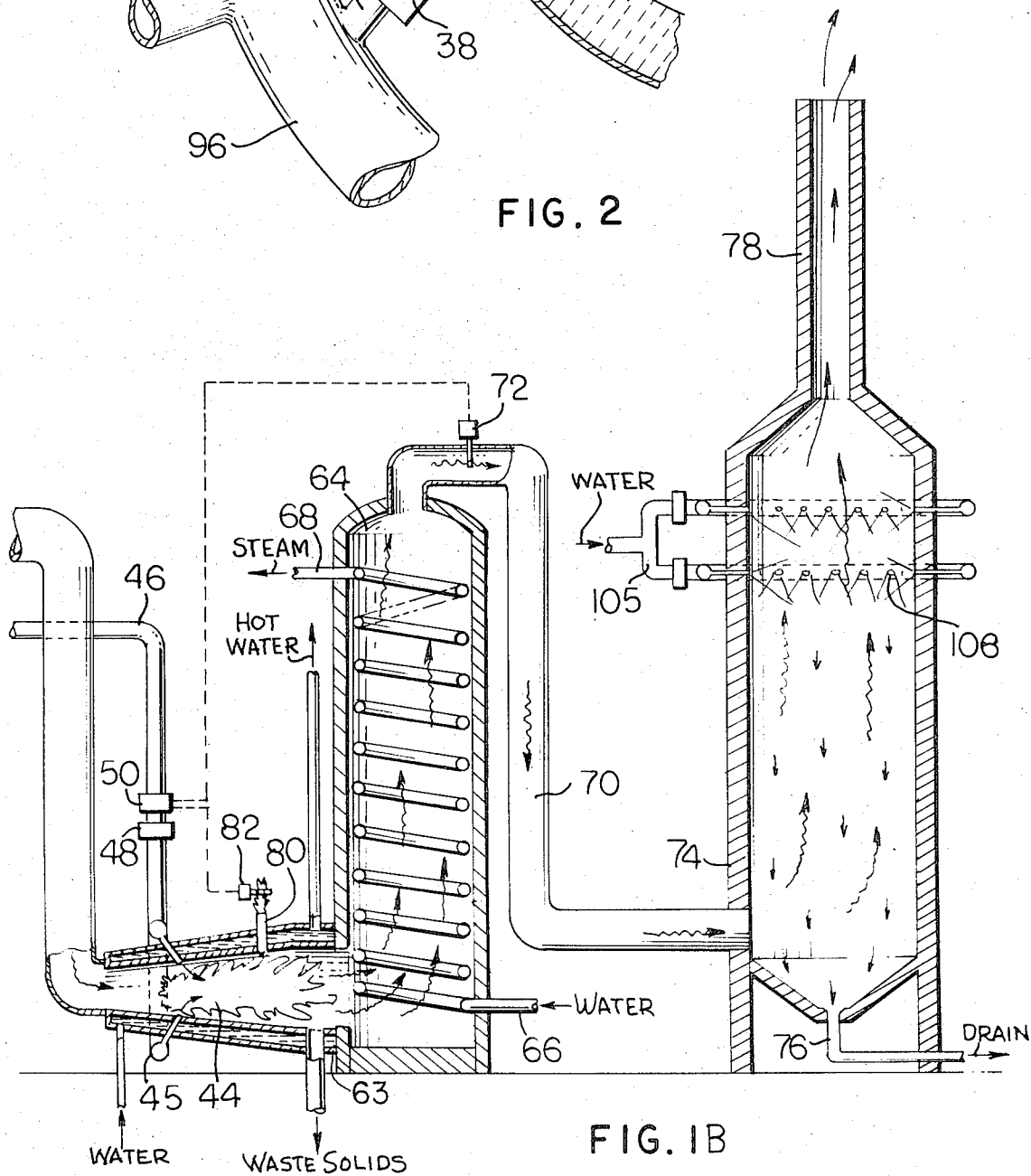


FIG. 1B

METHOD AND APPARATUS FOR THE THERMAL REDUCTION OF RUBBER OR PLASTIC MATERIAL

The present invention is concerned with a method and apparatus for waste disposal by combustion, and especially waste material consisting of, or bearing, plastic or rubber or rubber-like material.

Rubber bearing wastes, such as vehicle tires and the like, present a severe disposal problem. Such wastes are combustible but, heretofore, the combustion has been accompanied by the release of pollutants which makes the conventional combustion processes completely unsatisfactory.

The rubber in rubber bearing wastes is, furthermore, not biodegradable to any substantial degree and, thus, will not break down if left above ground and, if buried in land fill operations, is even more permanent because it is protected from the effect of the sun which, if the rubber bearing waste is left above ground, it will break up at least some of the chemical bonds of the polymers making up the rubber bearing part of the waste. In such land fill operations there is no known time for complete break down of the materials and such have been known to rise to the surface, in time, thus refusing to stay buried.

Some rubber can be recycled to produce secondary rubber products, but only insignificant amounts of the waste rubber can be employed in this manner, and a great deal of the rubber bearing waste is of such a nature that recycling of the rubber portion thereof is uneconomical.

It has been attempted to utilize rubber bearing waste material as a road building material by granulating the waste and incorporating it in asphalt mixes. The grinding of such material to a relatively fine state is quite difficult because of the nature of rubber and the chilling of the material to make it brittle enough to be ground to a fine condition makes the process relatively expensive. Also, the merit of such material in the forming of roads is yet to be established.

Considerable work has been done in respect of the combustion of rubber bearing wastes and the thermal reduction thereof but, heretofore, no particular success has attended these operations because of the air pollutants produced or because of the residue which remains. Rubber, however, has almost as high a heat content as good coal, averaging about 13,000 BTU per pound, and the combustion of rubber without the production of excessive smoke and noxious or toxic gaseous effluents or the production of a troublesome residue, or ash, appears to be a practical direction to take, assuming that the heat content which is released by the combustion process can be captured and used.

With the foregoing in mind, a primary object of the present invention is the provision of a method and apparatus for effecting the thermal conversion of wastes, especially wastes containing rubber or rubber like materials in such a manner as to avoid atmospheric pollution and to reduce to a minimum the residue or ash remaining at the completion of the conversion process.

Another object of the present invention is the provision of a method and apparatus of the nature above referred to which includes controls to maintain predetermined conditions within the processing apparatus for producing the desired results regardless of the varying characteristics of the materials charged.

Still another object of the present invention is the provision of a method and apparatus of the nature referred to which is economical to operate and in which the heat developed by the conversion of the waste material is recovered in a useful state.

The foregoing objects as well as still other objects and advantages of the present invention will become more clearly apparent upon reference to the following detailed specification taken in connection with the accompanying drawings in which:

FIGS. 1A and 1B is a schematic showing of the entire apparatus according to the present invention with a portion of the apparatus in section.

FIG. 2 is a fragmentary plan sectional view showing tangential air inlets for one of the reaction chambers.

BRIEF SUMMARY OF THE INVENTION

According to the present invention, waste material, particularly waste materials consisting of rubber or rubber-like material, or having rubber or rubber-like content, is thermally converted by first comminuting the waste material to a predetermined size and then feeding it into a closed chamber from the top into which chamber combustion air is introduced at the bottom under pressure for upward flow through the ignited waste material. The burning of the waste material, once it commences, is exothermic so that a continued supply of waste material to the chamber, together with a continued supply of air, will cause continued combustion.

The chamber is a substantially vertical cylinder and the bottom portion containing an air permeable grate receives the solid waste material and forms a primary combustion zone. Toward the top of the cylinder, a secondary combustion zone is established, wherein gases, hydrocarbon vapors and solid particles rising from the charge in the bottom of the chamber further react with air until a certain desired temperature is reached.

Air to the secondary zone is controlled to maintain the temperature at a predetermined upper limit so that combustion is not complete in the secondary zone. The gases from the secondary zone are then conveyed away from the first chamber to a second chamber forming a tertiary combustion zone and wherein the gases are admixed with further combustion air and burn substantially completely.

These last mentioned gases are supplied as the heat input to a waste heat boiler, such as a water wall boiler, so that the heat in the gases is recovered in a useful state, namely, in the form of steam. The gases, upon leaving the waste heat boiler, are conveyed to a cleaner, such as a bag cleaner or a cyclone cleaner, so that the solids in the gases are removed therefrom and the completely burned gases, free of noxious fumes and toxic vapors, are discharged to the atmosphere.

The air to the secondary combustion zone is automatically controlled in conformity with the temperature therein and which is sensed by a thermocouple.

The air supplied to the tertiary zone is also automatically controlled in conformity with the residual fuel content of the gases entering the tertiary combustion zone or in conformity with the oxygen content in the gas entering the waste heat boiler.

Preferably, steam is also introduced into the bottom of the primary chamber for temperature control of this zone and the combustion process and to properly condition the formation therein of clinkers and the like.

A grate in the bottom of the primary chamber supports the charge and the air for the primary combustion zone is supplied to the chamber beneath the grates. The grates advantageously define a somewhat restricted central opening through which the air flows upwardly into the charge and this prevents channeling of the air along the outer periphery of the primary combustion zone which would tend to cause a rubbery and substantially air impervious mass to form on the center of the grates and cause operations to cease.

By restricting the size of the air passage through the grates and by locating the air passage in the center of the grates, it has been found that this problem is avoided and substantially uniform combustion conditions can be maintained over the entire cross sectional area of the charge resting on the grates at the bottom of the first chamber.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the drawings somewhat more in detail, in the schematic showing of FIGS. 1A and 1B, a pile of incoming rubber or plastic waste material is indicated at 10 and this can consist of any sort of rubber or plastic combustible waste material, although the method and apparatus of the present invention is particularly designed for treating rubber or rubber-like waste materials or waste materials containing a substantial fraction of rubber and rubber-like materials, such as vehicle tires and the like.

In any case, the waste material is shredded in a shredder, generally indicated at 12, to produce shredded waste material as represented at 14, and which will vary from an average dimension of 1 inch up to about 4 inches. This material is conveyed by bucket 16 of a skip conveyor or belt conveyor 18 which discharges into a hopper 22 that supplies the comminuted waste material through a conduit 24 to the upper end of a vertical and substantially cylindrical refractory lined first chamber 26 so as to drop on grate 58 near the bottom of the chamber.

First chamber 26 is supplied with air at the bottom via a conduit 28 and in which conduit there is disposed valve means in the form of an adjustable control valve 30 and a shut off valve 32. Above the charge is another air inlet means supplied by conduit means 34 in which is disposed a shut off means 36 and a control valve means 38, the latter under the control of a thermostatic sensing element 40 located in an upper portion of chamber 26.

The high gases from the upper end of chamber 26 are conveyed by a refractory line conduit 42 to a water jacketed tertiary chamber 44 which forms a tertiary combustion zone. Tertiary combustion air is supplied by conduit 46 to a bustle pipe 45 which in turn feeds a multiplicity of tuyere introducing air into the tertiary combustion chamber 44. The conduit 46 is provided with a shut off valve 48 and a control valve 50 which is automatically controlled in a manner to be described hereinafter.

The feed conduit 24 includes a gating arrangement to prevent gases from flowing upwardly therethrough while waste material is being fed downwardly therein and includes an air purge arrangement including the conduit 52, shut off valve 54, and control valve 55.

All of conduits 28, 34, 46 and 52 lead from the discharge side of a blower 56. Also leading into the bottom of chamber 26 beneath the grate 58 therein is a

steam conduit 60 having a control valve 62 and shut off valve 61 therein.

The hot gases leaving the tertiary combustion zone pass through a conduit 63 to a waste heat boiler 64 which may be, for example, a water wall boiler to which feed water is supplied by conduit 66 and from which steam is withdrawn via steam line 68. The gases leave waste heat boiler 64 by way of a stack 70 to which is connected an oxygen analyzer 72.

The gases leaving stack 70 go to the inlet of an air cleaner 74 which may be a bag type cleaner, or a cyclone cleaner or scrubber. The cleaner 74 has a solid material discharge 76 at the bottom and a clean gas stack 78 leading from the top from which the cleaned gases are exhausted to the atmosphere.

The tertiary chamber 44 through which the hot gases flow from chamber 26 to the waste heat boiler has a bleed off nozzle 80 and adjacent thereto is a temperature sensitive element 82, such as a thermoelectric element. When the fuel content in the gases flowing in chamber 44 is above a relatively small amount, say, about ½ per cent, the gases leaving nozzle 80 will burn and carry current to element 82 and initiate control of valve 50 for the supply of more air through conduit 46 to the tertiary combustion zone.

Alternatively, valve 50 can be under the control of oxygen analyzer 72, or under the control of both element 82 and the oxygen analyzer. In any case, the control of valve 50 is such that the combustion in chamber 44 is substantially complete thereby preventing any combustible material from passing through the system and leaving via stack 78.

Valve 50 is controlled in such a manner that, when fuel content is detected by the presence of a flame from nozzle 80 impinging on thermoelectric element 82, valve 50 will open only slowly, or in steps, and will halt when the flame from nozzle 80 extinguishes. Valve 50 can be biased in such a manner that it will then move toward closed position until the gas from nozzle 80 again spontaneously ignites and again starts valve 50 on an opening cycle.

In this manner, a substantially stoichiometric mixture can be maintained in second chamber 44 leading to complete combustion. The oxygen analyzer 72 can be employed for controlling valve 50 on the basis of the oxygen content in the gases in stack 78 and this controller will operate in a manner to maintain the oxygen content in the gases above a predetermined minimum amount. Thus, valve 50 could be under the control of both thermoelectric element 82 and oxygen analyzer 72 and maintain the supply of air to the second chamber 44 within relatively close limits.

The grate means at 58 include an imperforate outer region 90 and a grid of bars at 92 in the central region forming the area through which primary air passes from conduit 28. The grate may consist of bars, for example, 1½ inch by 1 inch setting with the longer dimension vertically and with about 1 inch spacing between the bars.

The first chamber 26 is provided with refractory lining as indicated at 94, and this not only protects the chamber against deterioration, but also becomes hot from the combustion taking place in the gas above the charge resting on the grate so as to radiate heat back into the chamber and toward the top of the charge.

The gases burning above the charge, due to the high velocity secondary air supplied thereto from the con-

duits 34, also becomes highly luminous and the flame will also have a high radiation coefficient and this radiation, together with heat radiated from the refractory walls of the chamber, supplies heat to the charge and vapors and gases will be evolved therefrom to increase the breakdown of the rubber and rubber-like materials and to furnish added fuel for the secondary combustion zone.

This action, in combination with the blowing of primary air upwardly through the charge, causes consumption of the waste from the base of the charge upwardly through the charge and also at the surface of the charge simultaneously.

As will be seen in FIG. 1A, the conduits 34 are preferably interconnected by an annular header 96 which is connected to the main air line leading from blower 56.

The control of the air through conduits 34 can be effected by a valve disposed between header 96 and the main air supply conduit but, advantageously, individual sets of manual and automatic valves 36 and 38 are disposed in each conduit 34 so that the distribution of air completely about the secondary combustion zone can be regulated.

In FIG. 1A, the conduits 34 form tuyere arrangements which open radially into the top part of chamber 26 but, as will be seen in FIG. 2, conduits 34 could enter chamber 26 in a substantially tangential direction thereby to obtain even more uniform admixing of the secondary air with the combustion gases in the secondary zone.

Conduit 42 will be seen in FIG. 1A also to be refractory lined while the second chamber 44 forming the tertiary combustion zone is water jacketed.

The duct 24 through which material to be reduced is introduced into chamber 26 will be seen in FIG. 1A to comprise spaced seats 95 and 98 having associated therewith the closure members 100 and 102 with the lower one thereof having an actuating rod 104 connected thereto and with the upper one having an actuating tube 106 connected thereto and surrounding rod 104.

The arrangement is such that the closure members, when seated on the respective seats therefor, prevent loss of gas from chamber 26, but when material to be reduced is supplied to hopper 22, it will be held up by closure member 102 until this closure member is lifted, whereupon the material will fall into the space 101 between the closure members and can thereafter be dropped into the chamber by first lowering closure member 102 and then lifting lower closure member 100.

Sequential actuation of the closure members will, thus, prevent any loss of gas from chamber 26. It will also be seen that conduit 52 opens into the space between closure members 102 and, by opening air valve 54 and control valve 55 when closure member 100 is lifted, gases from chamber 26 which enter the space between the closure members can be purged therefrom.

In operation, a charge is placed on grate 58 and ignited in some manner, as by a gas flame or the like. The supply of primary air can then be commenced. As air is blown through the charge, the heat generated by the burning thereof will rise with the gases and will tend to drive off volatiles from the charge throughout the thickness thereof. This will leave a residue of carbon or charred material with which the primary air will react.

The area of reaction of the charge with the primary air becomes quite hot, creating a fused and dense ash or clinker which can be controlled by the introduction of steam through steam conduit 60 leading into the space in chamber 26 beneath the grates.

It has been mentioned that the gases above the charge burn due to the secondary air introduced at high velocity by conduits 34, and that the heat from the secondary combustion assists in the evolution of gases from the upper part of the charge.

The gases and vapors rising from the charge cannot be burned completely in chamber 26 in the space above the charge because the heat developed would exceed the allowable limit for the most heat resistant refractory lining. Accordingly, the amount of air introduced through conduits 34 into the secondary combustion zone is controlled in conformity with the temperature sensed by thermocouple 40. Enough air is supplied to gasify all vapors and to oxidize any free carbon rising from the charge to fuel content so that all substances are converted to gases in the secondary combustion zone, but the heat developed is not high enough to damage the refractory lining 94.

The gas flowing through refractory lined conduit 42 to the second chamber 44 is thus a mixture of partially burned, but, hot gases, and, when air is added thereto via conduit 46 into chamber 44, tertiary combustion will take place. The amount of air introduced into chamber 44 is sufficient to complete combustion and to develop the highest heat in the apparatus. Chamber 44 is, accordingly, of such a size that the gas will flow therefrom or may discharge directly into the boiler 64 and form the heat input thereto.

In the charge in the bottom of the first chamber, the air reacting with the carbon will release about 14,130 BTU for each pound of oxidized carbon and form carbon dioxide. This carbon dioxide will pick up another atom of carbon as it moves upwardly through the charge and become carbon monoxide, and this will result in an absorption of heat while still leaving a net amount of 3,947 BTU of sensible heat for each pound of carbon that was reacted and, therefore, a little over 10,000 BTU of potential heat in the resulting carbon monoxide and which is recovered as heat as the gases proceed through the system.

As mentioned, to this potential heat is added the potential heat of the volatile hydrocarbon vapors which rise from the surface of the charge due to the heat radiated thereto from the hot gases in the secondary combustion zone and because of the heat supplied to the charge from the primary combustion.

As to the grate 58, the central area at 92 through which air can pass may vary somewhat in size and may be as little as 40 per cent of the full cross sectional area of chamber 26 above the grates.

A feature of the present invention resides in the fact that any waste material supplied to chamber 26 drops into the chamber from the top and thus falls downwardly and strikes the hot charge on the top and the impact of the incoming waste material will serve to break up the charge and maintain the center filled with fuel.

What is claimed is:

1. In a process for thermally reducing waste material, especially waste material of which at least a substantial portion is plastic or rubber-like material; charging the material into the lower portion of a first chamber and igniting the material and passing primary air upwardly

through the material to cause primary combustion, supplying secondary air to the first chamber above the charge of material therein to cause secondary combustion to develop heat necessary to substantially gasify the vapors in the first chamber above the said charge, regulating the amount of secondary air to said first chamber to control the temperature in said first chamber, conveying gases from the upper region of said first chamber to a second chamber, supplying tertiary air to said second chamber to cause tertiary combustion, conveying gases from said second chamber, and recovering heat from the gases leaving said second chamber.

2. A process according to claim 1 which includes sensing the temperature of the gases in the upper portion of said first chamber, and adjusting the amount of secondary air supplied to said first chamber to maintain said sensed temperature below a predetermined maximum.

3. A process according to claim 1 which includes detecting the fuel content in the gases leaving said second chamber, and adjusting the amount of tertiary air supplied to said second chamber to obtain complete combustion of said fuel content.

4. A process according to claim 1 which includes sensing the temperature of the gases in the upper portion of said first chamber, adjusting the amount of secondary air supplied to said first chamber to maintain said sensed temperature below a predetermined maximum, detecting the carbon monoxide and any unburned fuel content in the gases leaving said second chamber, and adjusting the amount of tertiary air supplied to said second chamber to maintain the said carbon monoxide and unburned fuel below a predetermined maximum.

5. A process according to claim 1 which includes the supplying of steam to the lower portion of said first chamber.

6. A process according to claim 1 which includes supporting the said charge on a grate disposed near the lower end of said first chamber, supplying said primary air to the space beneath said grate, and confining the flow of air through said grate to the central portion thereof to prevent channeling of the air along the periphery of the said charge resting on said grate.

7. A process according to claim 1 which includes creating a turbulent condition in the region of introduction of said secondary and tertiary air into said first and second chambers to promote admixing of the air with vapors and the said gases.

8. A process according to claim 1 which includes passing the gases from said second chamber through a waste heat boiler to effect said recovery of heat from the gases.

9. A process according to claim 8 which includes detecting the oxygen content of the gases leaving said tertiary chamber, and adjusting the supply of tertiary air to said second chamber to maintain said oxygen content with predetermined limits.

10. A process according to claim 8 which includes cleaning the gases from said waste heat boiler to extract unwanted material therefrom, and exhausting the cleaned gases.

11. A process according to claim 2 in which said predetermined maximum temperature is not greater than about 2,500 degrees Fahrenheit.

12. A process according to claim 3 in which said predetermined maximum amount of fuel content is not greater than about one-half per cent.

13. An apparatus for the thermal reduction of waste materials, especially waste materials of which at least a substantial portion is plastic or rubber-like, a vertical first chamber and grate means therein near the bottom to support a burning charge of waste material, means for blowing primary air upwardly through said charge to maintain primary combustion in the charge on said grate means, means for supplying secondary air to said first chamber above said charge to maintain secondary combustion in said first chamber in the space above said charge, control means for regulating the amount of secondary air to said first chamber to control the temperature in said first chamber, a second chamber, a connector leading from near the top of said first chamber to said second chamber to convey combustible gases from said first chamber to said secondary chamber, means to supply tertiary air to said second chamber to maintain tertiary combustion therein, and means connected to said second chamber to receive burned gases therefrom and operable to extract heat from said gases.

14. An apparatus according to claim 13 which includes conduit means leading into said first chamber above said charge for the said supply of secondary air, valve means in said conduit means, temperature sensing means in the upper portion of said first chamber, and said control means operated by said temperature sensing means and connected in controlling relation to said valve means and operable to adjust the supply of secondary air to maintain the temperature in said first chamber above said charge below a predetermined maximum.

15. An apparatus according to claim 14 in which said conduit means include conduits connected to said first chamber at circumferentially spaced points, and a supply header connected to said conduits.

16. An apparatus according to claim 15 in which said conduits open tangentially into said chamber.

17. An apparatus according to claim 13 which includes detector means to sample the gases leaving said second chamber to detect the amount of fuel content therein, and means under the control of said detector means and operable for controlling the supply of tertiary air to said second chamber to maintain the said amount of fuel content below a predetermined maximum.

18. An apparatus according to claim 13 which includes conduit means opening into said second chamber for the supply of tertiary air thereto, valve means in said conduit means, detector means connected to receive gases leaving said second chamber and to detect the amount of fuel content therein, and control means under the control of said detector means and connected in controlling relation to said valve means and operable to adjust the supply of tertiary air to maintain the said amount of fuel content below a predetermined maximum.

19. An apparatus according to claim 13 in which said means to extract heat from the gases leaving said second chamber comprises a waste heat boiler.

20. An apparatus according to claim 19 which includes means to clean the gases leaving said waste heat boiler.

21. An apparatus according to claim 13 in which said grate means comprises an imperforate peripheral portion and an apertured central portion whereby said primary air is caused to pass through the central part of said charge.

22. An apparatus according to claim 13 which includes valved conduit means opening into said first chamber beneath said grate means for the supply of said primary air, and valved steam line means also opening into said first chamber beneath said grate means.

23. An apparatus according to claim 13 which includes feed means comprising an upwardly extending duct, and vertically spaced seal gates in the duct to permit waste material to be introduced into said first chamber without loss of gases from the upper part of said first chamber by sequential operation of said gates.

24. An apparatus according to claim 23 which includes means to supply air under pressure to the space between said gates to purge gases therefrom which enter the space when the lower one of said gates is opened.

25. An apparatus according to claim 18 in which the movement of said valve means is retarded in at least

one of the opening and closing directions thereof.

26. An apparatus according to claim 13 which includes first conduit means leading into said first chamber above said charge for the said supply of secondary air, first valve means in said first conduit means, temperature sensing means in the upper portion of said first chamber, and first control means operated by said temperature sensing means and connected in controlling relation to said first valve means and operable to adjust the supply of secondary air to maintain the temperature in said first chamber above said charge below a predetermined maximum, second conduit means opening into said second chamber for the supply of tertiary air thereto, second valve means in said conduit means, detector means connected to receive gases leaving said second chamber and to detect the amount of fuel content therein, and second control means under the control of said detector means and connected in controlling relation to said second valve means and operable to adjust the supply of tertiary air to maintain the said amount of fuel content below a predetermined maximum.

* * * * *

25

30

35

40

45

50

55

60

65