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"TREATMENT OF WASTE AND A ROTARY KILN
THEREFOR"

5 THIS INVENTION relates to a method of, and
apparatus for, the treatment of waste. In particular,
the apparatus preferably includes a rotary kiln.

 The disposal of urban solid waste and/or
10 liquid wastes is a major problem facing modern man.
Waste materials generally have a negative economic value
and many toxic wastes are extremely difficult to neutra-
lize or destroy.

 Examples of waste treatment methods are
15 disclosed in U.S. Patent Nos. 1,859,159 (Greenwalt);
3,249,551 (Bixley); 3,383,228 (Rekate et al); 3,957,528
(Ott et al) and 4,112,033 (Linge).

 It is an object of the present invention to
20 provide a method for the treatment of waste materials.

 It is a preferred object to provide a method
where the end product can be used as an aggregate, where
the aggregate has a positive economic value e.g. for
concrete production, road making or as porous fill.

25 It is a further preferred object to provide
a rotary kiln suitable for the method.

 Other preferred objects will become apparent
from the following description.

 In one aspect the present invention resides
in a method for the treatment of waste materials
containing fixed carbon and matter which is pyrolysable to
produce fuel gas, said method including the steps of:

 mixing solid and/or liquid wastes with a binding
material and extruding a thus formed mixture to form
silicate-containing pellets of waste material from said

mixture; thereafter passing the pellets through a kiln system providing the following treatments in succession:

(a) passage through a pyrolysis zone in a kiln to drive off at least a portion of the volatile gases in the waste;

(b) passage through an oxidation zone in a kiln where the oxygen causes the remaining volatile gases and at least a portion of the fixed carbon in the waste to be oxidized; and

(c) passage through a vitrification zone in a kiln to vitrify silicates present in the pellets to form a porous aggregate;

and wherein the volatile gases from the pyrolysis zone are used as fuel gas for combustion in the vitrification zone.

The binding material will be selected on the basis that, when fired, it will form a hard inert ceramic material and may include clay, shale or similar material with suitable ceramic properties.

Preferably the pellets are passed through a dryer before they are fed to the furnace or kiln, the pellets preferably being dried by a counter-current flow of hot gas from at least one of the zones of the furnace or kiln.

Preferably the aggregate is cooled in a cooler by a flow of air, the air heated in the cooler preferably being fed to the dryer to dry the pellets.

The exhaust gas from the dryer is preferably split into two streams, one being fed to an afterburner and gas cleaning system, the second to the oxidation and/or vitrification zones of the furnace or kiln.

Preferably the pellets are heated to approximately 650°C in the pyrolysis zone by the controlled burning of some of the volatiles driven off from the waste and by hot gases transferred from the oxidation zone, the resulting volatile-rich gas stream being used to fuel gas in vitrification zone and possibly in the

oxidation zone. Some of the fuel gas may be supplied to the afterburner.

Preferably the oxidation of the pellets, to burn off the remaining volatiles and the fixed carbon solids, occurs in the oxidation zone at or below 1000°C, the oxidation and the combustion of some of the fuel gas from the pyrolysis zone providing the heat in the oxidation zone. A portion of the fixed carbon may be left in the pellets to promote bloating, which reduces the specific gravity (S.G.) of the final aggregate.

10 A portion of the exhaust air from the dryer may be fed to the oxidation zone by a pipe passing through the vitrification zone to supply oxygen to the oxidation zone.

Preferably the vitrification of the silicates occurs at $1200^{\circ}\text{C} \pm 200^{\circ}\text{C}$ in the vitrification zone, the heat in the zone being generated by the the burning of fuel gas from the pyrolysis zone and by air from the dryer.

While it is preferred that the solids and gases in the kiln flow in counter-current direction, the gas flow in the oxidation and vitrification zones may be concurrent with the solids flow, where the exhaust gas from the dryer is fed to the oxidation zone. The hot gas is then fed to the vitrification zone and burn with some of the fuel gas from the pyrolysis zone to vitrify the solids. The gas from the vitrification zone is separated into two streams, one being directed to the pyrolysis zone to provide heat and oxygen for combustion in that zone, the other stream being directed to the gas cleaning system.

In a second aspect the present invention resides in a

kiln system for treatment of solid and/or liquid waste materials containing fixed carbon and matter which is pyrolysable to produce fuel gas said system comprising:

means defining a pyrolysis zone adapted to receive pellets of said waste materials mixed with a binding material, and means for heating said pellets in said zone to drive off at least a portion of the volatile gases contained in the waste;

means defining an oxidation zone downstream of said pyrolysis zone in which, in use, there is an excess oxygen environment for causing the remaining volatile gases and at least a portion of the fixed carbon in the waste to be oxidized;

means defining a vitrification zone downstream of said oxidation zone in which, in use, silicates in the pellets are vitrified to form a porous aggregate;

means for delivering said volatile gases formed in said pyrolysis zone to said oxidation and vitrification zones to be used as fuel gas therein, said fuel gas supplying the fuel for the process; there being means for conveying said waste materials successively through said pyrolysis, oxidation and vitrification zones.

The kiln system may include, upstream of the zone means, a dryer for pellets of solid and/or liquid waste mixed with a binding material; and, downstream of the zone means, a cooler for the solid aggregate.

Other features of the apparatus will be come apparent to the skilled addressee.

To enable the invention to be fully understood, a number of preferred embodiments will now be described with reference to the accompanying drawings, in which:

FIG. 1 is a schematic layout of a waste treatment plant;

FIG. 2 is a schematic layout of a first embodiment of the rotary kiln of the present invention;

FIG. 3 is a schematic layout of a second embodiment of the rotary kiln;

FIG. 4 is a schematic layout of a third embodiment of the rotary kiln;

FIG. 5 is a schematic layout of the solids and gas flow.

FIG. 6(a) is a graph of the solid and gas temperatures in the dryer and the pyrolysis, oxidation/vitrification zones of the kiln and the cooler; and

FIG. 6(b) is a graph of the oxygen (O_2)

- content in the dryer and the pyrolysis, oxidation/vitrification zones of the kiln and the cooler.

5 Referring to FIG. 1, urban solid waste 10 is
dumped in a receival pile and is fed as required by an
apron feeder 11 to a primary pulverizer 12. The pulver-
ized waste is transported via a conveyor 13 to a
magnetic separator 14 which removes any steel components
10 in the waste to a scrap steel bin at 15. The waste is
transported by a conveyor 16 to a secondary pulverizer
17 and is ground to size before being transported to
storage (not shown) by a conveyor 18. (The solid waste
passes a secondary magnetic separator to remove any
15 remaining metal to scrap at 18a.)

Clay 19 is crushed/hammermilled and screened
in a processing unit 20; before being fed to a predryer/
premixer 21 where it is mixed with the solid waste
transported from its store by a conveyor 22.

20 The dried pulverized solid waste/clay mixture
is mixed in a mixer 24 with liquid waste 25 from a
storage tank 26 and is fed to a pugmill 27 to produce
pellets 28 which are conveyed to a dryer 29, to be here-
inafter described in more detail, by a conveyor 30.
25 The pellets are dried and then transported to the rotary
kiln 31 to be fired, as hereinafter described. The
resultant aggregate is cooled and then fed to a crushing
and screening plant 32 before being fed to a stockpile
(not shown) by a conveyor 33.

30 Referring now to FIG. 2, the pellets are
conveyed by the conveyor 30 to a feed hopper 34 and are
supplied to the rotary dryer 29 by a screw conveyor 35.

The dryer 29 has a drum 36 (with internal
flights to convey the pellets upward for more efficient
35 heat transfer) mounted on a rotary support structure.

37. A hood 38 at the exhaust end receives hot dry gas which flows counter-current to the pellet flow to cause the latter to be dried. The hood has a discharge outlet 39 connected to a screw conveyor 40 which transports the dried pellets to a surge bin 41 at the inlet end of the kiln 31. An exhaust hood 42 at the inlet end of the dryer 29 receives the exhaust gas from the dryer being drawn off by a fan 43. The outlet of the fan is connected to an afterburner 44 and to rotary kilns as hereinafter described. The afterburner 44 is connected to a gas scrubber 45 and exhaust stack 46.

The pellets are fed from the surge bin 41 to the inlet end of the pyrolysis zone 47 of the rotary kiln 31.

The pyrolysis zone has a rotary tube 48 lined with refractory material (and lifters to improve heat transfer efficiency) and is mounted on a rotary support structure 49. A hood 50 is provided at the inlet end of the pyrolysis zone. The exhaust end of the zone has a reduced neck portion 51 co-axially received within the inlet end of the oxidation zone 52 of the kiln 31.

The oxidation and vitrification zones 52, 53 of the kiln 31 are formed by a second refractory-lined tube 54 mounted on a rotary support structure 55. The angles of inclination and the rotational speeds of the tubes 48, 54, and the neck portion 51, control the flow of the pellets and aggregate through the kiln.

A hood 56 surrounds the inlet end of the oxidation zone 52 (and the exhaust end of the pyrolysis zone 47) to receive exhaust gases from the oxidation zone 52.

A hood 57 surrounds the discharge end of the vitrification zone 53 and leads to a discharge chute 58 for the aggregate which directs the latter to an aggregate cooler 59 and then via the cooler discharge

59a and conveyor 59b to the crushing and screening plant 32.

The respective solids and gas flows will now be described with reference to FIG. 5.

5 A. Solids Flow

From the pugmill 27 the extruded pellets 28 enter the rotary drum dryer 29 (via screw conveyor 35) where most of the water in the pellets is removed. The water is evaporated into a hot air stream travelling
10 counter-currently to the pellets. This hot air is generated by heating fresh air 60 by direct contact with hot aggregate product in the aggregate cooler 59, and its flow and temperature are regulated to achieve the required degree and rate of drying.

15 The pellets 28 pass from the dryer 29 by way of screw conveyor 40 into the surge bin 41 which acts as a buffer between the dryer 29 and the pyrolysis zone 47. Pellets are removed as required from the bin 41 into the pyrolysis zone. Here, carefully controlled burning of
20 some of the volatiles in the pellets and heat transfer from the oxidation zone hot gas raises the solids temperature to approximately 650°C , enough to drive off most of the volatiles present. The resulting volatile-rich gas stream is drawn off via the hood 50
25 and is used as fuel gas elsewhere in the process. Any moisture remaining in the pellets is also driven off at this stage.

From the pyrolysis zone 47 the pellets pass into the oxidation zone 52. The pellets first enter the
30 oxidation zone where they are contacted against excess oxygen, and the remaining volatiles and fixed carbon are oxidized. This oxidation along with combustion of some of the fuel gas from the pyrolysis zone 47 provides the heat to raise the solids temperature to approxi-
35 mately 1100°C .

The pellets then pass into the vitrification zone 53 of the kiln. Further fuel gas from the pyrolysis zone 47 is burnt here to bring the solids temperature up to $1200^{\circ}\text{C} \pm 200^{\circ}\text{C}$. This final heating stage brings about vitrification of silicates present in the pellets, conferring desirable physical properties on the aggregate produced.

The hot aggregate passes from the kiln directly into the vertical aggregate cooler 59 where it is cooled against a counter-current flow of fresh air 60.

B. Gas Flow

Fresh air 60 enters the aggregate cooler 59, where it absorbs heat from the hot aggregate. This hot air stream is introduced to the raw feed dryer (via hood 38), counter-current to the flow of pellets. In the dryer 29 this gas stream evaporates most of the water from the pellets, cooling as it does so. The flow and temperature of the gas is set to achieve optimum drying conditions.

The exhaust gas from the dryer is controlled by hood 42 and is split into two streams. A large portion goes directly into the afterburner 44 for burning prior to gas cleaning.

Gas and solids flow in a counter-current manner in the oxidation/vitrification zones of the kiln. A proportion of fuel gas generated in the pyrolysis section is fed to a burner 61 located in the vitrification zone 33 of the kiln and the remaining air from the dryer 29 is introduced into the oxidation and vitrification zones. Some of this air is fed to the fuel gas burner 61 in the vitrification zone where gas temperatures are increased and some of the heat given up raising the solid temperatures to that required for vitrification. The remaining air introduced to the oxidation/vitrification zones is fed

to the oxidation zone 52 through a pipe 62 running down the centre of the vitrification zone 53. The air is pre-heated in this pipe 62 and on delivery to the oxidation zone 52 supplies the oxygen required for combustion of the remaining volatiles and fixed carbon in the pyrolysed pellets thereby releasing sufficient heat to raise the solids from the pyrolysis zone temperature to that required for oxidation. Hot gas leaving the oxidation zone 52 is in part returned to the pyrolysis zone 47 via the neck portion 51 counter-current to the pellet flow from the pyrolysis zone 47 to the oxidation zone 52 to provide heat and oxygen for combustion in that section of the process.

This stream is controlled to allow a small fraction of the volatiles present in the pellets to be burnt. The heat released by combustion and heat transfer from the hot oxidation zone gas raises the solids temperature sufficiently to drive off most of the volatiles present into the gas stream, in the pyrolysis zone. The resulting oxygen free, volatile-rich gas stream from this pyrolysis zone 47 is discharged from hood 50 and is used as fuel gas in the vitrification zone 53 and the afterburner 44.

The remainder of the off gas from the oxidation zone (i.e. not going to pyrolysis) passes through the hood 56 directly to the gas scrubber 45.

C. Alternative Gas Flow (as shown in dashed lines in FIG. 5)

As an alternative to the above, the gas flow in the oxidation/vitrification zones 52/53 can be co-current instead of counter-current to the solids flow. In this case the air returning to the process from the dryer 29 is introduced into the oxidation zone 52 of the kiln. Here it allows the combustion of remaining volatiles and the fixed carbon in the pyrolysed pellets

and absorbs that heat generated that is not taken up by the solids. The hot gas then passes into the vitrification zone 53 where its temperature is further increased by burning a portion of the fuel gas from the pyrolysis zone 47. Some of this heat is given up to bring the solids up to vitrification temperature. Gas leaving the vitrification zone 53 is in part returned to the pyrolysis zone 47 to provide heat and oxygen for combustion in that section of the process. The remainder of the gas is discharged from the plant via hood 57 to the gas scrubber 45.

The temperature of the waste and of the gases in the dryer 29, pyrolysis zone, oxidation/vitrification zones 52, 53 and the cooler 59 are shown in solid and dashed lines respectively in FIG. 6(a) while the oxygen (O_2) content in the above is shown in FIG. 6(b).

Referring now to FIG. 3, the layout of the rotary kiln is generally the same as for FIG. 2, except that the pyrolyzed pellets are transported from the exhaust end of the pyrolysis zone 47 to the inlet end of the oxidation zone 52 by a tube 70 passing through the hood 56 and where exhaust gas from the oxidation zone is fed to hood 71 at the exhaust end of the pyrolysis zone via an inlet pipe 72.

In the embodiment of FIG. 4, the oxidation and vitrification zones 52, 53 are provided in respective refractory-lined tubes 54a, 54b mounted on respective rotary supports 55a, 55b. The oxidized pellets are conveyed from the exhaust end of the oxidation zone 52 to the inlet end of the vitrification zone 53 via a hood 73 and discharge chute 74, the latter being received in a hood 75 in the vitrification zone.

The hot gases from the vitrification zone 53, through duct 43, are mixed with some of the exhaust gases from the dryer 29 and fed into the oxidation zone

- . 52, thereby eliminating pipe 62 through the vitrification zone 53.

As will be readily apparent to the skilled addressee, the process variations provide the potential
5 customer with a range of options from which to choose.

The aggregate can be used for concrete production, road making or high grade porous fill.

Variations and modifications may be made to the embodiments described without departing from the
10 present invention as defined in the appended claims.

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CLAIMS

1. A method for the treatment of waste materials containing fixed carbon and matter which is pyrolysable to produce fuel gas, said method including the steps of:

mixing solid and/or liquid wastes with a binding material and extruding a thus formed mixture to form silicate-containing pellets of waste material from said mixture; thereafter passing the pellets through a kiln system providing the following treatments in succession:

(a) passage through a pyrolysis zone in a kiln to drive off at least a portion of the volatile gases in the waste;

(b) passage through an oxidation zone in a kiln where the oxygen causes the remaining volatile gases and at least a portion of the fixed carbon in the waste to be oxidized; and

(c) passage through a vitrification zone in a kiln to vitrify silicates present in the pellets to form a porous aggregate;

and wherein the volatile gases from the pyrolysis zone are used as fuel gas for combustion in the vitrification zone.

2. A method according to claim 1 wherein the volatile gases from the pyrolysis zone are also used as fuel gas in the oxidation zone.

3. A method according to claim 1 or 2 wherein:

the pellets are passed through a dryer upstream of the



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kiln system, the pellets being dried by a countercurrent flow of hot gas from at least one of the zones of said kiln system.

4. A method according to claim 3 wherein:

the aggregate is cooled in a cooler by a flow of air, the heated air exhausted from the aggregate cooler being fed to said dryer in a countercurrent flow to the pellets.

5. A method according to any one of claims 1 - 4 wherein:

the binding material is clay, shale or other siliceous material which, when fired, forms a hard ceramic material.

6. A method according to any preceding claim wherein:

the flows of the pellets and gases in the pyrolysis zones are countercurrent, and the flows of the pellets and the gases in the oxidation and vitrification zones are countercurrent or concurrent.

7. The method according to any preceding claim wherein:

said pellets are heated in said pyrolysis zone to approximately 650°C, are heated in said oxidation zone to approximately 1,000°C, and are vitrified in said vitrification zone at approximately 1,200°C ± 200°C.

8. A kiln system for treatment of solid and/or liquid waste materials containing fixed carbon and matter which is pyrolysable to produce fuel gas said system comprising:

means defining a pyrolysis zone adapted to receive



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pellets of said waste materials mixed with a binding material, and means for heating said pellets in said zone to drive off at least a portion of the volatile gases contained in the waste;

means defining an oxidation zone downstream of said pyrolysis zone in which, in use, there is an excess oxygen environment for causing the remaining volatile gases and at least a portion of the fixed carbon in the waste to be oxidized;

means defining a vitrification zone downstream of said oxidation zone in which, in use, silicates in the pellets are vitrified to form a porous aggregate;

means for delivering said volatile gases formed in said pyrolysis zone to said oxidation and vitrification zones to be used as fuel gas therein, said fuel gas supplying the fuel for the process; there being means for conveying said waste materials successively through said pyrolysis, oxidation and vitrification zones.

9. The apparatus according to claim 8 wherein:

said means defining said oxidation and vitrification zones comprises a second refractory lined tube; and wherein

said first tube is formed with a neck portion which controls both the flow of pellets from the pyrolysis zone to the oxidation zone and the countercurrent flow of hot gas from the oxidation zone to the pyrolysis zone to provide heat and oxygen for combustion in said pyrolysis zone.



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10. The apparatus of claim 8 or claim 9 further including a dryer upstream of said pyrolysis zone for drying pellets conveyed to said dryer, and a cooler downstream of said vitrification zone for cooling the solid aggregate.

11. Apparatus according to claim 10 constructed and arranged so that in use hot gas from at least one of the zones of the kiln system and/or hot air from the cooler is fed to the dryer in countercurrent flow to the flow of pellets in the dryer.

12. The apparatus of any one of claims 8 - 11 wherein said means for heating said pyrolysis zone comprises means for delivering hot gases to said pyrolysis zone from oxidation zone.

13. The apparatus of claim 10 or 11 further including; means for delivering volatile fuel gas from said pyrolysis zone to said vitrification zone for combustion therein, and means for delivering a portion of the exhaust gases from the dryer for combustion in said vitrification zone.

14. The apparatus of claim 9 wherein said first and second tubes are inclined downwardly for gravity feed of said pellets, and are rotatable about their longitudinal axes.

15. The apparatus of any one of claims 8 - 14 wherein said means for delivering said volatile gases from said pyrolysis zone to said oxidation and vitrification zones comprises a first burner located adjacent the discharge end



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of said vitrification zone, and a second burner extending through said vitrification zone into said oxidation zone.

16. A method for the treatment of waste materials substantially as hereinbefore described with reference to the accompanying drawings.

17. A kiln system for the treatment of waste substantially as hereinbefore described with reference and as illustrated in the accompanying drawings.
