



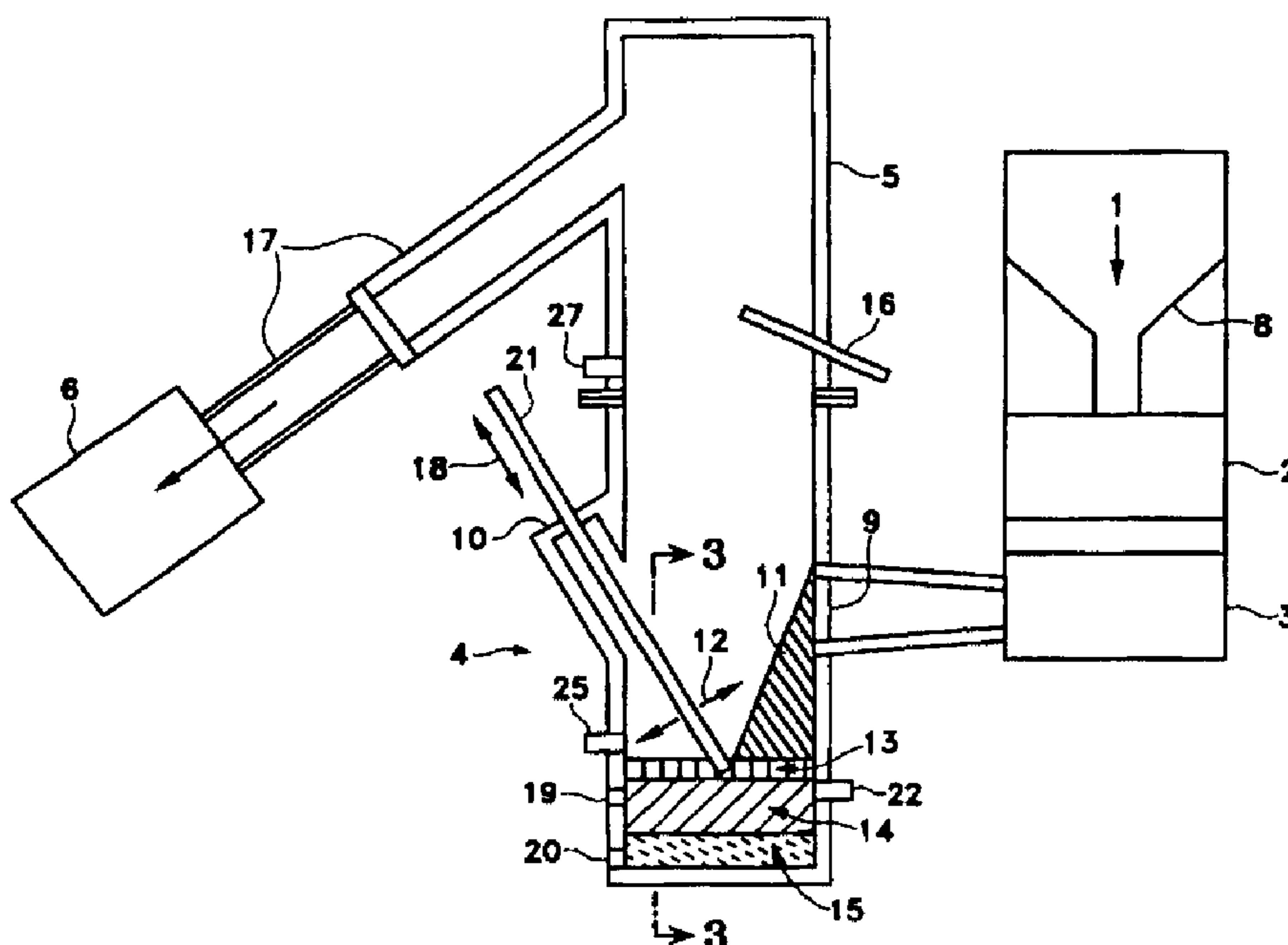
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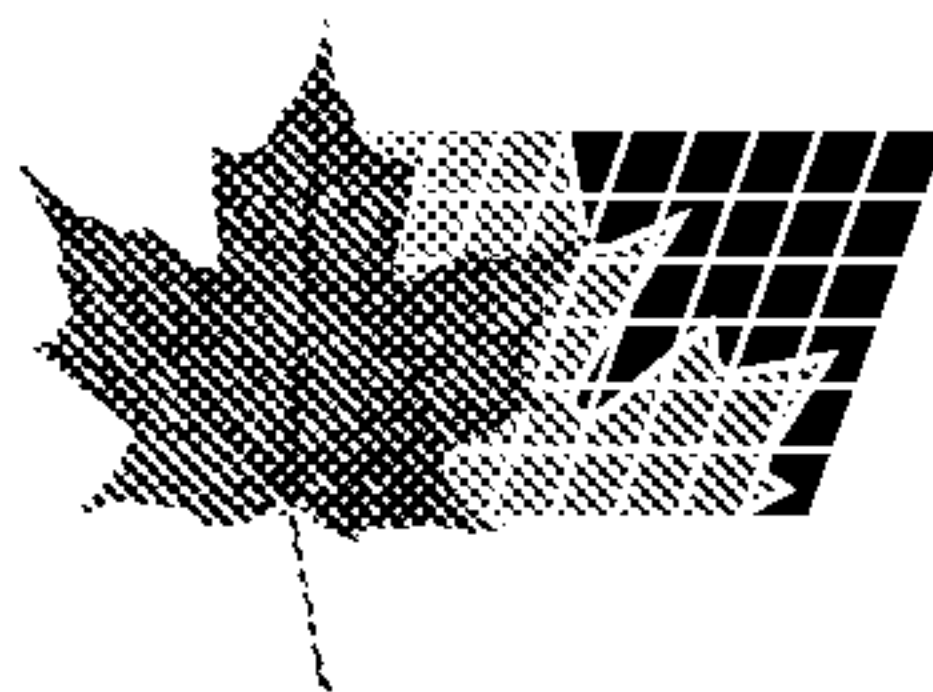
(30) 1996/12/12 (08/764,525) US

(54) **PROCEDE ET DISPOSITIF DE SEPARATION ET DE
TRAITEMENT THERMIQUE DE CHARGES HETEROGENES**
(54) **PROCESS AND APPARATUS FOR THE PARTITIONING AND
THERMAL TREATMENT OF HETEROGENEOUS
FEEDSTOCK**



(57) L'invention concerne un procédé et un dispositif de séparation thermique de charges (11) hétérogènes permettant de produire un produit métallique, un produit en vitrocéramique et un produit gazeux. Le procédé comprend la possibilité de soumettre à un traitement thermique des déchets dangereux, tels que définis par la Environmental Protection Agency (EPA), ces déchets contenant également dans certains cas des radio-isotopes (déchets mixtes, tels que définis par le Department of Energy), ainsi que la production, grâce à ce traitement, de produits stables de longue durée de vie. Plus particulièrement, cette invention concerne un procédé et

(57) A novel process and apparatus for the thermal partitioning of heterogeneous feedstock (11) for the production of a metal product, a glass ceramic product and a gaseous product. The process includes the capability for thermal treatment of hazardous waste as defined by the Environmental Protection Agency (EPA) which also contains radioactive isotopes in some cases (mixed waste as defined by the Department of Energy) and the production of stable long-lived products as a result of treatment. More specifically, this invention relates to a novel process and apparatus whereby an input feed stream (9) of a widely heterogeneous nature in the



un dispositif permettant de traiter un flux d'alimentation entrant (9) de nature très hétérogène en ce qui concerne sa forme physique, sa combustibilité, sa composition chimique et la taille de ses particules, et contaminé, à des concentrations variables, par des composants dangereux et/ou des radio-isotopes. Le traitement se fait dans un creuset de fusion à l'arc (4) en courant continu à électrode graphite, présentant un réacteur (5) d'oxydation thermique contigu destiné à la production de produits métalliques, de produits en vitrocéramique de type basaltique et d'effluents gazeux entièrement brûlés. Le dispositif décrit présente une configuration (17) d'extinction rapide d'effluents gazeux destinée à réduire la formation de dioxine, et à faciliter ainsi la décontamination des effluents gazeux.

descriptors of physical form, combustibility, chemical content, and particle size and contaminated with varying concentrations of hazardous components and/or radioisotopes is treated in a direct current graphite electrode arc melter (4) with a contiguous thermal oxidizing reactor (5) for the production of a metal product, a basalt-like glass ceramic product and a fully combusted offgas. The apparatus described incorporates an offgas fast quench configuration (17) for the minimization of dioxin formation and subsequent ease of cleansing of the offgas stream.

**CORRECTED
VERSION***

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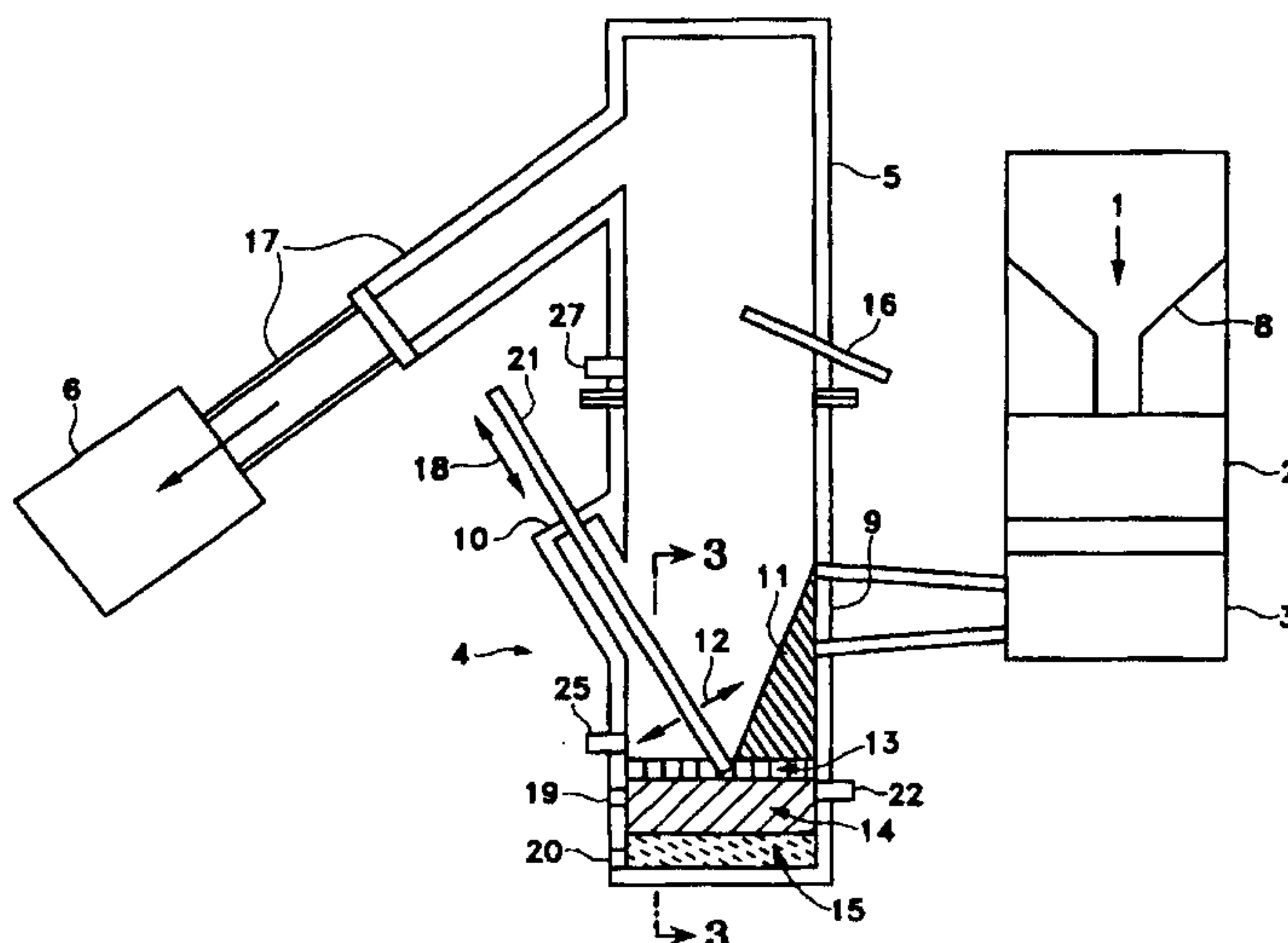
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(21) International Application Number: PCT/US97/23021 (22) International Filing Date: 12 December 1997 (12.12.97) (30) Priority Data: 08/764,525 12 December 1996 (12.12.96) US (71) Applicant (for all designated States except US): MELTTRAN, INC. [US/US]; Suite #207, 2300 N. Yellowstone Highway, Idaho Falls, ID 83404 (US). (72) Inventor; and (75) Inventor/Applicant (for US only): EDDY, Thomas, L. [US/US]; 2398 Hoopes Avenue, Idaho Falls, ID 83404 (US). (74) Agents: CANNON, Alan, W. et al.; Morrison & Foerster LLP, 755 Page Mill Road, Palo Alto, CA 94304-1018 (US).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: PROCESS AND APPARATUS FOR THE PARTITIONING AND THERMAL TREATMENT OF HETEROGENEOUS FEEDSTOCK



(57) Abstract

A novel process and apparatus for the thermal partitioning of heterogeneous feedstock (11) for the production of a metal product, a glass ceramic product and a gaseous product. The process includes the capability for thermal treatment of hazardous waste as defined by the Environmental Protection Agency (EPA) which also contains radioactive isotopes in some cases (mixed waste as defined by the Department of Energy) and the production of stable long-lived products as a result of treatment. More specifically, this invention relates to a novel process and apparatus whereby an input feed stream (9) of a widely heterogeneous nature in the descriptors of physical form, combustibility, chemical content, and particle size and contaminated with varying concentrations of hazardous components and/or radioisotopes is treated in a direct current graphite electrode arc melter (4) with a contiguous thermal oxidizing reactor (5) for the production of a metal product, a basalt-like glass ceramic product and a fully combusted offgas. The apparatus described incorporates an offgas fast quench configuration (17) for the minimization of dioxin formation and subsequent ease of cleansing of the offgas stream.

5 **PROCESS AND APPARATUS FOR THE PARTITIONING AND
THERMAL TREATMENT OF HETEROGENEOUS FEEDSTOCK**

**This application claims the benefit of U.S. provisional application
number 60/008,928, filed 12/18/95.**

10

FIELD OF THE INVENTION

The present invention pertains generally to the thermal processing of heterogeneous feedstock and the production of a metal product, a glass ceramic
15 product and a gaseous product. The process includes the capability for thermal treatment of hazardous waste as defined by the Environmental Protection Agency (EPA) which also contains radioactive isotopes in some cases (mixed waste as defined by the Department of Energy) and the production of stable long lived products as a result of treatment. More specifically, this invention relates to a
20 novel process and apparatus whereby an input feed stream of a widely heterogeneous nature in the descriptors of physical form, combustibility, chemical content, and particle size, and contaminated with varying concentrations of hazardous components or radioisotopes is treated in a direct or alternating current graphite electrode arc melter with a contiguous thermal oxidizing reactor
25 for the production of a metal product, a basalt like glass ceramic product and a fully combusted offgas. The apparatus described incorporates an offgas fast quench configuration for the minimization of dioxin formation and for subsequent ease of cleansing of the offgas stream.

BACKGROUND OF THE INVENTION

Joule heated melters have traditionally been used for the production of glass-based products. Graphite electrode arc melters have traditionally been used
5 for the reduction of ores to metals and for the production of value added products from a controlled and well defined input feed stream. Arc melters have also been used for the production of a value added mineral wool product from a well characterized and controlled input feedstock. Plasma arc torch melters have traditionally been used for the production of higher value precious metals such as
10 titanium. The various types of melters commonly used in industry can be classified as low temperature (900°C-1,200°C) medium temperature (1,200°C-1,500°C) and high temperature (1,500°C-2,000°C), with their use defined by the product desired and process required. The joule heated melters commonly used for the production of glass (including borosilicate glass for high level radioactive
15 waste) fall into the low temperature range. Medium temperature melters are required for the production of higher temperature glasses such as aluminosilicate glasses and glass ceramics.

High temperature melters are required for the reduction of ores to metals such as iron ore to iron and for the production of a basalt-like glass ceramic
20 product without the addition of fluxing agents to lower the viscosity. Arc melters use heat generated when an electric arc passes through a gas. The gas is ionized and forms a very high temperature plasma. The plasma temperatures can exceed many thousands of degrees centigrade. The high temperatures enable rapid and intense heating of process materials, making this technology ideal for high
25 temperature metals processing.

Current research and development by government and industry is being pursued for the purpose of applying arc melter technology to the treatment of hazardous and/or radioactive wastes. The application of traditional melter technology and equipment to the safe, efficient and economical treatment of
30 heterogeneous hazardous and /or radioactive waste involves the expansion of the allowable makeup of the input feed stream, the expansion of the flexibility of

process operation, and the tightening of specifications for the output products and offgases.

There have been a number of testing or development programs to apply electric arc melter technology to the treatment of radioactive wastes, mixed
5 wastes, municipal wastes, and hazardous wastes. In an arc melter, waste materials are heated to (a) volatilize, pyrolyze, and destroy organics, and (b) melt inorganic materials into molten slag or metal phases. By controlling reaction stoichiometry, mixing, and other operating parameters, the process can be used to chemically oxidize or reduce waste components, or react waste components to form new
10 products

PRIOR ART

Learn In US Patent 4,421,037 discusses a waste treatment furnace.

15 Rackley, et al. In US Patent 5,052,312 discusses a cyclone furnace for hazardous waste incineration and ash vitrification.

Alvi, et al. In US Patent 5,541,386 discusses the plasma arc decomposition of hazardous wastes into vitrified solids and non-hazardous gasses.

20 SUMMARY OF THE INVENTION

The described process and apparatus enables the continuous or intermittent feeding of widely varying heterogeneous input waste streams, the thermal partitioning of the input feed into inert and volatile fractions, the melting and
25 oxidation or reduction of the inert fraction into a glass ceramic (slag) phase consisting of oxidized metals and low vapor pressure materials, the melting and reduction of the inert fraction metals into a metal phase, and the complete combustion and oxidation of the vapor phase. Further, the flexibility of the operation and process enables control of the volatilization of higher vapor
30 pressure materials and forces partitioning of these materials to the glass ceramic phase.

The process and apparatus provides for the removal of the metal and glass ceramic phases by high temperature tapping techniques and fast cooling of the offgas from greater than 2,000°F to less than 150°F in a minimum time period. Further, the process provides for the reclamation of a glass ceramic product via product casting techniques and controlled cooling via insulation or heat addition to control the crystalline phase structure of the final cooled product.

The types of wastes applicable to treatment in the described invention include wastes having widely varying compositions in terms of soil content, metal content, combustible content, organic content and hazardous contaminant content.

The glass ceramic product produced exceeds the current requirements for Toxic Characteristic Leach Procedure (TCLP) as published in the Federal Register on March 29, 1989, and meets a more narrowly defined product specification suitable for reclamation. This specification may include narrowly defined compositional ranges and physical properties.

The metal product is also suitable for reclamation as industrial scrap metal from non-radioactive input feed and as recyclable metal within the nuclear industry from radioactive contaminated input feedstock.

The offgas is fast quenched from temperatures required for complete combustion and oxidation (>2,000°F) in minimal time to below the temperatures accepted as the formation temperature for dioxins and furans, thereby minimizing the production of dioxins. Further offgas cleansing enables the partitioning of the offgas particulates to volatile metals fractions and salts.

A homogeneous or heterogeneous feedstock is thermally treated to form a molten pool and a gaseous phase in a partitioning arc melter by: shredding (2) a feed material (1) to a particle size from submicron to less than one half the melter diameter; conveying the feedstock horizontally into a melter chamber (4); partitioning the feedstock into molten metal, slag, and offgas phases; oxidizing the offgas for greater than two seconds at a temperature above 2000 °F in a thermal oxidizer (5); quenching the offgas flow from the thermal oxidizer in an offgas fast quench chamber (17) to a temperature to less than 150°F in a minimal time; cleansing the offgas; and removing final molten products.

The nominal feedstock (11) characterization is heterogeneous and the general chemical composition of the matrix material feedstock varies between ranges of: soils 0-100%, metals 0-35%, combustibles 0-90%, volatile organics 0-60%, chlorinated organics 0-60%, chlorine 0-20%, carbon 0-40%, nitrates 0-20%,
5 and hydroxides 0-100%.

The feedstock (11) may contain organic and non-organic compounds and metals classified as hazardous or toxic according to a US Environmental Protection Agency classification. The feedstock (11) may contain radioactive isotopes emitting alpha, beta, or gamma radiation.

10 The feedstock (11) is extruded or conveyed through a sidewall of the melter (4) and a surface of the molten pool (14,15) may be regulated with a controlled depth of cold cap (13) to enhance the partitioning of volatile materials to a molten glass ceramic phase. A portion of the melter chamber can be operated with a cooled exterior wall to freeze a layer of molten product on the inside wall
15 for safe long term operation of the melter.

The arc melter electrode (21) tips can be raised in conjunction with a rise of the surface of the molten pool (14,15) in a portion of the melter chamber having a nominal depth to diameter ratio of less than one-half, and the chamber (4) itself may be readily removable as in a batch operation without any tapping
20 capability.

Oxygen may be injected into or near a surface of the molten pool (14,15) for control of oxidation reduction reactions in and above the molten pool (14,15) for generation of a syngas for process feedstocks and fuel gas cogeneration.

An auxiliary heat source (16) may be injected into the base of the thermal
25 oxidizer (5) to maintain temperature. An oxidation reduction reaction of the gaseous phase can be regulated and controlled for generation of a syngas for process feedstocks and fuel gas for cogeneration. Oxygen enriched air is injected into the base of the thermal oxidizer (5) to maintain temperature and provide oxygen for oxidation reactions, and for generation of a syngas for process
30 feedstocks and fuel gas cogeneration.

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The cleansed particulate, volatile metals, salts and air pollution control system maintenance material such as filters can be introduced back into the feed material (1) and processed through the system again.

5 A molten product tapping and casting system is operated in a manner to control the cooling rate of a cast molten glass-ceramic by means of mold insulation or addition of heat for the purpose of controlling an amorphous/crystalline phase structure of the final products.

Liquid can be absorbed into the feedstock (11) or injected onto the top of a cold cap (13) or molten pool (14,15) surface.

10 A thermal partitioning arc melter apparatus according to the present invention includes: a refractory-lined melter chamber (4) with a molten pool (14,15) having a nominal depth to diameter ratio of one-quarter to one-half and having multiple side outlets (19,20) for tapping molten metal and slag; the refractory-lined melter chamber further comprising electrode ports (10) $30^{\circ} \pm 10^{\circ}$
15 from vertical, a feed port (9) 90° from vertical, and a central offgas port vertically above the melter chamber; an electricity-based heat source comprising of parallel axial translating graphite electrode (21) current and voltage-conveying systems operating in a submerged or short arc joule heating resistance mode or a long arc radiant heating mode; a contiguous thermal oxidizing reactor (5) sufficiently large
20 to provide a gaseous residence time greater than two seconds, located vertically above the melter chamber, with an auxiliary heat source (16), located at a bottom of the thermal oxidizer, to maintain an operating temperature of $1,800^{\circ}\text{F}$ to $2,200^{\circ}\text{F}$; an offgas quench chamber (17) directly coupled to the top of the contiguous thermal oxidizer extending downward at 45° - 60° from horizontal; and
25 an air pollution control system (6).

The two graphite electrodes (21) have a nominal electrode tip spacing of one half the molten pool (14,15) nominal working diameter. The graphite electrodes (21) have translating mechanisms capable of positioning the electrode tips in the x, y, and z directions (12).

30 The heat source may be a direct current source further comprising of two parallel axis translating graphite electrode (21) current and voltage conveying

systems; an alternating single phase graphite electrode (21) current and voltage conveying system with electrodes in multiples of two; or an alternating three-phase graphite electrode (21) current and voltage-conveying system with electrodes in multiples of three.

5 The apparatus may further include a wet-dry offgas control system (6) for the purpose of collecting particulates, volatile metals and salts in an aqueous stream of dissolved and suspended sludge material and a gas filtration system for the purpose of final filtration of the gas stream.

 The apparatus may further include a dry-wet offgas cleansing system (6)
10 for the purpose of partitioning of particulates and volatile metals to a dry recyclable or processable secondary stream, salts from an acid gas scrubber to an aqueous stream of dissolved and undissolved suspended sludge material, and a gas filtration system for the purpose of final filtration of the gas stream.

15 **BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS**

Reference will herein be made to the accompanying drawings wherein like reference numerals throughout the various FIGURES denote like elements, and wherein:

 FIGURE 1 schematically depicts a flow diagram for the process
20 embodied by the present invention.

 FIGURE 2 depicts a representation of the system apparatus for thermal processing of heterogeneous feedstock and the production of a metal product, a glass ceramic product, and a gaseous product according to this invention.

 FIGURE 3 depicts the preferred primary heat source supply according to
25 this invention.

 FIGURE 4 depicts a representation of the system apparatus for thermal processing of heterogeneous feedstock and the production of a metal product, a glass ceramic product, and a gaseous product for the treatment of radioactive or hazardous wastes according to this invention.

30 The invention and its various embodiments are described in more detail in the following description.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

The present invention can process a wide variety of municipal, hazardous,
5 radioactive, and mixed (both radioactive and hazardous) wastes. Testing
conducted on the present invention design in this patent application has shown
that the present invention can process a range of feedstock shown in Table 1. The
chemical makeup of many of these components and similar components are
shown in Tables 2, 3 and 4.

10

Table 1. Acceptable limits of input feedstock variations.

Feedstock component	Weight %
Soils	0-100
Metals	0-35
Combustibles	0-90
Volatile organics	0-60
Chlorinated organics	0-60
Chlorine	0-20
Carbon	0-40
Nitrates	0-20
Hydroxides	0-100

Table 2. Typical chemical composition of feedstock material treatable by this invention.. Typical chemical composition of feedstock material treatable by this invention.

Constituent	Wt% of waste constituent								
	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Chlorine	Fluorine	Water	Inert
Noncombustible									
Glass									
Glass Raschig rings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Other glass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Metals									
Carbon steel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Stainless steel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Aluminum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Tantalum 10W	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Miscellaneous metal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Lead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
HVPM (Zn, Cd)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Miscellaneous Noncombustible									
Ceramic molds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Firebrick	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	97.00
Concrete	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.72	91.28
Portland cement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	95.00
Dirt/soil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	90.00
Ash	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Oil-Dri	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	95.00

9

Wt% of waste constituent									
Constituent	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Chlorine	Fluorine	Water	Inert
Vermiculite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	95.00
Evap. salts	0.85	0.13	0.00	0.00	0.00	0.00	0.00	0.13	98.88
Filters/Insulation									
Glass filter media	3.96	0.54	0.00	0.00	0.00	0.00	0.00	5.00	90.50
Asbestos filter media	3.96	0.54	0.00	0.00	0.00	0.00	0.00	5.00	90.50
Filter dust	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	90.00
Magnesia (insulation)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	98.00
Inorganic Sludge									
Sludge—high Na2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	60.00	40.00
Sludge—high CaO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	60.00	40.00
Aqueous solutions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.0
Partially Combustible									
Leaded rubber	33.16	4.47	1.01	0.28	0.51	0.00	0.00	0.00	60.56
Organic sludge	26.69	3.65	0.00	0.00	0.00	39.69	0.00	0.00	29.97
Uncemented resin	83.03	6.97	0.00	0.00	0.00	0.00	0.00	10.00	0.00
Cemented resins	27.68	2.32	0.00	0.00	0.00	0.00	0.00	20.00	50.00
Asphalt	4.294	0.49	0.05	0.05	0.12	0.00	0.00	0.00	95.01
Benelex/lead	33.20	3.53	25.19	0.00	0.03	0.00	0.00	3.35	34.70
Sheetrock	0.41	0.06	0.42	0.00	0.00	0.00	0.00	20.77	78.34
Combustibles									
Plastics									
Poly	84.93	13.40	0.35	0.11	0.02	0.00	0.00	0.00	1.19
PVC	47.38	5.73	9.09	0.00	0.01	35.72	0.00	0.00	2.07

Wt% of waste constituent									
Constituent	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Chlorine	Fluorine	Water	Inert
Teflon	24.00	0.00	0.00	0.00	0.00	0.00	76.00	0.00	0.00
Plexiglas	59.99	8.05	31.96	0.00	0.00	0.00	0.00	0.00	0.00
Rubber	76.23	10.28	2.32	0.65	1.18	0.00	0.00	0.00	9.34
Surgeon's glove	76.23	10.28	2.32	0.65	1.18	0.00	0.00	0.00	9.34
Miscellaneous Combustibles									
Graphite	99.19	0.70	0.00	0.00	0.01	0.00	0.00	0.00	0.10
Paper	49.54	5.27	37.59	0.00	0.05	0.00	0.00	5.00	2.55
Wood	46.94	5.00	35.61	0.00	0.05	0.00	0.00	10.00	2.42
Cardboard	49.54	5.27	37.59	0.00	0.05	0.00	0.00	5.00	2.55
Cloth	49.54	5.27	37.59	0.00	0.05	0.00	0.00	5.00	2.55

Table 3. Chemical composition of the inert fraction of feedstock material treatable by this invention expressed as a fraction of the inert chemicals.

Wt% of inert fraction									
Constituent	Aluminum	Boron	Barium	Calcium	CaSO ₄	Cadmium	Carbon	Chromium	Copper
Noncombustible									
Glass									
Glass Raschig rings	0.00	12.80	0.00	5.00	0.00	0.00	0.00	0.00	0.00
Other glass	0.00	5.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00
Metals									
Carbon steel	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00
Stainless steel	0.00	0.00	0.00	0.00	0.00	0.00	0.03	19.00	0.00
Aluminum	98.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tantalum 10W	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Miscellaneous metal	30.00	0.00	6.00	0.00	0.00	1.00	0.00	1.00	10.00
Lead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
HVPM (Zn, Cd)	0.00	0.00	0.00	0.00	0.00	50.00	0.00	0.00	0.00
Miscellaneous Noncombustible									
Ceramic molds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Firebrick	43.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Concrete	1.08	0.00	0.00	9.79	0.00	0.00	0.00	0.00	0.00
Portland cement	6.91	0.00	0.00	62.92	0.00	0.00	0.00	0.00	0.00
Dirt/soil	12.70	0.00	0.00	3.70	0.00	0.00	0.00	0.00	0.00
Ash	15.22	0.00	0.12	7.74	0.00	0.51	0.00	1.84	0.00
Oil-Dri	28.86	0.00	0.00	2.35	0.00	0.00	0.00	0.00	0.00

Wt% of inert fraction										
Constituent	Aluminum	Boron	Barium	Calcium	CaSO ₄	Cadmium	Carbon	Chromium	Copper	
Vermiculite	19.95	0.00	0.00	0.00	0.00	0.00	0.00	5.00	95.00	
Evap. salts	1.93	0.00	0.00	2.47	0.00	0.00	0.00	0.00	0.00	
Filters/Insulation										
Glass filter media	6.28	10.47	4.19	3.14	0.00	0.00	0.00	0.00	0.00	
Asbestos filter media	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Filter dust	12.70	0.00	0.00	3.70	0.00	0.00	0.00	0.00	0.00	
Magnesia (insulation)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Inorganic Sludge										
Sludge—high Na2O	8.34	0.00	0.00	4.80	0.00	0.00	0.00	0.10	0.17	
Sludge—high CaO	4.31	0.00	0.00	22.61	0.00	0.00	0.00	0.04	0.18	
Aqueous solutions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Partially Combustible										
Leaded rubber	0.07	0.00	0.00	1.39	0.00	0.00	0.00	0.00	0.09	
Organic sludge	0.00	0.00	0.00	37.89	0.00	0.00	0.00	0.00	0.00	
Uncemented resin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Cemented resins	6.91	0.00	0.00	64.00	0.00	0.00	0.00	0.00	0.00	
Asphalt	0.13	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	
Benelex/lead	0.31	0.00	0.00	1.56	0.00	0.00	0.00	0.00	0.00	
Sheetrock	0.06	0.00	0.00	0.31	99.00	0.00	0.00	0.00	0.00	
Combustibles										
Plastics										
Poly	0.10	0.00	0.00	99.70	0.00	0.00	0.00	0.00	0.00	
PVC	0.20	0.00	22.16	0.90	0.00	61.94	0.00	0.00	0.00	

Wt% of inert fraction										
Constituent	Aluminum	Boron	Barium	Calcium	CaSO ₄	Cadmium	Carbon	Chromium	Copper	
Teflon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Plexiglas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Rubber										
Rubber	1.00	0.00	0.00	20.70	0.00	0.00	0.00	0.00	0.00	
Surgeon's glove	1.00	0.00	0.00	20.70	0.00	0.00	0.00	0.00	0.00	
Miscellaneous Combustibles										
Graphite	15.00	0.00	0.00	7.10	0.00	0.00	0.00	0.00	0.00	
Paper	6.31	0.00	0.00	31.79	0.00	0.00	0.00	0.00	0.00	
Wood	6.31	0.00	0.00	31.79	0.00	0.00	0.00	0.00	0.00	
Cardboard	6.31	0.00	0.00	31.79	0.00	0.00	0.00	0.00	0.00	
Cloth	6.31	0.00	0.00	31.79	0.00	0.00	0.00	0.00	0.00	

Table 3 (cont'd)

Constituent	Wt% of inert fraction								
	Gallium	Iron	Lead	Magnesium	Manganese	Nickel	Phosphorus	Potassium	KNO ₃
Noncombustible									
Glass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glass Raschig rings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other glass									
Metals									
Carbon steel	0.00	99.10	0.00	0.00	0.45	0.00	0.00	0.00	0.00
Stainless steel	0.00	71.97	0.00	0.00	0.00	9.00	0.00	0.00	0.00
Aluminum	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00
Tantalum 10W	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Miscellaneous metal	0.00	50.00	1.00	2.00	0.00	2.00	0.00	0.00	0.00
Lead	0.00	0.00	99.90	0.00	0.00	0.00	0.00	0.00	0.00
HVPM (Zn, Cd)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Miscellaneous Noncombustible									
Ceramic molds	0.00	0.00	0.00	61.64	0.00	0.00	0.00	0.00	0.00
Firebrick	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Concrete	0.00	0.45	0.00	0.40	0.00	0.00	0.00	0.00	0.00
Portland cement	0.00	2.91	0.00	2.54	0.00	0.00	0.00	0.00	0.00
Dirt/soil	0.00	5.10	0.00	2.90	0.00	0.00	0.00	3.10	0.00
Ash	0.00	28.30	7.81	5.37	0.15	1.13	0.10	0.38	0.04
Oil-Dri	0.00	4.34	0.00	5.02	0.00	0.00	0.00	0.50	0.00
Vermiculite	0.00	41.30	0.00	17.98	0.00	0.00	0.00	0.00	0.00

15

Wt% of inert fraction									
Constituent	Gallium	Iron	Lead	Magnesium	Manganese	Nickel	Phosphorus	Potassium	KNO ₃
Evap. salts	0.00	0.66	0.00	0.45	0.00	0.00	0.00	0.30	28.49
Filters/Insulation									
Glass filter media	0.00	0.10	0.00	1.05	0.00	0.00	0.00	2.09	0.00
Asbestos filter media	0.00	0.00	0.00	21.16	0.00	0.00	0.00	0.00	0.00
Filter dust	0.00	5.10	0.00	2.90	0.00	0.00	0.00	3.10	0.00
Magnesia (insulation)	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00
Inorganic Sludge									
Sludge—high Na2O	5.51	6.52	0.64	5.20	0.00	0.00	0.00	4.46	0.00
Sludge—high CaO	0.08	5.84	0.31	10.55	0.00	0.00	0.00	3.74	0.00
Aqueous solutions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Partially Combustible									
Leaded rubber	0.00	0.07	93.20	0.42	0.00	0.00	0.09	0.00	0.00
Organic sludge	0.00	7.40	0.00	0.14	0.00	0.00	0.00	0.56	0.00
Uncemented resin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cemented resins	0.00	2.91	0.00	2.54	0.00	0.00	0.00	0.00	0.00
Asphalt	0.00	0.69	0.00	0.17	0.00	0.13	0.00	0.00	0.00
Benelex/lead	0.00	0.23	95.08	0.24	0.09	0.00	0.00	0.00	0.00
Sheetrock	0.00	0.04	0.00	0.05	0.02	0.00	0.00	0.00	0.00
Combustibles									
Plastics									
Poly	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
PVC	0.00	0.20	0.00	0.40	0.80	0.00	6.20	0.00	0.00
Teflon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Wt% of inert fraction										
Constituent	Gallium	Iron	Lead	Magnesium	Manganese	Nickel	Phosphorus	Potassium	KNO ₃	
Plexiglas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Rubber										
Rubber	0.00	1.00	0.10	6.20	0.00	0.00	1.30	0.00	0.00	
Surgeon's glove	0.00	1.00	0.10	6.20	0.00	0.00	1.30	0.00	0.00	
Miscellaneous Combustibles										
Graphite	0.00	17.30	0.00	2.30	0.00	0.00	0.00	2.30	0.00	
Paper	0.00	4.58	0.00	4.97	1.84	0.00	0.00	0.00	0.00	
Wood	0.00	4.58	0.00	4.97	1.84	0.00	0.00	0.00	0.00	
Cardboard	0.00	4.58	0.00	4.97	1.84	0.00	0.00	0.00	0.00	
Cloth	0.00	4.58	0.00	4.97	1.84	0.00	0.00	0.00	0.00	

Table 3 (cont'd)

Wt% of inert fraction									
Constituent	Silicon	Sodium	NaNO ₃	Tantalum	Tin	Titanium	Tungsten	Vanadium	Zinc
Noncombustible									
Glass									
Glass Raschig rings	62.20	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other glass	70.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metals									
Carbon steel	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stainless steel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aluminum	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tantalum 10W	0.00	0.00	0.00	90.00	0.00	0.00	10.00	0.00	0.00
Miscellaneous metal	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	2.00
Lead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HVPM (Zn, Cd)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00
Miscellaneous Noncombustible									
Ceramic molds	38.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Firebrick	52.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00
Concrete	87.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Portland cement	21.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dirt/soil	70.70	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ash	23.13	1.33	0.08	0.00	0.17	0.18	0.00	0.00	3.58
Oil-Dri	60.68	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00
Vermiculite	20.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Wt% of inert fraction

Constituent	Silicon	Sodium	NaNO ₃	Tantalum	Tin	Titanium	Tungsten	Vanadium	Zinc
Evap. salts	8.54	0.17	56.99	0.00	0.00	0.00	0.00	0.00	0.00
Filters/Insulation									
Glass filter media	59.32	10.99	0.00	0.00	0.00	0.00	0.00	0.00	2.36
Asbestos filter media	78.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Filter dust	70.70	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Magnesia (insulation)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Inorganic Sludge									
Sludge—high Na2O	36.09	28.14	0.00	0.00	0.00	0.02	0.00	0.00	0.01
Sludge—high CaO	46.32	5.59	0.00	0.00	0.00	0.42	0.00	0.00	0.01
Aqueous solutions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Partially Combustible									
Leaded rubber	0.28	0.09	0.00	0.00	0.00	0.14	0.00	0.00	4.17
Organic sludge	53.95	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
Uncemented resin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cemented resins	21.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Asphalt	95.37	0.85	0.00	0.00	0.00	0.00	0.00	0.94	0.00
Benelex/lead	0.83	0.83	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Sheetrock	0.15	0.15	0.00	0.00	0.00	0.81	0.00	0.00	0.00
Combustibles									
Plastics									
Poly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PVC	0.20	0.00	0.00	0.00	0.00	0.80	0.00	0.00	6.20
Teflon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Wt% of inert fraction										
Constituent	Silicon	Sodium	NaNO ₃	Tantalum	Tin	Titanium	Tungsten	Vanadium	Zinc	
Plexiglas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Rubber										
Rubber	4.20	1.30	0.00	0.00	0.00	2.10	0.00	0.00	62.10	
Surgeon's glove	4.20	1.30	0.00	0.00	0.00	2.10	0.00	0.00	62.10	
Miscellaneous Combustibles										
Graphite	45.50	0.80	0.00	0.00	0.00	1.60	0.00	0.00	0.00	
Paper	16.88	16.80	0.00	0.00	0.00	0.39	0.00	0.00	0.00	
Wood	16.88	16.80	0.00	0.00	0.00	0.39	0.00	0.00	0.00	
Cardboard	16.88	16.80	0.00	0.00	0.00	0.39	0.00	0.00	0.00	
Cloth	16.88	16.80	0.00	0.00	0.00	0.39	0.00	0.00	0.00	

Table 3 (cont'd)

Constituent	Wt% of inert fraction			
	SO ₃	CO ₂	Cl	
Noncombustible				
Glass				
Glass Raschig rings	0.00	0.00	0.00	
Other glass	0.00	0.00	0.00	
Metals				
Carbon steel	0.00	0.00	0.00	
Stainless steel	0.00	0.00	0.00	
Aluminum	0.00	0.00	0.00	
Tantalum 10W	0.00	0.00	0.00	
Miscellaneous metal	0.00	0.00	0.00	
Lead	0.00	0.00	0.00	
HVPM (Zn, Cd)	0.00	0.00	0.00	
Miscellaneous Noncombustible				
Ceramic molds	0.00	0.00	0.00	
Firebrick	0.00	0.00	0.00	
Concrete	0.27	0.17	0.00	
Portland cement	1.72	1.08	0.00	
Dirt/soil	0.00	0.00	0.00	
Ash	0.33	0.79	0.01	
Oil-Dri	0.00	0.00	0.00	
Vermiculite	0.00	0.00	0.00	

Constituent	Wt% of inert fraction			
	SO ₃	CO ₂	Cl	
Evap. salts	0.00	0.00	0.00	
Filters/Insulation				
Glass filter media	0.00	0.00	0.00	
Asbestos filter media	0.00	0.00	0.00	
Filter dust	0.00	0.00	0.00	
Magnesia (insulation)	0.00	0.00	0.00	
Inorganic Sludge				
Sludge—high Na2O	0.00	0.00	0.00	
Sludge—high CaO	0.00	0.00	0.00	
Aqueous solutions	0.00	0.00	0.00	
Partially Combustible				
Leaded rubber	0.00	0.00	0.00	
Organic sludge	0.00	0.00	0.00	
Uncemented resin	0.00	0.00	0.00	
Cemented resins	1.72	0.00	0.00	
Asphalt	1.51	0.00	0.00	
Benelex/lead	0.23	0.58	0.01	
Sheetrock	0.04	0.11	0.06	
Combustibles				
Plastics				
Poly	0.00	0.00	0.00	
PVC	0.00	0.00	0.00	
Teflon	0.00	0.00	0.00	

Wt% of inert fraction				
Constituent	SO ₃	CO ₂	Cl	
Plexiglas	0.00	0.00	0.00	
Rubber				
Rubber	0.00	0.00	0.00	
Surgeon's glove	0.00	0.00	0.00	
Miscellaneous Combustibles				
Graphite	8.10	0.00	0.00	
Paper	4.62	11.69	0.13	
Wood	4.62	11.69	0.13	
Cardboard	4.62	11.69	0.13	
Cloth	4.62	11.69	0.13	

Table 4. Estimated compositions of the additives used to prepare the surrogate waste mixtures.

Additive	Comp.	Additive	Comp.	Additive	Comp.	Additive	Comp.
Lime		Diatomite		Portland Cement		Soil	
CaO	91.6	Ag ₂ O	0.00	SiO ₂		Ag ₂ O	0.00
SiO ₂	0.34	Al ₂ O ₃	4.29	Al ₂ O ₃		Al ₂ O ₃	12.04
CO ₂	0.82	As ₂ O	0.00	Fe ₂ O ₃		As ₂ O	0.00
Fe ₂ O ₃	0.46	BeO	0.01	SO ₃		BeO	0.12
Al ₂ O ₃	0.16	CaO	0.59	CeO		CaCO ₃	9.08
MgO	1.24	CdO	0.00	MgO		CaO	0.24
SO ₃	0.00	CcO ₂	0.00	CO ₂		CdO	0.00
Ca ₂ O	0.00	Cl	0.02	Water		CeO ₂	0.01
HgO	0.00	CO ₂	0.00	Wood pellets (wood, paper, cloth)		Cr ₂ O ₃	0.01
K ₂ O	0.06	Cr ₂ O ₃	0.00	C	34.5	Cs ₂ O	0.00
ScO	0.00	Cs ₂ O	0.00	H	6.54	CuO	0.01
Ag ₂ O	0.00	CuO	0.00	O	48.9	Fe ₃ O ₄	4.75
CdO	0.00	Fe ₂ O ₃	2.09	N	0.09	HgO	0.00
Na ₂ O	0.03	HgO	0.00	Water	10.0	K ₂ O	2.32
P ₂ O ₅	0.03	K ₂ O	0.35	Microcel E		MgO	2.19
Cl	0.00	MgO	0.28	Ag ₂ O	0.00	MnO ₂	0.11
Pb	0.00	Na ₂ O	3.73	Al ₂ O ₃	1.57	Na ₂ O	1.59
As	0.00	NiO	0.00	As ₂ O	0.00	NiO	0.01
Water	5.20	P ₂ O ₅	0.04	BeO	0.01	PO ₄	0.24
Carbon steel		PbO	0.00	CeO	30.2	PbO	0.00
Fe	99.2	ScO	0.00	CdO	0.00	SO ₄	0.05
C	0.06	SiO ₂	86.21	CeO ₂	0.01	ScO	0.00
P	0.02	SO ₄	0.05	Cl	0.00	SiO ₂	61.40
S	0.01	TiO ₂	0.22	CO ₂	2.28	TiO ₂	0.66
Mn	0.45	ZnO	0.00	Cr ₂ O ₃	0.01	ZnO	0.02
Si	0.25	ZrO ₂	0.01	Cs ₂ O	0.00	ZrO ₂	0.02
		Water	2.09	CuO	0.00	Cl	0.00
				Fe ₂ O ₃	1.27	Water	5.13
				HgO	0.00		
				K ₂ O	0.25		
				MgO	0.78		
				Na ₂ O	0.31		

Table 4 (cont'd)

Additive	Comp.	Additive	Comp.	Additive	Comp.	Additive	Comp.
Zirconium		Latex rubber stoppers		Microcel E (cont'd)		Poly-ethylene	
Zr	93.0	C	76.2	NiO	0.01	C	85.6
Mo	4.70	H	10.3	P ₂ O ₅	0.07	H	14.1
Si	1.50	O	2.32	PbO	0.00	O	0.20
Fe	0.40	N	0.65	ScO	0.00	N	0.03
Cr	0.30	S	1.18	SiO ₂	49.4	S	0.05
Hf	0.10	Al ₂ O ₃	0.09	SO ₄	0.15	Al ₂ O ₃	0.00
Cu	0.09	CaO	1.93	TiO ₂	0.09	CzO	0.00
Mn	0.09	Fe ₂ O ₃	0.09	ZnO	0.01	MgO	0
Copper	100	PbO	0.01	ZrO ₂	0.00	Al(OH) ₃	100
Lead		MgO	0.58	Water	13.6	Fe(OH) ₃	100
Pb	99.9	P ₂ O ₅	0.12	Teflon		Ca(OH) ₂	100
Cu	0.10	SiO ₂	0.39	C	24.0	Mg(OH) ₂	100
Cadmium	100	Na ₂ O	0.12	F	76.0	NaOH	100
Aluminum		TiO ₂	0.20	Wheel bearing grease		NaNO ₃	100
Al	95.6	ZnO	5.80	C	82.5	Na ₂ SO ₄	100
Mg	2.80	KOH	100	H	12.2	NaCl	100
Si	1.60	KNO ₃	100	S	1.36	Texaco Regal Oil	
Lead Oxide		Neoprene Rubber		O	3.77	C	85.4
Pb ₃ O ₄	98	C	54.70	N	0.14	H	13.5
Mn	0.00005	H	5.65	Vermiculite		S	0.10
Acid insol. matter	0.03	Cl	37.87	Al	19.0	O	0.87
H ₂ O insol. matter	0.05	N	0.26	Fe	39.2	N	0.10
		S	1.52	Mg	17.1		
		PVC		Si	19.7		
		C	44.4	H ₂ O	5.00		
		H	5.57				
		Cl	49.6				
		N	0.05				
		S	0.39				

The present invention can process wastes to (a) reduce volume and solid mass by evaporating moisture, thermally decomposing carbonates, and pyrolyzing organics, (b) destroy hazardous and non-hazardous organics, (c) melt inorganic oxides to form a homogeneous, easy to characterize and dispose/recycle slag (glass ceramic rock-like waste form), (d) separate metals into a molten, tappable metal phase, and (e) decontaminate the metal phase from radionuclides (if present). The resultant products are very homogeneous and easy to characterize, compared to the variety of heterogeneous materials which can be fed to the melter. The melter chamber 4 can receive wastes that vary widely in physical and chemical content. The slag composition is inherently less variable owing to (a) less variability of the inorganic materials of many waste materials, and (b) mixing effects of varying inorganic feed in the molten slag pool. Occasionally, depending on the feed compositions, desired operating conditions, and slag or metal products, additives are used to modify the glass ceramic rock-like waste form or metal products.

An example schematic of the process embodied by the present patent is shown in Figure 1. The particle size of the feed material 1 can range from submicron-size up to one-half of the melter diameter. Feed materials and containers of feed materials are fed through a shredder hopper 8 and size-reduced in the waste handling and feeding system using a low-speed, high-torque shredder 2. This type of shredder, commercially available and included as a component of the present invention, can process most types of waste including heterogeneous combustibles, inorganics including bricks and concrete, and metals up to 1/4-inch thick. The shredder 2 is capable of shredding the contents of waste containers and/or entire waste drums, boxes, and other containers.

The waste is shredded into a hopper which also serves as the feed hopper for a commercial feeder 3. The feeder 3 can reliably extrude or convey the shredded feed material (feedstock) through a feed port in the sidewall of the melter chamber 4.

30

A close-coupled thermal oxidizer 5 effectively oxidizes gaseous and entrained organics that evolve from the melt and feed materials. The offgas with entrained and volatilized particulate is cleansed and treated in an offgas treatment system 6 to control emissions. Output products 7 which may included a metal
5 form and a glass ceramic form are removed and processed into value added products.

The present invention can process waste liquids, sludges, slurries, or gases. Liquids, sludges, and slurries can be fed into the melter through injectors or nozzles, absorbed into the dry sorbents, or delivered in small, intact containers.
10 The present invention is also capable of processing a feedstock 11 containing radioactive isotopes emitting alpha, beta, or gamma radiation.

The present invention can meet or surpass the Resource Conservation and Recovery Act (RCRA) best demonstrated available technology (BDAT) treatment requirements for essentially any hazardous organic contaminants, and can produce
15 a very leach-resistant glass ceramic rock-like waste form or value-added product that can immobilize oxides of toxic metals and radionuclides in compliance with regulatory limits.

A more detailed illustration of the present inventions process and apparatus is shown in FIGURES 2, 3, and 4. Processes that occur in the melter
20 chamber 4 include rapid heat transfer, chemical reactions, and physical transformations from solids to liquids and gases. Feedstock 11 that enters the melter chamber 4 is heated and absorbed into the melt through a cold cap 13 due to (a) radiant heat transfer from the arc and the melt pool, (b) conductive and convective heat transfer and mixing in the melt pool, and (c) resistance heating
25 (joule heating) in the melt. As the feedstock heats up, (a) moisture and water of hydration evaporate, (b) organics, nitrates, carbonates, sulfates, and other materials thermally decompose, pyrolize, and oxidize to form primarily gases and oxides that are soluble in the melt, (c) inorganics melt into the molten slag 14, and (d) metals in the feedstock 11 either oxidize when there is sufficient oxygen
30 available from solid or gaseous oxidants and combine with the slag 14 or melt and sink through the slag, due to a greater metal density and form a metal pool 15.

Some elements such as plutonium are highly oxidizable, but very non-volatile, and will tend to concentrate in the molten slag 14, as desired, leaving the offgas and metal products with reduced contamination. Volatile species like chlorides, sulfates, and some metals (such as mercury, lead, cadmium, and arsenic) partially or more completely volatilize. This can enable concentration of these species in the offgas for cleansing, if desired, or the present invention's operating conditions can be adjusted to more effectively retain some of these species in the melt by creating a continuously consumable filter (cold cap) 13 thereby increasing the residence time of a volatile material in the melt for increased chemical reactions and incorporation into the slag. The surface of the molten pool (14,15) is regulated with a controlled depth of cold cap 13 to enhance the partitioning of volatile material to the molten glass ceramic phase. Liquid can be absorbed into the feedstock (11) or injected onto the top of the cold cap (13) or molten pool surface.

The melter chamber 4 can be operated with a cooled exterior wall/bottom to freeze a layer of molten product on the sidewall/bottom for the safe long term operation of the melter. The refractory-lined melter chamber 4 is comprised of an electrode port 10 at 30 degrees $\pm$ 10 degrees from vertical, a feed port 9 at 90 degrees from vertical, and a central offgas port vertically above the melter chamber.. In this present invention, oxygen is injected into the molten pool through an oxygen port 22 or near the surface of the molten pool through an oxygen port 25 for control of oxidation reduction reactions in and above the molten pool.

A contiguous thermal oxidizer 5 sufficiently large to provide a gaseous residence time greater than two seconds is located vertically above the melter chamber 4. In the present invention, an auxiliary heat source 16 is injected into the base of the thermal oxidizer 5 to maintain an operating temperature of 1,800 °F to 2,200 °F. In addition, oxygen enriched air is injected through an oxygen port 27 into the base of the thermal oxidizer 5 to help maintain the desired temperature and provide additional oxygen for oxidation reactions, and for regeneration of a syngas for process feedstocks and fuel gas cogeneration. Other

operating conditions can be varied to optimize or reduce the amount of metal 15 product or change the slag 14 chemistry.

The present invention includes a tapping and casting system which can be operated in such a manner as to control the cooling rate of the cast molten glass-ceramic by means of a mold insulation or the addition of heat for the purpose of
5 controlling the amorphous/crystalline phase structure of the final cooled product. The present invention incorporates a refractory-lined melter chamber 4 with a melt pool 14, 15 having a nominal depth to diameter ratio ranging from one quarter to one-half and includes multiple side outlets for tapping molten metal and
10 slag. A slag port 19 is located at a depth from the desired melt surface equal to one half the melt radius and a metal port 20 is located at the bottom of the melt zone to allow for intermittent or continuous tapping of either materials. Alternatively a portion of the melt chamber 4 containing the molten products can be readily removable as in a batch operation without any tapping capability or
15 need.

The offgas with entrained and volatilized particulate is cleansed and treated in an offgas treatment system 6 to efficiently control emissions of organics, particulate, acid gases, toxic metals, or other undesired emissions. In the present invention the cleansed particulate, volatile metals, salts and air
20 pollution control system maintenance material such as filters can be introduced back into the feed material 1 and processed through the system again. The unique, close-coupled thermal oxidizer 5 is designed to efficiently oxidize gaseous and entrained organics that evolve from the melt and feed materials. The thermal oxidizer 5 is designed specifically to perform oxidation of gas which
25 contains large amounts of entrained particulate without problematic particulate slagging or fouling by close coupling the thermal oxidizer 5 vertically to the melter chamber 4. This capability is very important for hazardous and radioactive waste treatment, when worker access for maintenance is limited or prevented. A unique arrangement of an offgas quench chamber 17 to the thermal oxidizer 5
30 enables near instantaneous reduction of gas temperature from greater than 2000 °F to less than 150 °F in a minimum space. The offgas quench chamber 17 is directly

coupled to the top of the contiguous thermal oxidizer 5 extending downward at 45-60 degrees from horizontal. The quench chamber 17 to thermal oxidizer 5 configuration reduces the potential for offgas duct plugging common in horizontal crossover duct arrangements and also minimizes the potential for dioxin formation due to the very short gas residence time in the dioxin formation/synthesis temperature range (around 450 °F - 750 °F).

An alternative option included in the present invention is to produce a synthesis gas or low-Btu fuel gas from the melter offgas. The oxidation reduction reactions of the gaseous phase can be regulated and controlled to maximize the generation of a syngas for process feedstocks or fuel gas for cogeneration. In this option, the thermal oxidizer 5 is replaced with a reaction chamber 5 that allows the addition of steam or other reagents to react with the melter offgas to form hydrogen, carbon monoxide, methane gas, or other gases. Particulate in the offgas is filtered either upstream or downstream of the reaction chamber 5. Thus, oxygen is injected into or near a surface of the molten pool for control of oxidation reduction reactions in and above the molten pool for generation of a syngas for process feedstocks and fuel gas cogeneration.

The present invention has an offgas treatment system 6 with particulate and acid gas removal options that include (a) wet particulate and acid gas removal, followed by reheating and removal of trace organics, trace toxic metals, and trace submicron particulate, or (b) dry particulate removal in a baghouse or high temperature filter, followed by wet acid gas removal, gas reheating, and removal of trace organics, trace toxic metals, and trace submicron particulate. Heat recovery through gas-to-air heat exchange, water heating, or steam generation are additional options.

The wet-dry offgas treatment system 6 is designed specifically for radioactive waste applications, and is very reliable and compact. A single secondary waste stream consisting of scrubber liquor blowdown is produced, with much smaller amounts of recyclable, spent HEPA filters, and possibly spent charcoal absorbers or other trace organics and metals absorbers. The scrubber liquor contains dissolved salts of any absorbed chloride, sulfate, and fluoride acid

gases, other dissolved species absorbed from the offgas such as nitric acid and carbonic acid, and suspended undissolved particulate solids.

The dry-wet offgas treatment system 6 is designed to enable automatic separation of a dry particulate secondary waste stream separately from a wet scrubber aqueous blowdown. This is desired if the particulate can be (a) used as a value added product such as a feedstock for metals recovery operations, (b) recycled to the melter, or (c) stabilized in processes that do not readily tolerate chlorides or other scrubber species. Filtration of the particulate separately from acid gas scrubbing reduces the amounts, if any, of chlorides that are not desired in downstream particulate processing or recycling.

Other offgas treatment systems 6 that may also be incorporated based on regulatory or other requirements include dry or semi-dry scrubbing for acid gas control, followed by dry particulate filtration.

The present invention uses a direct current electricity-based heat source comprising of two axial translating (as at arrow 18) graphite electrodes 21 penetrating at an angle to the axis of the melter chamber 4. Two alternatives for current and voltage-conveying systems are alternating single-phase graphite electrodes 21 in multiples of two and alternating three-phase graphite electrodes 21 in multiples of three. The graphite electrodes 21 are located with the nominal tip spacing of one half the molten pool diameter and can be operated in either an immersed short arc joule heating resistance mode or a long arc radiant heating mode. The graphite electrodes 21 are equipped with translating mechanisms capable of positioning the electrode tips in the x, y, and z directions 12. The graphite electrodes 21 tips can be adjusted separately to account for a changing melt surface level or electrode consumption rate. 8. The arc melter electrode tips can be raised in conjunction with a rise of the surface of the molten pool in a portion of the melter chamber having a nominal depth to diameter ratio of less than one-half, and the chamber itself being readily removable as in a batch operation without any tapping capability.

This invention has benefits for the industrial thermal partitioning (processing) of heterogeneous feedstock. The invention process and apparatus

extend to the treatment of industrial hazardous wastes, medical wastes, and radioactive (mixed) wastes. The invention can also extend to the thermal treatment of municipal solid wastes or sludges.

5 The output products 7 (Fig. 1) are a metal form suitable for recycling, a glass ceramic form stable in nature with high leach resistance, a fully combusted offgas form suitable for final cleansing, or a fuel-rich gaseous form suitable for process feedstocks or cogeneration. An additional advantage from the production of solid products is a significant volume reduction compared to the input feedstock.

10 Referring exclusively to FIGURE 4, when radioactive or hazardous material is processed an additional isolation gate 24 and air lock 23 is added to the shredder hopper 8 to ensure complete containment.

From the foregoing description, it will thus be evident that the present invention provides a design for process and apparatus for the partitioning and
15 thermal treatment of heterogeneous feedstock. Various changes can be made in the above embodiments and operating methods without departing from the spirit or scope of the following claims. It is intended that all matter contained in the above description or shown in the accompanying drawings should be interpreted as illustrative and not in a limiting sense.

20 Variations or modifications to the design and construction of this invention, within the scope of the appended claims, may occur to those skilled in the art upon reviewing the disclosure herein (especially to those using computer aided design systems). Such variations or modifications, if within the spirit of this invention, are intended to be encompassed within the scope of any claims to
25 patent protection issuing upon this invention.

I Claim:

1. A process wherein a homogeneous or heterogeneous feedstock is thermally treated to form a molten pool and a gaseous phase in a partitioning arc melter comprising:
- a. shredding (2) a feed material (1) to a particle size from submicron to less than one half the melter diameter;
 - b. conveying the feedstock horizontally into a melter chamber (4);
 - c. partitioning the feedstock into molten metal, slag, and offgas phases;
 - d. oxidizing the offgas for greater than two seconds at a temperature above 2000 oF in a thermal oxidizer (5);
 - e. quenching the offgas flow from the thermal oxidizer in an offgas fast quench chamber (17) to a temperature to less than 150°F in a minimal time;
 - f. cleansing the offgas; and,
 - g. removing final molten products.
2. The process as in claim 1 wherein the nominal feedstock (11) characterization is heterogeneous and the general chemical composition of the matrix material feedstock varies between ranges of: soils 0-100%, metals 0-35%, combustibles 0-90%, volatile organics 0-60%, chlorinated organics 0-60%, chlorine 0-20%, carbon 0-40%, nitrates 0-20%, and hydroxides 0-100%.

3. The process as in claim 1 wherein the feedstock (11) contains organic and non-organic compounds and metals classified as hazardous or toxic according to a US Environmental Protection Agency classification.

5 4. The process as in claim 1 wherein the feedstock (11) contains radioactive isotopes emitting alpha, beta, or gamma radiation.

5. The process as in claim 1 wherein the feedstock (11) is extruded or conveyed through a sidewall of the melter.

10

6. The process as in claim 1 wherein a surface of the molten pool (14,15) is regulated with a controlled depth of cold cap (13) to enhance the partitioning of volatile materials to a molten glass ceramic phase.

15 7. The process as in claim 1 wherein a portion of the melter chamber can be operated with a cooled exterior wall to freeze a layer of molten product on the inside wall for safe long term operation of the melter.

20 8. The process as in claim 1 wherein arc melter electrode (21) tips can be raised in conjunction with a rise of the surface of the molten pool (14,15) in a portion of the melter chamber having a nominal depth to diameter ratio of less than one-half, and the chamber (4) itself being readily removable as in a batch operation without any tapping capability.

25 9. The process as in claim 1 wherein oxygen is injected into or near a surface of the molten pool (14,15) for control of oxidation reduction reactions in and above the molten pool (14,15) for generation of a syngas for process feedstocks and fuel gas cogeneration.

30 10. The process as in claim 1 wherein an auxiliary heat source (16) is injected into the base of the thermal oxidizer (5) to maintain temperature.

11. The process as in claim 1 wherein oxygen enriched air is injected into the base of the thermal oxidizer (5) to maintain temperature and provide oxygen for oxidation reactions, and for generation of a syngas for process feedstocks and
5 fuel gas cogeneration.

12. The process as in claim 1 wherein the cleansed particulate, volatile metals, salts and air pollution control system maintenance material such as filters can be introduced back into the feed material (1) and processed through the
10 system again.

13. The process as in claim 1 wherein an oxidation reduction reaction of the gaseous phase can be regulated and controlled for generation of a syngas for process feedstocks and fuel gas for cogeneration.
15

14. The process as in claim 1 wherein a molten product tapping and casting system is operated in a manner to control the cooling rate of a cast molten glass-ceramic by means of mold insulation or addition of heat for the purpose of controlling an amorphous/crystalline phase structure of the final products.
20

15. The process as in claim 1 wherein liquid can be absorbed into the feedstock (11) or injected onto the top of a cold cap (13) or molten pool (14,15) surface.

25 16. A thermal partitioning arc melter comprising:

a. a refractory-lined melter chamber (4) with a molten pool (14,15) having a nominal depth to diameter ratio of one-quarter to one-half and having multiple side outlets (19,20) for tapping molten metal and slag;
30

35

b. the refractory-lined melter chamber further comprising electrode ports (10) $30^{\circ} \pm 10^{\circ}$ from vertical, a feed port (9) 90° from vertical, and a central offgas port vertically above the melter chamber;

5 c. an electricity-based heat source comprising of parallel axial translating graphite electrode (21) current and voltage-conveying systems operating in a submerged or short arc joule heating resistance mode or a long arc radiant heating mode;

10 d. a contiguous thermal oxidizing reactor (5) sufficiently large to provide a gaseous residence time greater than two seconds, located vertically above the melter chamber, with an auxiliary heat source (16), located at a bottom of the thermal oxidizer, to maintain an operating temperature of 1,800oF to 2,200oF;

15 e. an offgas quench chamber (17) directly coupled to the top of the contiguous thermal oxidizer extending downward at 45° - 60° from horizontal; and,

20 f. an air pollution control system (6).

17. The apparatus as in claim 16 wherein the two graphite electrodes (21) have a nominal electrode tip spacing of one half the molten pool (14,15) nominal working diameter.

25

18. The apparatus as in claim 17 wherein the graphite electrodes (21) have translating mechanisms capable of positioning the electrode tips in the x, y, and z directions (12).

19. The apparatus as in claim 16 wherein the heat source is a direct current source further comprising of two parallel axis translating graphite electrode (21) current and voltage conveying systems.

5 20. The apparatus as in claim 16 wherein the heat source is an alternating single phase graphite electrode (21) current and voltage conveying system with electrodes in multiples of two.

21. The apparatus as in claim 16 wherein the heat source is an alternating
10 three-phase graphite electrode (21) current and voltage-conveying system with electrodes in multiples of three.

22. The apparatus as in claim 16 further comprising a wet-dry offgas control system (6) for the purpose of collecting particulates, volatile metals and
15 salts in an aqueous stream of dissolved and suspended sludge material and a gas filtration system for the purpose of final filtration of the gas stream.

23. The apparatus as in claim 16 further comprising a dry-wet offgas cleansing system (6) for the purpose of partitioning of particulates and volatile
20 metals to a dry recyclable or processable secondary stream, salts from an acid gas scrubber to an aqueous stream of dissolved and undissolved suspended sludge material, and a gas filtration system for the purpose of final filtration of the gas stream.

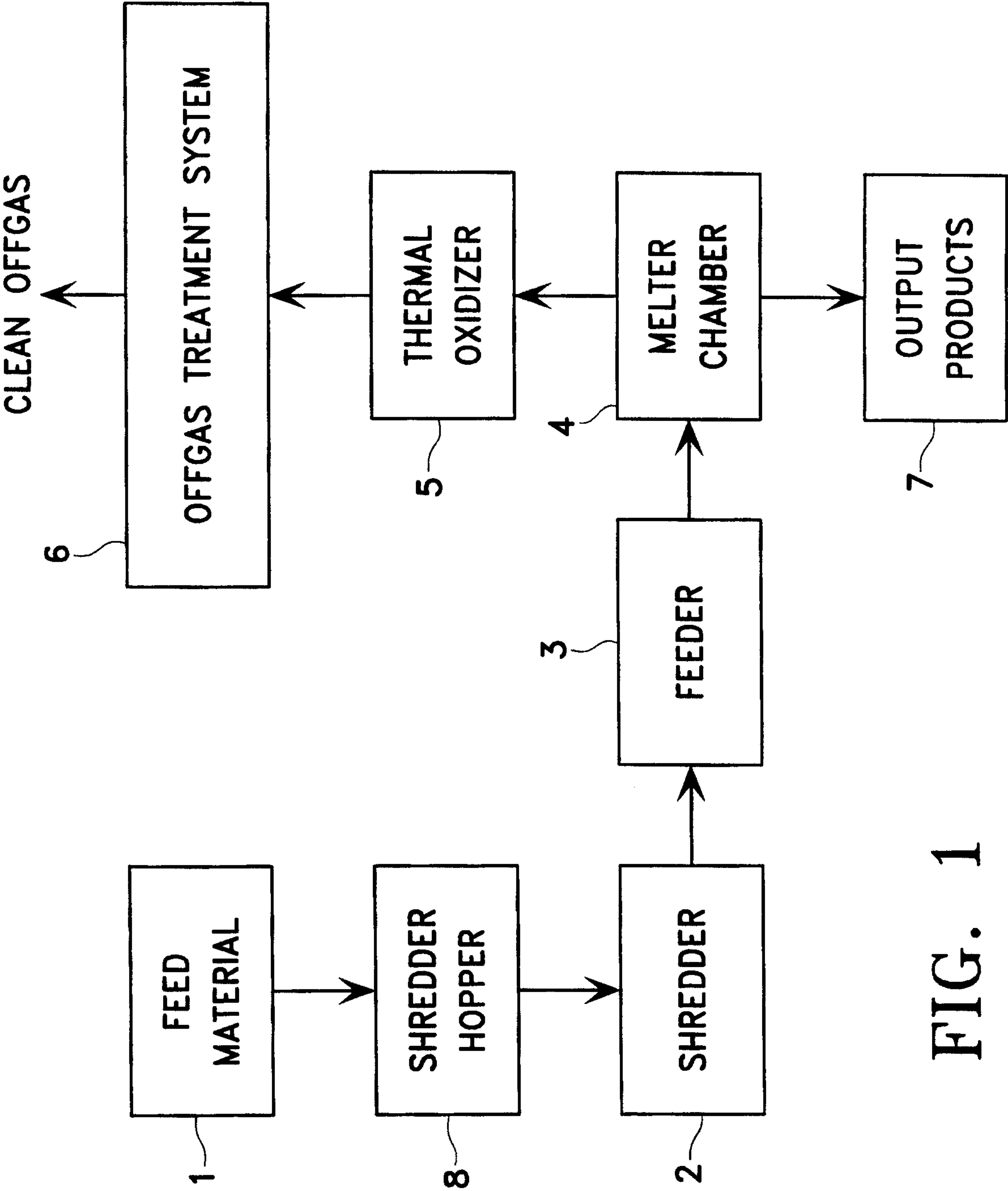
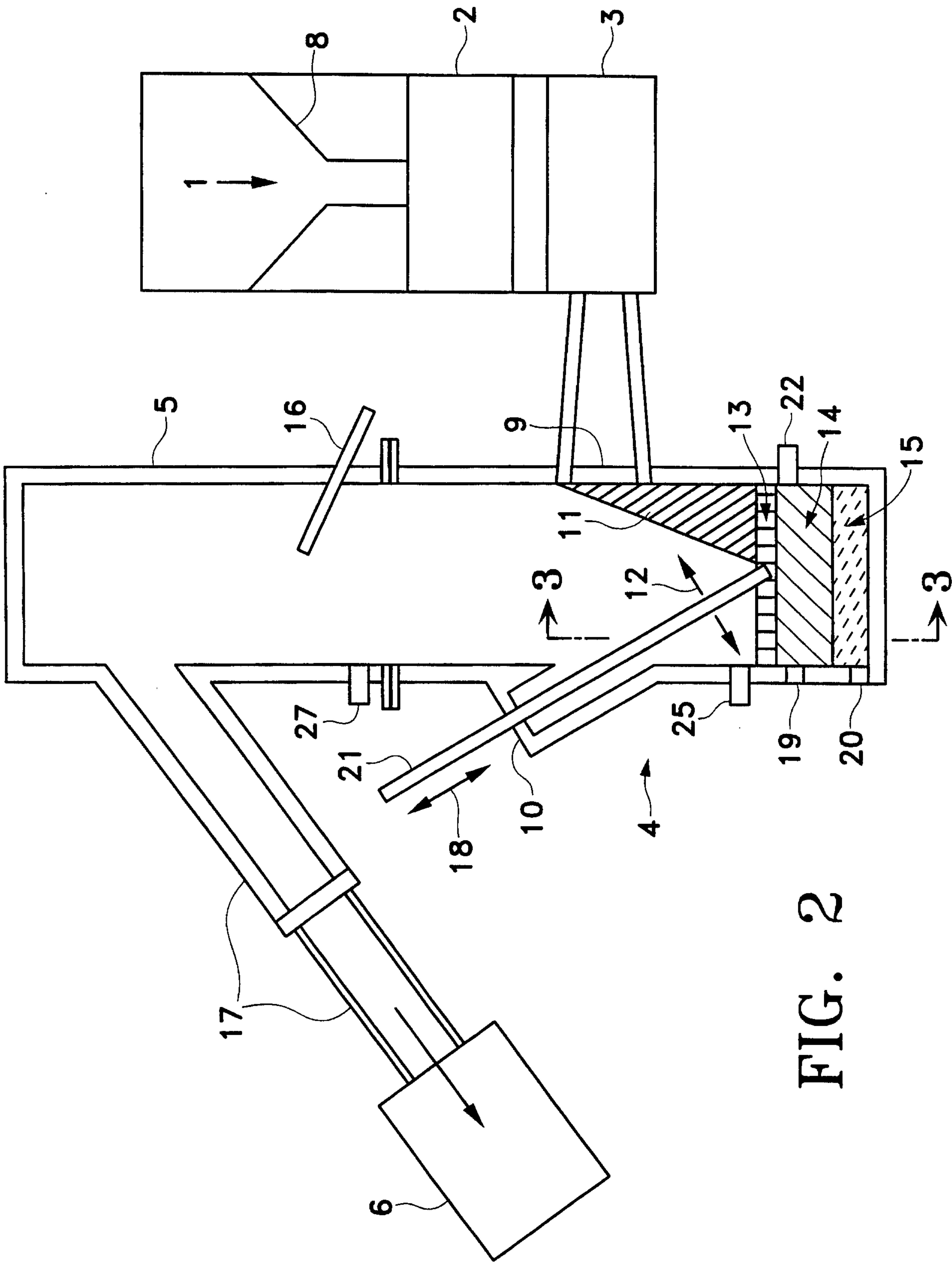


FIG. 1

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3/4

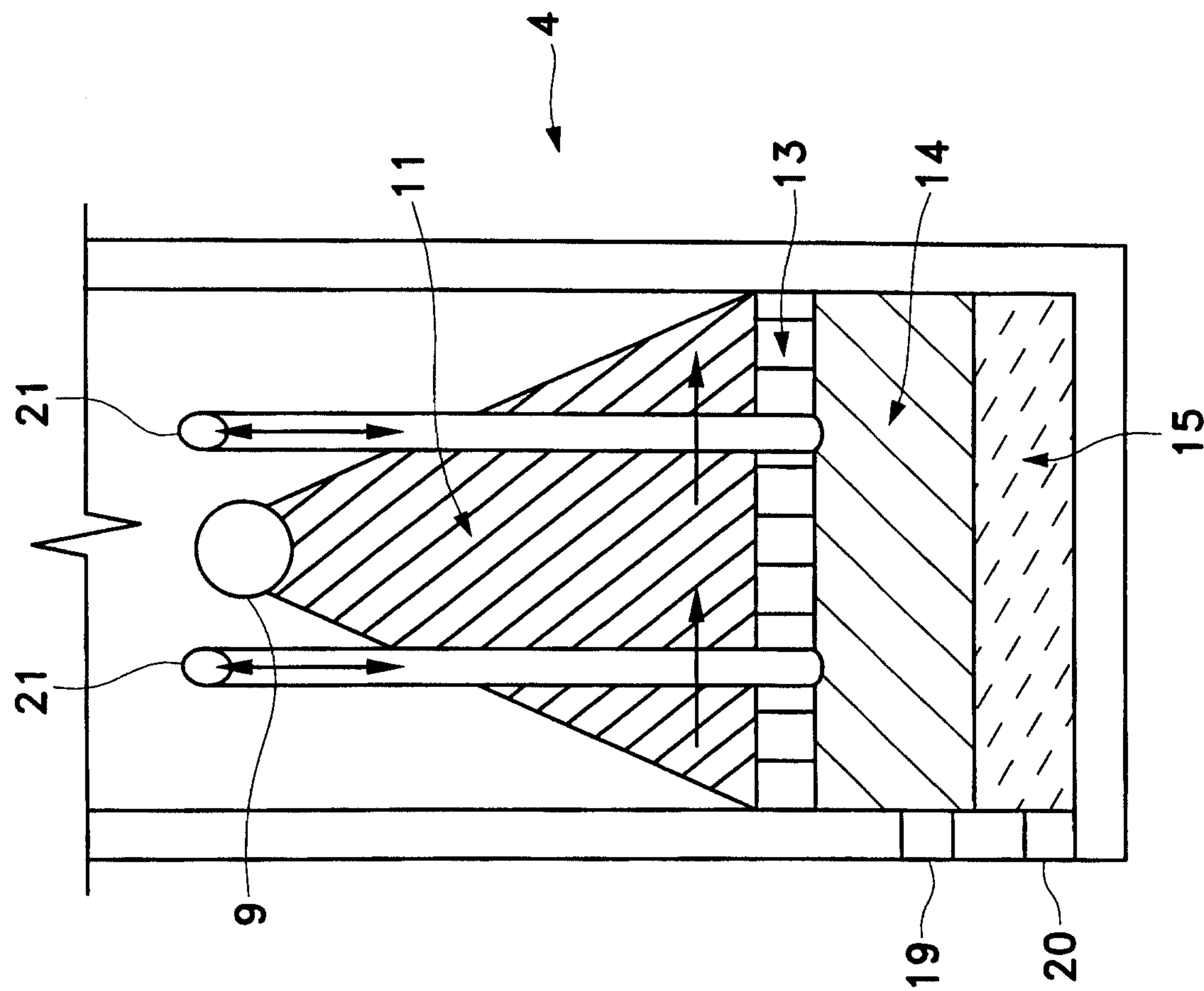


FIG. 3

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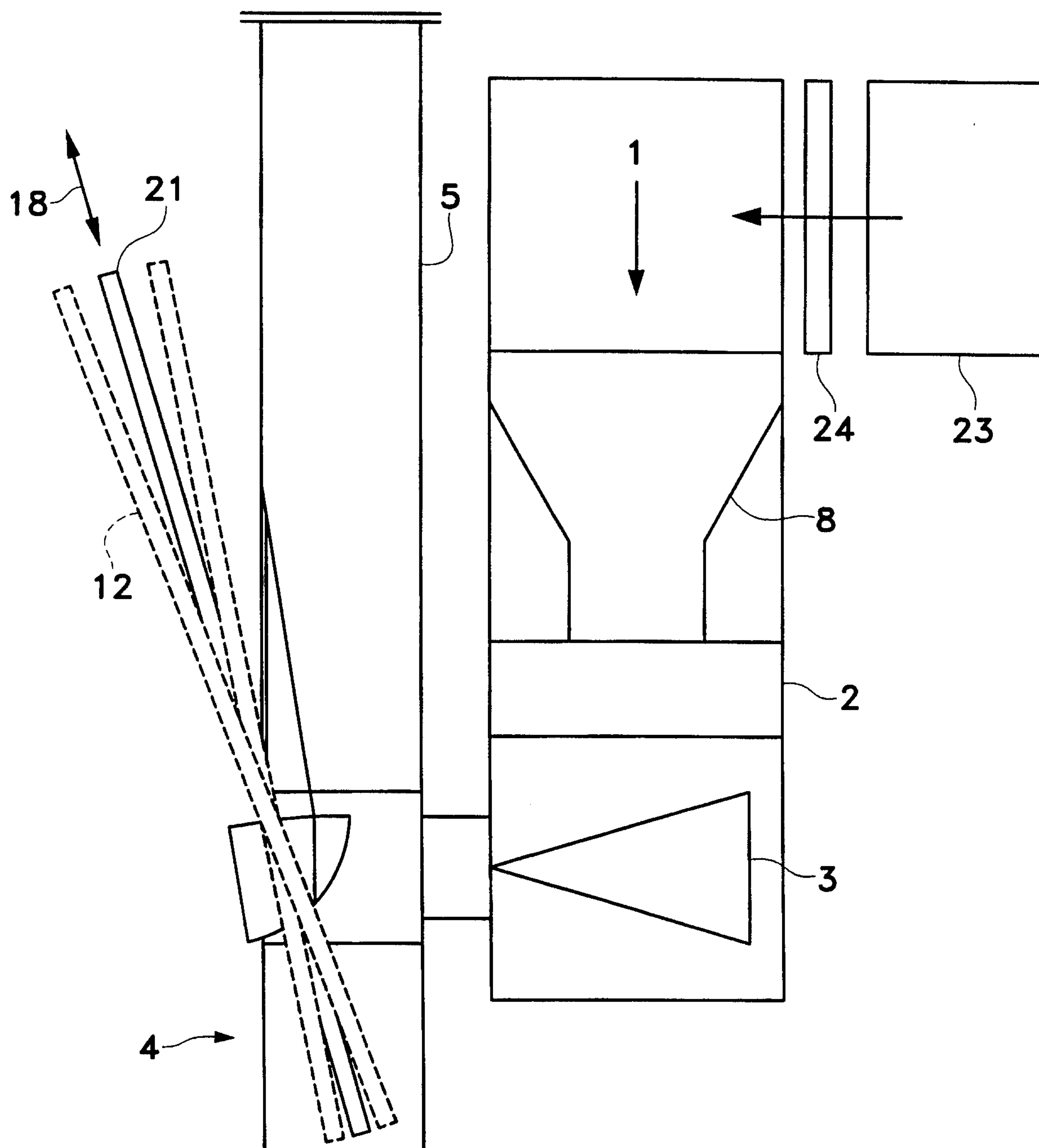


FIG. 4