A method and apparatus are disclosed which are based on utilizing a plural number of long arc column forming plasma torches in combination with a refractory lined furnace chamber to continuously pyrolyze household and industrial refuse material fed into the chamber and convert the same to usable materials and useful forms of energy.

10 Claims, 4 Drawing Figures
REFUSE CONVERTING METHOD AND APPARATUS UTILIZING LONG ARC COLUMN FORMING PLASMA TORCHES

CROSS-REFERENCE TO RELATED APPLICATIONS

This invention is related to copending application, Serial No. 283,552, entitled "Trough Hearth Construction And Method For Plasma Arc Furnace," which discloses an electric circuit for initiating and sustaining long arc plasma columns utilizing long arc column forming plasma generators or "torches" of the type previously taught in U.S. Pat. No. 3,673,375, entitled "Long Arc Column Plasma Generator and Method," issued to the same inventor.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to methods and apparatus for reducing the physical weight and volume of refuse by subjecting it to direct radiated and convected heat from a long plasma arc column.

2. Description of the Prior Art

Pyrolysis (or destructive distillation) techniques were until very recently unrecognized as a means for converting municipal and industrial refuse into useful solid, liquid and gaseous products. In the past, conventional incinerators have been widely used to reduce refuse to ash through combustion. This process necessarily introduced fly ash and many other types of airborne pollutants into the atmosphere, due to the tremendous amounts of air utilized to effect combustion. As an alternate measure, sanitary landfills were developed to prevent air pollution. It is now recognized, however, that water leaching through such landfills may constitute a pollutant to ground water. It is a well-known and documented fact that refuse contains both combustible and non-combustible materials. The University of California, as a result of a study analyzing municipal refuse, has stated that the composition of municipal "mixed" (unsegregated) refuse by weight is: cans, 9.8 percent; bottles and glass, 11.7 percent; metals (other than cans) 9.9 percent; other 77.6 percent. (See University of California Technical Bulletin No. 9, Sanitary Engineering Laboratory 1973 American Public Works Association, "Municipal Refuse Disposal"). It is also a well-known fact that the non-combustible portion which approximates 25 percent of the total weight of refuse is never appreciably reduced by either conventional incineration or landfill practices. Typically, these items are either shredded and buried at the landfill or are simply heaped near the incinerator.

In its 1970 study entitled "Conversion of Municipal and Industrial Refuse into Useful Materials by Pyrolysis," the United States Department of the Interior, Bureau of Mines, revealed the usefulness of pyrolyzing refuse and obtaining usable solid, liquid, and gaseous products. In this study, various samples of shredded municipal and industrial refuse with the metallic component largely removed were placed in a sealed retort and subjected to various levels of conducted heat to as much as 900° centigrade. Among the resulting products were solid residue (a source of charcoal briquettes and filter medium), propane, ethylene and methane gas, solid ammonium sulphate, tar, light oil (a source of benzene and toluene) and liquor 95 percent water and the remainder formed of acids, ketones and aldehydes. In terms of recoverable heat energy, the products of pyrolysis of refuse produced more than a sufficient Btu content to provide the heat for pyrolysis. (See W. S. Sanner et al.: "Conversion of Municipal and Industrial Refuse into Useful Materials by Pyrolysis," Report of Investigations No. 7428, U.S. Department of the Interior, Bureau of Mines, August, 1970.) Although the study conducted by the Bureau of Mines was instrumental in determining the potential value of converting refuse into usable products by pyrolysis, it did not suggest an efficient method and apparatus to do so. The system used was based upon a "batch" method of charging the retort and did not suggest a method and apparatus for more efficient continuous operation. Furthermore, the solid residue contained bottle caps and bits of metal which required further separation before the solid residue could be utilized. In addition, the bulk of the metallic refuse component was required to be segregated from the combustible or carbonaceous component prior to pyrolysis, and the combustible component required drying and shredding for maximum efficiency of the process.

Additional prior art has suggested the use of conventional arc-forming electrodes in an incinerator in U.S. Pat. No. 3,503,347 to intermittently generate heat and thereby reduce the volume and weight of waste confined inside the incinerator. The above patent does not, however, teach the continuous operation of such an incinerator and does not teach a practical application of the evolved noxious gases. In general, the prior art has not suggested an efficient method and apparatus utilizing long arc column plasma torches for reducing substantially large amounts of unsegregated refuse to usable and valuable products from which energy may be readily obtained, while at the same time not polluting the environment. Furthermore, the prior art has not suggested such a method and apparatus which would be adapted for continuous rather than batch operation and capable of reducing the physical weight and volume of substantially large amounts of refuse while generating more energy than being consumed.

SUMMARY OF THE INVENTION

This invention utilizes a plurality of long arc column forming plasma torches in combination with a furnace chamber to thermally decompose unsegregated refuse into a gaseous and molten fluid state. Conveyor means are adapted to continuously supply refuse to the furnace chamber while smoke recycling means are adapted to prevent the gases being produced within the chamber from escaping. The furnace chamber is formed so as to have a somewhat bowl-shaped refractory lined interior hearth portion into which the long arc forming plasma torches are directed. The hearth portion further includes a normally electrically disconnected graphite electrode but which may be appropriately connected into the electrical circuit when needed as an electrode. A lip formed along one edge of the refractory material provides a fluid outlet for the molten refuse. Pyrolysis of the refuse proceeds as long arc plasma mas are generated between the various torches residing in vertical wall portions of the furnace chamber, and molten metallic portions of the refuse collects in the hearth. The heat radiated and convected from the generated long arc plasma columns is sufficient to reduce the remaining organic and non-combustible portion of the refuse to either a molten or gaseous state. Some of
the evolved gases rise, preheat the refuse and are then reintroduced into the reduction process. In a preferred embodiment as the molten refuse reaches the level of the outlet, lip it is oxidized by an incoming stream of gas, e.g., air. The oxidized molten refuse then enters a water bath which effectively provides a water seal and forms into a solid slag for later recovery by appropriate handling means. In some instances the slag may be maintained heated for purposes of melding the same. The gaseous products of the pyrolyzed refuse are simultaneously converted into saturated steam and other gases which may be neutralized or combusted by introduction of gases other than the mentioned air. The hot gases may then drive appropriate energy conversion means such as a turbine generator and may be scrubbed or otherwise purified before being released to the atmosphere.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross sectional side view of a typical refuse converting apparatus according to the invention.

FIG. 2 is a cutaway side view of a long arc column forming plasma torch employed in the instant invention generally shown in operating position inside a furnace chamber.

FIG. 3 is a top plan view of a refuse converting apparatus according to the invention.

FIG. 4 is a somewhat schematic diagram of an electrical circuit employed in the instant invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, as previously mentioned, the present invention is directed to an apparatus and method for continuously reducing by pyrolysis the physical weight and volume of municipal and industrial refuse material and converting it into energy, recoverable and useful products, utilizing long arc column plasma generators, also known in the art as plasma torches. In a preferred embodiment, a complete refuse converting apparatus includes a furnace chamber 15, a plurality of directionally stable long arc column forming plasma torches, generally designated 12, of the type disclosed in previously referred to U.S. Pat. No. 3,673,375, projecting through selected apertures 11 in vertical walls 14 of said furnace chamber 15. Also included is a somewhat concave refractory lined furnace hearth 17 having an integrally formed graphite electrode 18. Said refuse converting apparatus is also provided with a refuse hopper 20 including sealed refuse conveying means 21 and smoke recovery means 23, together being adapted to continuously feed refuse materials 25 into said furnace chamber 15, while maintaining smoke and noxious gases within the chamber. The term "refuse" as used in this disclosure includes raw unsegregated refuse of a municipal or industrial nature or any mixture of both. By "unsegregated" what is meant is that organic wastes are mixed with tin cans, bottles, paper, etc.

In accordance with the instant invention during operation, later described in greater detail, each plasma torch 12 is adapted to form a transferred long arc column of from 10 to 40 inches with molten refuse material 19 a portion of which is metallic. Due to the intense heat being generated (1,000° to 2,000°K), the non-molten refuse (represented by dashed lines 22) is rapidly pyrolyzed into gaseous and molten fluid compo-

nents in the absence, at this point, of appreciable combustion.

Hot gases and molten refuse evolved from the heat of the arc columns flow past a lip 16 formed in the con-

cave refractory lined hearth 17 and into an oxidation chamber 30 which includes a gas inlet manifold 31 for oxygen or air which enables the evolved gases to be combusted into an oxidation dioxide and steam vapor. Depending on the nature of the refuse gases produced, gases other than air or oxygen may be introduced to combust or neutralize such refuse gases. Gas vent 32 receives the hot combusted vapor while a water bath 33 receives the molten residue and reduces it into a solidified slag material 38. The solidified slag aggregate is a highly salable item due to its silica and metallic content. A ridge of molded refractory material 34 adjacent lip 16 further enhances combustion and further degrada-
tion of the molten refuse by increasing the surface area over which the refuse is exposed to oxidation. The action of the water seal with the molten refuse serves to generate additional steam. A turbine generator 35, for example, may receive the hot gases entering gas vent 32 and be used to generate more electrical power than is consumed by the torches. Appropriate gas treat-
ment means (not shown) receive and scrub the combusted gases until safe for release to atmosphere. Alter-
nately, selected valuable gases, e.g., methane, may be separated by well-known means before being combusted by withdrawing a portion of the gas by appropri-
ate means (not shown). The new solidified slag 38 may be handled by appropriate blade or other suitable con-
voyor means 60 and finally withdrawn from the water bath by additional handling apparatus 61 for later use.

Referring to FIG. 2, a long arc column plasma torch, according to the invention and as previously taught in U.S. Pat. No. 3,673,375, is defined as being an apparatus and an electrical conductor in the arc circuit and includes a cylindrical shaped electrode 36, a gas direct-
ing nozzle 37 axially aligned with, forwardly spaced and insulated from electrode 36, and appropriate gas and electrical supply means (not shown). As previously disclosed in copending application, Ser. No. 283,552 a "sleeve pilot arc" 45 may be located between electrode 36 and nozzle 37 by introducing a current potential therebetween while simultaneously applying a vertical flow of gas directed outward through said nozzle 37. Such a pilot arc is readily trans-
ferred to a metallic material 46 also in the electrical cir-
cuit when such pilot arc 45 becomes proximate said metallic matter (i.e., 4-7 inches) by appropriately ad-
vancing said torch 12 into a position proximate said metallic refuse 46. In the instant invention, it has been recognized that such a long arc column plasma torch has particular effectiveness in a refuse converting apparatus since one component (typically 25 percent) of refuse is metal.

Referring now to FIG. 3, a first long arc column plasma torch 40, in preferred form, is adapted to extend through an aperture 47 in a portion of a rear wall 51 of said furnace chamber 15 while second 41 and third 42 long arc column plasma torches are adapted to extend through apertures 48, 49 in adjacent corner wall portions 52 of said furnace chamber. As is perhaps ap-
parent, many other torch mounting configurations will appear to those skilled in the art, and the particular mounting details described herein are for purposes of example only. A sleeve or collar 53 (FIG. 2) which may
be stainless steel, for example, lining each respective aperture 47, 48, 49 is adapted to enable horizontal and vertical angular, as well as axial, movement of each plasma torch within its respective mounting position while preventing heat and noxious gases from escaping through apertures 47, 48, 49. Remotely-controllable torch positioning means 24 (FIG. 1) are provided to enable accurate positioning of the plasma torches.

Referring now to FIG. 4, as previously mentioned, each long arc column forming plasma torch utilized in the present invention (shown in cross section) includes a cylindrical shaped internal electrode 36 and a gas directing nozzle 37 axially aligned with, forwardly spaced and insulated from electrode and appropriate gas, water and electrical supply means (not shown). while the last mentioned gas and water supply means are considered well-established in the art requiring no further elaboration herein, a better understanding may be gained of the invention by a discussion of its advantageous use of power in starting and maintaining the various long arc plasma columns. Utilizing a three phase A. C. wye 55 having a floating neutral 56 to conveniently supply power to three long arc column forming plasma torches 12, a given torch internal electrode 36 is connected to an individual current phase. It is apparent that if more than three torches are employed, a greater number of phases may be utilized. Each torch nozzle 37 is connected to an adjacent phase 58 via an appropriate choke 59. In this manner, a “pilot arc” 45 may be struck between the nozzle 37 and internal electrode 36 of each torch without introducing a consumable electrical conductor by applying the phase to adjacent phase voltage differential, caused by choke 59, across internal electrode 36 and nozzle 37 and simultaneously introducing a gas vertical flow through nozzle 37. The current passing through the “pilot arc” 45 is substantially smaller than that of the “main arc” 13 (see FIGS. 1 and 2) which is subsequently adapted to be transferred to the metal scrap to be melted. Simultaneous transfer of at least two “pilot arcs” 45 to the metallic refuse component establishes at least two main transferred arcs (not shown) and completes a phase 57 to adjacent phase 58 loop whereby the full available current is now utilized.

Since the nature and physical arrangement of the refuse with respect to the torches will vary widely during operation it is contemplated that one or more torches may become inoperative. For example, a falling porcelain coated refrigerator or a sudden deluge of rotten vegetables may stifle an arc. In this event, any single torch may be operated phase to neutral and a new plasma column path may be established by restarting with a pilot arc. Thus, when contact with an electrically conductive melt or an electrically conductive unmelted refuse is lost to a particular plasma column connection may be made to graphite electrode 18 to a ground or neutral 79 (FIG. 1) by a suitable manual or remotely operated contactor 78. Once a molten metallic pool is reestablished the other torches may be again utilized.

Once a molten pool 19 of metallic refuse has been formed and preferably all long arc plasma columns 13 have made electrical contact with said molten pool, it is possible to then continuously dump unsegregated refuse 25 into the furnace chamber 15. The small molten metallic component of the unsegregated refuse will then be sufficient to sustain electrical connection between the three plasma arcs. Furthermore, the above described method of operating long arc column plasma torches in electrical connection with a molten pool of metallic refuse 19 assures continuous operation of the furnace since the metal having a higher specific gravity than the bulk of other refuse will tend to remain in the concave refractory lined hearth 17 while the continuously melting mixed metallic-non-metallic refuse will tend to flow out of the concave furnace hearth 17, pass the outlet lip 16 through oxidation chamber 30 and into water bath 33. It is also a recognized advantage of the particular embodiment shown to utilize the hot gases being evolved in the furnace chamber to pre-heat refuse materials 25 entering the furnace thereby promoting even greater efficiencies. Based on the foregoing invention operation parameters, the specific furnace design and construction is deemed well within the established electric arc furnace art and therefore requires no further elaboration here. While specific refuse conveying means, material handling and energy recovery means have been suggested, these aspects of the instant invention are also well-known in the established art. A complete but not definitive method of converting refuse into usable energy recoverable products based on the described invention may include:

a. initially charging a furnace built in accordance with the invention with refuse having a high metallic content;

b. initiating and sustaining a plurality of long arc plasma columns and reducing the largely metallic refuse to a molten pool;

c. conveying refuse of any class or mixture into the furnace;

d. reducing by heat pyrolysis the physical weight and volume of said conveyed refuse into molten fluid and gaseous products;

e. converting the evolved molten fluid and gaseous products to usable energy;

f. treating and purifying the final products before returning them to the atmosphere.

On the basis of the foregoing description, it is apparent that the instant invention provides an efficient and environmentally safe alternative to landfill, and combusting incineration practices of refuse disposal while at the same time providing a source for energy through the use of long arc column forming plasma torches. According to the invention, it is now possible to continuously decrease the physical weight and volume of raw unsegregated refuse while converting the evolved products to useful materials and useful energy.

What is claimed is:

1. An apparatus for reducing by pyrolysis raw unsegregated refuse comprising:
   a. a furnace chamber;
   b. a refractory lined hearth in said furnace chamber;
   c. conveyor means adapted to introduce raw unsegregated refuse, at least a portion of which is metallic, into said furnace chamber;
   d. long arc column forming plasma generator means mounted in said chamber and adapted to initiate and sustain at least one long arc column plasma having a portion thereof in electrical contact with said refuse and being adapted to reduce said refuse to gaseous and molten fluid products by utilization of the column heat.

2. The apparatus of claim 1 including gas supply means adapted to contact and chemically react with said gaseous and molten fluid products.
3. The apparatus of claim 2 including energy conversion means adapted to recover energy from said products.

4. The apparatus of claim 2 wherein said gas supply means comprises an oxidizing supply.

5. The apparatus of claim 1 wherein said generator means comprises a plurality of peripherally spaced generators and including electrical circuit means adapted to initiate a pilot arc in each said generator and enabling a main long arc column to be transferred between at least two said generators and said refuse.

6. The apparatus of claim 1 including groundable electrode means included in said hearth and being adapted to enable a long arc plasma column to be generated between at least one said generator and said groundable electrode.

7. A method for reducing by pyrolysis a volume of raw unsegregated refuse comprising:
   a. initially charging a furnace chamber with refuse materials of which a substantial portion is metallic;
   b. providing long plasma arc column generation means extending through at least one wall portion of said furnace chamber;
   c. establishing and maintaining at least one long plasma arc column between said generation means and said refuse thereby reducing by heat at least said metallic refuse portion to a molten state;
   d. conveying additional raw unsegregated refuse into said furnace chamber; and
   e. pyrolyzing all of said raw unsegregated refuse by heat from said long plasma arc column into molten and gaseous products.

8. The method of claim 7 including chemically reacting a selected gas with said molten and gaseous products.

9. The method of claim 8 wherein said gas comprises an oxidizing gas.

10. The method of claim 7 including the step of recovering energy from said products.

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CERTIFICATE OF CORRECTION

Patent No. 3,779,182 Dated December 18, 1973

Inventor(S) Salvador L. Camacho

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 66, a parenthesis mark should be inserted before "95 percent".

Column 4, line 8, "an oxidation" should be deleted before "dioside" and -carbon- should be inserted.

Signed and sealed this 17th day of December 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR. C. MARSHALL DANN
Attesting Officer Commissioner of Patents