IMPROVED WASTE TREATMENT

The present invention relates to an improved method of treating waste, in particular municipal waste, and to a system for such use in such a method of treatment. The present invention also relates to a method of generating and storing of steam and to the associated apparatus.

There are limited options available for the safe disposal of municipal solid waste (MSW). Landfill and incineration are the most popular. One of the reasons for the limited options is that the MSW contains a variety of different solids. These can be categorised into cellulosics (paper and garden waste based products), proteins (waste food), aluminium (cans), ferrous materials (iron), and silicon based materials (glass, ceramics, stone), and plastics. Landfill has been a very popular option. However, this is expensive since the landfill sites must be purchased, excavated and made safe against pollution to allow the depositing of the waste and, when full, it is usually necessary to landscape the site to return it to its original condition, or an alternative acceptable state. Incineration is an option which can provide heat energy for the production of power from MSW. However there are a number of acute disadvantages to this option. Municipal waste can contain a variety of noxious materials which, when incinerated can produce poisonous by-products such as dioxins, in which there is a family of some 200 compounds. Other gases produced, although not harmful, could be perceived as harmful or at the least, undesirable. Having said this, incinerators produce only a very small proportion of the total pollutants in the atmosphere as they destroy more dioxin compounds than they create. Incineration, although helpful, cannot destroy a large proportion of the MSW (glass, metal, etc), and therefore a reasonable percentage volume of the residue of the original MSW is often taken to landfill and therefore the problems associated with that method remain.

With the disposal of municipal waste either by incineration or in a landfill site, it is very difficult to make use of any of the waste material. However, some of the waste material may be re-usable or recyclable and physical and manual sorting and separation is used to recover the materials which could be re-used or recycled. This sorting may either be carried out after the waste material has been collected, in which case this may be done employing manual picking or with some automation. It may be done prior to collection, for example by providing different bins or collections for different types of waste material. There are in existence, central-sites where waste materials of different types can be collected. There are also kerb-side collections for recyclable products such as glass, cans and paper. However, such separations systems have disadvantages. For example, it is possible for the collection of separate materials to become contaminated with materials of an inappropriate type. Further to this, where producers of the waste material are asked to separate the material, and especially where they are required to travel to a collection point to dispose of certain types of material, there is likely to be some apathy to sorting and recycling the material, therefore much of the material is merely collected, mixed with other waste material and cannot be recycled or re-used. Where systems are provided for separating material of particular types from general waste material, whether this is manual or automatic, there will be some inefficiencies in the separation, and therefore not all of the material that could be re-used or recycled will be so re-used or recycled. This is especially the case where the waste is dirty, wet or may be contaminated with unsafe, dangerous material.

According to a first aspect of the present invention, a method for the treatment of waste material includes providing a totally enclosed and sealed vessel in which the waste material is treated, in use, and a source of steam, charging the vessel with said steam to a temperature in excess of at least 130°C at a pressure in excess of 2 bar gauge, to create a high temperature, high pressure environment, maintaining the waste material in said high temperature, high

pressure environment for at least 20 minutes during which time water and any condensate is removed from the vessel, and passing the treated waste material through a separation unit to separate out of the treated waste material particles having a particle size of less than 25 mm.

The particles separated from the processed waste material are predominantly cellulosic in nature.

Typically, the separated particles are of a shape having a diameter of less than 25 mm.

The advantage of separating out these particles from the waste material is that it has been found that these particles may be used in a number of applications. For example, the separated particles have been found to be useful as a composting and soil enhancing agent. It has also been found that the particles can be combined with plastics materials for mouldings or otherwise forming articles. It has also been found that the particles can be used as a fuel source. Each of these uses, and potentially other uses, have the advantage that waste material is re-used, rather than being deposited or treated in an expensive un-ecological manner.

The method involves the use of dry saturated steam from a steam accumulator thermally to treat the MSW in a pressure vessel. In contrast known treatments, e.g. US 5655718, involve steam generation in the pressure vessel itself, this producing 'wet' contaminated steam. The fact that it is 'wet' severely limits the ability to re-use the extracted steam.

MSW is loaded into an autoclave where the material is subjected to clean, dry, saturated steam at a high pressure and temperature, typically at a pressure in excess of 2 bar gauge (approximately 200 kPa) and at a temperature of 135°C. This thermal conditioning of the waste material over a prolonged period acts to

sanitise the material, making it safe to handle. It also acts to clean much of the waste, for example removing the labels and printing on cans and bottles. The above conditions tend to raise the temperature of many commonly used plastic material above their Glass/Rubber transition temperatures (T^g) and encourages plastic material to reduce in volume and attain a roughly spherical shape. Other material, such as fibres, plant matter, paper and the like tends to form a fibre mass having small particle sizes up to 25 mm.

In the thermal treatment system, the vessel is provided with a series of fixed internal vanes that act to agitate the material in the autoclave whilst the autoclave is rotating This ensures that the high pressure, clean, dry, saturated steam is able to contact all of the material. The vane arrangement and rotating motion also brings the material into contact with other material in the autoclave, thereby compacting and breaking down the structure of the material.

The result is that the volume of the waste after thermal treatment is greatly reduced, typically by around 60 to 70%, compared to the volume of the material provided to the system. Nevertheless, the overall mass of the processed material is generally the same as that of the unprocessed material, (subject to the initial moisture content of the MSW). This significant reduction in the volume of the material by the exposure to clean, dry, saturated steam is of particular advantage as this processed waste material takes up less volume in a landfill site, and is sanitised, and therefore is less expensive and more environmentally acceptable than where larger volumes of unprocessed waste are disposed of in a similar manner.

The waste material, which may be municipal or other waste, is preferably processed by being subjected to a temperature in the range of 130 to 186°C. Advantageously, the temperature does not exceed 192°C, since above this temperature chlorine-containing plastics may exceed their melting point (T^m). The pressure within the vessel is advantageously in the range of 2.7 to 10 bar

gauge (approximately 270 kPa to 1000 kPa). The high pressure and temperature are preferably maintained for a period of between 20 and 50 minutes. Maintaining the waste material at such temperatures and pressures over such a period of time ensures the material is fully treated to obtain the advantages of the present invention, without incurring additional costs and energy to treat the material.

It is preferred that the particles separated from the processed waste are long fibre-like particles having a particle size of less than about 25 mm.

The particles may be separated from the remaining waste material using a number of different systems. However, it is preferred that a traditional rotating screen is used to separate out the small particles. This has been found to be efficient. The rotation of the screen helps ensure that all of the waste material has an opportunity to be separated. There is no accepted, automatic separation process for raw municipal solid waste.

To avoid the means for separating the small particles from becoming blocked or blinded by large matter, especially textiles, it is preferred that a system is provided for removal of such matter. This may include a textile picking mechanism that has a series of grippers or hooks for removal of such matter. Alternatively, the textile may be removed by a high speed, revolving drum (swift), fed by a series of licker-in roller mechanisms. The action of these rollers and the swift, serve to shred the textile into long fibrous form, after which the fibres may be amalgamated with the mainstream long fibre particles already separated.

The particles removed from the processed waste are advantageously treated to reduce the moisture content. This may be achieved by passing the small particles through at least one dryer. Preferably a series of dryers are provided to successively reduce further moisture content within the particles. Prior to the

drying process, a press or series of presses may be used to mechanically remove moisture from the separated fibre. The moisture content of the particles is reduced to below about 30%, and most preferable to between about 8 and 12%. Ultimately, the moisture content should be below 5%.

It is beneficial to remove glass shards and other deleterious material from the separated particles. This may be achieved through the use of an air knife separation unit, which consists of an in-feed conveyer, which places the fibre and its various heavy impurities such as glass over an orifice which forces pressurised air through the fibre and its impurities. The fibre is carried over with the air onto a baffle plate, which deposits the fibre onto an out-feed conveyer. The heavy particles such as glass (using gravity) fall through the air stream onto an alternative conveyor. Thus the fibre is separated from any heavy particles and deleterious material. This is standard and accepted technology.

Where the separated particles are to be used as fuel, the particles may be extruded to produce compacted, solid sections. Typically, the sections will have a length of around 0.5 to 2m and a diameter of around 400-800 mm. Of course, other sizes are possible depending upon the extrusion apparatus used. The section will typically have a moisture content of between 18 and 22%. The moisture content may vary dependent on the nature of raw waste material, the conditions under which this was processed, and the drying units provided. The sections could be advantageously stored in a heated environment to further reduce the moisture content. In a preferred embodiment of the present invention, the sections are dried out using waste heat from a steam raising apparatus of the system. The water content of the logs is advantageously reduced to between about 8 and 12%.

Although the fuel may be used in many applications, a preferred option is to use the fuel for the generation of the steam used for the treatment of waste according to the present invention. In this way, the waste material itself is able

to provide the fuel required to treat further waste, and therefore the steam raising apparatus can be self-sustaining, or at least reduce the additional energy that must be provided to treat the waste material. The fuel produced may be used alone, but could be mixed with other solid fuels for use in combustion.

Where the fibre is to be used in the production of plastics articles, the material is preferably processed to form particles of small size, which are then mixed as a filler with plastics material for forming the articles.

The other treated material not removed by the small particle separation system may be further processed. For example, the other material may include plastics, metals, glass etc. These materials may be sorted and recycled. It is preferred that automatic separation system such as eddy current separator (for non-ferrous metals), magnetic separators (for ferrous metals) and the like are provided to remove materials of a particular type from the waste stream for separate handling. Alternatively, the material may be sorted manually. The materials processed by the system of the present invention are clean, having had the labels and printing removed from their surfaces and converted into small particles and therefore require minimum further processing before they are recycled. Further, due to the treatment, the waste material will generally be compacted, and therefore is easy and economical to handle. For example, plastics materials will tend to ball up, and therefore may be separated and handled more easily than if they retained their original structure.

Due to the heat treatment of the waste material with steam, the volume of processed waste material will be greatly reduced compared to the untreated material. Further, since the material is subjected to high temperature and high pressure steam for a prolonged period, the material will be sanitised. Therefore, for any material that is not re-used or recycled, the material may safely be disposed of in a landfill site without risk of contamination. Further, as the volume of material is reduced, even without the removal for re-use or recycling

of some of the material, any material that is deposited in a landfill site or the like will occupy less volume. This therefore makes such disposal more economical and more environmentally acceptable.

The pressure vessel may be formed of carbon steel or other material that is able to withstand the high temperatures and pressures required in accordance with the present invention. The size of the pressure vessel will be dependent upon the volume of waste that is to be processed, and on the number of vessels that are provided. In preferred examples, the vessel has a diameter of 2.75 m. The vessel may have a length of around 7.7 m to prove a capacity of between 5 and 7 tonnes, 10.7 m to provide a capacity of 12 and 15 tonnes, or 16.7 m to provide a capacity of between 20 and 30 tonnes.

It is advantageous to provide a plurality of pressure vessels. Accordingly one may be discharged and refilled whilst another is processing waste material. This allows for generally continuous treatment of waste material and economically sized processing and handling plant. This arrangement allows for cascading of steam from a charged vessel into a vessel awaiting charge.

The vessel is preferably mounted on a support that allows the vessel to be moved between a first position, in which the axis of the vessel is generally horizontal for ordinary operating conditions where during processing the angle is 1° to the horizontal. This allows the necessary area for the steam to gain maximum contact with the vessel contents and allows a fall of condensate to the condensate removal equipment. A second position in which the axis of the vessel is inclined to the horizontal is for the purpose of loading and unloading. This is advantageous as it allows the vessel to be inclined during charging the vessel with waste material to be processed, and therefore uses gravity to assist in filling the vessel.

The pressure vessel preferably includes a means for assisting with the loading, unloading and/or distribution of material within the vessel. The means may be in the form of fixed vanes provided within the vessel. In this case, due to the fixed, helical vanes, rotation of the vessel in one direction will tend to move material towards one end of the vessel, and rotation of the vessel in the opposite direction will tend to move material towards the other end of the vessel. Therefore when loading the vessel, it may be rotated in a direction such that the material is moved towards the end of the vessel opposite the end through which the material enters the vessel. When unloading the vessel, it may be rotated in the opposite direction to move material towards the open end of the vessel. During processing of the material, the vessel may be rotated to agitate the material, to help ensure that the material is subjected to the steam.

The opening to the vessel through which the waste material is added to and removed from the vessel is hermetically sealed with a door mechanism which may be automatic, open-close or manual, open-close. It is preferred that the door or other closure is automatically controlled, for example using hydraulic actuators. Advantageously, sensors are provided to ensure that the door is closed, and/or that the vessel is sealed, before the vessel is charged with steam or before the door is opened, following depressurisation.

The vessel preferably includes a filter, for example in the form of a mesh screen at the opposite end of the vessel from the material inlet. The screen would extend over the circular cross sectional area of the vessel and would prevent solid material above the screens size mesh from entering the condensate removal equipment, thereby reducing its efficiency. Typically, the steam inlet and condensate outlet will be provided at opposite ends of the vessel.

The vessel includes an outlet through which water and any condensate may be discharged from the vessel. The removal of condensates reduces the time taken

to achieve the processing temperature/pressure and also reduces the depressurisation time, or steam within the vessel. It also ensures that the vessel is relatively dry and therefore that the moisture content in the treated waste material is kept as low as possible. The removal of condensates also reduces the time taken to achieve the processing temperatures/pressures and also reduces the depressurisation time.

It is preferred that the charging of the vessel with steam and/or the removal of condensate, is automatically controlled. In this case, the pressure and/or temperature in the pressure vessel may be monitored, and the flow steam into, and/or the venting of steam or removal of condensate may be varied accordingly.

According to a further aspect of the invention, an apparatus for use with the first aspect of the present invention includes a rotatable thermal vessel within which the waste material is treated.

According to a further aspect of the present invention a steam generation system comprises a boiler for providing a source of steam and steam storage apparatus fed with steam from said boiler and arranged to supply, in use, a volume of steam in excess of the capacity of the boiler alone for finite periods of time. Preferably the storage apparatus is a steam accumulator arranged to provide steam to an autoclave. During processing, the condensed steam is passed into a condensate pumping vessel which returns the condensate to a heat exchanger which uses waste heat to pre-heat boiler feed water. When the autoclave is ready to be discharged, a valve opens and the entire steam content of the autoclave is vented to a receiving vessel, where the flash steam is controlled and condensed in a form to be passed to the heat exchanger for cooling. The whole process is controlled by a central plant monitoring system. It is preferred that the steam generation system according to the second

embodiment of the present invention be used in the waste treatment system of the first aspect of the present invention.

An example of the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a schematic view of the steam generation system and waste treatment method and apparatus of the present invention,

Figure 2 shows a cross sectional view through an autoclave, and

Figure 3 a schematic scrap view of a modified Figure 1 embodiment.

Figure 1 shows a schematic view of a waste processing system according to the present invention. The system includes a thermal vessel (autoclave) 2, shown in greater detail in Figure 2. The autoclave 2 may be formed from a carbon steel material with suitable external insulation. The autoclave 2 includes an open end through which waste material to be treated is provided to and removed from the autoclave 2. The open end is sealed with a closure 30, such that the pressure within the autoclave 2 can be increased. In a preferred embodiment, the closure 30 is hydraulically controlled and includes an interlock mechanism with a sensor to ensure that the autoclave is hermetically and safely sealed. The closure is able to quickly open and given a large clearance. A steam inlet 34 is provided for the introduction of clean, dry, saturated steam into the autoclave 2.

The autoclave 2 includes fixed internal helical vanes 31, as shown in Figure 2. The vessel and thus the vanes 31 fixed thereto are rotated such that waste introduced into the autoclave is mixed and moved towards the rear of the autoclave 2 by the action of the vanes 31 when the autoclave rotates. During this filling, the autoclave 2 is inclined to assist filling. The axis of the vessel may be inclined to about 8°, at least, from the horizontal. During the processing

of waste, the autoclave 2 is moved to a generally horizontal orientation, for example at an inclination of 1°. The inclination of the vessel is achieved using hydraulic rams that pivot the vessel about a rear pivot point. When the waste material has been processed within the autoclave 2, the direction of rotation of the vanes 31 is reversed to cause the processed waste material to be elevated from and out of the autoclave 2. During emptying, the autoclave 2 may be returned to its inclined orientation.

Towards the end of the autoclave opposite the opening, there is provided a mesh screen 32 that prevents large particles of waste material from reaching and clogging the bottom of the autoclave 2 into which the steam is provided, and from which condensate, (i.e. water and any other condensate) is removed from the autoclave 2 through a dip pipe. The removal of condensate from the autoclave 2 allows the duration of the steaming and venting cycle to be minimized. The removal of condensate increases the volume within the autoclave for steam, and ensures that the steam is as dry as possible, minimising the moisture content of the processed waste. The condensate may be removed through a condensate outlet 33 that has a flexible rotating coupling at the rear of the autoclave 2, through which the condensate removal dip pipe is provided. Condensate removal is preferably continuous, but occurs for at least the time the material is processed in the high temperature, high pressure enviroment.

In use, waste material to be processed is introduced into the open end of the autoclave 2, for example using a conveyor feed system. The amount of waste material that may be introduced will depend on the size of the autoclave 2, and the nature of the waste. The waste can typically have a density of between about 250 and 750 kg/m3, for general municipal waste, with the autoclave 2 having a 2.75 m diameter, the capacity will typically be between 5 and 7 tonnes for a 7.7 m long autoclave, between 12 and 15 tonnes for a 10.7 m long

autoclave and between 20 and 30 tonnes of a 16.7 m autoclave thermal treatment vessel.

The amount of waste material added to the autoclave 2 is controlled, for example using a computerised system. This control can be based on the measured weight of material being added to the autoclave 2, and/or analysis of the composition of the waste material, and/or on previous loads. The closure 30 is then closed over the open end of the autoclave 2, hermetically sealing the autoclave 2 to enable the pressure within the autoclave 2 to be increased.

Steam is introduced into the autoclave 2 through the inlet 34. This could be 100 mm or 150 mm rotary steam joint axially located on the autoclave. The steam is clean, dry and saturated, and is supplied to the autoclave 2 to increase the pressure. Typically, the temperature within the autoclave will be increased to between 130 and 185°C. The temperature should be increased to at least 130°C to ensure proper sanitation of the waste material being processed. However, the temperature should not be too high as it should not exceed the melting point of some of the materials that may be treated. For example, chlorine-containing plastics have a melting point of 192°C, and it is therefore preferred that the temperature should not be increased to this level. The pressure in the autoclave 2 should be increased, typically to between 2 bar gauge and 10 bar gauge (about 200-1000 kPa).

The charging of the autoclave 2 with steam is controlled via the central controller by means of a valve. The control may be based on the determination of temperature and/or pressure within the autoclave 2, and may be dependent on the determined load of waste materials.

The increased pressure and temperature within the autoclave 2 are maintained for a period in excess of 20 minutes to ensure that the waste material is

sanitised. Ideally, the material is processed from between 30 and 50 minutes to ensure that the material is treated optimally.

In one example, two 10 tonne capacity vessels are provided, each weighting about 18 tonnes. The peak demand for steam to charge one vessel will be around 6,750 kg/h (about 15,000 lbs./hr) over a 15-minute period. The average steam demand to two vessels over a 120 minute cycle time will be around 1,700 kg/h (about 3,750 lbs./hr). For two 20 tonne capacity vessels, weighing approximately 20 tonnes, a peak demand for steam would be about 12,250 kg/h (about 27,000 lbs/hr) over 15 minutes, with an average demand of about 2,900 kg/h (about 6,400 lbs/hr) over a 120 minute cycle time.

During the heat treatment, the vessel 2 rotates. This ensures that the material being processed is agitated so that all of the material comes into contact with the clean, dry, saturated steam, and the material is broken down by contact with other material in the autoclave 2. Typical rotation speeds are of the order of 0 to 10 rpm, depending on the material being processed. The rotation is achieved using a hydraulic drive, for example using a chain drive with a sprocket wheel on the vessel. The autoclave vessel may be supported on suitable rollers, such as two tyre paths.

The processing of the material in the rotating autoclave 2 sterilises the material and breaks down much of the material. Typically, the volume of the processed material is reduced by as much as 70%.

At the conclusion of the steam treatment of the waste, the steam is vented to atmospheric pressure. The venting can be arranged to allow the temperature to cool at a predetermined rate of, typically, 4°C per minute, allowing the vessel to cool from 160°C to 100°C in 15 minutes, all under the control of the central controller.

After treatment, the waste is removed from the autoclave 2 by removing the closure 30, and reversing the rotation of the vessel/vanes 31, thereby lifting the material out of the autoclave 2. The processed material is discharged onto a conveyor, on which it is transported to a rotary screen 3 shown in Figure 1.

A large proportion of the processed waste will have a particle size of less than 25 mm. These particles are largely formed from organic waste, paper and lightweight packaging fraction that produces strands of cellulose fibre during the processing of the waste material in the autoclave. As the processed material is passed through the rotary screen shown in Figure 1, the "fibre" or small particle size material is separated from the processed waste. The remaining waste, which includes particles having a particle size greater than 25 mm and the non-organic fraction, may be passed for further sorting and processing. For example, as shown in Figure 1, the remaining material may pass through an over-band magnetic separator 11 that removes ferrous material, and eddy current separator 12 that removes non-ferrous metal. Other non-metal sorting means are indicated schematically as 13, which may be automated or manual sorting systems, for example to remove glass, plastics and other separable materials. All of the separated materials will be clean and sanitised, for example cans and bottles will be stripped of their labels and lacquers, as well as any paints or grease. Bottles will be clean and, in many cases, crushed. Plastics materials will have reduced their volume considerably, and will be mouldable. Therefore, the materials are in an ideal condition to be further processed, for example recycled.

In one example of the present invention, a textile grabber is provided upstream of the rotary screen. This picks out relatively large pieces of textile that may otherwise blind the screen.

The small particles, or fibre, removed by the rotary screen will have a high moisture content, having absorbed steam in the autoclave 2. Typically, the fibre

may have a moisture content of 40 to 50%. The moisture content is reduced, for example by passing the fibre through a series of hydraulic presses. The fibre material may also include shards of glass and other deleterious materials.

The dried, cleaned, fibre has a number of possible applications and uses. One use is as a fuel. In particular, the fibre can be used as a fuel to produce energy for the generation of steam that is used in the autoclave 2 to treat future loads of waste material. In this case, the material may be extruded using an established technique of a hydraulic press extrusion system which introduces the municipal solid waste (MSW) fibre into a hopper by conveyor feed at the bottom of which is a high pressure hydraulic ram which compresses the wet MSW against a steel stop which is removed on the final press to allow the extrusion of a dewatered slab of compressed MSW, for example to produce a section, having a length of around 2 m and a diameter of around 800 mm. The log will typically have a moisture content of between 18 and 22%. The logs of dewatered MSW are then stored in a heated environment to further reduce the moisture content. In a preferred embodiment of the present invention, the logs are dried out using waste heat from the steam generation system, reducing the water content of the logs to between about 8 and 12%. Whilst it is expected that the calorific content of the resulting logs may vary with the different waste materials, and the compositions of waste material, a calorific value in the range of 3000 to 5000 kcal/kg may be achieved. In this case, it is possible to create about 13 to 17 tonnes per hour of dry, saturated steam at 18.3 bar gauge (1930 kPa) at 210°C (and 55°C superheat). This may be passed through a standard low-pressure steam turbine to generate around 6MW of electricity with sufficient surplus steam to supply the thermal processing system.

The fibre material has also been found to be useful for composting, as a fertiliser, and for mixing with plastics materials to form plastics articles.

Dependent upon the use of energy and heat balance available, the reclaimed fibre and other reclaimed fuel components are directed to a steam raising waste heat boiler 9 where it is burned.

The steam generated from waste heat is used to drive a steam turbine 10 which in turn drives a generator 8 to produce electricity. Pass out steam from the turbine 10 can be used for a manufacturing process and/or for a sterilization and heating or cooling system.

Alternatively the reclaimed fibre and other reclaimed items components designated for fuel can be taken to a gasifier 6, where syn (methane) gas is produced. The gas is used as fuel in a gas engine 7 connected to the generator 8 to produce electricity.

Exhaust gases from the turbine/engine are taken to waste heat boiler 9 where steam is generated to be used in the autoclave 2 and/or to any other steam user in a manufacturing process and/or sterilization and heating or cooling system.

In each alternative, condensate from the chosen steam user is returned to supply water back into the waste heat boiler.

In a preferred embodiment, multiple autoclaves 2 are provided, and are arranged such that some are able to be sealed and pressurised to process waste material contained within it, whilst the others are being emptied of the processed waste material and being filled with more, raw, material. In this way, it is possible to continually process material, rather than needing to wait until material in a single autoclave is processed and removed from the autoclave before the next load of material can be added. It will be appreciated that the additional autoclaves may be provided, and these can each run independently or in sequence to achieve the optimum processing. Steam can be cascaded from a charged vessel into a vessel awaiting charge.

Steam Generation

The autoclave 2 requires a volume of dry, saturated steam for the processing of the waste material. Whilst this may be provided using any form of steam generator, it would be inefficient. According to one embodiment of the present invention, an efficient steam generation and storage method is used.

As shown in Figure 1, the steam is generated in a boiler 16. In the example shown in the Figure 1, the boiler 16 is powered using either gas oil (diesel) from a gas oil tank 14, or using natural gas from a gas source 21, for example from the mains supply. Alternatively or additionally, the boiler 16 may be fired using processed fibre fuel as described above, or using biogas. Where a gas oil tank 14 is provided, the tank may be filled with gas oil, for example from a tanker. The gas oil tank 14 should have an air vent. Suitable isolation and control valves are provided to control the flow of fuel to the boiler 16. The use of isolation valves allows the supply to be shut off, for example to allow maintenance of the boiler 16. Where necessary, a booster may be provided to the burner mechanism 15 of the boiler 16 to permit the use of gas having a low pressure.

The preferred boiler 16 is a three-pass, economic, wetback fire-tube type boiler. A suitable boiler is a BEEL, BEEVOR or MINSTER. To improve efficiency, the burner should be a high efficiency boiler with suitable controls, with direct digital combustion controls known as a THERMBURN, which allow for continuous monitoring of fuel and air input to the boiler/burner to optimise the burner and hence fuel efficiency.

In normal use, there will be a tendency for dissolved solids in the boiler feed water to concentrate. These are known as TDS (Total Dissolved Solids). These solids must be removed to ensure the continued, efficient operation of the

boiler 16. As described later, the removal of these solids is achieved by a blowdown operation, and this is automatically controlled to reduce manual intervention in the operation of the boiler 16.

To ensure optimum efficiency of the boiler 16, the rate at which the water is introduced to the boiler 16 to be heated, and the amount of air introduced to the boiler 16 for efficient burning of the fuel is carefully controlled. This is achieved by providing a variable speed controller to drive the pumps that supply water to the boiler 16 at variable speeds, and by providing a variable speed controller to the variable drive of a forced air fan on the boiler 16 that forces air into the boiler 16. The provision of the variable speed drives also reduces the amount of energy required to drive the pumps, since these are not unnecessarily overdriven.

The water supplied to the boiler 16 should be clean to avoid contamination of internal parts of the system and damage to the components. Accordingly, the steam generation system is provided with a Raw Water Break Tank 23 to treat water before this is supplied to the boiler 16. Water may be taken from any available source 22, for example from a bore hole, reservoir or from the mains supply. The provision of the water from the water supply 22 to the Raw Water Break Tank 23 will automatically be controlled to ensure the optimum rate of supply. A break tank is required by law, to be interposed between the mains supply and any potential polluting mechanisms. All industrial sites requiring water-based systems must have a break tank on entry of mains water onto an industrial site.

The size of the Raw Water Break Tank 23 will depend on the capacity of the boiler 16, the steam storage system or accumulator 18 and the autoclave 2. The raw water is pumped from the Raw Water Break Tank 23. The raw water is pumped into a water softening unit 24. The water softening unit may include a softening resin that may be regenerated by back flushing with brine. This

regeneration should be carried out periodically to ensure the correct operation of the unit. The water softening unit 24 may include a pair of activated resin units that are arranged in a duty/standby mode, in which one of the pairs of units is treating the water at any one time. During operation of one of the units, the other unit may be regenerated. Ideally, the control of the water softening units is automated.

From the water softening unit, the treated water is supplied to the boiler 16 via a waste heat recovery system 25. This may use waste heat from a suitable part of the system. The waste heat recovery system 25 pre-heats the water to typically around 80°C before this is supplied to a boiler feed tank 28, from which the water is supplied to the boiler 16 as required.

The boiler feed tank 28 is provided at a level, higher than the boiler 16, such that the water from the feed tank 28 can be fed to the boiler feed pump by a gravity feed, then via the feed pump at high pressure into the boiler. The supply of water to the boiler 16, may be automatically controlled by suitable control valves. The level of water in the tank is monitored to control the water volume.

Within the boiler feed tank 28, the water is further treated and pre-heated. As shown in Figure 1, some of the steam from the boiler 16 is injected, at reduced pressure, from the boiler 16 into the boiler feed tank 28. This pressure reduction is effected for fuel economy and safety reasons and the typical pressure reduction would be from 17.2 to 6.9 bar gauge (790 kPa). To maintain the desired temperature of the water in the feed tank 28 at between 80° and 85°C, a temperature sensor is provided to determine the temperature of the water, and this is used to control the rate at which steam is injected from the boiler 16 into the feed tank 28.

The water in the feed tank 28 is treated to minimise the oxygen content in the water. This assists in the efficiency of the system, helps inhibit corrosion and

prevents the formation of scale. Chemical treatment is also added to adjust the pH levels of the water. This treatment may include the addition of chemicals, which are added to the water in the feed tank 28 in a controlled, preferably automated manner. Further, the amount of chemical required can be reduced by designing the boiler feed tank 28 as a partial de-aerator, which provides a system where the boiler feed water is heated to between 80-85°C, initially from using the condensate and the heat from flash steam to drive off as much oxygen gas as possible prior to the water being fed into the boiler. The water in the boiler feed tank 28 is then heated by an automatically controlled steam injection system which not only heats the water but causes turbulence within the water to avoid stratification of water temperature and maintain water temperature consistency. The water may also pass through a filter to remove any solids.

To further assist the pre-heating of the water supplied to the boiler 16, the water passing from the feed tank 28 to the boiler 16 may pass through a flue gas economiser system 46. This comprises a heat exchanger 29 through which the flue gas from the boiler passes. This heats the water passing through the heat exchanger 29 to the boiler 16. The heat exchanger 29 may include a run-around coil, and suitable safety features, for example including a safety valve. The use of the flue gases to pre-heat the water allows some of the energy of the boiler fuel lost due to the inefficiencies of the boiler to be recovered. This has been found to give a saving of between 3 and 5% of the total fuel used. This also increases the evaporative capacity of the boiler because more heat energy is converted into steam by raising the boiler water temperature from between 80-85°C to between 100-110°C therefore enhancing the efficiency of the boiler.

The boiler 16 is provided with an automatic TDS controlled blowdown system 17. A blowdown vessel 17 permits periodic bleeding of the boiler water to restrict and maintain dissolved solid material within the boiler to a reasonable

level. The blowdown vessel 17 includes a pressure vessel that is able to accept blowdown from a number of points on the boiler 16.

Water within the boiler 16 may include some suspended solids that are present within the incoming water. These suspended solids will tend to collect towards the bottom of the boiler 16. There is provided a lower exit from the boiler 16 to the blowdown vessel 17 through which high pressure, high temperature water containing the contaminants is transmitted to the blowdown vessel 17. As the steam enters the blowdown vessel 17, it falls to atmospheric pressure and vents the latent heat in the form of flash steam, which is vented to the atmosphere. The remaining water, which will be cooled can then be discharged. Due to the minimal blowdown when removing the suspended particles in this way, it is neither considered practical or efficient to seek to recover the energy.

Another form of contamination in the water in the boiler 16 are dissolved solids. A second exit is provided around the horizontal centre line of the boiler 16. The positioning at the horizontal centre line is important as this is the only point on the boiler shell circumference, which cannot contaminate the instrument, as it is the only point on the shell surface which runs at a tangential parallel to vertical. This exit is also connected to the blowdown vessel 17. The boiler 16 includes a sensor to monitor the level of total dissolved solids within the boiler 16. When the sensor determines that the level exceeds a predetermined level, a small volume of boiler water is bled off, through the exit until the correct concentration of total dissolved solids is reached.

By automatically monitoring and controlling the level of total dissolved solids within the boiler 16, it is possible to ensure that the water being heated remains of an acceptable quality. This in turn eliminates the effects of contamination that may occur, including foaming of the water within the boiler that would result in the actual amount of water within the boiler differing from the measured volume of water. This may lead to errors in the calculation of

parameters and control of the steam generation apparatus. Further, the foaming may be carried into the other components of the steam generation apparatus, resulting in corrosion of the pipework and fittings and poor performance of the autoclaves 2. By automatically controlling the suspended and dissolved solids, it is ensured that only the minimum amount of water must be removed from the boiler 16 to correct the levels of total dissolved solids, and therefore ensures minimum waste of steam.

A third outlet may be provided from the bottom of the water level gauge on the side of the boiler 16 to meet health and safety requirements.

The majority of the steam generated in the boiler 16 is provided to the autoclave 2 (or autoclaves where a number of theses are provided). To obtain a sufficient volume of steam for charging the autoclave 2 to a sufficiently high temperature, the steam is collected in a steam accumulator or storage system 18. This allows the provision of a large quantity of steam in a short period that is much greater than the quantity of steam that can be provided directly from the boiler 16.

The steam storage system includes a pressure vessel with a quantity of water within it which is calculated to store a finite amount of steam at the boiler pressure and temperature. The finite amount of steam will depend on the size of the boiler supplying the steam, the pressure of the boiler, the internal size of the autoclave(s) and the length of time that steam is required within the process cycle. This in turn ensures that the autoclave 2 can quickly be brought to the required temperature and pressure with dry steam at the saturation temperature, without detrimental effects on the steam generating plant.

It should be noted that without the provision of a steam storage system within the total apparatus described, the throughput of MSW and hence the production of fibre for fuel will be adversely affected. Additionally, without a steam

storage facility, the steam generating plant shall work it below optimum efficiency levels and compromise the economic running of the total apparatus.

To remove condensate from the steam line from boiler 16 to the accumulator 18, steam traps are provided, for example on each vertical rise and vertical fall of the steam line, and every 30 m of the pipe run. This condensate is recovered.

Typically, the accumulator 18 will be formed of carbon steel or other material able to withstand the high temperatures and pressures that are present within the boiler 16. The accumulator 18 is filled with water, typically to about 90% of its volume, and the steam from the boiler 16 is injected into the water in such a way that the steam condenses in the water without breaking the surface of the water. This may be achieved by providing a series of steam injectors that inject the steam into the water in a suitable geometrical pattern. This also ensures non-stratification within the vessel. By accumulating the steam in this way, and especially where the supply of the steam to the accumulator is automatically controlled, it is possible to charge the accumulator at a steady rate, allowing the boiler 16 to operate in a steady condition without requiring the burners in the boiler to be repeatedly turned on and off. This steady state operation is a more efficient way of operating the boiler 16 than repeatedly turning the burner on and off, thereby giving greater fuel efficiency and avoiding damage to the boiler 16 due to excessive cyclic demands, Further, there will be less boiler water carry over and faster, more efficient, autoclave cycle times. Carry over occurs when there is a large pressure drop within the boiler steam space due a peak steam demand on the boiler. The steam pressure reduction causes an increase in volume which, because of the fixed outlet and pipework dimensions will cause the steam to travel faster down the outlet pipe. This can cause a partial pressure loss at the crown of the boiler and consequently induces boiler water into the steam distribution pipework system with the resultant associated problems.

A pressure control valve is provided to ensure that the steam pressure is correct before it is supplied to the autoclave 2. The steam is provided to the autoclave 2 through a control valve which controls the rate of flow and therefore the rate of temperature increase via a signal from the central controller. To ensure that the steam supplied is dry and of a high quality, steam traps may be provided in the vertical rises and falls of the supply line.

The condensate removed from the autoclave 2 through the dip pipe 33 can be connected, through a series of valves, to a condensate receiver vessel 19. From the condensate receiver vessel 19, the water is pumped using steam as the motive force into the steam vent/condensate vessel 20. All condensate discharged from the steam mains drain is recovered. This is pure water and may go straight back to the boiler feed tank. The condensate which is discharged from the autoclave 2 into the condensate receiver/pumping vessel 19, which is then pumped to the steam vent/condensate vessel, 20 (as previously described) is in turn pumped from the steam vent/condensate vessel, 20 to the waste heat recovery system (WHRS), 25. Cold boiler feed is taken through the WHRS and heat from the condensate from the steam vent/condensate vessel 20 is recovered to the cold feed (thereby providing a fuel saving) and as a by- product, the condensate is cooled. The cooled condensate is taken from the WHRS 25 to discharge to a reclaimed cooling water tank, 26. The reclaimed water is used as cooling water in the steam vent/condensate vessel 20 until such times as it is so heavily contaminated that it must either be disposed of to sewer or directed to a treatment system for re-use.

When the material within the autoclave 2 has been processed, the steam within the autoclave is exhausted into the steam vent/condensate vessel 20. The rate of venting steam to the steam vent/condensate vessel 20 can be automatically controlled by the central controller and thereby balance the cooling rate. The presence of the vented steam in the vessel is detected, for example using a

temperature probe. In response to this, the water is sprayed into the vessel, condensing most of the vented steam. The condensed steam and water are collected in the bottom of the steam vent/condensate vessel 20, and is pumped to the reclaimed cooling water tank 26 via the waste heat recovery system 25 to preheat water from the Raw Water Break Tank 23. The water from the reclaimed cooling water tank 26 may be used as the spray to condense the vented steam in the steam vent/condensate vessel 20.

It will be appreciated from the above description that the system of the present invention provides control of the steam generation apparatus, by monitoring temperatures and pressures within the apparatus, and ensuring these are optimised, for example by the use of waste heat to pre-heat fluid at different parts of the apparatus, to control the amount and rate of fuel and combustion air provided to the burners of the boiler, and to control the rate at which water is provided to the boiler. The control system may also control the rate at which waste is introduced to the autoclave, and the timing of filling and emptying the autoclave and any other variables

The control may be monitored by the central controller. This allows Programmable Logic Control (PLC) and Personal Computer (PC) hardware or software to be provided to calculate fuel usage, water usage and period audits, as well as providing management reports. The computer may be connected, for example via a modem, to allow the information obtained by the controller to be sent to a remote location, for example to allow remote fault and error resolution. The central controller may also be networked to onsite monitoring.

Without limitation, the control system may control one or more of the following.

a) The maintained pressure within the boiler 16.

b) The steam accumulator/storage system 18 pressure.

c) The sequenced supply of steam to the autoclave 2.

d) The rate of pressure/temperature increase within autoclave 2.

e) The time at which the autoclaves 2 are held at the pre-determined pressure.

f) The operation of the condensate evacuation system.

g) The rate of depressurisation.

h) The operation of the condensate receiver/pumping vessel 19.

i) The operation of the steam vent/condensate vessel 20.

j) The operation of the reclaimed cooling water tank 26.

k) All associated pumps.

l) Autoclave 2 operation, i.e. rotational speed, rotational direction, operational angle of the vessel, door control and all sequencing of process cycle events.

m) All safety interlocks and safety sequence stepping.

n) Monitoring, recording and trending of all variables.

o) Batch weighing for safe loading and auditing.

p) The speed of filling the vessel and emptying autoclave 2.

ANY OTHER VARIABLES ON THE INVENTION CAN BE CONTROLLED AND MONITORED.

The contamination level in the boiler water is monitored. If the contamination level is determined to be too great, a suitable blowdown operation, as described previously, is implemented.

All boiler controls may be achieved using the plant controller system. This can include the measurement and blowdown of total dissolved solids, the frequency of the bottom blowdown, status of the Direct Digital Combustion Controls, measurement of the temperature of the flue gases into and out of the economiser, level of water in the boiler feed tank, control of the boiler feed water pump, forced draught fan, gas flow pressure, the flow of fuel and steam to the accumulator.

Alarms may be provided to indicate levels that are outside a predetermined acceptable range and a manual override facility may be provided, however for others the determination of an unacceptable limit may result in the system automatically being shut down.

Figure 3 shows a modified system/method which incorporates assisted steam evacuation from the vessel 2 during the vent cycle. By means of the assistance, the steam is 'pulled out' of the vessel so that the pressure therein can be reduced much more rapidly to a value at which the vessel door can be opened. Conveniently the assistance means include venturi means 35, shown schematically in Figure 3, with air or water flow, creating a negative pressure.

Figure 3 also shows a line 36 for cascading steam from a first of a pair of vessels 2 to a second one thereof when appropriate valves in the line 36 and associated lines between the vessels are correctly operated.

CLAIMS

1. A method for the treatment of waste material comprising providing a totally enclosed and sealed vessel in which the waste material is treated, in use, and a source of steam, charging the vessel with said steam to a temperature in excess of at least 130°C at a pressure in excess of 2 bar gauge, to create a high temperature, high pressure environment, maintaining the waste material in said high temperature, high pressure environment for at least 20 minutes during which time water and any condensate is removed from the vessel, and passing the treated waste material through a separation unit to separate out of the treated waste material particles having a particle size of less than 25 mm.

2. A method as claimed in Claim 1, comprising rotating said vessel.

3. A method as claimed in Claim 1 or Claim 2, wherein the waste material being treated in the vessel, in use, is mixed during said rotation of the vessel by vanes in the interior thereof.

4. A method as claimed in Claim 3, wherein the vanes are helical and their direction of rotation is reversed, in use.

5. A method as claimed in any one of Claims 1 to 4, wherein condensate is continually removed from the vessel.

6. A method as claimed in any one of the preceding Claims, wherein the temperature within the vessel during said treatment of the waste material is between 130°C and 185°C.

7. A method as claimed in any one of the preceding Claims, wherein the pressure in the vessel during said treatment of the waste material is between 2 bar gauge and 10 bar gauge.

8. A method as claimed in any one of the preceding Claims, wherein the waste material is treated in said high temperature, high pressure environment for between 30 and 50 minutes.

9. A method as claimed in any one of the preceding Claims, wherein at the conclusion of the treatment the steam is vented from the vessel and the temperature therein accordingly reduces.

10. A method as claimed in Claim 9, wherein assisted steam evacuation is effected during the vent cycle.

11. A method as claimed in Claim 10, wherein the assisted evacuation is by the use of at least one venturi.

12. A method as claimed in any one of the preceding Claims, wherein after treatment in said vessel, the waste material is conveyed therefrom to said separation unit.

13. A method as claimed in Claim 12, wherein after removal of said particles, the remaining waste material is sorted.

14. A method as claimed in any one of the preceding Claims, wherein the particles separated out are predominantly cellulosic in nature.

15. A method as claimed in Claim 14, wherein the particles are of a shape having a diameter of less than 25 mm.

16. A method as claimed in any one of the preceding Claims, in which the source of steam is a steam accumulator.

17. A method as claimed in Claim 16, wherein the steam accumulator is fed from a boiler.

18. A method as claimed in Claim 17, wherein water is supplied to the boiler via a waste heat recovery system which pre-heats the water prior to its supply to the boiler.

19. A method as claimed in Claim 18, wherein the pre-heated water is fed to a boiler feed tank, thence to a boiler feed pump by a gravity feed, and then via the feed pump at high pressure into the boiler.

20. A method as claimed in Claim 19, wherein the water is pre-heated in the boiler feed tank by steam from the boiler.

21. A method as claimed in Claim 19 or Claim 20, wherein the boiler feed tank is a partial de-aerator.

22. A method as claimed in Claims 19, 20 or 21, wherein water passing from the boiler feed tank to the boiler passes through a heat exchanger through which flue gases from the boiler pass.

23. A method as claimed in any one of Claims 17 to 22, wherein the boiler is connected to a blowdown vessel.

24. A method as claimed in any one of the preceding Claims, wherein one or more variables thereof is controlled and/or monitored by a central controller.

25. A method as claimed in any one of the preceding Claims, comprising providing at least two of said totally enclosed and sealed vessels, and cascading steam between the vessels.

26. Apparatus for carrying out the method of any one of Claims 1 to 25, comprising a rotatable thermal vessel having an inlet for passage of waste material into the interior of the vessel, an outlet for removal of treated waste from the vessel, a steam inlet for the introduction of steam into said vessel interior, a condensate outlet, and vanes in said vessel interior.

27. Apparatus as claimed in Claim 26, wherein the thermal vessel is movable from a horizontal or substantially horizontal position during treatment of the waste material, to a position where its axis is inclined to the horizontal for loading the vessel with waste material prior to treatment.

28. Apparatus as claimed in Claim 26 or Claim 27, wherein said vanes are of helical form and rotatable in opposite directions to move waste material towards opposite ends of the vessel respectively.

29. Apparatus as claimed in any one of Claims 26 to 28, wherein a filter is provided at or near the end of the vessel remote from the vessel inlet to prevent material above a selected size reaching said condensate outlet.

30. Apparatus as claimed in Claim 29, wherein the filter is a mesh screen.

31. Apparatus as claimed in any one of Claims 26 to 30, including a separation unit to separate out of the treated waste material particles having a particle size of less than 25 mm.

32. Apparatus as claimed in Claim 31, including means for conveying treated waste material to the separation unit.

33. Apparatus as claimed in Claim 31 or Claim 32, wherein the separation unit is a screen.

34. Apparatus as claimed in Claim 33, wherein the screen is a rotary trommel screen.

35. Apparatus as claimed in Claim 33 or Claim 34, wherein further separation units are provided downstream of said separation unit for sorting the remainder of the treated waste material.

36. Treated waste material particles producible by the method of any one of Claims 1 to 24, which have thereafter been treated to reduce their moisture content.

37. Particles as claimed in Claim 36, which have been extruded to produce compacted solid sections.

38. Particles as claimed in Claim 37, wherein each section has a length of from 0.5m to 2.0m and a diameter of from 400 mm – 800 mm.

39. Particles as claimed in Claim 36, having a water content reduced to between 8% and 12%.

40. Particles as claimed in Claim 39, having a calorific value from between 3000 to 5000 kcal/kg.

41. A steam generation system comprising a boiler for providing a source of steam and steam storage apparatus fed with steam from said boiler and arranged to supply, in use, a volume of steam in excess of the capacity of the boiler alone for finite periods of time.

42. A system as claimed in Claim 41, wherein the storage apparatus is a steam accumulator arranged to provide steam to an autoclave.

43. A system as claimed in Claim 41 or Claim 42, wherein water is supplied to the boiler via a waste heat recovery system which pre-heats the water prior to its supply to the boiler.

44. A system as claimed in Claim 43, wherein the pre-heated water is fed to a boiler feed tank, from which it passes by gravity feed to a boiler feed pump which supplies it under high pressure to the boiler.

45. A system as claimed in Claim 44, wherein the water is pre-heated in the boiler feed tank by steam from the boiler.

46. A system as claimed in Claim 44 or Claim 45, wherein the boiler feed tank is a partial de-aerator.

47. A system as claimed in any one of Claims 44 to 46, wherein water passing from the boiler feed tank to the boiler passes through a heat exchanger through which flue gases from the boiler pass.

48. A system as claimed in any one of Claims 41 to 47, wherein the boiler is connected to a blowdown vessel.

49. A system as claimed in Claim 41, including a totally enclosed and sealed vessel to which steam is supplied from the steam storage apparatus, condensed steam removed from said totally enclosed and sealed vessel passing to a condensate pumping vessel which supplies the condensate to a heat exchanger.

50. A system as claimed in Claim 49, wherein the condensate is pumped from the condensate pumping vessel to a condensate vessel prior to supply to said heat exchanger.

51. A system as claimed in Claim 49 or Claim 50, wherein the heat exchanger uses waste heat from the condensate to pre-heat water for feeding the boiler.

52. A system as claimed in any one of Claims 41 to 51, wherein one or more variables thereof is controlled and/or monitored by a central controller.

53. A waste material treatment system comprising, in combination, apparatus as claimed in any one of Claims 26 to 35, together with a steam generation system as claimed in Claims 41 to 52.