

**Method for Improving Properties of Combustion Residues
Produced by Combustion Plant, and Method for Treatment of
the Residues**

5 Background of the Invention

Field of the Invention

The present invention relates to a method for
improving the properties of combustion residues produced by
a combustion plant, more particularly a waste-to-energy
10 conversion plant, in which fuel is burned on a combustion
grate and the temperature of the generated combustion
residues is increased under appropriate fuel control.

Also, the present invention relates to a method for
15 treatment of combustion residues produced by a combustion
plant, more particularly a waste incineration unit, in which
fuel is burned on a combustion grate, the generated residues
are quenched in a wet-type discharger and subsequently
transported from the discharger to the outside.

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Further, the present invention relates to a method for
treatment of combustion residues produced by a combustion
plant, more particularly a waste-to-energy conversion plant,
in which fuel is burned on a combustion grate and the
25 temperature of the generated combustion residues is

increased under appropriate fuel control.

In a method of this kind, which is known from EP 0 667 490 B1, fuel is heated on a combustion grate to the extent
5 that the bottom ash generated by combustion has a temperature just below the bottom ash melting point before proceeding to a melting stage outside the combustion grate. This method regulates combustion in such a way that the bottom ash at the end of the grate has as high a temperature
10 as possible in order to keep the amount of energy involved in the downstream melting stage as low as possible. However, no sintering or melting of the bottom ash occurs at this point. In order to nonetheless achieve the required bottom ash quality, a downstream melting stage is therefore
15 required. This downstream melting stage requires not only the relevant equipment but also an increased amount of energy despite the previously mentioned heating operation.

Inorganic and organic pollutant constituents from the
20 wastes are of significance for the required bottom ash quality. In particular, heavy metals and salts are the main inorganic pollutant constituents. Organic pollutants are produced particularly due to incomplete combustion. Essential to the assessment of the bottom ash quality is,
25 further, how much of the pollutants present are leached out

during elution trials. In addition, the mechanical properties of bottom ash are of importance for assessing the suitability for use in construction work, for example, in landfill, earthwork, and road construction.

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Due to the high temperatures involved in the treatment of combustion residues in the melting stage, molten combustion residues are characterized by low percentages of organic compounds. While typical bottom ash types from a waste-to-energy conversion plant contain 1 to 5% by weight of unburned matter, normally measured as loss on ignition, the loss on ignition of molten combustion residues is less than 0.3% by weight. In addition, the molten combustion residues are characterized by low percentages of leachable salts and heavy metals because these have either evaporated or have been integrated in a glass matrix formed when the molten mass cools.

On the other hand, DE 701 606 C has described a technology in which combustion residues are conveyed to a discharger having an inlet section and a discharge tub with an ascending outlet chute and are taken out from there to the outside using a discharging ram. These combustion residues are called bottom ash. Water for quenching the bottom ash is supplied to the discharge tub. Only

sufficient fresh water necessary for counterbalancing the amount of water discharged along with the moistened bottom ash is introduced into the tub. A steady-state concentration for numerous substances and compounds adhering to the residues, for example, salts, establishes itself with the result that their concentrations cannot be reduced. Unsatisfactory bottom ash quality in terms of suitability for landfill and for being recycled to building materials results. The fact that the residues are not separated (classified) into fractions of better and poorer quality is the reason for this disadvantage. Consequently, the entirety of the combustion residues is inevitably of unsatisfactory quality.

Also, DE 4 423 927 has described a technology in which residues coming from a furnace is conveyed directly to a water bath for coarse cleaning without prior quenching. The dry and coarsely cleaned bottom ash is separated into at least two fractions. All particles smaller than 2 mm are allotted to a first fraction and all other particles are allotted to a second fraction. This method goes on to further separate the second fraction into at least two fractions via a screening step. All particles smaller than 27 to 35 mm are allotted to a third fraction. The remaining particles are allotted to a fourth fraction. In this way,

residue fractions with satisfactory quality are produced. Extensive dust evolution and problems with inclusion of air from the furnace are disadvantages of this method.

5 Summary of the Invention

The present invention has been made in view of the above-described various problems with the prior art.

An object of an invention of the first group of the present invention is to provide a method in which a combustion process can be regulated in such a way that fully sintered bottom ash with the required quality can be obtained without using a downstream melting or vitrification unit.

Also, an object of an invention of the second group of the present invention is to provide a method in which good-quality bottom ash fractions can be separated, disadvantages of dust evolution and problems with inclusion of air from a furnace can be avoided, and further water consumption can be reduced.

Further, an object of an invention of the third group of the present invention is to provide a method in which a combustion process can be regulated in such a way that fully

sintered bottom ash with the required quality can be obtained without using a downstream melting or vitrification unit, disadvantages of dust evolution and problems with inclusion of air from a furnace can be avoided using a minimum of equipment, and further water consumption can be reduced.

Brief Description of the Drawings

A method for improving properties of combustion residues produced by a combustion plant, and a method for treatment of the residues in accordance with the present invention will now be described with reference to the embodiments shown in the accompanying drawings.

Figure 1 is a work flow diagram for illustrating an embodiment of a method in accordance with the invention of the first group;

Figure 2 is a work flow diagram for illustrating another embodiment of a method in accordance with the invention of the first group;

Figure 3 is a work flow diagram for illustrating an embodiment of a method in accordance with the invention of the second group;

Figure 4 is a work flow diagram for illustrating another embodiment of a method in accordance with the

invention of the second group;

Figure 5 a work flow diagram for illustrating still another embodiment of a method in accordance with the invention of the second group;

5 Figure 6 is a work flow diagram for illustrating still another embodiment of a method in accordance with the invention of the second group;

Figure 7 is a work flow diagram for illustrating an embodiment of a method in accordance with the invention of
10 the third group;

Figure 8 is a work flow diagram for illustrating another embodiment of a method in accordance with the invention of the third group;

Figure 9 is a work flow diagram for illustrating still
15 another embodiment of a method in accordance with the invention of the third group; and

Figure 10 is a work flow diagram for illustrating still another embodiment of a method in accordance with the invention of the third group.

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Detailed Description of the Preferred Embodiments
A method for improving the properties of combustion residues
produced by a combustion plant in accordance with the
invention of the first group

25 The object of the invention of the first group is

achieved by running a combustion control system in such a way that the combustion residues are sintered and/or melted into bottom ash beforehand on the fuel bed of the main combustion zone, and that the combustion residues that are
5 not yet molten or sintered are discharged at the end of the combustion process and then returned once more to the combustion process.

The idea on which the invention of the first group is
10 based is firstly to implement the combustion process on the grate in such a way that sintering or melting takes place beforehand on the fuel bed of main combustion zone, and secondly to return the combustion residues that are not yet sintered or molten so that the required level of sintering
15 and/or melting can be achieved on the second or third attempt.

In the invention of the first group, the term "fully sintered bottom ash" means a material that consists of
20 sintered and/or molten chunks typically having a grain size of at least 8 mm, for example. These chunks consist of combustion residues from refuse that agglomerates through complete or surface melting.

25 The sintered and/or molten chunks preferably have a

porous structure due to gas release during sintering or melting. The possible porosity of fully sintered bottom ash is to be attributed to the fact that the temperature of the molten ash on the fuel bed is not high enough to bring about
5 adequately low viscosity, and pores remain after gas bubbles are driven out by a process similar to the publicly known bubble removing process in glassmaking. There lies a difference between the fully sintered bottom ash and typical vitrified bottom ash obtained by a downstream high-
10 temperature treatment method using a refractory-lined crucible furnace or other melting units.

Refuse constituents, such as glass or metals, which travel through the grate virtually unaffected by the
15 combustion process are in the stricter sense of the word neither melted nor sintered on the fuel bed. However, the fully sintered bottom ash can contain such glass or metals. These constituents have the requisite characteristics in terms of burnout and leachable pollutants.

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The term "sintering" is described as a "special case of melting and solidification", according to Hämmerli (Müll and Abfall 31, Supplement on Disposal of Bottom Ash and Other Residues, page 142, 1994). In the following,
25 therefore, the term "sintering" used in the sense of

"surface melting or melting together of particles" often extends beyond its common scientific usage. The chunks yielded by sintering of fully sintered bottom ash may be melted completely or partially.

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The bottom ash constituents that are not sintered and/or melted are defined as residual bottom ash. The residual bottom ash is characterized by a small grain size, a high loss on ignition, and a high percentage of leachable
10 pollutants, as compared with the fully sintered bottom ash.

The invention of the first group focuses on sintering and/or melting the combustion residues already while on the fuel bed of main combustion zone, which has not been
15 considered possible up to now. It is, in actuality, extremely detrimental to mechanical combustion grates if liquid bottom ash gets between individual grate bars or other moving parts of the grate. For this reason, melting of the bottom ash on the grate has been avoided and care has
20 been taken so that the melting point of the bottom ash is not reached on the fuel bed.

With the method of the invention of the first group, the sintering and/or melting process occurs in the upper
25 fuel bed. The reason for this is that the greatest heat

impact occurs from above through radiation of flame body and the temperature of material lying directly on the grate can be kept lower from below by adding colder (in relative terms) underfire air than is the case for the top of the
5 fuel bed. Since not all combustion residues can be converted to fully sintered bottom ash of the requisite quality when regulating combustion in this way, the combustion residues that do not yet have the characteristics of fully sintered bottom ash are returned to the combustion
10 process.

No additional external energy source is required to achieve the sintering and/or melting process on the fuel bed. The obtained quality of bottom ash corresponds largely to
15 that obtained by products with which a person skilled in the art is familiar from the well-known downstream thermal high-temperature processes for melting and vitrification. Units such as a rotary kiln, a crucible furnace, and a melting chamber are used. A major disadvantage of these known
20 methods, however, is the need for very complex additional units and high energy consumption they have. The invention of the first group solves this problem, and can produce bottom ash having quality approximately similar to that of the bottom ash obtained by the known method.

According to a significantly advantageous embodiment of the combustion control system in accordance with the method of the invention of the first group, the underfire air is subject to oxygen enrichment according to the quality of wastes to be burned (refuse quality) so that the content of oxygen is about 25 to 40% by volume, preferably 25 to 30% by volume. Also, according to a further advantageous embodiment, the underfire air is preheated to about 100 to 400°C. These measures may be used singly or together depending on the circumstance. The temperature of the fuel bed (typically, refuse layer), which is a function of fuel characteristics, is preferably set at 1000 to 1400°C.

All combustion control measures for achieving desired conditions at which the combustion residues are transformed into sintered and/or molten bottom ash are chosen in such a way that a certain percentage of fully sintered bottom ash (for example, about 25 to 75% by weight of the entire amount of combustion residues) is present. In this way, it is ensured that there is sufficient non-melting material on the fuel bed of the main combustion zone to surround the melting ash, so that this measure does not adversely affect the mechanical grate parts.

In a further advantageous embodiment of the invention,

fly ash is returned to the combustion process. This fly ash leaves the fuel bed together with combustion gas and is introduced to a downstream flue gas filter via the boiler.

5 The incompletely and completely sintered bottom ash can be separated in a screening stage of bottom ash after it has been discharged from the combustion system (through a sieve at a grain size of e.g. 2 to 10 mm). Oversize is the fully sintered bottom ash and undersize is the fraction to
10 be returned. There are various mechanical separating methods for carrying out this separating process that are familiar to a person skilled in the art.

 Separation can occur either by screening or by
15 combining screening and washing steps as described in another advantageous embodiment of the invention.

 There are of course other measures for improving the bottom ash quality that take place outside the combustion
20 plant and are to be seen in particular in a special washing step with and without chemical additives.

 The fine fraction having a grain size smaller than 2 to 10 mm is returned to the combustion process. This can be
25 done by adding the fine fraction to the fuel to be fed or by

feeding it directly to the fuel bed. To avoid dust build-up and to provide ease of handling, the fine fraction is suitably pelletized or briquetted before being returned.

5 A method for treatment of combustion residues produced by a
combustion plant in accordance with the invention of the
second group

The object of the invention of the second group is
10 achieved by technical features described below based on two
different procedures.

A first procedure consists of a step in which wet
combustion residues coming from a wet-type discharger are
15 mechanically separated into two fractions. The main
fraction consists essentially of a coarse fraction and an
oversize fraction. This main fraction is washed with water
drawn from the wet-type discharger, thus separating finer
parts adhering to the combustion residues, and the wash
20 water is brought to the wet-type discharger together with
the finer parts taken up in the washing step.

If the water originating in the wet-type discharger is
recirculated in this manner, a good-quality main fraction is
25 freed, without having to use large quantities of fresh water,

of the fine parts that otherwise adhere to the combustion residues and which experience has shown to have an adverse effect on the quality of main fraction. Consequently, the combustion residues from which the finer parts have been
5 washed away are of good quality and effectively available as bottom ash for recycling such as for building materials.

A second procedure consists of a step in which the wet combustion residues coming from the wet-type discharger are
10 mechanically separated into two fractions. The main fraction consists essentially of a coarse fraction and an oversize fraction. This main fraction is first crushed and then washed with water drawn from the wet-type discharger, thus separating finer parts adhering to the crushed
15 combustion residues, and the wash water is brought to the wet-type discharger together with the finer parts taken up in the washing step.

The second procedure has an advantage of setting free
20 pollutants, which are contained in the main fraction, before washing. In this way, these contained pollutants are removed in the washing step. Another advantage is a bigger surface of the crushed material, which improves the efficiency of washing. This is particularly important due
25 to the porous morphology of the material obtained from the

main fraction. The second procedure is used in the case where a very high quality of combustion residues is requested or the main fraction has many inclusions of pollutants or the porosity of combustion residues is important. The second procedure is also used in the case where the main fraction of bottom ash is further crushed in the subsequent treatment steps. For example, in the case where the main fraction (end product) of bottom ash must be crushed in leaching tests in order to determine its quality, it is favorable to use the second procedure. The crushed and washed main fraction must not be confused with the fine fraction. In most cases, since the main fraction has been melted or sintered, the content of unburned or leachable pollutants is low, so that these properties are not changed by the crushing. Therefore, the main fraction crushed according to the second procedure has very different properties compared with the bottom ash fine fraction which has a high content of the above-mentioned pollutants.

According to one embodiment of the invention of the second group, the finest fraction and fine fraction generated during mechanical separation are conveyed (circulated) to the combustion process. These fractions are subjected to the combustion process once more, thus making it possible for them to melt and sinter.

Through these measures, the disadvantages of the procedure of prior art described first (according to which all the combustion residues are sent for recycling even if small amounts of residues of poorer quality are contained) are avoided. In comparison with the prior art method described second, the disadvantages of dust evolution and sealing the furnace are avoided. Moreover, by returning the finest and fine fractions of poorer quality, the percentage of recoverable combustion residues is further increased, because the returned fine parts are provided with the opportunity to agglomerate to combustion residues with desired quality either the first time they are returned or after repeatedly being returned. The prior art method described second does not have this advantage because there is no return to the combustion process.

According to another embodiment according to the first or second procedure of the invention of the second group, the main fraction prewashed with water from the wet-type discharger is rinsed with fresh water, and the discharger water which carries relatively large amounts of pollutants is washed out, which results in an additional improvement in the quality of the combustion residues and/or sintered bottom ash. Since fresh water is used to rinse the coarse

fraction, this has an advantage that a certain percentage of the water coming from rinsing can be conveyed to the flue gas cleaning system without having to be precleaned because the percentage of pollutants it contains is relatively low.

5 Furthermore, this embodiment offers an advantage that a certain percentage of the water coming from rinsing can be supplied to the wet-type discharger. The level in the discharger can be maintained in this way. Since water is constantly carried out with the discharged combustion
10 residues, the water level in the discharger drops. The water level has to be topped up in any case. Since the water coming from rinsing has negligible amounts of calcium and sulfate, there is no danger of pipes and nozzles becoming clogged.

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According to the second procedure in accordance with the invention of the second group, even if the main fraction contains a high percentage of oversize fraction (normally contains much scrap metal) after the first separation step
20 has been carried out, the oversize coarse fraction is further separated in a mechanical separation step in accordance with still another embodiment of the invention. Metals are separated by a magnetic separator.

25 In an embodiment of the invention of the second group,

as an example, the grain size is specified so as to be smaller than 2 mm for the finest fraction, not smaller than 2mm and smaller than 8 mm for the fine fraction, not smaller than 8 mm and smaller than 32 mm for the coarse fraction, and not smaller than 32mm for the oversize fraction. These values are provided to act as a guideline for better understanding of the invention. Obviously, each fraction contains a certain percentage of finer fraction subordinate to itself as long as this percentage is negligible.

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Usually, the fine fraction with a grain size smaller than about 8 mm, which comes directly from the discharger, should preferably be returned to the combustion process because of its unfavorable properties. In the second procedure, a crushed main fraction having grain sizes comparable to those of the fine fraction is yielded, and the crushed main fraction has much better quality, so that it can be used as a building material.

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For example, in the second procedure, if a cut-off point of 32 mm is observed for the first coarse separation step, i.e. if the oversize fraction is separated, it is recommended that a second mechanical step, for example, with a cut-off point of 8 mm be provided with all parts smaller than 8 mm being returned to the combustion process.

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In order to obtain as large a fraction as possible for recycling, according to still another embodiment of the invention of the second group, it is logical that the coarse
5 fraction separated from the main fraction is mixed with the crushed combustion residues produced by the size reduction step (using a crusher, rock drill, etc.) for the oversize fraction. In this case, it is advisable to subject this
10 first mixed fraction to mechanical separation to remove particles with an unfavorable grain size because grain sizes that are undesirable in terms of further recycling and which are for example to be returned to the combustion process occur during size reduction.

15 If the combustion residues are to be prepared for a particularly interesting area of application in the manufacture of bases for road construction, the material must be compactible. This is virtually impossible to
20 achieve without fine fraction (which has a grain size, for example, not smaller than 2 mm and smaller than 8 mm as described above). For this reason, it is recommended that a part of the coarse fraction be subjected to a size reduction step in order to deliberately ensure the presence of this
25 necessary fine fraction. Thus, it is not left to chance to see that the percentage of this grain size occurring is

sufficient. Advantageously, about 30% by weight of the coarse fraction is subjected to this size reduction step. The resultant fine and finest fractions are mixed with the coarse fraction to form a second mixed fraction. Preferably,
5 70% by weight of the mixed fraction intended for road construction is made up of a coarse fraction.

In this second mixed fraction, the predominant grain size is larger than 8 mm, and experience has shown that
10 these components have the quality necessary for recycling. However, a low percentage with a grain size not smaller than 2 mm and smaller than 8 mm is necessary in order to ensure the above-mentioned compactibility of the residues for road construction.

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According to still another embodiment of the invention of the second group, the second mixed fraction is washed with water from the wet-type discharger and the first mixed fraction is separated. In this case, the parts under 2-mm
20 grain size, which often carry particularly severe pollutant burdens, can be separated surely from the recoverable residues.

This wash water can advantageously be conveyed to the
25 wet-type discharger as has already been explained in another

context. By returning water in this manner, the consumption of fresh water can be made as low as possible.

It is recommended that the separated metals be
5 subjected to a washing step using water from the discharger so that any combustion residues adhering can be washed off. Advantageously, a screening step is used to mechanically separate the fractions.

10 Addition of precipitating agents for soluble heavy metals to the water in the discharger is extremely helpful in increasing the quality of the recovered combustion residues. Consequently, these heavy metals can be separated by the addition of precipitating agents.

15 A method for treatment of combustion residues produced by a combustion plant in accordance with the invention of the third group

The above-described object is achieved by a method of
20 the invention of the third group described below based on two different methods.

The first of these methods consists, according to the invention, of running the combustion control system in such
25 a way that the combustion residues are sintered and/or

melted into bottom ash beforehand on the fuel bed of the main combustion zone, of quenching the entirety of the generated combustion residues in a wet-type discharger and subsequently taking them out of the discharger, of first
5 separating the wet combustion residues coming from the wet-type discharger through a mechanical separation step into two fractions, of subsequently washing the main fraction, essentially consisting of a coarse fraction and an oversize fraction, with water drawn from the wet-type discharger,
10 thus separating finer parts adhering to the combustion residues, and of conveying the wash water together with the finer parts taken up during the washing step to the wet-type discharger.

15 This first method is useful when it can be assumed that the recyclable main fraction contains a negligible percentage of pollutants that can be washed out, for example, salts or heavy metals.

20 The invention of the third group mainly has two technical features. A first technical feature includes a combustion control system, and a second technical feature includes mechanical treatment of the residues generated by the combustion process. Of these, the second technical
25 feature includes two different methods depending on the fuel

composition.

The combustion control included in the first technical feature is common to both of the following two methods in terms of the mechanical treatment of residues, and is based on the combustion process on the grate implemented in such a way that sintering or melting takes place on the grate in the main combustion zone, and on returning the combustion residues that are not yet sintered or molten, so that the required level of sintering and/or melting can be achieved on the second or third attempt.

The term "fully sintered bottom ash" means a material that consists of sintered and/or molten chunks typically having a grain size of at least 8 mm, for example. These chunks consist of combustion residues from refuse that agglomerates through complete or surface melting.

The sintered and/or molten chunks preferably have a porous structure due to gas release during sintering or melting. The possible porosity of fully sintered bottom ash is to be attributed to the fact that the temperature of the molten ash on the fuel bed is not high enough to bring about adequately low viscosity, and pores remain after gas bubbles are driven out by a process similar to the publicly known

bubble removing process in glassmaking. There lies a difference between the fully sintered bottom ash and typical vitrified bottom ash obtained by a downstream high-temperature treatment method using a refractory-lined crucible furnace or other melting units.

Refuse constituents, such as glass or metals, which travel through the grate virtually unaffected by the combustion process are in the stricter sense of the word neither melted nor sintered on the fuel bed. However, the fully sintered bottom ash can contain such glass or metals. These constituents have the requisite characteristics in terms of burnout and leachable pollutants.

The term "sintering" is described as a "special case of melting and solidification", according to literature (before-mentioned Hämmerli). In the following, therefore, the term "sintering" used in the sense of "surface melting or melting together of particles" often extends beyond its common scientific usage. The chunks yielded by sintering of fully sintered bottom ash may be melted completely or partially.

The bottom ash constituents that are not sintered and/or melted are defined as residual bottom ash. The

residual bottom ash is characterized by a small grain size, a high loss on ignition, and a high percentage of leachable pollutants, as compared with the fully sintered bottom ash.

5 This invention focuses on sintering and/or melting the combustion residues already while on the fuel bed of the main combustion zone, which has not been considered possible up to now. It is, in actuality, extremely detrimental to mechanical combustion grates if liquid bottom ash gets
10 between individual grate bars or other moving parts of the grate. For this reason, melting of the bottom ash on the grate has been avoided and care has been taken so that the melting point of the bottom ash is not reached on the fuel bed.

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 With the method of the invention of the third group, the sintering and/or melting process occurs in the upper fuel bed. The reason for this is that the greatest heat impact occurs from above through radiation of flame body and
20 the temperature of material lying directly on the grate can be kept lower from below by adding colder (in relative terms) underfire air than is the case for the top of the fuel bed. Since not all combustion residues can be converted to fully sintered bottom ash of the requisite
25 quality when regulating combustion in this way, the

combustion residues that do not yet have the characteristics of fully sintered bottom ash are returned to the combustion process.

5 No additional external energy source is required to achieve the sintering and/or melting process on the fuel bed. The obtained quality of bottom ash corresponds largely to that obtained by products with which a person skilled in the art is familiar from the well-known downstream thermal high-
10 temperature processes for melting and vitrification. Units such as a rotary kiln, crucible furnace, and melting chamber are used. A major disadvantage of these known methods, however, is the need for very complex additional units and high energy consumption they have. The invention of the
15 third group solves this problem, and can produce bottom ash having quality approximately similar to that of the bottom ash obtained by the known methods.

 In the above-described first method regarding
20 mechanical treatment, if the water originating in the wet-type discharger is recirculated, the good-quality main fraction is freed, without having to use large quantities of fresh water, of the fine parts that otherwise adhere to the combustion residues and which experience has shown to have
25 an adverse effect on the quality of the main fraction.

Consequently, the combustion residues from which the finer parts have been washed away are of good quality and effectively available as bottom ash for recycling.

5 In the second method that is suitable for treatment of combustion residues containing much pollutants that can be washed out, for example, salts or heavy metals, the object is achieved by running the combustion control system in such a way that the combustion residues are sintered and/or
10 melted beforehand into bottom ash on the fuel bed of the main combustion zone, by quenching the entirety of the generated combustion residues in the wet-type discharger and subsequently taking them out of the discharger, by first separating the wet combustion residues coming from the wet-
15 type discharger through a mechanical separation step into two fractions (the separated main fraction, essentially consisting of a coarse fraction and an oversize fraction, is subjected to a size reduction step and is then washed with water drawn from the wet-type discharger), and by conveying
20 the wash water together with the fine parts taken up during the washing step to the wet-type discharger. As a result of crushing the main fraction, the pollutants trapped in the larger particles in the combustion residues can be washed out in the subsequent washing step, and thus separated from
25 the recyclable main fraction. In this way, a high

percentage of the residues can be recovered as reusable bottom ash despite the fact that much pollutants are contained in these residues, without having to expect large-scale washing out of pollutants later on.

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In the above-described second method as well, the combustion control included in the first technical feature of this invention is carried out before mechanical treatment.

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According to a significantly advantageous embodiment of the combustion control system in accordance with the method of this invention, the underfire air is subject to oxygen enrichment according to the quality of wastes to be burned (refuse quality) so that the content of oxygen is

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about 25 to 40% by volume, preferably 25 to 30% by volume.

Also, according to a further advantageous embodiment, the underfire air is preheated to about 100 to 400°C. These measures may be used singly or together depending on the circumstance. The temperature of the fuel bed (typically, refuse layer), which is a function of fuel characteristics, is preferably set at 1000 to 1400°C.

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All combustion control measures for achieving desired conditions at which the combustion residues are transformed into sintered and/or molten bottom ash are chosen in such a

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way that a certain percentage of fully sintered bottom ash (for example, about 25 to 75% by weight of the entire amount of combustion residues) is present. In this way, it is ensured that there is sufficient non-melting material on the fuel bed of main combustion zone to surround the melting ash, so that this measure does not adversely affect the mechanical grate parts.

In a further advantageous embodiment of the invention, fly ash is returned to the combustion process. This fly ash leaves the fuel bed together with combustion gas and is introduced to a downstream flue gas filter via the boiler.

The second feature of the invention of the third group, that is, the mechanical treatment of combustion residues including two methods, is carried out as described below.

According to one embodiment of the invention of the third group, the finest fraction and fine fraction generated during mechanical separation are conveyed to the combustion process. These fractions are subjected to the combustion process once more, thus making it possible for them to melt and sinter.

Through these measures, the disadvantages of the

procedure of prior art described first (according to which all the combustion residues are sent for recycling even if small amounts of residues of poorer quality are contained) are avoided. In comparison with the prior art method

5 described second, the disadvantages of dust evolution and sealing the furnace (inclusion of air) are avoided.

Moreover, by returning the finest and fine fractions of poorer quality, the percentage of recoverable combustion residues is further increased, since the returned fine parts

10 are provided with the opportunity to agglomerate to combustion residues with desired quality either the first time they are returned or after repeatedly being returned.

The prior art method described second does not have this advantage because there is no return to the combustion

15 process.

According to another embodiment of the invention of the third group, the main fraction prewashed with water from the wet-type discharger is rinsed with fresh water, and the

20 discharger water which carries relatively large amounts of pollutants is washed out, which results in an additional

improvement in the quality of the combustion residues and/or sintered bottom ash. Since fresh water is used to rinse the coarse fraction, this has an advantage that at least a

25 certain percentage of the water coming from rinsing can be

conveyed to the flue gas cleaning system without having to be precleaned because the percentage of pollutants it contains is relatively low. Furthermore, this embodiment offers an advantage that at least a certain percentage of the water coming from rinsing can be supplied to the wet-type discharger. The level in the discharger can be maintained in this way. Since water is constantly carried out with the discharged combustion residues, the water level in the discharger drops. The water level has to be topped up in any case. Since the water coming from rinsing has negligible amounts of calcium and sulfate, there is no danger of pipes and nozzles becoming clogged.

In the second method of mechanical treatment according to this invention, even if the main fraction contains a high percentage of oversize fraction (normally contains much scrap metal) after the first separation step has been carried out, the coarse fraction is further separated in a mechanical separation step in accordance with still another embodiment of the invention. Metals are separated by a magnetic separator.

In an embodiment of the invention of the third group, for example, the grain size is specified so as to be smaller than 2 mm for the finest fraction, not smaller than 2mm and

smaller than 8 mm for the fine fraction, not smaller than 8 mm and smaller than 32 mm for the coarse fraction, and not smaller than 32mm for the oversize fraction. These values are provided to act as a guideline for better understanding of the invention. Obviously, each fraction contains a certain percentage of finer fraction subordinate to itself as long as this percentage is negligible. The fine fraction coming directly from the discharger and with a grain size not smaller than 2mm and smaller than 8 mm is the part of the combustion residues that is preferably returned to the combustion process. On the other hand, the grain size of fine part included in the grain size distribution of bottom ash obtained as a result of the crushing procedure according to the second method corresponds to the grain size of the fine fraction supplied directly from the discharger, and this fine part has favorable quality suitable for recycling. Therefore, the fine part of crushed bottom ash is referred to as a high-quality fine fraction.

For example, in the second method, if a cut-off point of 32 mm is observed for the first coarse separation step, i.e. if the oversize fraction is separated, it is recommended that a second mechanical step, for example, with a cut-off point of 8 mm be provided with all parts smaller than 8 mm being returned to the combustion process.

It is recommended that metal be separated from the main fraction to prevent mechanical separating devices from being damaged by large pieces of scrap metal.

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Not only large pieces of scrap metal but also other metal parts are freed from the main fraction containing an undersize fraction, that is, a coarse fraction smaller than 32 mm. Such metal parts can be used for a separate recycling process.

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Depending on the procedure and type of recycling intended for use of the generated combustion residues, it may be expedient to remove metal separately from the oversize fraction and the coarse fraction.

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If the combustion residues are to be used in road construction, for example, it is recommended that the oversize fraction be subjected to a further size reduction step after metal parts larger than 32 mm, which are less suited for this purpose, have been removed.

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In the second method, in order to obtain as large a fraction as possible for recycling, according to still another embodiment of the invention of the third group, it

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is logical that the coarse fraction separated from the main fraction is mixed with the crushed combustion residues produced by the size reduction step for the oversize fraction to form a first mixed fraction. In this case, it
5 is advisable to subject this first mixed fraction to mechanical separation to remove particles with an unfavorable grain size because grain sizes that are undesirable in terms of further recycling and which are for example to be returned to the combustion process occur
10 during size reduction.

If the combustion residues are to be prepared for a particularly interesting area of application in road construction, the material must be compactible. This is
15 virtually impossible to achieve without fine fraction (which has a grain size, for example, not smaller than 2 mm and smaller than 8 mm as described above). For this reason, it is recommended that part of the coarse fraction be subjected to a size reduction step in order to deliberately ensure the
20 presence of this necessary fine fraction. Thus, it is not left to chance to see that the percentage of this grain size occurring is sufficient. Advantageously, about 30% by weight of the coarse fraction is subjected to this size reduction step. The resultant fine and finest fractions are
25 mixed with the coarse fraction to form a second mixed

fraction. Preferably, 70% by weight of the mixed fraction intended for road construction is made up of coarse fraction.

In this second mixed fraction, the predominant grain size is larger than 8 mm, and experience has shown that these components have the quality necessary for recycling. However, a low percentage with a grain size not smaller than 2 mm and smaller than 8 mm is necessary in order to ensure the above-mentioned compactibility of the residues for road construction.

According to still another embodiment of the invention of the third group, the second mixed fraction is washed with water from the wet-type discharger and the first mixed fraction is separated. In this case, the parts under 2 mm grain size, which often carry particularly severe pollutant burdens, can be separated surely from the recoverable residues.

This wash water can advantageously be conveyed to the wet-type discharger as has already been explained in another context. By returning water in this manner, the consumption of fresh water can be made as low as possible.

It is recommended that the separated metals be

subjected to a washing step using water from the discharger so that any combustion residues adhering can be washed off. Advantageously, a screening step is used to mechanically separate the fractions.

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Addition of precipitating agents for soluble heavy metals to the water in the discharger is extremely helpful in increasing the quality of the recovered combustion residues. Consequently, these heavy metals can be separated
10 by the addition of precipitating agents.

Embodiments of the present invention in accordance with the first to third group will now be further described with reference to the accompanying drawings. The specific
15 values (quantities) used hereunder, such as weight and percentage, are typical ones for explaining the embodiments, and the present invention should not be construed with these values (quantities) being limited.

20 Figures 1 and 2 are two work flow diagrams typically showing methods in accordance with the invention of the first group. The invention of the first group will be described in more detail with reference to these figures.

25 In the methods shown in Figures 1 and 2, 1000 kg of

wastes with an ash content of 220 kg (Block 100 in the figures) are fed to a mass-burn system and burned in such a way that 25 to 75% by weight of combustion residues occurring are transformed into fully sintered bottom ash (Block 102). A total of 300 kg of combustion residues are obtained. These residues fall into a wet-type discharger (Block 104) where they are quenched and then discharged (Block 106). Through a separating process, which includes screening and possibly a washing step (Block 108), 200 kg of fully sintered bottom ash is separated (Block 110) and taken for recycling (Block 112). 100 kg of combustion residues that are not yet sintered (Block 114) are returned to the combustion process. The fly ash leaving together with flue gases has a weight of 20 kg and is recovered in a flue gas filter (Block 116) and by the cleaning of boiler tubes (Block 118). The recovered fly ash is conveyed to a separate disposal path (Block 120).

In the method shown in Figure 2, 310 kg of combustion residues fall into the wet-type discharger, and also 10 kg of fly ash is returned to the combustion process. Otherwise the method shown in Figure 2 is the same as that shown in Figure 1. Therefore, the same reference numerals are applied to the same blocks as those in Figure 1.

Next, embodiments of methods in accordance with the invention of the second group will be described with reference to work flow diagrams of Figures 3 to 6.

5 As shown in Figure 3, 1000 kg of wastes with an ash content of 220 kg (Block 300) are supplied to a grate-based system (Block 302) and then burned. This combustion process produces 800 kg of flue gas (Block 301) and 300 kg of combustion residues. These residues are forwarded to a wet-
10 type discharger (Block 304), from which, on account of wetting, 315 kg of combustion residues or bottom ash (Block 306) is taken out. The taken-out residues are subjected to mechanical separation, in this case, screening to a grain size of 8 mm (Block 308). This process separates 215 kg of
15 combustion residues or bottom ash into a main fraction with a grain size larger than 8 mm (Block 310) and about 100 kg of a fine fraction and finest fraction with a grain size smaller than 8 mm (Block 312). The bottom ash with a grain size larger than 8 mm consisting of a coarse fraction and an
20 oversize fraction is subjected to wetting treatment (Block 314). In this process, 1000 liters of water, which is taken out of the wet-type discharger, is applied to wash the bottom ash, thus sluicing out 15 kg of fine constituents with a grain size smaller than 8mm. Actually, the bottom
25 ash is washed on a sieve that allows fraction of 8mm or

smaller to pass through. The water having been used for washing the bottom ash is returned to the wet-type discharger together with the fine fraction and finest fraction. The washed bottom ash is taken out ready to be
5 used in a recycling process such as road construction, for example (Block 316). Also, about 100 kg of fine fraction removed by screening is normally returned to the grate-based system for the purpose of further sintering. However, the fine fraction may also be used for other processes (Block
10 318). 40 liters of make-up water or fresh water is added to make up for a loss of water in the wet-type discharger because the combustion residues naturally carry water with them when they are taken out of the wet-type discharger.

15 The above-described process may be modified as shown in Figure 4. In this modified embodiment, the wetting treatment of the main fraction having a grain size larger than 8 mm is followed by rinsing with fresh water. Specifically, in order to remove entrained constituents that
20 result from the wetting treatment using water from the wet-type discharger, 80 liters of fresh water (Block 320) is added to 200 kg of main fraction (Block 322). 40 liters of this rinsing water is trapped off for flue gas scrubbing or other disposal treatment, and another 40 kg thereof is
25 returned to the wet-type discharger as make-up water for

compensating for a water loss. The bottom ash washed in this way can be introduced into other recycling processes.

Figure 5 shows another embodiment of the process in accordance with the invention of the second group. In this modified embodiment, 1000 kg of wastes with an ash content of 220 kg (Block 500) are forwarded to the grate-based system (Block 502). This combustion process produces 800 kg of flue gas (Block 504) and 320 kg of combustion residues. The combustion residues are forwarded to the wet-type discharger (Block 506). 336 kg of combustion residues are taken out of the wet-type discharger. This increase in weight is due to fine particles from the bottom ash, that is, fine particles contained in the bottom ash washing water returned to the wet-type discharger. 40 liters of water is added to the wet-type discharger in order to make up a water loss. 336 kg of bottom ash or combustion residues are forwarded to a strainer that allows fraction with a grain size of 32 mm to pass through (Block 508). An oversize fraction with a grain size larger than 32 mm is initially conveyed to a metal separator (Block 510). The bottom ash from which metal is separated is conveyed to a crusher that produces bottom ash having a grain size of about 8 mm (Block 512). The crushed bottom ash is conveyed to another strainer that allows fraction with a grain size of 8 mm to

pass through (Block 514). 100 kg of bottom ash or combustion residues with a grain size smaller than 8 mm are removed by this mechanical separation process and, preferably, are returned to the grate-based system. The bottom ash is subjected to disposal or further treatment (Block 515). The remaining coarser residues are conveyed to a metal separator (Block 516). The metal constituents removed by the metal separator and the metal constituents separated by the above-described metal separation step are collected and subjected to wetting treatment. By this wetting treatment, particles of bottom ash adhering to the metal constituents are washed off (Block 518). As a result, 20 kg of iron and non-ferrous metals used for recycling process (Block 520) are obtained. The bottom ash or coarse fraction (grain size: 8 to 32 mm) from which metals have been removed (Block 522) weighs 215 kg. 60 kg of the coarse fraction is forwarded to a crusher (Block 524) and reduced to a grain size larger than 2 mm. After crushing, the crushed fraction is mixed with 155 kg of uncrushed coarse fraction, and the mixture is subjected to wetting treatment using a strainer that allows fraction with a grain size of 2 mm to pass through (Block 526). 1000 liters of wash water required for the wetting treatment is supplied from the wet-type discharger. This wetting treatment yields 155 kg of bottom ash with a grain size from 8 to 32 mm and 45 kg of

fine fraction with a grain size from 2 to 8 mm. These two kinds of fractions are used for a recycling process, that is, for building materials or road sub-base layers (Block 528). On the other hand, fine fractions having a grain size smaller than 2 mm, which are removed by the wetting treatment, are returned to the wet-type discharger.

The work flow diagram of Figure 6 shows a basic modification of the embodiment shown in Figure 3, in which a precipitating agent for soluble heavy metals is used. This precipitating agent is injected into the wet-type discharger in order to reduce the concentration of lead in the water in the discharger from the usual level of 2 mg/L to 0.05 mg/L (Block 326). This precipitating agent reduces the lead, which is dissolved in about 20 liters of bottom-ash water wetting 200 kg of bottom ash, to 1 mg. 400 g of lead is entrained in the flue gas produced by combustion treatment (Block 302). In the mechanical separation process using a sieve that allows fraction with a grain size of 8 mm to pass through (Block 308), of 400 g of lead, 200 g of lead remains in 200 kg of bottom ash (Block 310) sent to the recycling process after washing. On the other hand, 200 g of lead is returned to the grate-based system (Block 302) together with fine fraction having a grain size smaller than 8 mm (Block 312).

Further, embodiments of the methods in accordance with the invention of the third group will be described in further detail with reference to Figures 7 to 10.

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As shown in Figure 7, 1000 kg of wastes with an ash content of 220 kg (Block 700) are fed to a grate-based system (Block 702) and burned in such a way that 25 to 75% by weight of the combustion residues generated are transformed into fully sintered bottom ash. The combustion results in 800 kg of flue gas (Block 704) and 300 kg of combustion residues. The residues are forwarded to a wet-type discharger (Block 706), from which, on account of wetting, 315 kg of combustion residues or bottom ash is taken out (Block 708). The taken-out residues are subjected to mechanical separation, in this case, screening to a grain size of 8 mm (Block 710). This process separates 215 kg of combustion residues or bottom ash into a main fraction with a grain size larger than 8 mm (Block 712) and about 100 kg of a fine fraction and finest fraction with a grain size smaller than 8 mm (Block 714). The bottom ash with a grain size larger than 8 mm consisting of a coarse fraction and an oversize fraction is subjected to wetting treatment (Block 716). In this process, 1000 liters of water, which is taken out of the wet-type discharger, is applied to wash the

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bottom ash, thus sluicing out 15 kg of fine constituents with a grain size smaller than 8mm. Actually, the bottom ash is washed by a strainer that allows fraction of 8mm or smaller to pass through. The water having been used for washing the bottom ash is returned to the wet-type discharger together with the fine fraction and finest fraction. The washed bottom ash is taken out ready to be used in a recycling process such as road construction, for example (Block 718). About 100 kg of fine fraction removed by screening is normally returned to the grate-based system for the purpose of further sintering. However, the fine fraction may also be used for other processes (Block 720). 40 liters of make-up water or fresh water is added to make up for a loss of water in the wet-type discharger because the combustion residues naturally carry water with them when they are taken out of the wet-type discharger.

The above-described process may be modified as shown in Figure 8. In this modified embodiment, the wetting treatment of the main fraction having a grain size larger than 8 mm is followed by rinsing (Block 724) with fresh water (Block 722). Specifically, in order to remove entrained constituents that result from the wetting treatment using water from the wet-type discharger, 80 liters of fresh water is added to 200 kg of main fraction.

40 liters of this rinsing water is trapped off for flue gas scrubbing (Block 726) or other disposal treatment, and another 40 kg thereof is returned to the wet-type discharger as make-up water for compensating for a water loss. The
5 bottom ash washed in this way can be introduced into other recycling processes.

Figure 9 shows another embodiment of the process in accordance with the invention of the third group. In this
10 embodiment, 1000 kg of wastes with an ash content of 220 kg (Block 900) are forwarded to the grate-based system (Block 902). This combustion process produces 800 kg of flue gas (Block 904) and 320 kg of combustion residues. The combustion residues are forwarded to the wet-type discharger
15 (Block 906). 336 kg of combustion residues are taken out of the wet-type discharger. This increase in weight is due to fine particles that are contained in the bottom ash washing water returned to the wet-type discharger. 40 liters of water is added to the wet-type discharger in order to make
20 up a water loss. 336 kg of bottom ash or combustion residues are forwarded to a strainer that allows fraction with a grain size of 32 mm to pass through (Block 908). An oversize fraction with a grain size larger than 32 mm is initially conveyed to a metal separator (Block 910). The
25 bottom ash from which metal is separated is conveyed to a

crusher that produces bottom ash having a grain size of about 8 mm (Block 912). The crushed bottom ash is conveyed to another strainer that allows fraction with a grain size of 8 mm to pass through (Block 914). 100 kg of bottom ash or combustion residues with a grain size smaller than 8 mm are removed by this mechanical separation process and, preferably, are returned to the grate-based system. The bottom ash is subjected to disposal or further treatment (Block 915). The remaining coarser residues are conveyed to a metal separator (Block 916). The metal constituents removed by the metal separator and the metal constituents separated by the above-described metal separation step are collected and subjected to wetting treatment (Block 918). By this wetting treatment, particles of bottom ash adhering to the metal constituents are washed off. As a result, 20 kg of iron and non-ferrous metals used for recycling process are obtained (Block 920). The bottom ash or coarse fraction (grain size: 8 to 32 mm) from which metals have been removed (Block 922) weighs 215 kg. 60 kg of the coarse fraction is forwarded to a crusher (Block 924) and reduced to a grain size larger than 2 mm. After crushing, the crushed fraction is mixed with 155 kg of uncrushed coarse fraction, and the mixture is subjected to wetting treatment using a strainer that allows fraction with a grain size of 2 mm to pass through (Block 926). 1000 liters of wash water required for

the wetting treatment is supplied from the wet-type discharger. This wetting treatment yields 155 kg of bottom ash with a grain size from 8 to 32 mm and 45 kg of fine fraction with a grain size from 2 to 8 mm. These two kinds of fractions are used for a recycling process (Block 928). On the other hand, fine fractions having a grain size smaller than 2 mm, which are removed by the wetting treatment, are returned to the wet-type discharger.

10 The work flow diagram of Figure 10 shows a basic modification of the embodiment shown in Figure 7, in which a precipitating agent for soluble heavy metals is used. This precipitating agent is injected into the wet-type discharger in order to reduce the concentration of lead in the water in 15 the discharger from the usual level of 2 mg/L to 0.05 mg/L (Block 728). This precipitating agent reduces the lead, which is dissolved in about 20 liters of bottom-ash water wetting 200 kg of bottom ash, to 1 mg. 400 g of lead is entrained in the flue gas (Block 702) produced by combustion 20 treatment (Block 702). In the mechanical separation process using a sieve that allows fraction with a grain size of 8 mm to pass through (Block 710), of 400 g of lead, 200 g of lead remains in 200 kg of bottom ash (Block 712) sent to the recycling process after washing. On the other hand, 200 g 25 of lead is returned to the grate-based system (Block 706)

together with fine fraction having a grain size smaller than 8 mm (Block 714).

As has been described in the above, according to the invention of the first group of the present invention, there is provided a method in which fully sintered bottom ash with the required quality can be obtained without using a downstream melting or vitrification unit.

Also, according to the invention of the second group, of the present invention, there is provided a method in which good-quality bottom ash fractions can be separated, disadvantages of dust evolution and problems with inclusion of air from a furnace can be avoided, and further water consumption can be reduced.

Further, according to the invention of the third group of the present invention, there is provided a method in which a combustion process can be regulated in such a way that fully sintered bottom ash with the required quality can be obtained without using a downstream melting or vitrification unit, disadvantages of dust evolution and problems with inclusion of air from a furnace can be avoided using a minimum of equipment, and further water consumption can be reduced.

Although the present invention has been described with reference to the embodiments, it is not limited to them. All modifications, changes, and additions that are
5 easily made by a person skilled in the art are embraced in the technical scope of the present invention.

Claims

1. A method for improving properties of combustion
residues produced by a combustion plant in which fuel is
5 burned on a combustion grate and the temperature of the
generated combustion residues is increased under appropriate
combustion control, characterized in that

a combustion control system is run in such a way that
the combustion residues are sintered and/or melted into

10 bottom ash beforehand on the fuel bed of the main combustion
zone, and residues that are not molten or sintered are
discharged to the outside at the end of the combustion
process and then returned once more to the combustion
process.