

United States Patent

[11] 3,589,313

[72] Inventors **Richard D. Smith**
Palo Alto;
Dale A. Furlong, Sunnyvale; Ronald D.
Kinsey, Cupertino, all of, Calif.
 [21] Appl. No. **756,595**
 [22] Filed **Aug. 30, 1968**
 [45] Patented **June 29, 1971**
 [73] Assignee **The United States of America as**
represented by the Secretary of Health,
Education and Welfare

[56] **References Cited**
UNITED STATES PATENTS

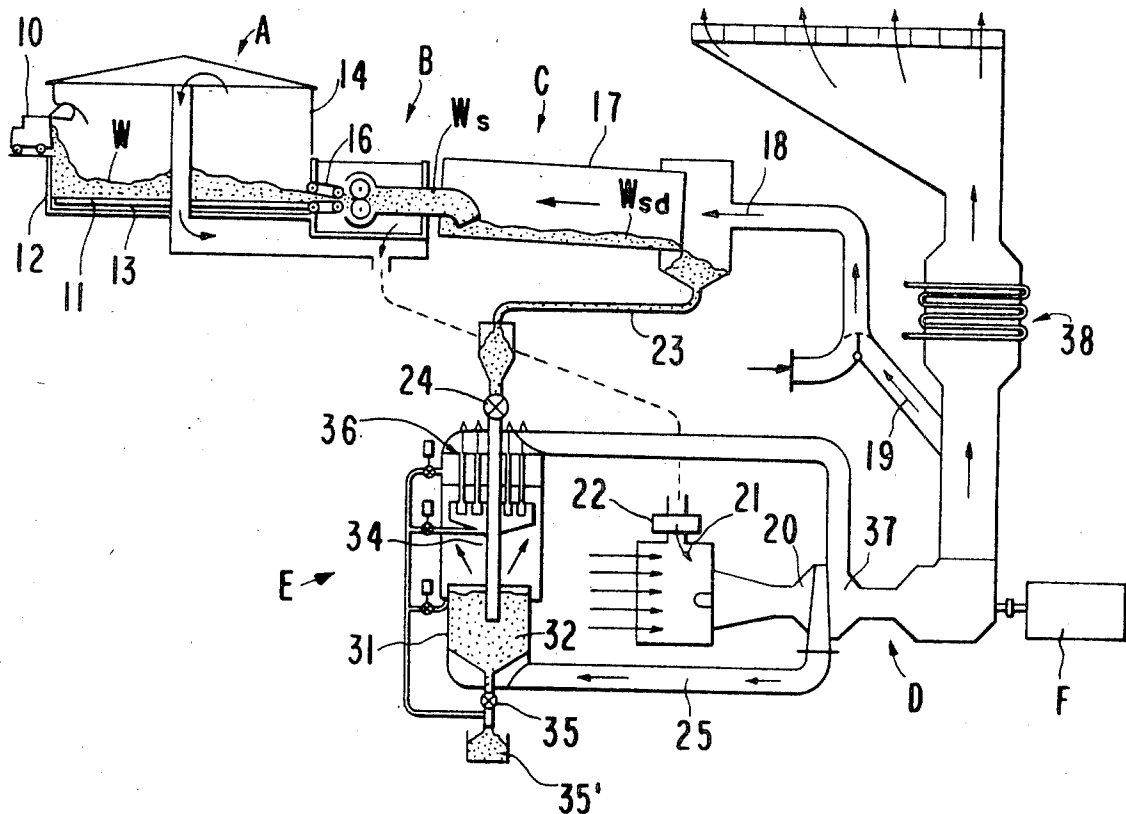
2,958,298	11/1960	Mayers.....	110/28
2,648,950	8/1953	Miller.....	110/28 X
2,911,065	11/1959	Yellott et al.	110/165
3,109,392	11/1963	Riepl et al.....	110/8
3,319,587	5/1967	Albertson et al.	110/8
3,418,788	12/1968	Sugimoto	53/126 X

Primary Examiner—Edward G. Favors
Attorney—Limbach, Limbach & Sutton

[54] **SOLID WASTE DISPOSAL METHOD AND**
APPARATUS
 17 Claims, 10 Drawing Figs.

[52] U.S. Cl..... 110/8,
 55/126, 55/315
 [51] Int. Cl..... F23g 5/02
 [50] Field of Search..... 110/7, 8,
 29, 28; 55/126, 315

ABSTRACT: A solid waste disposal system is described with a storage and receiving carousel, a shredder, a dryer, a compressor-turbine assembly for compressing air for combustion of waste and for receiving hot gasses produced in the combustion process. Two combustion systems, a fluid bed reactor and a gasifying pyrolyzer, are described. Particulate matter harmful to the turbine and also causing air pollution is removed from the hot high pressure gas upstream of the turbine. The malodorous air from the waste storage, shredding and drying is compressed and used for combustion and the part of the hot exhaust gases from the turbine are used in the dryer.



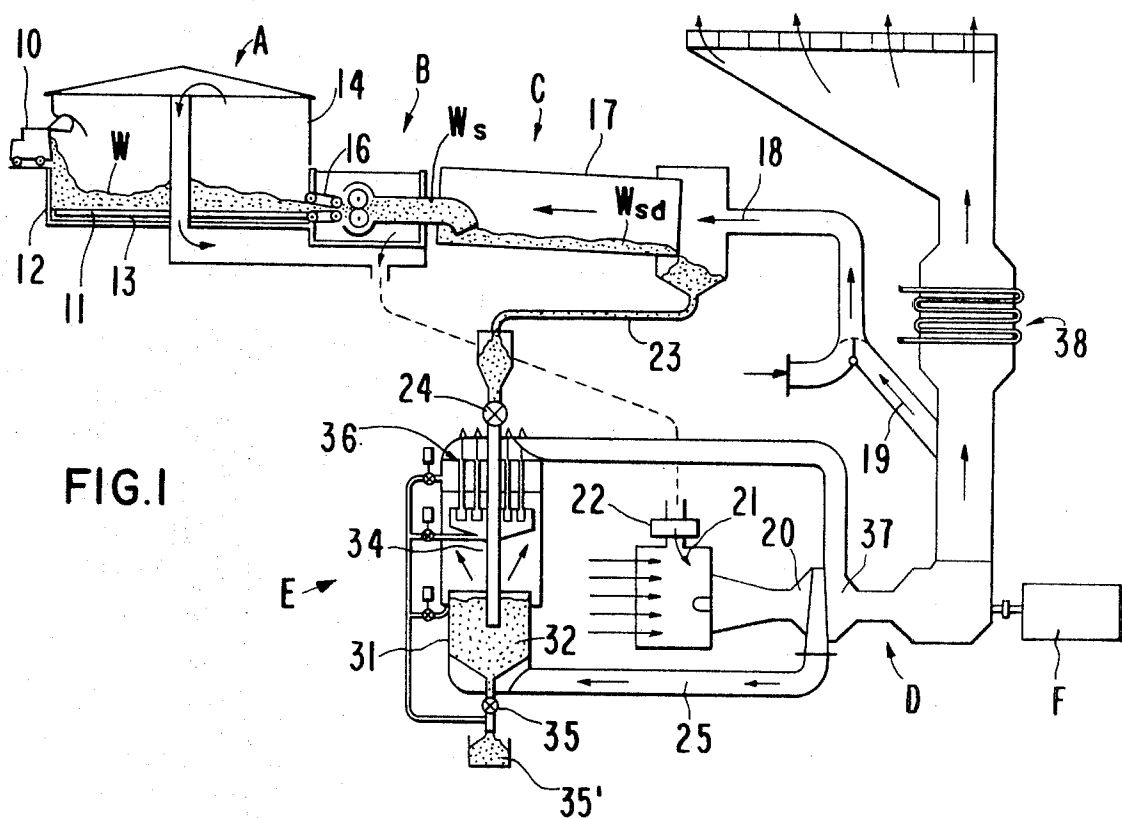


FIG. 1

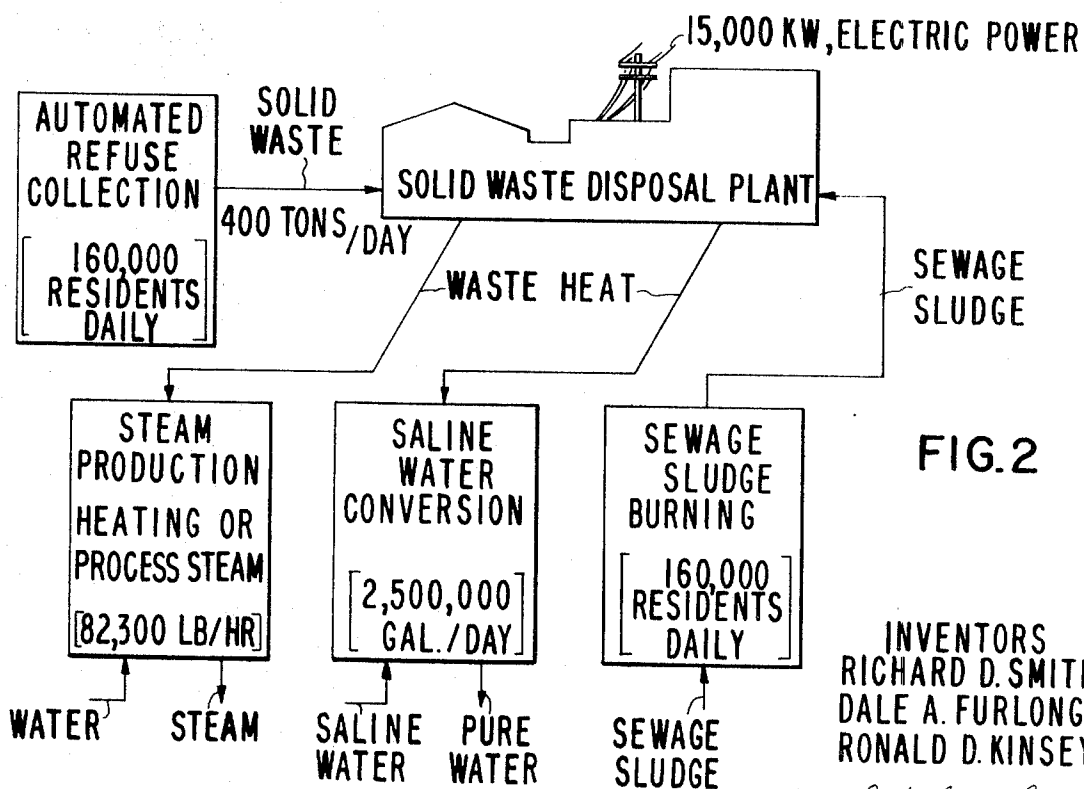


FIG. 2

INVENTORS
RICHARD D. SMITH
DALE A. FURLONG
RONALD D. KINSEY

BY *Simbach and Simbach*
ATTORNEYS

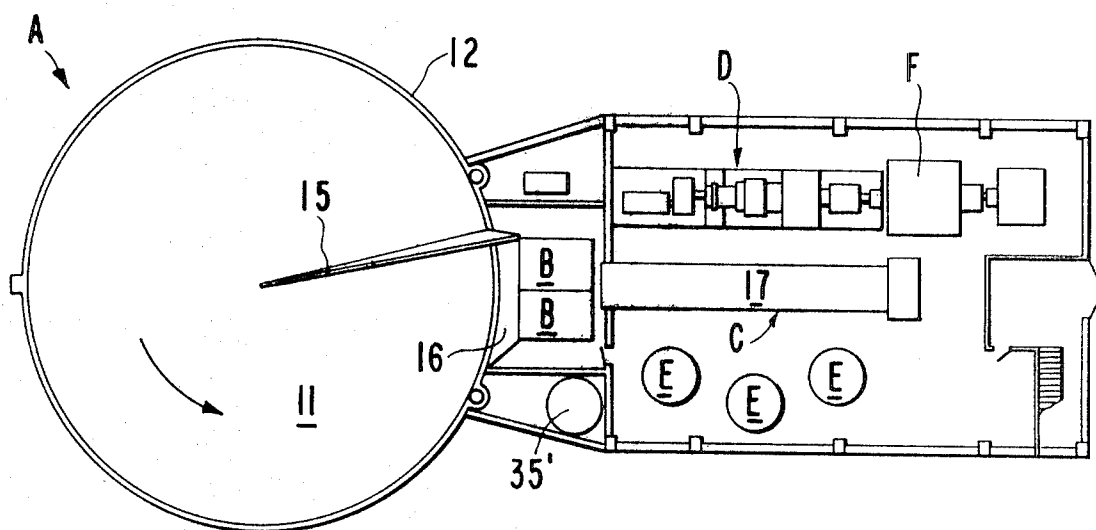


FIG. 3

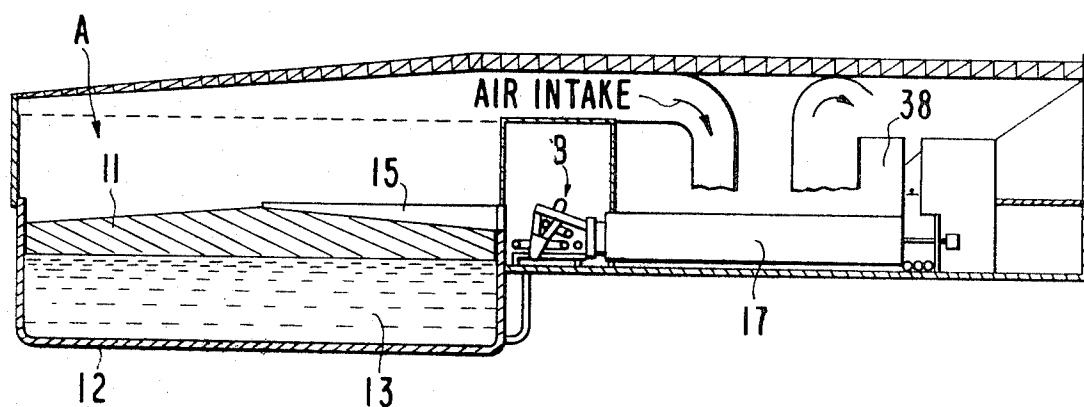


FIG. 4

INVENTORS
 RICHARD D. SMITH
 DALE A. FURLONG
 RONALD D. KINSEY
 BY *Smith, Furlong & Kinsey*
 ATTORNEYS

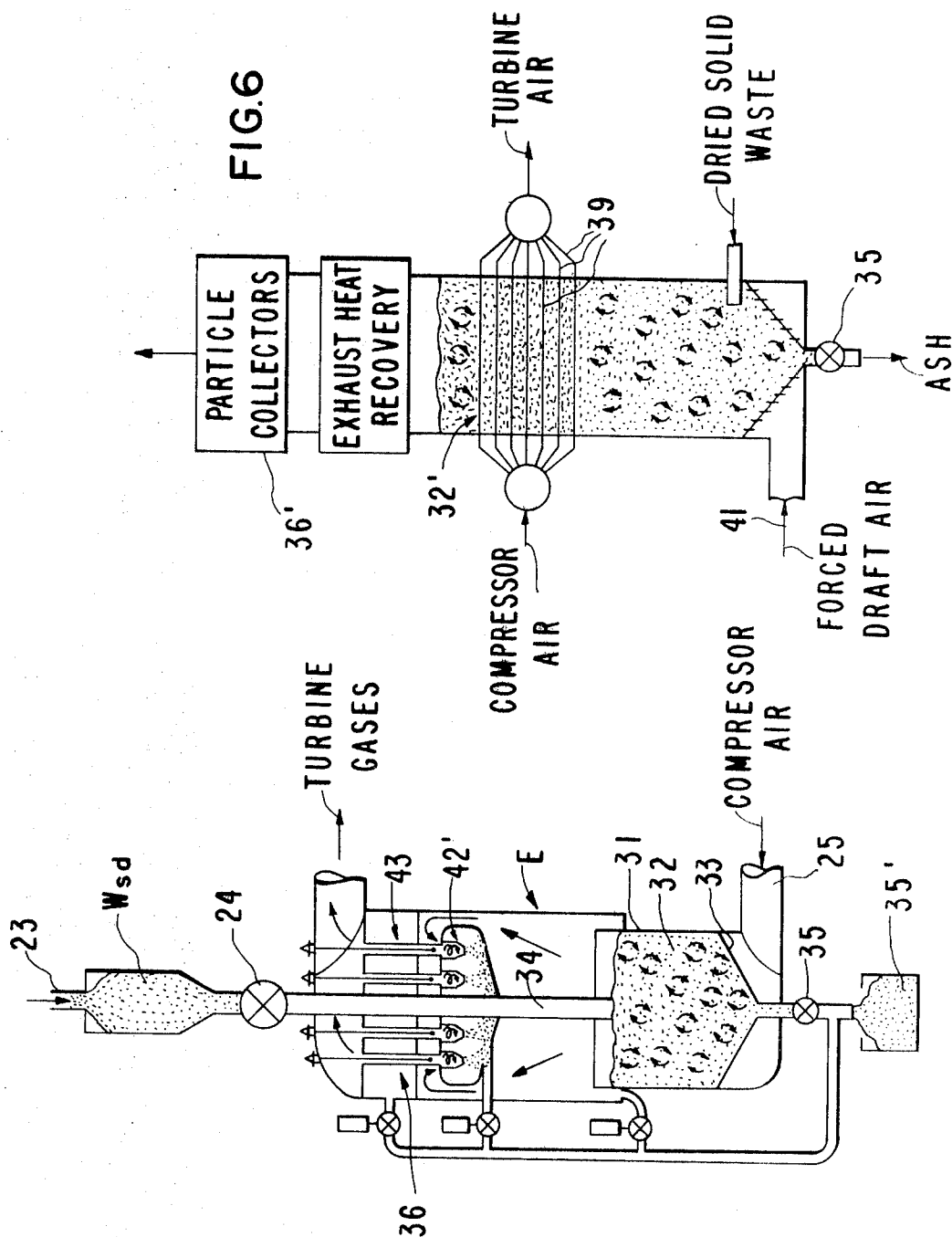
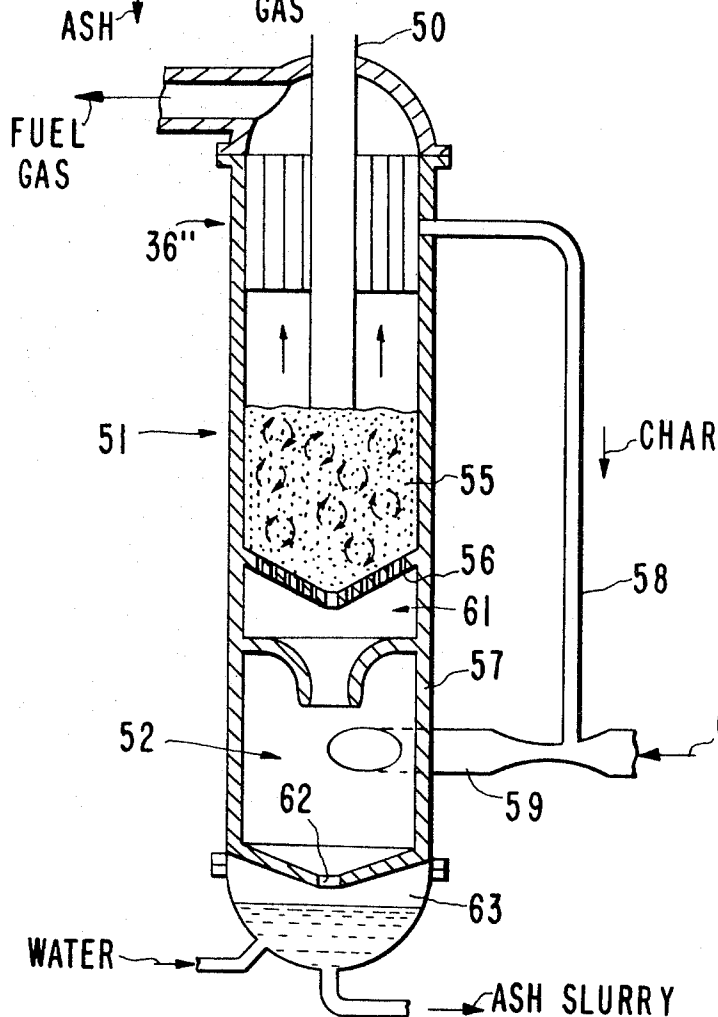
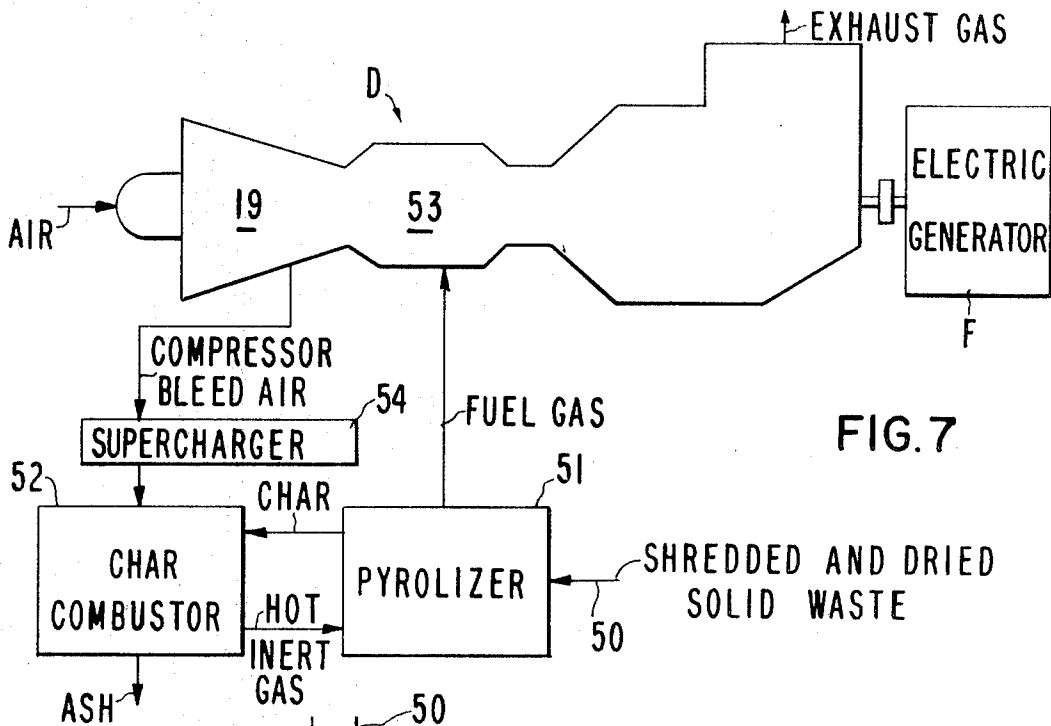


FIG. 5

FIG. 6

INVENTORS
 RICHARD D. SMITH
 DALE A. FURLONG
 RONALD D. KINSEY

BY *Limbach and Limbach*
 ATTORNEYS



INVENTORS
RICHARD D. SMITH
DALE A. FURLONG
RONALD D. KINSEY

BY *Limbach and Limbach*
ATTORNEYS

FIG. 9

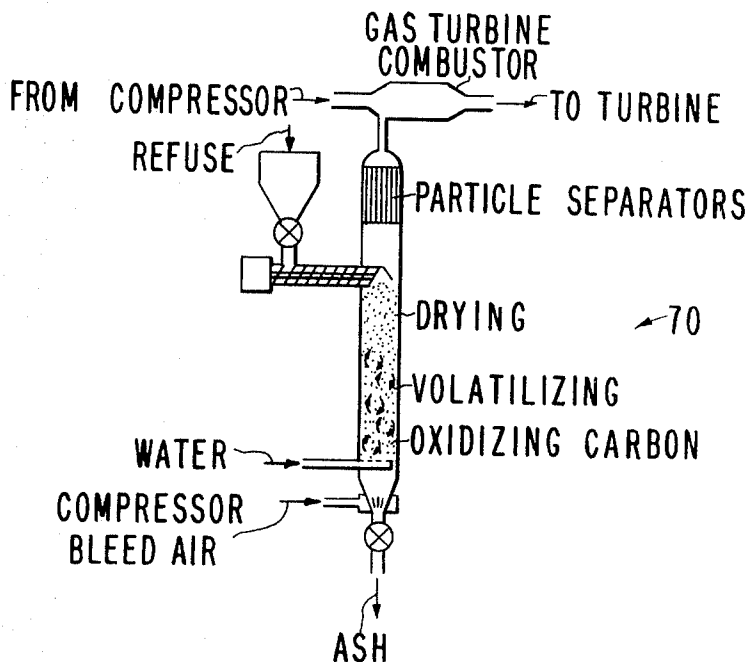
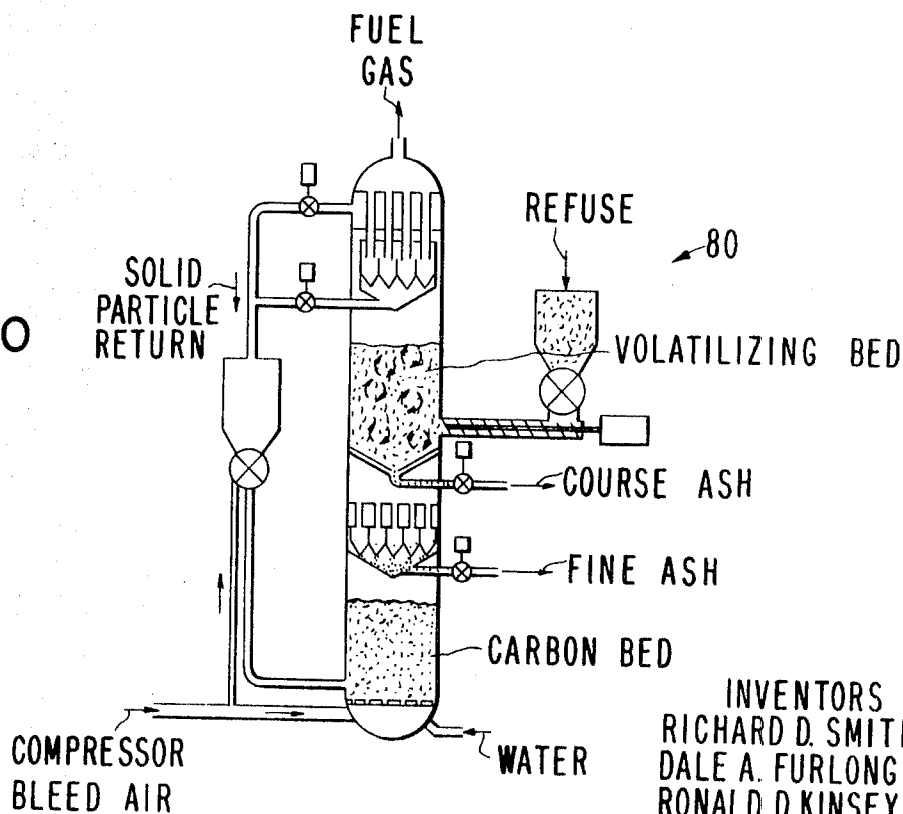


FIG. 10



INVENTORS
RICHARD D. SMITH
DALE A. FURLONG
RONALD D. KINSEY

BY *Simbach and Simbach*
ATTORNEYS

SOLID WASTE DISPOSAL METHOD AND APPARATUS

The invention described herein was made in the course of or under a contract with the Department of Health, Education and Welfare.

The present invention relates in general to a solid waste disposal system and more particularly, to a combustion system wherein the waste is consumed under pressure.

The disposal of solid waste (refuse) is one of the most critical social problems today facing countries with large urban populations. In the United States the urban areas where 67 percent of the population lives produce 117 million tons of refuse a year, an average of 5 pounds per person per day. City dumps, which have historically been employed for economical refuse disposal, are being closed because they are polluting the air.

Incineration of solid wastes is widely accepted as the most desirable solution to the problem but has not been universally adopted because of its high cost, particularly if the incinerator meets air pollution standards. Sanitary land fills do not pollute the air and are inexpensive, but sites adjacent to urban areas are filling up and suitable new sites are not generally available.

The object of the present invention is to provide an economical solid waste disposal method and apparatus acceptable for urban use.

Broadly stated, the present invention, to be described in greater detail below, is directed to a solid waste disposal system including a compressor-turbine assembly which operates to compress air for combusting waste material and for receiving hot gases produced in the combustion of such waste, means for combusting the combustible portions of the waste, means for directing the compressed and heated air from the compressor-turbine assembly to the combustion chamber assembly and hot gases from the combustion chamber assembly to the compressor-turbine assembly to drive the turbine, and means for directing waste into the combustion chamber assembly.

One feature and advantage of the present invention lies in the fact that the energy of the refuse extracted by combustion is utilized to operate the waste disposal system. A solid waste disposal system can be provided efficiently to consume the refuse from a community of 160,000 residents. Additionally, by combusting the waste under pressure, greater efficiency is achieved and a smaller facility can be utilized. In the burning chamber, the elevated pressure increases the amount of available oxygen and also increases the heat transfer from the hot gases to the solid waste.

In accordance with another aspect of this invention, a generator, such as an electric generator, is connected to and driven by the compressor-turbine assembly so that power can be generated from refuse energy and provided to the community responsible for the waste which serves as the fuel to drive the generator. Thus, the disposal plant can provide five to ten percent of the electric power requirements of the community generating the waste handled by the plant. Besides a direct return to the community to effectively reduce the cost of waste disposal this system conserves the natural resources.

In accordance with still another aspect of the present invention, the combustion means for the disposal system is a particle fluid bed reactor. The fluid bed provides heat transfer rates from the bed to the incoming solid waste approximately 5 to 10 times greater than conventional grate burners and at the same time provides a scrubbing action between the bed and the waste to continuously remove char from the burning surface of a solid thereby exposing virgin material to the oxygen environment for combustion. Still further, the fluid bed reactor provides a highly uniform temperature throughout eliminating regions of high local temperature where undesirable nitrogen-oxygen compounds would be formed.

In accordance with still another aspect of the present invention, combustion of the solid waste is accomplished by volatilization and subsequent burning of the volatilized fuel gas in a conventional gas turbine combustion chamber which

is a part of the compressor-turbine assembly. In accordance with this aspect of the present invention, the solid waste is directed to a pyrolyzing chamber and there subjected to hot inert gases for pyrolysis and vaporization of volatile combustible material. From the pyrolyzing chamber, volatilized fuel gas is conducted to the combustion chambers of the compressor-turbine assembly and the remaining char is conducted to a char combustion chamber. A portion of the compressed air from the compressor of the compressor-turbine assembly is fed to the char combustor to burn the char and produce hot inert gas that is carried to the pyrolyzing chamber.

With the gasifier system in place of the fluid bed reactor, the particle collection problem from the stream of burned material is eased because only a small percentage of the total air flow of the gas turbine passes through the combustor. Furthermore, the gas turbine combustors normally supplied can be used to burn the hot gases with no alterations to the compressor-turbine assembly required to conduct the air away from the compressor, or the hot gas to the turbine.

In accordance with still another aspect of the present invention, the waste material is first shredded and then dried before combustion utilizing part of the hot exhaust gases from the gas turbine in the drying step. This feature of the present invention not only increases the efficiency of the waste disposal method and apparatus by increasing the burning rate and eliminating operational variations due to different moisture contents but also accomplishes the drying function with heat that is a byproduct of the system.

As still another aspect of the present invention the malodorous air from the refuse storage, shredding and drying area is drawn into the turbine air compressor so that the waste disposal plant does not create an undesirable smell and is acceptable for placement in an urban area.

In accordance with still another embodiment of the present invention the compressor-turbine assembly is used as a vacuum pump to pull refuse through vacuum lines into the waste disposal system to serve as the waste collection means.

In accordance with still another aspect of the present invention, particle separators are provided for the combustion chamber assembly to remove particulate matter harmful to the turbine. The particle separators can be inertial separators, electrostatic precipitators and/or mat filters. In one embodiment of this invention, the particle separator assembly includes an inertial separator followed by an electrostatic precipitator. The inertial separator removes all but the smallest particles and these small particles are removed by the electrostatic precipitators.

A feature and advantage of the particle separation utilized in the present invention lies in the fact that removal of the particles upstream of the turbine not only prevents damage to the turbine but also removes the particles that would cause air pollution.

In accordance with still another aspect of the present invention, a multistage flash evaporator system or equivalent system can be added to the solid waste disposal system to provide 2,500,000 gal/day of fresh water from sea water or 20 to 30 percent of the water required by 160,000 people. The waste heat from the hot gases downstream of the turbine are used to provide the energy for the evaporator systems.

In accordance with still another aspect of the present invention, a sewage sludge disposal system can be provided by the waste disposal system aforementioned for burning the sewage sludge residue from a sewage plant handling the sewage from the same 160,000 people served by the solid waste disposal plant.

These and other features and advantages will become more apparent upon a perusal of the following specification taken in conjunction with the accompanying drawings wherein similar characters of reference refer to similar structures in each of the several views.

In the drawings:

FIG. 1 is a schematic flow diagram of a waste disposal system and illustrates the operation of several different aspects of the present invention.

FIG. 2 is a schematic diagram illustrating different system utilizations for the present invention.

FIG. 3 is a plan view of an operative embodiment of the present invention.

FIG. 4 is an elevational view, partially in section, of the embodiment illustrated in FIG. 3.

FIG. 5 is an elevational schematic view of a fluid bed reactor operable with the present invention.

FIG. 6 is a schematic block diagrammatic view of an alternative fluid bed reactor system in accordance with the present invention.

FIG. 7 is a schematic block diagram of a gasification system utilized with the present invention.

FIG. 8 is an elevational sectional view through an operative embodiment of a gasifier system in accordance with the present invention.

FIGS. 9 and 10 are elevational schematic views illustrating alternative gasifier systems utilizable with the present invention.

Referring now to the drawing, with particular reference to FIG. 1, there is shown an illustrative embodiment of the present invention. As schematically illustrated, the method and apparatus of the present invention are practiced utilizing a waste receiving and storage assembly A, a shredding assembly B, a drying assembly C, a compressor-turbine assembly D, a combustion chamber assembly E, and an electric generator assembly F.

The solid wastes are typically received in accordance with one embodiment of the present invention from municipal collection trucks 10 which dump the waste into the receiving and storage assembly A which includes a circular turntable or carousel 11 floating on a pond of water 13 within a hollow cylindrical housing 12 with suspended glass cloth panels 14 permitting truck access to the carousel and with the carousel rotatable to feed the solid wastes W into the shredding assembly B. The carousel 11 can be raised and lowered to assist refuse dumping and feeding operations by adjusting the level of pond 13 thereby eliminating the need for a crane and associated high-bay construction in the solid waste storage area. A large effective tipping area for the collection trucks 10 is provided by the circular shape of the carousel 11 and the panels 14 screen off the storage area while permitting an inflow of fresh air.

The solid wastes W are directed by a fixed leveling blade 15 over the carousel 11 into conveyors or a chute 16. The turntable elevation and the rotational speed can be controlled automatically or remotely controlled by an operator in the central control room of the waste disposal plant where the operator observes the carousel operation by closed circuit television.

In the shredding assembly B, all of the solid wastes W are shredded to form a more nearly homogenous shredded material W_s which is easily transported through the remainder of the system by conventional automated devices for materials handling. While various solid waste constituents, such as magnetic material, can be separated at this stage of operation, such as by magnetic separators, such separation assemblies unduly increase the cost of the system, and if separated at this stage, noncombustible would be contaminated and would require special handling. Since shredders are high maintenance items compared to the other subassemblies of the operating system, two shredder assemblies are utilized in the operating embodiment of the invention illustrated in FIG. 3 so that an operational standby unit is available in the event of failure.

The shredded solid wastes W_s are dried in the drying assembly C to increase the burning rate of waste in the overall system and eliminate the variability in burning rate resulting from widely different moisture contents. A rapid and uniform burning rate promotes clean combustion and reduces the required size of the combustion chamber to be described below. In the embodiment illustrated in the drawings the drying assembly C includes a hollow cylindrical rotating dryer 17 which produces considerably mixing and blending during the drying step to offset any local concentration of one constituent of solid waste.

In accordance with one aspect of the present invention, the heat utilized in the drying assembly C is provided by a heated air stream 18 which obtains its heat from a portion of the exhaust gases 19 from the gas turbine assembly D.

The compressor-turbine assembly draws at least a portion of its compressor intake air 21 through a filter 22 from the air space above the waste in the receiving and storing, shredding and drying assemblies, A, B, and C, respectively, to prevent dust and odors from escaping to the environment. All of the malodorous gases carried on into the compressor portion 20 of the gas turbine assembly D are subsequently subjected to elevated temperatures and sterilization before release. The shredded and dried solid waste W_{sd} is transported via a conduit 23 and fed into the high pressure environment of the combustion chamber assembly E such as by a rotary feeder 24. The speed of the rotary feeder is adjusted by a control system to maintain proper temperature and gas flow within the disintegration assembly E.

In the compression portion 20 thereof the compressor-turbine assembly D compresses the intake air 21 from the other assemblies and from the outside environment to elevated pressures and temperatures such as 100 p.s.i.a. and 584° F. or 200 p.s.i.a. and 700° F. This hot high pressure air is ducted via conduit 25 to the combustion chamber assembly E to provide the oxygen for combustion of the solid wastes.

The combustion chamber assembly illustrated in FIG. 1 and in enlarged scale in FIG. 5 includes a combustion chamber 31 in the form of a fluid bed reactor. Sand or other inert particles 32 are contained within the chamber 37 above a porous grate 33 and suspended or fluidized during operation by passing air therethrough. Limestone or dolomite can be added to the particle bed for control of noxious gases. The shredded dried waste W_{sd} is injected directly into the bed of particles 32 by a conduit 34 from the rotary feeder 24. This bed of particles 32 is initially heated by an external source (not shown) to an elevated temperature for combustion of waste material and combustion is maintained with the compressed hot gases from the compressor-turbine assembly D passing into combustion chamber 31 from conduit 25 and through the grate 33.

The fluidized bed promotes dispersion of the incoming shredded and dried solid waste which is heated to ignition temperature and maintained in the bed a sufficient time for combustion of all burnable solid waste particles. The particles are selected within suitable range of size, shape and density and of a material to withstand high temperatures without slagging and the air is caused to flow through the particles under carefully controlled conditions. Chief among these conditions is the necessity that the fluid velocity through the bed, and hence the pressure drop, be greater than the value required to support the bed weight but less than the value required to sweep the particles out of the chamber. When these conditions are satisfied, the bed particles exist in a fluidized state. If the movement of one specific particle could be observed, it would undergo a continuous turbulent motion, being bouyed by flowing fluid and not at rest against adjacent particles. Superimposed upon this localized motion are convection motions of the entire bed. Viewed as a whole, the dynamic condition of a fluidized bed is quite analogous to that of a boiling liquid.

The high pressure and turbulence in the fluid bed reactor combine to promote rapid combustion of the solid wastes. Thus, the fluidized inert material promotes dispersion of the incoming shredded solids, heats the solid waste to ignition temperature, and maintains residence time sufficient for combustion of all burnable solid waste particles within the reactor. The fluid bed will hold a kleenex long enough for it to be burned without escaping while at the same time heavy chunks heavy rubber will remain in the bed until finally consumed. Large pieces of inert material will sink to the bottom of the bed and be removed from the fluid bed through an air lock feeder 35 and combined with other ash in a residue storage 35'.

The burning rate of this combustion chamber assembly in accordance with the present invention is greatly increased

over the burning rate of conventional assemblies by reason of the increased pressure for availability of additional oxygen, increased heat transfer to the solid waste by the radiation from the large surface area of the particulate matter and convective heat transfer from the hot gas, the large direct surface area of the waste due to shredding, the continual abrasion of the charred surface by the bed material to expose virgin waste surface, and the continual mixing of gases in the bed enhancing the flow of gases to and from the burning solid surface thereby enhancing the completeness and rate of gas phase combustion reaction.

Most of the ash remaining after combustion is complete will be carried off with the gases leaving the fluid bed surface and subsequently collected by particle collectors 36. The ash particles and inerts from the solid waste which are larger or more dense than the inert particles 32 forming the bed eventually reach the bottom of the fluid bed reactor in the combustion chamber where they are removed by the rotary air lock 35.

In addition to the advantages of the high pressure fluid bed combustor mentioned above, the highly uniform temperature, the presence of CaO and MgO in the ash, or the addition of limestone or dolomite, greatly reduce the air pollution from burning of solid wastes. The thorough mixing of the fluid bed maintains a highly uniform temperature so that few nitrogen-oxygen compounds, formed when nitrogen and oxygen gases are exposed to elevated temperatures, are formed. The CaO and MgO in the ash or limestone or dolomite suppresses evolution of sulfur dioxide and other acid vapors by chemically combining with the acids to form a salt. Although solid waste has a relatively low sulfur content (0.1 percent) compared to petroleum or bituminous fuels, it contains polyvinylchloride plastic which evolves hydrochloric acid vapor when burned. The fluid bed combustor is ideally suited to the efficient utilization of the natural properties of the ash or of limestone or other suppressant because this material would be retained in the bed and the chemical reactant continuously removed from the suppressant by the fluid bed turbulence.

The hot gases leaving the fluid bed 32 entrain many ash particles which must be removed such as by the particle collectors 36 before the gases are allowed to enter the turbine. Large particulate matter, if allowed to pass through the turbine, will damage the turbine severely. Gas cleaning by the particle collectors 36 and accomplished for the turbine also satisfies the clean air requirements for exhaust gases. The particle collectors can take a number of different forms such as inertial separators, electrostatic precipitators and mat filters. The particle collectors 36 in FIGS. 1 and 5 are schematically illustrated as a combination of inertial separators 42 followed by electrostatic precipitators 43. The inertial separators 42 remove all but the smallest particles, and these small particles are removed by the electrostatic precipitators 43.

Inertial separators use centrifugal force to separate particles from the gas stream and can provide efficiencies of 97.8 percent and greater for particles as small as 10 microns in diameter, but the efficiency degrades for particles smaller than this size. The fine particles which tend to follow the air flow out of inertial separators are least likely to injure the turbine. Inertial separators are particularly suited for use in the first stage of a two stage separator because they efficiently remove large particles, leaving only the fines for the second stage.

Electrostatic precipitators directly charge the particles in the gas and subsequently attract them to a surface charged with opposite polarity. Since the forces of separation are applied directly to the particles without disturbing the gas flow, all sizes of particles are collected efficiently; however, the high collection efficiency for the fine particles (5 microns and below) is particularly good. As temperature is increased in an electrostatic precipitator, the electrical characteristics of the hot gas change due to molecular action, and it becomes more difficult to charge the dust particles. Fortunately, increased pressure as utilized in the air chamber of the present invention tends to offset this characteristic. Mat filters have excellent collection efficiency for both coarse and fine particles and

filter material is available made of fine fibers (5 to 7 microns in diameter) of silicon dioxide and aluminum oxide which can be used as filter material up to 2300° F.

The hot gases leaving the particle collectors 36 are expanded through the expansion and drive portion 37 of the compressor-turbine assembly D which drives the compressor portion 20 of the assembly D, and drives the electric generator assembly F to produce electric power.

The hot gas leaving the compressor turbine assembly D is near atmospheric pressure but at elevated temperature so that the portion 19 can be utilized for drying shredded solid waste material in the drying assembly C as described above. If solid waste has a moisture content of 20 percent and this moisture is boiled out in the dryer, less than 10 percent of the exhaust gases need be recirculated. An optional exhaust heat recovery boiler 38 can be provided in the exhaust line from the gas turbine for utilization of the heat for producing steam for heating, air conditioning, or desalting water. The hot exhaust gas is decelerated in an enlarged exhaust plenum and released to the atmosphere from a large area in the roof of the plant.

As illustrated in FIG. 2, use of the gas turbine cycle for waste collection allows performance of many services to the community besides incineration of solid wastes. For example, the capability of the gas turbine compressor can be utilized to draw a powerful vacuum and suck the solid waste through underground pipes and deposit this waste in the carousel for combustion in the disposal system. Alternatively, the exhaust heat from the gas turbine can be utilized to produce fresh water daily from saline or brackish water. Still further, the disposal system can be utilized to incinerate the sewage sludge resultant from sewage systems.

In the modern field of power generating equipment, the gas turbine is most suited for the capacity range of 5 to 30 megawatts, above diesel and gas engine generators for lower powers and below steam turbine generators for higher powers. The present invention is specifically designed for providing as an advanced incinerator a compact module consuming between 200 and 800 tons per day and generating through an electric generator between 7 megawatts and 30 megawatts of electric power. By way of example, several gas turbines are presently available in the 15 megawatt capacity and correspond to a solid waste disposal capacity of 400 tons per day, approximately in the middle range of interest. A 400 ton per day unit will dispose of solid wastes from approximately 150,000 people; for their entire population San Francisco would require 5 units of this size, New York would require 40 units. Such a unit will dispose of solid waste for 95 per ton, approximately one-half the cost of sanitary land fill and 16 percent the cost of modern conventional incinerators. Additionally, such a unit can supply 5 to 10 percent of the electric power requirements of the community serviced by the incinerator. By using a carousel storage volume 15 feet deep with an inside diameter of 80 feet, 2,790 cubic yards of solid waste can be stored which supports over 26 hours of continuous operation of the 400 ton per day disposal unit. Also, such a 400 ton per day unit will operate with two fluid bed reactors (plus a spare for emergencies) each operable with a maximum air flow of 100 pounds per second and solid waste feed rate of 200 tons per day. Typical reactors can have a diameter of 10 feet, a reactor bed depth of 3 feet, an average air velocity of 12 feet per second and a reactor pressure drop of 6 p.s.i. Such reactors have a heat release rate of 500,000 B.t.u. per hour for each cubic foot of fluid bed and a heat release rate of 1,000,000 B.t.u. per hour per square foot of area.

In accordance with another aspect of the present invention, an alternate configuration for the fluid bed reactor as shown in FIG. 6 is provided. In this arrangement, the compressor air from the compressor portion of the compressor-turbine assembly D is heated by passing through pipes 39 immersed in the fluid bed 32' with the heated air from these pipes then expanded through the expansion and drive portion 37 of the compressor-turbine. Since the combustion process takes place outside these pipes 39 rather than directly in the gas that

passes through the turbine, the process of this aspect of the present invention can be considered as external combustion. Air 41 is supplied to the external fluid bed reactor 32' by a forced draft fan (not shown). Only enough excess air 41 is supplied to insure complete combustion, and thus the weight flow rate of air passing through the fluid bed reactor is approximately one-fifth that passing through the gas turbine. To minimize the heat transfer area, the bed is operated as hot as possible such as 1900° F. without slagging the ash. Since the combustion gases do not pass through the gas turbine, they may be cooled prior to particle collection.

An external fluid bed reactor constructed in accordance with this embodiment of the present invention can provide a solid waste disposed rate of about 250 tons per day with an average air velocity of 5 feet per second in a bed area and volume of 3880 ft.² and 930 ft.³ respectively, with a heat release of over 100,000 B.t.u. per cubic foot utilizing a forced draft fan power of 610 horsepower.

The combustion of hydrocarbon materials principally found in solid waste occurs in three distinct phases and these phases occur almost independently in all combustion processes. In the first phase, called pyrolysis or volatilization, the material is heated, causing decomposition of the hydrocarbon solids into hydrocarbon gases; next these gases are oxidized in a gas phase reaction; and finally, the solid carbonaceous char remaining after volatilization is oxidized.

In accordance with still another aspect of the present invention, the combustion of the waste material can be accomplished in cooperation with the gas turbine by a gasification method and apparatus as illustrated in FIGS. 7-10 taking advantage of the distinctions between these phases.

In the gasifier concept of the present invention, each of these phases occurs in a separate location. The shredded and dried solid waste material W_{sd} is first injected into a pyrolyzer or pyrolyzing chamber 51 from a conduit 50 where the first phase pyrolysis or volatilization takes place. The combustible hydrocarbon gases generated in the pyrolyzing chamber 51 serve as a gaseous fuel for the gas turbine where the gas phase oxidation occurs in the gas turbine combustors 53. Hot inert gases are also injected into the pyrolyzer for pyrolyzation of the solid wastes. These hot inert gases are separately generated in a char combustion chamber 52 which for the third phase oxidizes the residual solid char coming from the pyrolyzer with air bled from the compressor portion 19' of the gas turbine assembly D'. The bleed air that is directed into the char combustion chamber 52 from the gas turbine compressor is compressed in a supercharger 54 (approximately 5 percent of the gas turbine flow rate) to account for pressure losses in both the char combustor chamber 52 and the pyrolyzing chamber 51.

The purpose of the pyrolyzer is to chemically decompose, or pyrolyze, the incoming solid wastes. Pyrolysis is accomplished by heating in an oxygen-free environment and the necessary heat is derived from hot inert gases (over 3000° F.) supplied to the pyrolyzer 51 from the char combustor 52. In one embodiment of the gasifier system illustrated in FIG. 8, the pyrolyzer 51 includes a fluid bed reactor of inert particles 55 similar to but smaller than the fluid bed reactor described above with reference to FIGS. 5 and 6 and wherein the particle bed is supported on a downwardly directed conical, porous injector plate 56 apertured at the conical apex. Abrasion by the fluid bed will rapidly remove char as it is formed on the surface of waste material and this fine char material thus abraded will be carried out of the fluid bed by gases and subsequently separated by particle collectors 36''.

The primary constituent of the organic fraction of the solid waste material is cellulose, the chief component of all wood and plant fibers, and hence of all paper products. In the fluid bed 55 in the pyrolyzing chamber 51, degradation of the cellulose material will occur and eventually all the oxygen and hydrogen, and a substantial part of the carbon, will be driven off leaving a carbonaceous char and nondecomposable ingredients such as metal and glass. Most of the carbon driven

off is in the form of fine particles produced by the abrading action of the particle bed. Oxidation of this fixed carbon particulate in the pyrolyzer 51 could not be accomplished without burning some of the fuel gases. Therefore, in accordance with this aspect of the present invention, this char particulate is removed from the pyrolyzer and returned via a conduit 58 to the char combustor 51 where it is burned at near stoichiometric fuel air ratios for generation of the inert gases for the pyrolyzer 51.

One construction for the char combustor 52 in accordance with the present invention and as illustrated in FIG. 8, is a vortex combustor consisting of a cylindrical housing 57 with a ceramic lining and into which compressor air with entrained fine char particles recovered from the pyrolyzer gases by the particle collectors 36'' via conduit 58 is introduced tangentially via a conduit 59 at high velocity such as 300 feet per second causing gases in the combustor chamber 52 to flow in free vortex motion. Centrifugal force causes solid particles entrained in the vortex to continue to rotate until consumed or slowed by contact with the walls while the inert gases increase in angular velocity and are removed from the core of the vortex and pass through a reentrant throat section 61 and the ceramic injector plate 56 into the fluid bed pyrolyzer 51. Since the temperature in the combustor is above 3000° F., the ash and metals are melted and these molten droplets collect on the wall of the chamber. Larger particles stick to the molten ash and are exposed to a relatively high velocity air stream promoting rapid combustion. The liquid ash and metal subsequently drain through a hole 62 in the bottom of the char combustor 52 into a quench tank 63. There the molten residue is suddenly quenched in water resulting in the formation of granular residue which is removed as a water slurry.

As described above the hot inert gases from the combustor 52 fluidize the particle bed 55 and volatilize combustibles therein. Large pieces of solid waste that are not buoyed up by the fluid bed 55 migrate to the apex of the conical injector 56. There, these pieces are continuously exposed to the entering 3000° F. gas stream from the combustor 52 and rapidly are either pyrolyzed or melted. If melted, the molten residue drips directly into the quench tank 63 through the core of the vortex combustor chamber 57.

An integrated gasifier in accordance with this construction approximately 4 feet in diameter and 20 feet high will process 200 tons of solid waste material in 24 hours.

The high temperature of the fuel gas going from the pyrolyzer 51 to the gas turbine combustors 53 will assist rapid, complete combustion, and since only this high temperature gaseous fuel is combusted, it becomes unnecessary to use a high core temperature combustor thereby avoiding generation of the usual nitrogen oxides and promoting uniform temperature profile in the combustor.

The gasifier combustion method and apparatus of FIGS. 7 and 8 operates exceptionally well to avoid air pollution. For example, SO₂ and HCl are removed in the fluid bed pyrolyzer 51 by reaction with basic ash materials such as CaO and MgO. Limestone or dolomite can be added to the pyrolyzer bed to aid this reaction, however, in most cases sufficient CaO and MgO already exist in the solid waste ash. Furthermore, nitrogen-oxygen compounds will not be generated in the pyrolyzer chamber 51 since practically no oxygen is present.

For a 400 ton per day capacity waste disposal plant of the type described in FIGS. 7 and 8 existing gas turbines such as the General Electric G5191 heavy duty industrial gas turbine or the Pratt & Whitney ST4A-8 gas turbine can be utilized with only minor modification.

Other combustion methods and apparatus besides the fluid bed reactor described with reference to FIGS. 5 and 6 and the gasifier described with reference to FIGS. 7 and 8, can be utilized with the present invention.

By way of example, a simple gravity feed gasifier schematically illustrated in FIG. 9 can be utilized. In this construction, solid wastes are introduced at the top of a volatilizing chamber and fed by gravity as they are volatilized and burned to ash,

which is removed continuously from the bottom. Air is directed up through the gasifier 70 after being introduced into the ash region and the air velocities are low to preclude agitation of the pyrolyzing products. After passing through the ash, the air reaches the carbon combustion zone where the carbon is combined with a limited supply of oxygen to form carbon monoxide. Water is also introduced and the resultant steam and hot carbon result in the "producer gas" reaction which yields hydrogen and carbon monoxide and absorbs heat. The flow rates of water and air are controlled such that all the carbon is consumed, while assuring that slagging temperatures are not reached. The hot gases rising from the carbon combustion zone furnish heat to pyrolyze or volatilize the incoming solid waste, thereby generating the fuel gas which is ducted into the gas turbine combustors for final combustion with the primary air flow coming from the turbine compressor.

Another combustion method and apparatus is schematically illustrated in FIG. 10 and consists of a dual fluid bed gasifier 80. In the dual bed the oxygen necessary to combust the carbon is separated from the initial pyrolysis process. Solid wastes are introduced into the upper or volatilizing fluid bed where they are pyrolyzed by hot inert gases coming from the carbon combustion fluid bed. Rapid, uniform pyrolysis is assured by the highly stirred conditions existing in the fluid bed. The fuel gas resulting from the pyrolysis passes through particle collectors on its way to the gas turbine combustor. The particles collected contain both ash and carbonaceous char generated by the pyrolysis process. This char is burned by introducing the particles into the second or carbon combustion fluid bed and fine ash is separated from the second bed affluent by a second set of particle collectors. Ash slagging temperatures are prevented in the carbon bed by limiting the available oxygen and by introducing water or steam.

With the present invention still other combustion chamber assemblies could be used such as a horizontal vortex combustor, a vertical vortex combustor or a more conventional grate burner.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, it is understood that certain changes and modifications may be practiced within the spirit of the invention as limited only by the scope of the appended claims.

We claim:

1. Waste disposal apparatus comprising, in combination, a gas turbine for compressing air and combusting substantially gaseous material, a char combustion chamber, means for directing a portion of the compressed air from said gas turbine to said char combustion chamber, a pyrolyzing chamber, means for directing combustibles into said pyrolyzing chamber, means for conveying char produced in said pyrolyzing chamber into said char combustion chamber and for directing inert gaseous products from said char combustion chamber to said pyrolyzing chamber, and means for directing gaseous products from said pyrolyzing chamber to said gas turbine for combustion.

2. A waste disposal apparatus comprising, in combination, waste storage means for receiving and storing solid waste; shredder means for shredding the solid waste; dryer means for drying the shredded waste; combustion means for burning the burnable portions of said shredded dried waste at elevated pressure; means for conveying solid waste from said storage means to said shredder means, shredded waste from said shredder means to said dryer means, and shredded dried waste from said dryer means to said combustion means for combustion; a compressor-turbine assembly including means for compressing and heating air for combustion of said waste; means for directing said turbine compressed air to said combustion means; means for drawing malodorous air into said gas turbine from said dryer means, said shredder means and said storage means for compression; said combustion means including a bed of inert particles to which said shredded dried waste and said compressed gases are directed for burning; means for collecting and removing the unburnable portions of

said waste from said combustion chamber; means for removing the particles from the gaseous combustion stream produced in said combustion means; means for directing the combustion gases combustion gases from said combustion means to said compressor-turbine assembly; means for expanding said compressed hot gas in compressor-turbine assembly and means for directing hot gas from said compressor-turbine assembly to said dryer means.

3. The waste disposal apparatus of claim 2 including means for generating power connected to and driven by said gas turbine.

4. The method of disposing of waste comprising the steps of shredding the waste, drying the waste, mixing and burning the waste with hot compressed air, expanding the burning exhaust to generate shaft work to compress air and net shaft work, and drying other waste with a portion of the expanded exhaust.

5. The method of consuming waste comprising the steps of shredding the waste, drying the waste, compressing air, consuming the char combustion products of the volatilization step with the compressed air to produce hot inert gas and ash, volatilization of the waste with hot inert gas to produce char combustion products and fuel gas, burning the fuel gas in compressed air, and expanding the exhaust to compress the air and provide shaft work.

6. A waste disposal apparatus of the type for consuming solid waste refuse in a burner with minimal residue characterized by shredder means for shredding solid waste material, dryer means for drying the shredded waste, means for combusting portions of said shredded refuse at elevated pressure and temperature, means for removal of particulate matter from the hot high pressure gas which would be injurious to a turbine or cause air pollution, means for conveying solid waste from said shredder means to said dryer means and shredded dried waste from said dryer means to said combustion means, a compressor-turbine assembly for compressing intake gases and directing the compressed gases to said combustion means, means for directing gases heated by said combustion means to said compressor-turbine assembly to drive said turbine, and means for drawing into said compressor-turbine assembly malodorous air from said shredder means, said dryer means, and said storage means as intake gases for compression.

7. A waste disposal apparatus of the type for consuming solid waste refuse in a burner with minimal residue characterized by shredder means for shredding solid waste material, dryer means for drying the shredded waste, means for combusting portions of said shredded refuse at elevated pressure and temperature, means for removal of particulate matter from the hot high pressure gas which would be injurious to a turbine or cause air pollution, means for conveying solid waste from said shredder means to said dryer means and shredded dried waste from said dryer means to said combustion means, a compressor-turbine assembly for compressing intake gases and directing the compressed gases to said combustion means, means for directing gases heated by said combustion means to said compressor-turbine assembly to drive said turbine, and means for directing hot exhaust gases from said turbine to said dryer means for drying said waste.

8. A waste disposal apparatus of the type for consuming solid waste refuse in a burner with minimal residue characterized by shredder means for shredding solid waste material, dryer means for drying the shredded waste, means for combusting portions of said shredded refuse at elevated pressure and temperature, means for removal of particular matter from the hot high pressure gas which would be injurious to a turbine or cause air pollution means for conveying solid waste from said shredder means to said dryer means and shredded dried waste from said dryer means to said combustion means, a compressor-turbine assembly for compressing intake gases and directing the compressed gases to said combustion means, and means for directing gases heated by said combustion means to said compressor-turbine assembly to drive said turbine, said combustion means including means for volatilizing at least portions of said shredded dried waste and removing

particulate matter from fuel gas and including means for burning material volatilized in said volatilizing means.

9. The waste disposal apparatus of claim 8 including a char combustion chamber, means for feeding compressor-turbine assembly compressed air into said char combustion chamber, means for conveying char produced in said volatilizing means into said char combustion chamber and for directing inert gaseous products from said char combustion chamber to said volatilizing means.

10. A waste disposal apparatus of the type for consuming solid waste refuse in a burner with minimal residue characterized by shredder means for shredding solid waste material, dryer means for drying the shredded waste, means for combusting portions of said shredded refuse at elevated pressure and temperature, means for removal of particulate matter from the hot high pressure gas which would be injurious to a turbine or cause air pollution, means for conveying solid waste from said shredder means to said dryer means and shredded dried waste from said dryer means to said combustion means, a compressor-turbine assembly for compressing intake gases and directing the compressed gases to said combustion means, and means for directing gases heated by said combustion means to said compressor-turbine assembly to drive said turbine, said combustion means including a char combustor chamber, means connected to said compressor-turbine assembly and said char combustor chamber for conducting compressed air from said compressor-turbine assembly to said char combustor chamber, a pyrolyzer connected to said dryer means via said conveying means for receiving said dried shredded waste and connected to said char combustor chamber for combustion and passing inert gaseous products from said char combustor chamber to said pyrolyzer to volatilize dried shredded waste, and a gas combustion chamber means connected to said pyrolyzer to receive and burn volatilization materials produced in said pyrolyzer.

11. A waste disposal apparatus of the type for consuming solid waste refuse in a burner with minimal residue characterized by shredder means for shredding solid waste material, dryer means for drying the shredded waste, means for combusting portions of said shredded refuse at elevated pressure and temperature, means for removal of particulate matter from the hot high pressure gas which would be injurious to a turbine or cause air pollution, means for conveying solid waste from said shredder means to said dryer means and shredded dried waste from said dryer means to said combustion means, a compressor-turbine assembly for compressing intake gases and directing the compressed gases to said combustion means, means for directing gases heated by said combustion means for directing gases heated by said combustion means to said compressor-turbine assembly to drive said turbine, and means connected to said compressor-turbine assembly for establishing a partial vacuum and refuse collection vacuum pipe means connected to said vacuum means for conveying refuse to said storage and shredder means.

12. A waste disposal apparatus of the type for consuming solid waste refuse in a burner with minimal residue characterized by shredder means for shredding solid waste material, dryer means for drying the shredded waste, means for combusting portions of said shredded refuse at elevated pressure and temperature, means for removal of particulate matter from the hot high pressure gas which would be injurious to a turbine or cause air pollution, means for conveying solid waste from said shredder means to said dryer means and shredded dried waste from said dryer means to said combustion means, a compressor-turbine assembly for compressing intake gases and directing the compressed gases to said combustion means, means for directing gases heated by said combustion means to said compressor-turbine assembly to drive said turbine, and means connected to the exhaust of said compressor-turbine assembly for generating steam.

13. A waste disposal apparatus of the type for consuming solid waste refuse in a burner with minimal residue characterized by shredder means for shredding solid waste material,

dryer means for drying the shredded waste, means for combusting portions of said shredded refuse at elevated pressure and temperature, means for removal of particulate matter from the hot high pressure gas which would be injurious to a turbine or cause air pollution, means for conveying solid waste from said shredder means to said dryer means and shredded dried waste from said dryer means to said combustion means, a compressor-turbine assembly for compressing intake gases and directing the compressed gases to said combustion means, means for directing gases heated by said combustion means to said compressor-turbine assembly to drive said turbine, and means for directing sewage sludge into said combustion chamber assembly.

14. Waste disposal apparatus of the type for consuming solid waste refuse in a burner with minimal residue and substantially pollution-free gaseous output characterized by: a compressor-turbine assembly including means receiving hot gases produced in the combustion of such waste; means for shredding solid waste material, combustion means for consuming most of the shredded waste under elevated pressure and temperature including a bed of incombustible inert particles, means for feeding compressor-turbine assembly compressed air into said combustion chamber beneath said particle bed, and means for feeding shredded waste from said shredding means into said particle bed without additional fuel whereby substantial portions of said waste are combusted in said particle bed; means for removal of particulate matter from the hot gases produced in said combustion means at substantially the consuming elevated pressure and temperature; and means for directing compressed and heated air from said compressor-turbine assembly to said combustion means and hot gases from said combustion and particle removal means to said compressor-turbine assembly to drive said turbine; and means for directing at least certain of the combustion gases from said turbine to atmosphere.

15. Waste disposal apparatus of the type for consuming solid waste refuse in a burner with minimal residue characterized by: a compressor-turbine assembly including means for compressing air for combusting waste material and means receiving hot gases produced in the combustion of such waste; combustion means for consuming most of the waste under elevated pressure and temperature including means for volatilizing at least portions of said waste and means for combusting material volatilized in said volatilizing means; means for removal of particulate matter from the hot gases produced in said combustion means at substantially the consuming elevated pressure and temperature; means for directing compressed and heated air from said compressor-turbine assembly to said combustion means and hot gases from said combustion and particle removal means to said compressor-turbine assembly to drive said turbine; and means for directing waste into said combustion means.

16. The waste disposal apparatus of claim 15 including a char combustion chamber to receive compressor-turbine assembly compressed air and means for conveying char produced in said volatilizing means into said char combustion chamber and for directing inert gaseous products from said char combustion chamber to said volatilizing means.

17. A waste disposal apparatus of the type for consuming solid waste refuse in a burner with minimal residue and substantially pollution-free gaseous output characterized by shredder means for shredding solid waste material; dryer means for drying the shredded waste; means for combusting portions of said shredded refuse at elevated pressure and temperature including a combustion chamber and a bed of inert particles positioned within said combustion chamber, said particles being incombustible at the combustion temperature of said shredded dried waste; means for removal of particulate matter at substantially said elevated pressure and temperature from the hot high pressure gas which would be injurious to a turbine or cause air pollution; means for conveying solid waste from said shredder means to said dryer means and shredded dried waste from said dryer means to said particle bed without

13

additional fuel; a compressor-turbine assembly for compressing intake gases and directing the compressed gases to said combustion chamber beneath said particle bed; means for directing high pressure exhaust gases heated by said com-

14

bustion means to said compressor-turbine assembly for expansion and drive of said turbine; and means for exhausting at least certain of the combustion gases from said turbine to atmosphere.

5

10

15

20

25

30

35

40

45

50

55

60

65

70

75