PATENT SPECIFICATION (11) 1 594 370

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(21) Application No. 53743/77 (22) Filed 23 Dec. 1977 (19)
(31) Convention Application No. 849588 (32) Filed 8 Nov. 1977 in
(33) United States of America (US)
(44) Complete Specification Published 30 Jul. 1981
(51) INT. CL.^{3} G21F 9/14
B01J 8/24
F23G 7/00
G21F 9/32
(52) Index at Acceptance
G6R 1A10
B1F C1K

THE PATENT OFFICE LONDON

(54) TREATMENT OF WASTE

(71) We, ENERGY, INCORPORATED, a corporation organised and existing under the laws of the State of Idaho, United States of America, of P.O. Box 736, Idaho Falls, Idaho 83401, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The present invention is concerned with a method for treating and disposal of waste materials. The present invention is especially advantageous in the treatment of radioactive wastes such as those which include radioactive halogens such as iodine 131 isotope. The present invention is particularly directed to a method which substantially reduces the volume of both liquid and solid radioactive waste materials including concentrated chemical wastes, filter sludges, spent ion exchange resin beads, rags, and other similar materials. The process of the present invention reduces all liquid and combustible solid waste to anhydrous granular solids, all of which is carried by fluidizing gases into an off-gas system designed for their collection.

During the last few years, there has been a significant increase in the use of energy including nuclear energy for power plants. This increased demand has been accompanied by increased treatment and disposal problems of the waste materials. One significant problem is that due to the increase in the number of operating facilities, there is a great demand on available space at licensed disposal sites. Moreover, it is believed that selection of new commercial disposal sites in the future will involve close government supervision and strict regulation.

In particular, it is believed that government regulatory agencies will now review and monitor low level radwaste disposal installations. Requirements to obtain a license will probably become more stringent.

A major concern in disposal is the safety of transporting the treated waste to its final disposal site. In dealing with this concern, it is desirable to reduce the volume of the waste as much as possible along with increasing the stability of the materials.

Therefore, an object of the present invention is to provide a treatment process which makes it possible to significantly reduce the volume of the waste material.

A major problem in the treatment of wastes generated in nuclear plants is that the types of waste can differ significantly in chemical and physical characteristics and many treatments of waste must be tailored for only a single facility. The present invention provides a process which is as independent as possible from the chemical composition of the waste material and therefore useful for treatment of a myriad of waste materials.

Fluidized beds have been employed for liquid calcination or combustible waste incineration in industrial plants for several years. For instance, see Richard C. Corey, *Principals and Practices of Incineration*, Wiley-Interscience, New York, 1969, page 239. Moreover, fluidized bed calcination of radioactive wastes was developed during the period of 1952 to 1959 at the Idaho National Engineering Laboratory. Use of calcination for liquid radwaste reduction was employed in an engineering scale facility, the Waste Calcining Facility (WCF), at the Idaho Chemical Processing Plant in 1963.

A batch operated fluidized bed calciner was designed and built as part of the Midwest Fuel Recovery Plant (MFRP) at Morris, Illinois for General Electric Company. A batch calcination process was employed on a fully radioactive basis in the WSEP program from about 1966 to about 1970. This process was developed at Oak Ridge National Laboratory for the specific purpose of solidification of high level radioactive liquid waste but did not employ a fluidized bed process.

Incineration of combustible radioactive wastes has been in use as a disposal technique since 1948 when a pilot plant incinerator and off-gas clean-up system was built at Mound Laboratory. The earlier systems were adaptations of standard refuse incinerators and demonstrated that considerble volume reduction in waste handling was possible. Data taken in the early 1960's at the General Electric Atomic Power Equipment Department in San Jose, California showed that about 99% of the radioactivity of the incinerated wastes remained in the ash. Similar data was reported from an incinerator at Pratt and Witney Aircraft where approximately 99.1 to 99.98% of the radioactivity remained in the ash.

For a discussion of various incinerators for radwaste treatment, attention is directed to B. L. Perkins, "Incineration Facilities for Treatment of Radioactive Wastes: A Review", LA-6252, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, 1976.

Fluidized beds which have been previously employed in converting liquid waste streams including radioactive streams to solid particles are composed of the resulting solid products from previous drying or calcining a liquid waste stream similar to the one being treated.

The difficulty encountered with the above approach is that the fluidized particles are simultaneously subject to growth, from deposition of new liquid waste on the surface where the water flashes off and leaves a layer of resulting solids, and size reduction caused by the "self-grinding" action of the particles colliding with each or with any solid surface to which they are exposed.

The simultaneous growth and size reduction processes are very critical to proper operation because if the fluidized bed particles become too large, they cannot be properly fluidized thereby limiting the successful operation of the process. On the other hand, if the bed particles become too small, they will be blown out at the top of the fluidized bed as the terminal velocity of the particles will approach the fluidizing air superficial velocity in the vessel. Entrainment of solid particles in the effluent gas is commonly referred to as elutriation. Accordingly, in such a system, due to the delicate balance between growth and size reduction, it is necessary to continually monitor the particle size distribution of the fluidized-bed media and make adjustments in operating conditions to control the particle size and particle growth phenomena to assure proper particle size.

These particle growth and size reduction phenomena are greatly influenced by the chemical characteristics and composition of the liquid waste stream being converted to the solid. For instance, if the total solids content (dissolved and undissolved) of the waste is less than a certain value dependent upon the chemical identity of the liquid waste, it is not possible to grow fluidized-bed particles. This is due to the size reduction (attrition) rate being greater than the size increase (growth) rate because of the small amount of solid-building material present in the liquid waste stream.

This dependency of such fluidized-bed calcination or evaporation processes upon the chemical identity of the liquid waste is a major disadvantage which requires extremely close process supervision to assure proper operation. According to the present invention, a process is provided whereby the calcination and incineration is not so critically dependent upon the liquid waste chemistry.

Moreover, the above type of calcination processes cannot handle very dilute liquid waste streams in view of this particle size control problem. The process of the present invention is capable of successfully treating very dilute liquid waste steams as well as entirely solid waste material. The present invention makes it possible to employ the same fluidized bed but operating at different conditions (e.g., different temperatures) for both calcination and incineration.

In a booklet by the present applicants entitled "RWR-1 Radioactive Waste Reduction" which was available in about October 1975, at a trade conference in Switzerland, a system was suggested wherein an afterburner was required after the incinerator-calciner. According to the present invention, in view of the particular controls on certain process parameters, it is no longer necessary to employ a separate afterburner. Any afterburning needed occurs directly in the incinerator/calciner rather than after leaving the incinerator/calciner and after a subsequent cyclone treatment. The above booklet did not disclose the necessary details concerning the fluidised bed which are essential to the present invention.

The present invention is concerned with a method for the treatment of and the volume reduction of waste material which comprises in the process of providing a fluidised bed incinerator and calciner containing a fluidizable bed material maintaining the bed material in a fluidised state by introducing gas into the fluidised bed region of the incinerator maintaining combustion conditions in the incinerator by supplying fuel and oxygen containing gas thereto, feeding the waste into the fluidised bed region of the incinerator and calciner, and incinerating or calcining the waste, the improvement which comprises selecting the bed material from those materials which are resistant to oxidation, agglomeration and attack by chemicals at temperatures up to at least 1000°C. whereby the material of the bed can remain unaffected under the normal operating conditions of the incinerator by the waste handled or by solid particulate material formed as a product of the incineration or calcining, and operating the incinerator and calciner so that the solid particulate material formed does not remain as a deposit in the particles of the bed but is expelled therefrom into the gaseous zone above the bed; removing from an upper region of the incinerator or calciner a gas effluent containing extrained solid particulate material expelled from the bed; and cleaning the gas effluent by passing it to a gas cleaning system in which the solid particulate material is separated from the effluent gas.

In a preferred gas cleaning system, the gaseous effluent removed from the incinerator and calciner is directed to a dry cyclone. Solid particles are separated from the effluent in the dry cyclone. The solid particles are removed from the dry cyclone and directed to a storage container for possible subsequent treatment and/or packaging, if desired. The gas effluent is removed from the cyclone and directed to a quench tank wherein liquid is introduced for cooling of the gas effluent and wetting of particles still contained in the effluent. Liquid and wetted particles not remaining entrained in the gas effluent are then removed from the quench tank and are directed to a scrub solution tank. A gas effluent is removed from the quench tank and passed to a venturi scrubber, and additional liquid is added to the venturi scrubber to wet particles particles remaining in the gas effluent and to cause condensation of water vapor. A gas effluent containing wet particles is removed from the venturi scrubber and directed to a wet cyclone. Liquid particules are removed from the wet cyclone and are directed to a scrub solution tank. A gas effluent is removed from the wet cyclone and is directed to a condenser. A gas effluent and condensed liquid particles are removed from the condenser and are directed to a demister wherein liquid particles are removed. The liquid particles are then conveyed to a scrub solution tank. The gas effluent is removed from the demister and is heated. The heated gas effluent is then passed through a filter for removal of remaining solid particles and then through a sorber for removing halogen gases threrefrom. The scrub solution tank or tanks are employed primarily as a collection means for maintaining a reserve of scrub solution. The scrub solution is withdrawn, when needed, for the scrub solution tank or tanks for supplying liquid to the quench tank and venturi scrubber, and/or recyling to the plant liquid waste system. Thus, radioactive halogens which may be introduced into the scrub solution tank are retained within the treatment system for a sufficient amount of time to allow decay to a nonradioactive daughter. In the preferred embodiments, a halogen treating or getting agent is introduced into the scrub tank.

The figure illustrates a sequence of processing steps within the scope of the present invention.

The present invention can be more fully understood by reading the following description in conjunction with the figure which schematically illustrates a preferred process according to the present invention. Also, for convenience, the process will be described in terms of treating low level radioactive waste materials with the understanding that other waste materials can be treated according to the present invention.

Reference to the figure shows a feed system which includes vessels 1, 3, 4, and 6; and incineration and calcination system which includes vessel 9, and an off-gas clean-up system which includes vessels 10, 12, 13, 14, 15, 16, 17, 18, 19, and 21.

When desired, the waste can be pretreated prior to introduction into the feed system. For instance, relatively large noncombustible solids such as tools and piping, can be separated by sorting means. Explosive materials can be removed by conventional methods, if needed.

The feed system to the incinerator and calciner vessel 9 shown in the figure is arranged for feeding three separate types of waste. These three types of waste include a low-level radioactively contaminated combustible waste, spent resins and sludges, and liquid waste. Of course, this feed system is only exemplary of the myriad systems which may be employed depending upon the exact waste being treated and/or the existence of a feed system already at a facility.

In handling combustible waste, when needed, it is desirable to reduce the size of the individual particles of waste such as by shredding so that they can be efficiently transported into the incinerator. The maximum size of the particles must be smaller than the inside diameter (ID) of the transport piping leading to the process vessel and is limited, when a pneumatic feed is employed, by the flow rate of the feed gas. Moreover, the particle size must be small enough to substantially preclude migration to the bottom of the vessel 9 before incineration can be completed.

For a potential commercial system now being pursued, the limiting condition on particle size is the ID of the transport piping. In particular, the preferred maximum dimension of particles for the above-mentioned commercial system is less than about 2". Reduction of particle size when desired can be done by way of a shredder located within the storage hopper 6. By including the shredder within the storage hopper 6, the shredding and hopper loading operations can occur at the same time with a minimum amount of effort and radiological exposure. It is desirable that the storage hopper be large enough so as to maintain at least about a month's supply of shredded waste. Preferably, the storage hopper is sealed to the atmosphere to guard against possible radiological contamination of the surrounding area. Some typical low level radioactive combustible waste materials include protective fabric clothing, gloves, rags, plastics, paper respiratory filters, and wood.

The combustible waste can be conveyed to incinerator and calciner 9 via, for instance, a screw conveyor 31 and conduit 32. Other means of conveyance can, of course, be employed. In order to ensure against the possibility of outleakage of radioactive contamination from the radioactive material in the system, the vessel 9 is maintained at a pressure lower than ambient pressure and the feed is to a portion of the vessel wherein the pressure is lower than ambient pressure. A convenient pressure at which process vessel 9 can be maintained is about 10.35 mm Hg and preferably about 28 mm Hg vacuum. In addition, if desired, the screw feeder can include an isolation valve (not shown) which is used to provide a positive air-tight seal when the combustible feed system is not in use. The shredder and hopper 6, as well as accompanying feed conduits, are preferably constructed of carbon steel.

The flow rates of the waste feeds are primarily dependent upon the size or capacity of vessel 9. Suitable sizing of vessel 9 for many applications is designed to be capable of handling about 200 to about 300 pounds/hour of combustible solid wastes.

Resin and sludge are introduced into tank 3 via conduit 33 and collected therein. Typical resin and sludge feeds include cation and anion exchange resin beads, powdered resin filter precoat materials (e.g., "Powdex"), nonresinous filter precoat materials (e.g., "Solkafloc" and diatamaceous earth, along with varying amounts of water. The resin and sludge are conveyed via conduit 34 to a mixing and dewatering tank 4. From tank 4, the material is then conveyed to a metering device and pump 5 whereafter it is injected into the vessel 9 via conduit 35.

Suitable sizing of vessel 9 for many application is designed to be capable of handling about 100 to about 175 pounds of resin and sludge feed wastes. In the dewatering and mixing tank 4, the waste is mechanically agitated which helps prevent bridging, compaction, or adhesion to the tank walls. After dewatering, the slurry desirably includes only as much water as is necessary to maintain a pumpable slurry. Typically, feed slurries contain at least about 70% by weight of solids and up to about 80% by weight of solid.

Water which is obtained from the dewatering can be returned to the slurry pumping system as make-up water or can be pumped to the liquid waste storage tank 1 via conduit 36 by pump 25. The pump can be a positive displacement mechanical feed device which meters the waste as it is injected into the incinerator. When desired, the system can be continuously operated since dewatering, metering, and injection are simultaneous operations. Also, desired, the rate of feed can be automatically regulated.

The resin and sludge are introduced into vessel 9 at a position wherein the pressure is below atmospheric and generally about 1 to 2 psi below ambient. The equipment for the mixing and dewatering of the resin and sludge is preferably constructed of stainless steel.

Liquid waste is introduced into liquid waste tank 1 via conduit 37. Suitable sizing of vessel 9 for many applications is designed to be capable of handling about 30 to about 50 gallons/hour of the liquid waste. Liquid waste is pumped from tank 1 by pump 2 via conduit 38 to vessel 9. It is preferred that the liquid waste be introduced into the vessel 9 through atomizing nozzles. The liquid waste is desirably at a temperature sufficient to maintain the solids in solution. The liquid waste should be at a temperature above the saturation temperature of the solid wastes at the concentration in the solution. The temperature is generally from about 50°F to about 200°F depending upon the amount and type of solids. This tends to at least retard precipitation of dissolved solids from the waste stream onto the nozzles and conveying equipment and in turn inhibits subsequent plugging of process piping, valves, nozzles, and the like.

Typical liquid waste can contain about 50 to about 90% water along with such soluble materials as sodium sulfate, ammonium sulfate, sodium chloride, and boric acid. Some specific liquid waste compositions include Boiling Water Reactor (BWR) waste from a forced recirculation evaporator which contains about 75% water, about 22.9% sodium sulfate, about 2% sodium chloride, and 0.1% miscellaneous ingredients; Pressurized Water Reactor (PWR) waste from a forced recirculation evaporator which includes about 73.4% water, about 14.9% sodium sulfate, about 9.6% ammonium sulfate, about 2% sodium chloride, and about 0.1% miscellaneous ingredients; and boric acid waste from a forced recirculation evaporator which contains about 87.9% water, about 12% boric acid, and the remainder miscellaneous ingredients. The above percents are all by weight.

It is understood, or course, that since the different types of feed require different temperatures of treatment depending on whether calcination or incineration is needed, only one stream is introduced into the vessel 9 at any one time and is treated therein. Accordingly, when one of the streams is being introduced into the vessel 9, the other two streams are closed off from the vessel.

It is possible, according to the present invention, to employ the same vessel for both calcination and incineration depending on the temperature conditions present in the vessel. This is accomplished by employing as the fluidized bed material a material which is resistant to oxidation, agglomeration, and attack by chemicals such as acids and bases at temperatures up to at least 1000°C. The use of such an inert material eliminates problems existent in prior fluidized-bed incinerators which required a close monitoring of the system to assure proper operation. This was due to the fact that the particle growth and size phenomena as discussed hereinabove had to be properly controlled. Bed materials which do not possess the above properties such as quartz have not been successful in the process of the present invention.

The preferred inert bed materials possess the following characteristics:

Hardness (Moh)	6.0 – 9.0
Specific Gravity	3.2 – 3.9
Dry Bulk Density (lbs/cu. ft.)	100 – 125
Coefficient of Thermal Expansion (in/in/°F)	0.0083
Fusion Point	2300 – 3200°F (1538 – 1760°C)
High temperature reaction	Basic
High heat absorption	
Silicosis free	
Particle size	About 0.5 – 1.5 mm

Some examples of bed materials which can possess all of the above properties are chrysolite, olivine, kyanite, corundum, and alumina. Mixtures of such bed materials can be employed when desired.

The most preferred inert bed materials are the magnesium-iron silicates known as olivine and chrysolite. A typical olivine material suitable as the fluidized-bed material, according to the present invention, has the following chemical and physical characteristics.

	Olivine
Hardness (Moh)	6.5 – 7.0
Dry bulk density (lbs./cu. ft.)	100 – 125
Specific gravity	3.2 – 3.6
Thermal expanison (in./in.)	0.0083
Apparent heat transfer	Low
Fusion point	2300°F – 3200°F (1538°C – 1760°C)
High temperature reaction	Basic
Wettability to molten metal	Not generally
Chemical reaction	Basic
Particle size	About 0.5 – 1.5 mm.

Chemical Analysis Range

MgO	45 – 49%
SiO_2	39 – 43%
FeO	6 – 8%
CR_2O_3	.6 – .8%
Ni	.2 – .3%
Al_2O_3	.2 – .8%
Trace elements	.5%

Mineralogical Analysis

Olivine	92 – 93%
Enstatite	5%
Serpentines	1 – 2%
Chromite	1%
Total	100%

Other Properties

Constant coefficient of expansion.
High heat absorption.
High heat conductivity at low temperatures.
Tough, durable grain.
Silicosis free.
Insulator at high temperatures.

The maximum temperature employed in the calcination process is primarily limited by the melting point of the feed solids. The maximum temperature for incineration is primarily determined by economic and practical considerations concerning the strength of the material of construction of vessel 9. The bed material is generally maintained at a temperature of between about 350°C and 550°C and preferably about 400°C for calcination, between about 800 and about 1000°C and preferably about 800°C for the incineration treatment of resin and sludge; and between about 900 and about 1200°C and preferably about 1000°C for the treatment of compactible solids.

A gas such as air is blown into the bottom of vessel 9 via blower 7 and conduit 39 to maintain the bed in its fluidized condition and at proper height. This gas when air is employed also supplies the oxygen necessary for combustion. Moreover, if desired, additional air can be injection above the bed to enhance complete combustion via conduit 32. In view of the interrelationship between the height of the vessel 9 and the flow rate of the treated material, the material remains above the bed for a sufficient amount of time that any necessary afterburning for combustion occurs before the entrained particulate matter is exhausted into the dry cyclone. This eliminates the need for an afterburner. An overall height of vessel 9 of about 15 feet is suitable for processing the amounts of materials discussed hereinabove. The static bed height for processing the amounts of materials discussed hereinabove can be from about 18 to about 36 inches. Of course, the bed height and/or vessel height can be scaled up or down depending upon the actual amount of material to be processed.

The heat for the calcination or incineration and for preheating the bed is provided by combustion within the bed of a liquid hydrocarbon fuel in a burner (not shown). Combustion within the bed provides the needed heat transfer. The fuel is pumped via pump 8 and conduit 40 to the burner. The incinerator and calciner are preferably constructed of Inconel (Registered Trade Mark; a nickel - chromium - iron base alloy) or alternatively titanium, Hastelloy (Registered Trade Mark; a nickel - chromium - molybdenum base alloy or steel with a refractory or ceramic lining. A gas effluent leaves vessel 9 via conduit 41 and is directed to a dry cyclone 10.

The table below sets forth some approximate typical operating conditions for the various operating modes for dry cyclone 10 of the dimensions given.

Capacity of Unit – 1750 CFM

Inlet velocity – 50 ft/sec

Inlet duct – .5 ft × 1.0 ft

(long dimension is vertical)

Cyclone I.D. – 2 ft.

Calcination of liquid wastes

O_2 – 166 lb/hr

N_2 – 858 lb/hr

CO_2 – 235 lb/hr

H_2O – 86 lb/hr

Solids – 50 lb/hr

Total – 1395 lb/hr

Temperature – 375°C

Pressure – 14 psia

CFM – 900

Incineration of resins/filter sludges

O_2 – 33 lb/hr

N_2 – 724 lb/hr

CO_2 – 157 lb/hr

H_2O – 141 lb/hr

Solids – 2 lb/hr

Total – 1058 lb/hr

Temperature – 800°C

Pressure – 14 psia

CFM – 1150

Incineration of compactible waste

O_2 – 44 lb/hr

N_2 – 874 lb/hr

CO_2 – 294 lb/hr

H_2O – 120 lb/hr

Solids – 8 lb/hr

Total – 1340 lb/hr

Temperature – 1000°C

Pressure – 14 psia

CFM – 1750

The controlling dimensions of the dry cyclone are the inlet duct dimensions which establish the inlet flow rate and the inlet diameter which determines flow rates, and thus centrifugal force, developed within the dry cyclone. The dry cyclone is for removing any solid material in the gas effluent and preferably removes at least about 82% of the solids contained therein. The gas effluent enters the cyclone at a side approximate the top of the cyclone to achieve a circular swirling motion. The solids which are separated from the gas effluent settle towards the bottom of the dry cyclone and are exited therefrom via conduit 42 and are directed to disposable container 11. The solid particles are then solidified by conventional means for subsequent disposal such as by burial. Approximately at least 82% of radioactivity from the solid particulate matter is removed from the dry cyclone along with at least about 17% of radioactive halogens.

In the dry cyclone, the swirling motion of the air causes a centrifugal force to act upon the solid particles so that they migrate to the wall. The air velocity is lower close to the wall due to the boundary effect, so that the particles slide downward along the wall to the particulate exit 42. The gas effluent exits upward from the top center of the cyclone 10 via conduit 43 and is directed to quench tank 12. The dry cyclone can be constructed of the same types of materials as the incinerator and calciner.

In quench tank 12, the gas effluent is cooled to a temperature of about 70°C by a liquid spray which is introduced into the quench tank via conduit 44 and spray nozzles (not shown). In quench tank 12, turbulent gas motion is created which causes intimate contact between the gas and liquid streams. This causes both cooling of the gas effluent and wetting of most of the remaining solid particles in the gas effluent. The larger droplets fall to the bottom of quench tank 12 and are returned to scrub solution tank 21 via conduit 45 taking the wetted solid particles along with them. Smaller liquid droplets are swept out of the quench tank 12 with the gas effluent via conduit 47. The quench tank and scrub solution tank are preferably of 300 series stainless steel or of "Inconel", "Hastelloy" or steel lined with glass or fluorocarbon polymers e.g., Teflon. (Registered Trade Mark).

The liquid particles are admixed with water in scrub solution tank 21 and preferably with a halogen "getter" (i.e., material for capturing halogens). Some examples of getters for iodine include resorcinol, soidum thiosulfate, sodium sulfate, cyclohexyl amine, potassium ferrocyanide, potassium carbonate and potassium hydroxide. The halogen getter and any pH adjusting materials can be added to the scrub solution tank usually as an aqueous composition via conduit 46. The amount of halogen getter employed is generally from about 10 to about 100 ppm in the scrubbing solution.

The gas effluent exits the quench tank via conduit 47 and is directed to venturi scrubber 13. Scrub solution is sprayed into the gas effluent via conduit 48 at the throat of the venturi scrubber. In venturi scrubber 13, it is desirable to achieve saturation and entrainment of water to facilitate wetting of those particles which were not wetted in quench tank 12. The gas effluent leaving vessel 9 contains a great deal of water vapor e.g. about 9 to about 17%. Moreover, as the gas effluent passes through quench tank 12, water vapor, in addition to entrained water, was acquired. At the venturi scrubber 13, the gas effluent is substantially saturated with water vapor. Saturation is ensured by spraying additional scrub solution via conduit 48 into the gas effluent as it passes through the throat of the venturi scrubber 13. As the gas effluent passes through the venturi throat, the pressure drops which in turn causes an increase in the amount of moisture which the gas can maintain in vapor form. Accordingly, evaporation occurs. As the gas effluent enters the divergent section of the venturi scrubber, the velocity decreases and the pressure increases thereby resulting in condensation of water vapor. This condensation in turn causes the existing droplets to become larger along with causing new droplets to form on the unwetted particles which serve as condensation nuclei.

As can be seen, the primary purpose of the quench tank and venturi scrubber is to cool the off-gas so as to wet as many of the solid particles as possible to facilitate removal. It is easier to remove a liquid droplet than it is to remove a much smaller solid particle. The liquid particles are removed subsequently whether the particles are composed of soluble material which have gone into solution in the droplet or the particles are composed of insoluble material which is retained as a wetted solid within the droplet. In either situation, the solid particle moves with the liquid droplet. The venturi scrubber can be constructed from the same types of materials as the quench tank. The following table sets forth some typical process parameters for quench tank and venturi scrubber of the sample dimensions given below.

	Quench Tank	*Venturi Scrubber*
Gas flow rate (CFM)	900–1800	500–900
Inlet temperature (°C)	400–1000	60–75
Outlet temperature (°C)	60–75	45–65
Inlet pressure (psia)	13.7	13.7
Δp (psi)	negligible	2
Scrub solution flow rate (gpm)	5	11
Sizing	4′ dia × 8′	6″ dia 32″ length 2.7″ throat

A gas effluent containing liquid particles is removed from the venturi scrubber via conduit 49 and introduced into wet cyclone 14 near the top. In wet cyclone 14, liquid runs down the side of the cyclone to a drain in the bottom thereof. The liquid is then removed from the cyclone via conduit 50 and directed to scrub solution tank 21.

Typical operating parameters for the cyclone 14 include a temperature range of about 45°C to about 65°C, an inlet pressure of about 12 psia, a Δp of about 0.5 psia, and a gas flow rate of about 400 to about 750 CFM.

A gas effluent is removed from the top of wet cyclone 14 via conduit 51 and is conducted to a condenser 15 for cooling the gas effluent. The condenser can be a shell and tube type heat exchanger if desired. In the condenser, the liquid particles grow in size to a point wherein a significant amount of the water in the gas effluent is removed by gravitational or momentum effects. In a gravitational removal mechanism, the drops are so large that they fall to the bottom of the vessel. On the other hand, in a momentum removal mechanism, the droplets are not large enought to fall out of the off-gas stream but they are not large enough to fall out of the off-gas stream but they are large enough so that when the gas changes direction suddenly, the droplets impinge upon the wall of other solid material which has caused the direction change.

Typical operating parameters for the condenser 15 include a gas flow rate of about 400-800 CFM, about 5-20 gallons/minute of cooling liquid, inlet temperature of about 45 to 65°C, a ΔT of about 10-30°C, inlet pressure of about 11.5 psia, and a Δp of about 2 psi.

The gas effluent and liquid droplets exit the condenser via conduit 52 and are directed to the demister 16. The demister operates to remove the liquid particles by the momentum removal effect. Gas is passed through a filter of woven fibers which causes the gas to undergo rapid and frequent changes in direction. However, since the liquid droplets are too large to turn as sharply as the gas particles, they collide with the filter fibers. The liquid droplets then run down the fiber to the wall of demister 16 and from there to the drain and conduit 53 which returns the liquid droplets to scrub tank 21.

The gas effluent leaves the demister 16 near the top via conduit 54 and is directed to a heater 55 which heats the gas effluent to a temperature between about 40°C and about 55°C. The heater is employed to control to relative humidity of the gas effluent in order to protect the High Efficiency Particulate Air (HEPA) filter 17 from clogging of plugging due to moisture overloading. The gas effluent is conducted from the heater to the HEPA filter via conduit 56 wherein solid particles which have not been wetted or which have been formed when those droplets which were not removed in the demister were evaporated in the heater are trapped. The filter is composed of a medium with very small pores and the particles are removed by impingement.

The gas effluent exits the HEPA filter via conduit 57 and enters a halogen adsorber 18 which removes halogen by adsorption. The halogen atoms are held on the surface of the material by chemical bond with the adsorbing agent and decay to a stable atom. For instance, radioactive iodine decays to stable xenon. Examples of adsorbing agents include activated charcoal and silver impregnated solids such as silver silicates and silver zeolites.

The temperature and flow rate of the gas effluent through the HEPA filter and iodine adsorber is between about 40 and about 55°C and about 350 CFM and about 550 CFM, respectively. Following the iodine adsorber, the gas effluent is directed via conduit 58 to a second HEPA filter 19. Combinations of the two HEPA filters 17 and 19 and iodine adsorber 18 are commercially available and need not be disclosed in any greater detail herein.

The gas effluent leaving the HEPA filter via conduit 59 is sufficiently decontaminated that any amounts of radioactive material which may be present in the gas are well below the levels permitted by the plant operating license and accordingly can then be discharged by means of a pump 20 and conduit 60 to the atmosphere.

As discussed hereinabove, a halogen getter can be introduced into the scrub solution tank 21 via conduit 46 so as to maintain the halogens in ionic form in solution for decay to a stable nonradioactive daughter. The scrub solution is removed from the scrub tank via conduit 61 and pump 23. In addition, if desired, a strainer 22 for removing solid particles can be included in line 41 between scrub tank 21 and pump 23. Scrub liquor is then fed to a heat exchanger 24 wherein it is cooled sufficiently so that a portion of it can be recycled as the spray in quench tank 12 and venturi scrubber 13 via conduit 62. The remaining scrub tank liquor can then be returned to scrub tank 21 via conduit 63. The temperature downstream of the scrub cooler is typically about 30°C. A typical flow rate of the scrub solution to the quench tank and venturi scrubber is about 15 gallons/minute and that of the scrub solution recirculating to the scrub solution tank is about 10 gallons/minute.

The present invention makes it possible to reduce the volume of dry compacted solids by at least about 80 times, spent resins by at least about 18 times, concentrated liquids by at least about 8 times, and filter sludges by at least about 5 times.

WHAT WE CLAIM IS:

1. In a method for the treatment of waste which comprises providing a fluidised bed incinerator and calciner containing a fluidizable bed material maintaining the bed material in a fluidised state by introducing gas into the fluidised bed region of the incinerator maintaining combustion conditions in the incinerator by supplying fuel and oxygen containing gas thereto, feeding the waste into the fluidised bed region of the incinerator and calciner, and incinerating of calcining the waste, the improvement which comprises selecting the bed material from those materials which are resistant to oxidation, agglomeration and attack by chemicals at temperatures up to at least 1000°C. whereby the material of the bed can remain unaffected under the normal operating conditions of the incinerator by the waste handled or by solid particulate material formed as a product of the incineration or calcining, and operating the incinerator and calciner so that the solid particulate material formed does not remain as a deposit in the particles of the bed but is expelled thereform into the gaseous zone above the bed; removing from an upper region of the incinerator or calciner a gas effluent containing entrained solid particulate material expelled from the bed; and cleaning the gas effluent by passing it to a gas cleaning system in which the solid particulate material is separated from the effluent gas.

2. A method according to Claim 1, wherein the incinerator or calciner is operated so that solid particulate material expelled from the bed is afterburned before it is removed from the incinerator or calciner.

3. A method according to Claim 1 or 2, comprising: passing the gas effluent from said incinerator and calciner to a dry cyclone wherein particles are separated from the effluent;
removing solid particles from said dry cyclone and passing them to a storage container;
removing a gas effluent from the cyclone and passing it to a quench tank;
introducing liquid into said quench tank for cooling the gas effluent and wetting particles contained in the gas effluent;
removing liquid and wetted particles from said quench tank and passing them to a scrub solution tank;
removing a gas effluent from the quench tank and passing it to a venturi scrubber;
introducing liquid into the venturi scrubber to wet particles remaining in the gas effluent and cause condensation of water vapor;
removing a gas effluent and wetted particles from the venture scrubber and passing them to a wet cyclone;
removing liquid paticles from the wet cyclone and passing it to a scrub solution tank;
removing a gas effluent from the wet cyclone and passing it to a condenser for condensing liquid vapor;
removing a gas effluent and condensed liquid particles from the condenser and passing them to a demister;
removing liquid particles from the demister and passing them to a scrub solution tank;
removing a gas effluent from the demister and passing it to a heater for raising the temperature of the effluent for evaporation of remaining liquid droplets;
passing the effluent through a filter for removal of remaining solid particles and through a sorber for removing halogen gases therefrom.

4. The method of any preceding claim wherein said waste is radioactive waste.
5. The method of any preceding claim wherein said bed material is olivine.
6. The method of claim 5 wherein said olivine has a particle size of about 0.5 – 1.5 mm.
7. The method of any preceding claim wherein said calcining is carried out at about 400°C.
8. The method of any preceding claim wherein said incinerating is carried out at about 1000°C.
9. The method of any preceding wherein liquid introduced into said quench tank is from said scrub solution tank.
10. The method of any preceding claim wherein liquid introduced into said venturi scrubber is from said scrub solution tank.
11. The method of claim 1 wherein said bed material has the following properties:

Hardness (Moh)	6.0 – 9.0
Specific Gravity	3.2 – 3.9
Dry Bulk Density (lbs./cu. ft.)	100 – 125
Coefficient of Thermal Expansion (in./in./°F)	0.0083
Fusion Point	2300 – 3200°F (1538 – 1760°C)
High temperature reaction	Basic
High heat absorption	
Silicosis free	
Particle size	About 0.5 – 1.5 mm.

12. The method of claim 11 wherein said bed material is selected from the group consisting of chrysolite, olivine, kyanite, corundum, alumina, and mixtures thereof.
13. A method for treating waste substantially as herebefore described.
14. An installation fior treatment of waste constructed, arranged and adapted to operate substantially as hereinbefore described with reference to the accompaning drawing.

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Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1981.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1594370 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*