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(54) Title: A METHOD FOR TREATMENT OF MINED MATERIAL WITH ELECTROMAGNETIC RADIATION

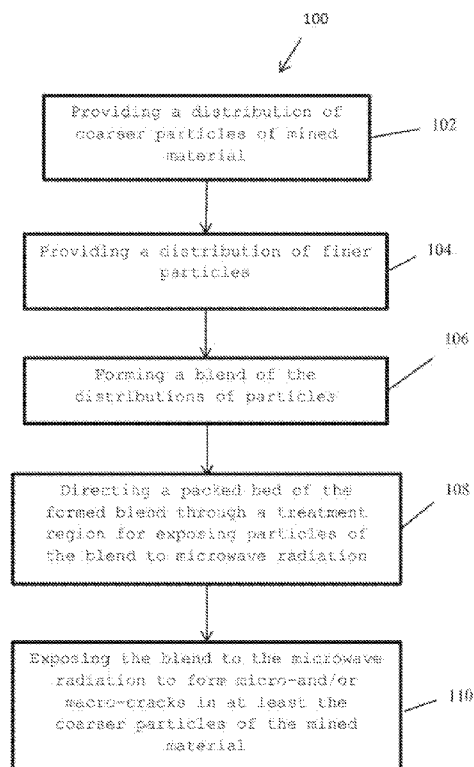


Fig. 1

(57) Abstract: The present disclosure provides a method of treating particles of mined material with electromagnetic radiation. The method comprises forming a blend of a distribution of coarser particles of the mined material and a distribution of finer particles of the mined material. The method further comprises directing the formed blend through a conduit comprising a treatment region for exposing particles of the blend to the electromagnetic radiation. The method also comprises exposing particles of the blend to the electromagnetic radiation. The finer particles at least partially occupy otherwise void spaces between the coarser particles when the formed blend is directed through the conduit.



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A METHOD FOR TREATMENT OF MINED MATERIAL WITH
ELECTROMAGNETIC RADIATION

5 Field of the Invention

The present invention relates to a method for treatment of mined material with electromagnetic radiation, and relates particularly, although not exclusively, to a method for treatment of mined materials with microwave radiation.

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The term "mined" material is understood herein to include metalliferous material and non-metalliferous material. The term "mined" material is also understood herein to include (a) run-of-mine material and (b) run-of-mine material that has been subjected to at least primary crushing or similar diameter reduction after the material has been mined and prior to being sorted. Further, the term "mined" material includes mined material that is in stockpiles.

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20 Background of the Invention

It has recently been proposed to treat mined material with high intensity microwave radiation to cause formation of cracks in fragments of the mined material. The fragments may include gangue and valuable material (such as copper or iron containing minerals) and the exposure of the fragments to high intensity electric fields related to the high power microwave radiation causes preferential heating and resultant thermal expansion of some of the components of the fragments, which results in formation of micro-cracks and macro-cracks. Such cracks reduce energy required to break the fragments apart and improve access for leach solutions.

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Further, it has recently been proposed to use microwave heat treatments for sorting purposes.

However, electrical discharge develops in air voids between the fragments of the mined material. Such

5 electrical discharge can lead to high temperature plasmas that can also damage equipment. Further, the electrical discharge can result in a significant reduction in power available for treatment of the mined material as the discharge can be a highly efficient microwave heater.

10

Summary of the Invention

In accordance with a first aspect of the present invention, there is provided a method of treating particles of mined material with electromagnetic

15 radiation, the method comprising the steps of:

forming a blend of a distribution of courser particles of the mined material and a distribution of finer particles of the mined material;

20 directing the formed blend through a conduit comprising a treatment region for exposing particles of the blend to the electromagnetic radiation, and

exposing the coarser and finer particles of the blend to the electromagnetic radiation;

25 wherein the finer particles at least partially occupy otherwise void spaces between the coarser particles when the formed blend is directed through the conduit.

The step of directing the formed blend through the conduit may comprise directing a packed bed of the formed blend
30 through the conduit, whereby the packed bed of the formed blend has a bulk density that is greater than a bulk density that a packed bed of only the coarser particles would have.

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The step of forming the blend of the distribution of particles may be performed such that a bulk density of the formed blend is greater than 20%, 30%, 40%, 50%, 60%, 70%,
5 80%, 90%, or even 95% of a solid density of the coarser particles.

The step of forming the blend of the distribution of particles may comprise the steps of:

- 10 providing a distribution of coarser particles of the mined material;
- providing a distribution of finer particles of the mined material; and
- blending the distribution of coarser particles and
15 the distribution of finer particles.

The step of forming the blend of the distribution of particles may also comprise the steps of:

- providing particles of the mined material;
- 20 reducing a size of some of the particles of the mined material so as to provide the blend of the distributions of the coarser and finer particles.

After reducing the size of at least some particles of the
25 mined material, the particles of the mined material may be sorted, for example using a screening system, so as to remove particles below a predefined size or within a predefined range of sizes.

30 The step of reducing the size of at least some particles of the mined material may comprise selecting a particular type of particle size reducing apparatus, such as a

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crusher, so as to obtain the size distribution of the particles.

The step of exposing the coarser and finer particles of the blend to the electromagnetic radiation may be conducted such that an energy absorbed by at least some of the coarser particles is sufficient to cause structural alterations of these coarser particles.

The term "structural alterations" is understood herein to mean any type of structural alterations, such as formation of micro-cracks, macro-cracks and/or fragmentation.

Alternatively, the step of exposing the coarser and finer particles of the blend to the electromagnetic radiation may be conducted such that an energy absorbed by at least some of the coarser particles is sufficient to heat at least a portion of these coarser particles without causing structural alterations. In this case the method may further comprise the subsequent step of sorting the particles based on a temperature of the particles.

The step of providing the distribution of coarser particles may comprise providing coarser particles having a first P80 (80% passing) diameter or diameter range and the step of providing the distribution of finer particles may comprise providing finer particles having a second P80 diameter that is smaller than that of the coarser particles.

The blend may comprise at least a bi-modal distribution of diameters of the coarser and finer particles.

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The P80 diameter of the finer particles may be selected such that a percentage of volume of the packed bed within the treatment region of the conduit that is not occupied with particles is less than 70%, 60%, 50%, 45%, 40%, 35%,
5 30%, 25%, 20%, 15%, 10%, or even less than 5%.

Embodiments of the present invention have significant advantages. It is often impractical or uneconomical to reduce the diameter of the particles of the mined material
10 below a minimum diameter. By blending the coarser particles of the mined material with the smaller finer particles, bulk densities of a packed bed can be achieved that can otherwise only be achieved with smaller particles of the mined material. A volume of void regions between
15 the coarser particles of the mined material can be reduced and likelihood of electrical discharges between the coarser particles can consequently also be reduced, which increases the treatment efficiency. Further, filling voids between the coarser particles at least partially with the
20 finer particles increases the flow performance (and consequently the throughput) of the particles through a chute and for some applications the use of the blend also simplifies sorting prior to treatment.

25 The finer particles may also be particles of the mined material. Alternatively, the finer particles may be of any other suitable material type.

The finer particles may have a P80 diameter that is less
30 than 20, 15, 10, 5, 2 or 1mm.

The coarser particles may have any suitable diameter and in one example have a P80 diameter or diameter range that

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is at least 10, 15, 20 30 50mm, 75 or even 100mm larger than that of the finer particles.

In one embodiment the finer particles comprise a single
5 type of material. Alternatively, the finer particles may comprise a blend of different types of material.

The method may also comprise providing third particles that have a P80 diameter that is smaller than that of the
10 coarser particles and different to that of the finer particles. The method may comprise forming a blend of the coarser, finer and third particles.

The electromagnetic radiation typically is microwave
15 radiation. The microwave radiation may have any suitable microwave frequency, such as a frequency in the range of 300 MHz - 300 GHz, 500 MHz - 30 GHz or 600 MHz - 3 GHz, for example 2450 MHz or 915 MHz. Alternatively, the electromagnetic radiation may be radio frequency
20 radiation. The radio frequency radiation may have any suitable radio frequency, such as a frequency in the range of 1MHz - 10GHz.

The method may be conducted such that a power-density in
25 the heated phase of an electromagnetic radiation absorbing phase of at least some of the coarser particles of the mined material is of the order of 1×10^7 W/m³ to 1×10^{13} W/m³, such as at least 1×10^9 W/cm³, 1×10^{10} W/cm³, typically at least 1×10^{11} W/cm³.

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The method may comprise feeding the blend of the coarser and finer particles into a conduit and passing the blend through the treatment region by virtue of gravity.

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The method may be conducted such that a throughput of the mined material is at least 50, 100, 250, 500, 1000, 2000, 3000, 4000 or 5000 tonnes per hour.

5

The method may also comprise subsequent processing of the treated fragments, such as by milling and leaching.

In accordance with a second aspect of the present invention, there is provided an apparatus for treatment of mined material, the apparatus comprising:

a blending portion for forming a blend of a distribution of coarser and a distribution of finer particles of the mined material;

15 a source for generating electromagnetic radiation; and

a conduit for throughput of the blend of the distributions of the coarser and finer particles of the mined material and comprising a treatment region for exposing the blend to the electromagnetic radiation generated by the source.

The blending portion may be arranged so as to form the blend of the distribution of particles such that a bulk density of the formed blend is greater than 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, or even 95% of a solid density of the coarser particles.

The blending portion may be of any suitable type. For example, the blending portion may comprise a first chute portion for receiving the distribution of the coarser particles of the mined material and a second chute portion

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for receiving the distribution of the finer particles of the mined materials.

The blending portion may comprise a particle size reducing apparatus, such as a crusher, arranged to:

receive particles of the mined material; and

reduce a size of at least some particles of the mined material to form the blend of the distribution of coarser and finer particles.

Alternatively, the blending portion may comprise a particle size reducing apparatus, such as a crusher, arranged to:

receive a distribution of coarser particles of the mined material; and

reduce a size of at least some particles of the distribution of coarser particles of the mined material so as to provide the distribution of finer particles.

The blending portion may further comprise a sorting system, such as a screening system, arranged to remove particles below a predefined size or within a predefined size range after a size of at least some particles of the mined material has been reduced.

The source typically is arranged to generate microwave radiation. The microwave radiation may have any suitable microwave frequency. The frequency may be in the range of 300 MHz - 300 GHz, 500 MHz - 30 GHz or 600 MHz - 3 GHz, for example 2450 MHz or 915 MHz. An associated power-density in the heated phase of an electromagnetic radiation absorbing phase of at least some of the coarser particles may be of the order of 1×10^7 W/m³ to 1×10^{13}

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W/m³, such as at least 1×10^9 W/cm³, 1×10^{10} W/cm³, typically at least 1×10^{11} W/cm³.

Alternatively, the electromagnetic radiation may be radio
5 frequency radiation. The radio frequency radiation may have any suitable radio frequency, such as a frequency in the range of 1MHz - 10GHz.

The apparatus may further comprise a separator arranged
10 for separating the coarser particles from the finer particles after treatment of the blend using the electromagnetic radiation.

The apparatus may be arranged such that the mined material
15 passes through the conduit and the treatment region by gravity.

The apparatus may be arranged for a throughput of at least
20 100, 250, 500 or 1000 tonnes per hour.

The invention will be more fully understood from the following description of specific embodiments of the invention. The description is provided with reference to the accompanying drawings.

25

Brief Description of the Drawings

Figure 1 is a flow chart illustrating method steps of a method of treating a mined material in accordance with a specific embodiment of the present invention;

30

Figures 2 and 3 show photographic images of a packed bed of particles of the mined material within a conduit;

- 10 -

Figure 4 is a diagram illustrating a calculated air void volume as a function of a packing density in accordance with an embodiment of the present invention;

- 5 Figure 5 is a schematic representation of an apparatus for treatment of mined material in accordance with a specific embodiment of the present invention;

Figure 6 is a flow chart illustrating method steps of a
10 method of treating a mined material in accordance with a further embodiment of the present invention; and

Figure 7 is a schematic representation of an apparatus for treatment of mined material in accordance with a specific
15 embodiment of the present invention.

Detailed Description of Specific Embodiments

One embodiment of the present invention relates to a method of treating fragments of mined materials with
20 electromagnetic radiation, such as high intensity microwave radiation. The fragments of the mined material include gangue and valuable material and the exposure of the fragments to high power-density electric fields related to the high intensity microwave radiation causes
25 preferential heating and resultant thermal expansion of some of the components of the fragments, which results in formation of micro-cracks and macro-cracks.

Another embodiment of the present invention relates to a
30 method of treating fragments of mined materials with electromagnetic radiation to heat portions of fragments that include the valuable material and then sort the

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fragments based on a temperature difference between the heated fragments and remaining fragments.

Referring initially to Figure 1, a method 100 of treating mined material is now illustrated. The method 100 may be performed using an apparatus 400 that is illustrated in Figure 4 and will be described further below.

Steps 102 and 104 of the method 100 provides distributions of coarser and finer particles. The coarser particles are of the mined material and comprise gangue and valuable material, i.e. an ore, such as a copper, nickel or iron containing ore or another suitable ore. The finer particles have a P80 diameter that is smaller than that of the coarser particles. In this example the finer particles are also of the mined material. However, in a variation of the described embodiment the finer particles are not particles of the mined materials and may be of another suitable type of material. In this case the finer particles usually have dielectric properties that are similar to those of mined material. For example, the finer materials may be silica sand, granite or limestone. The dielectric constant of the finer particles may range from 2 to 5 with the loss factor being in the range of 0.0001 to 0.1, such as significantly less than 0.1, 0.01 or 0.001

The coarser particles may have any suitable diameter, such as a P80 diameter in the range of 20 - 70mm. In one example the finer particles have a P80 diameter that is at least 10 to 40mm smaller than that of the coarser particles.

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Step 106 blends the distributions of the coarser and finer particles and the resulting blend has a bimodal distribution of particles diameters.

- 5 Step 108 directs a packed bed of the formed blend through a conduit and through a treatment region for exposing the particles to electromagnetic radiation. The packed bed is moved through the treatment region by gravity.
- 10 As the finer particles have a P80 diameter that is smaller than that of the coarser particles, the finer particles reduce a percentage of void spaces that would otherwise be present between the coarser particles. The finer particles may be significantly smaller than coarser particles and
- 15 may partially fill spaces between adjacent coarser particles in the packed bed even if adjacent coarser particles are in contact. Further, relatively large particles have the disadvantage that arcs form within air gaps between the larger particles and the finer particles
- 20 are in one embodiment sized to reduce the likelihood that the coarser particles form such arcs.

The finer particles are exemplarily shown in Figure 2a. Figure 2a shows a photographic image of a packed bed of

25 particles 302 that are directed through a conduit. The particles 302 shown in Figure 2a have a diameter in a range of 2 to 6 mm.

The coarser particles may for example have a diameter in a

30 range of 20 to 40 mm as shown in Figure 2b. Figure 2b shows a photographic image of a packed bed of particles 304 that are directed through a conduit. The void regions 303 between the particles 302 are larger than the void

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regions 305 between the smaller particles 302 shown in Figure 2(a).

When the packed bed shown in Figure 2a was exposed to the
5 high intensity microwave treatment, a microwave power
above 50kW did not result in significant electrical
discharge ("arcing"). However, when the packed bed shown
in Figure 2b was exposed to the microwave radiation, a
microwave power of 10kW already resulted in electrical
10 discharge. This demonstrates the advantage of reducing the
size of the void region between the particles by blending
with finer particles.

It is for various reasons often impractical to reduce the
15 size of all particles of the mined material prior to
microwave treatment. Blending larger particles with
smaller particles in accordance with embodiments of the
present invention results in a reduction of an extension
of the void regions and consequently in a reduction of the
20 above-mentioned "arcing".

Figure 3 shows blends as formed by method step 106 of the
above-described method 100.

25 The packed bed of the blend shown in Figure 3a consists of
25% coarser particles having a diameter in a range of 20
to 40 mm, 25% finer particles having a diameter in a range
of 10 to 20mm, 25% third particles having a diameter in a
range of 5 to 10mm and 25% fourth particles having a
30 diameter in a range of 2 to 14mm. The bulk density of the
blend is 1.56 Mg/m³ and the void regions occupy 41% of the
total volume within the conduit.

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The packed bed of the blend shown in Figure 3b consists of 25% (volume or mass percentage) coarser particles having a diameter in a range of 20 to 40 mm, 25% finer particles having a diameter in a range of 5 to 14 mm and 50% third
5 particles having a diameter in a range of 2 to 5 mm. The bulk density of the blend is 1.61 Mg/m³ and the void regions occupy 39% of the total volume within the conduit.

Figure 3c shows an example in which the particles 302
10 shown in Figure 2b (the "coarser particles") are blended with the particles 304 (the "finer particles") shown in Figure 2a. In this example the blend has a bimodal distribution of particle diameters. Approximately 50% of the volume of the blend contains coarser particles 302
15 having a diameter in a range of 20 to 40 mm and 50% of the volume contains finer particles 304 having a diameter in a range of 2 to 6 mm. In this example, the bulk density of the blend is 1.7Mg/m³ void regions occupy 38% of the total volume within the conduit.

20

Figure 4 shows a graph illustrating a calculated percentage volume of air gaps as a function of packing density for various fragment diameters and blends (blend 1: 25% 20 - 40mm, 50% 2 - mm, 25% 6 - 14mm; blend 2: 50%
25 20 - 40mm, 50% 2 - 6mm; blend 3: 25% 10 - 20mm, 25% GNF1, 25% 6 - 10mm, 25% 2 - 6mm). As can be seen from the graph, the blends (especially blend 2) have a significantly reduced percentage of air voids compared to the unblended particles for which the package densities were calculated.

30

Step 110 exposes the blend of coarser and finer particles to the high intensity microwave radiation to form the micro-and/or macro-cracks. As the packed bed of the blend

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has an increased density (compared with a packed bed including exclusively coarser particles) and a percentage of void spaces is reduced, it is less likely that high power intensity electrical fields cause electrical

5 discharge between the particles. Such electric discharges consume a large amount of energy and by avoiding or reducing the discharges a larger portion of the electrical energy is used to cause the structural alternations.

10 The microwave radiation is selected such that a resulting power-density in the microwave absorbing phase of the coarser particles is in the region of 10^7 - 10^{13} W/m³.

Different types of materials have different absorption
15 coefficients for microwave radiation (depending on their dielectric properties or electrical conductivity) and different thermal expansion coefficients. For example, minerals, silicates or similar that form rock have a thermal expansion coefficient that is different to that of
20 copper or iron containing minerals and also absorb a different amount of energy when exposed to the microwaves. Consequently, when for example copper-containing minerals are surrounded by gangue and are exposed to such treatment, structural alterations in the form of, for
25 example, micro cracks form due to the differential expansion between the hot mineral and the cold gangue. The micro-cracks typically form around the boundaries of the hotter mineral phase enclosed in the gangue, which facilitates material separation.

30

The energy absorbed by the coarser and finer particles is a function of a power density created by the microwave radiation and an exposure time. For non-ferromagnetic

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ores, the power density is proportional to the square of the electric field component inside the material.

The exposure time of the blend within the conduit at the treatment region is 0.05 to 1 second. The power density is of the order of $1 \times 10^7 \text{ W/m}^3$ - $1 \times 10^{13} \text{ W/m}^3$ in the heated phase within the ore. The frequency of the microwave radiation typically is in a range of 300 MHz to 300 GHz.

The method 100 may further comprise a step of providing further particles, such as third, fourth or fifth particles, having further diameters that are smaller than that of the coarser particles. The further particles may also be of the mined material or alternatively be of any other suitable type. If further particles are provided, the step 106 is conducted such that the coarser and finer particles are blended with the further particles.

A person skilled in the art will appreciate that the particles of different diameters may be of different or identical type of material. For example, the finer particles may be of a material type that does not contain mineral material. In this case, the method 100 may further comprise separating the particles of the mined material from the particles that do not contain mineral material.

After the treatment of the mined material with the microwave radiation, the treated particles may be processed further, such as milling, further hydrometallurgical processing and leaching.

Referring now to Figure 5, there is shown the apparatus 400 for performing the method steps of the method 100.

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The apparatus 400 comprises a blender 402 that is arranged to receive the coarser particles of mined material and the finer particles of mined material. The blender 402 is
5 arranged to blend the coarser and finer particles in accordance with step 106 of the method 100.

The blend of coarser and finer particles is then directed by conveyor belt 404 into a chute that comprises chute
10 portions 406, 408 and 412.

The chute provides a vertical passage through which the blend of coarser and the finer particles falls by gravity in the form of a packed bed, i.e. the majority of
15 particles are in direct contact with another particle. The chute portion 406 is a conduit that surrounds the falling particles.

The chute portion 408 comprises a microwave applicator 410
20 that includes the majority of a treatment region. Further, the apparatus 400 comprises a microwave generator (not shown) that is arranged to generate high-intensity microwave radiation. The microwave applicator 410 is positioned such that the particles that flow in the form
25 of a packed bed are exposed to the microwave radiation within the treatment region 408.

The microwave radiation to which the particles of the mined material are exposed in the apparatus 400 is
30 continuous (but may in a variation of the described embodiment also be pulsed).

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The throughput of the mined material may be at least 100, 250, 500 1000, 2000, 3000, 4000 or 5000 tonnes per hour.

As mentioned previously, one embodiment of the present
5 invention relates to sorting based on a temperature of the particles. In this embodiment the method exposes the fragments of the mined materials to a lower intensity of the microwave radiation that is insufficient to form the cracks or micro-cracks, but sufficient to selectively
10 increase a temperature of valuable components of the fragments. A sorting component is used to identify and separate "hot" particles from "cold" particles using a thermal detector (for example in the form of an infrared camera). The detector is calibrated to determine whether a
15 given particle is "hot" or "cold". This information is used to operate ejectors selectively to emit a jet of gas (typically compressed air) into the path of "hot" particles so that they are deflected onto an alternate trajectory. "Cold" particles continue on their original
20 trajectory. As a result, "hot" particles and "cold" particles are separated into two respective streams.

An alternative embodiment will now be described with reference to Figures 6 and 7. In this embodiment, instead
25 of providing a distribution of courser particles of mined material, providing a distribution of finer particles of mined material, and forming a blend of the distributions of particles, mined material is provided as a single stream and at least some of the particles of mined
30 material are reduced in size so as to form the blend of the distributions of particles.

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A method 600 of treating particles of mined material with electromagnetic radiation is shown in Figure 6. The method 600 is similar to the method 100, however the step of forming the blend of the distribution of particles

5 comprises a step 602 of reducing a size of at least some particles of the mined material, for example using a crusher, so as to provide the distributions of coarser and finer particles.

10 The formed blend is then directed, in step 604, through a conduit comprising a treatment region for exposing particles of the blend to the electromagnetic radiation, and the coarser and finer particles of the blend are exposed to the electromagnetic radiation in step 606.

15 In the example of the method 600, the size of the finer particles is selected such that gaps between the coarser particles are reduced by the finer particles in the formed blend.

20 The step 602 of reducing the size of at least some particles of the mined material can be performed such that a bulk density of the formed blend approaches an average solid density. In one embodiment, an amount of air in the
25 formed blend is minimised.

After reducing a size of at least some particles of the mined material, the particles of the mined material can be sorted, for example using a screening system, so as to
30 remove particles at or below a predefined size.

The step 602 of reducing the size of at least some particles of the mined material is typically performed so

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as to obtain a size distribution of the particles that is appropriate for exposure to the electromagnetic radiation.

The step 602 of reducing the size of at least some
5 particles of the mined material can comprise a step of selecting a particular type of particle size reducing apparatus, or configuring or operating an already selected type of particle size reducing apparatus, so as to obtain
10 a size distribution of the finer and coarser particles that is particularly suitable for exposure to the electromagnetic radiation.

Referring now to Figure 7, there is shown the apparatus 700 for performing the steps of the method 600.

15 The apparatus 700 comprises a crusher 702 that is arranged to receive particles of mined material and to reduce a size of at least some particles of the mined material to form the blend of the distribution of coarser and finer
20 particles in accordance with step 602 of the method 600. It will be appreciated that any appropriate particle size reducing apparatus can be used to perform the function of the crusher 702.

25 The blend of coarser and finer particles is then directed by conveyor belt 704 into a chute that comprises chute portions 706, 708 and 712.

The chute provides a vertical passage through which the
30 blend of coarser and the finer particles falls by gravity in the form of a packed bed, i.e. the majority of particles are in direct contact with another particle. The chute portion 706 is a conduit that surrounds the falling

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particles.

The chute portion 708 comprises a microwave applicator 710 that includes the majority of a treatment region. Further,
5 the apparatus 700 comprises a microwave generator (not shown) that is arranged to generate high-intensity microwave radiation. The microwave applicator 710 is positioned such that the particles that flow in the form of a packed bed are exposed to the microwave radiation
10 within the treatment region 708.

The microwave radiation to which the particles of the mined material are exposed in the apparatus 700 is continuous (but may in a variation of the described
15 embodiment also be pulsed).

The throughput of the mined material may be at least 100, 250, 500 or 1000 tonnes per hour.

20 A screening system (not shown) may be arranged after the crusher 702, the screening system being arranged to remove particles at or below a predefined size after a size of at least some particles of the mined material has been reduced.

25 It is to be appreciated that various variations of the described embodiments are possible. For example, the chute portion 406, 706 may not necessarily be arranged vertically and may have any suitable cross-sectional
30 shape, diameter and length.

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The Claims defining the Invention are as Follows:

1. A method of treating particles of mined material with electromagnetic radiation, the method comprising the steps
5 of:

forming a blend of a distribution of courser particles of the mined material and a distribution of finer particles of the mined material;

directing the formed blend through a conduit
10 comprising a treatment region for exposing particles of the blend to the electromagnetic radiation, and

exposing particles of the blend to the electromagnetic radiation;

wherein the finer particles at least partially occupy
15 otherwise void spaces between the coarser particles when the formed blend is directed through the conduit.

2. The method of claim 1, wherein the step of directing the formed blend through the conduit comprises directing a
20 packed bed of the formed blend through the conduit, whereby the packed bed of the formed blend has a bulk density that is greater than the bulk density that a packed bed of only the coarser particles would have.

25 3. The method of claim 1 or 2, wherein the step of forming the blend of the distribution of particles is performed such that a bulk density of the formed blend is greater than 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, or 95% of a solid density of the coarser particles.

30

4. The method of any one of the preceding claims, wherein the step of forming the blend of the distribution of particles comprises the steps of:

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providing a distribution of coarser particles of the mined material;

providing a distribution of finer particles; and

blending the distribution of coarser particles and
5 the distribution of finer particles.

5. The method of any one of claims 1 to 3, wherein the step of forming the blend of the distribution of particles comprises the steps of:

10 providing particles of the mined material; and
reducing a size of some of the particles of the mined material so as to provide the distributions of the coarser and finer particles.

15 6. The method of claim 5, wherein, after a size of at least some particles of the mined material has been reduced, the particles of the mined material are sorted so as to remove particles below a predefined size.

20 7. The method of any one of claims 5, wherein the step of reducing the size of at least some particles of the mined material comprises a step of selecting a particular type of particle size reducing apparatus, so as to obtain the size distributions of the particles.

25 8. The method of any one of the preceding claims, wherein the step of providing the distribution of the coarser particles comprises providing the coarser particles having a first P80 (80% passing) diameter or
30 diameter range, and wherein the step of providing the distribution of the finer particles comprises providing the finer particles having a second P80 diameter that is smaller than that of the coarser particles.

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9. The method of any one of claims 1 to 7, wherein the finer and coarser particles in the blend have at least a bi-modal distribution of diameters.

5

10. The method of any one of the preceding claims, wherein the P80 diameter of the finer particles is selected such that a percentage of volume of the blend within the treatment region of the conduit that is not occupied with either the coarser or the finer particles is less than 70%, 60%, 50%, 45%, 40%, 35%, 30%, 25%, 20%, 15%, 10%, or even 5%.

11. The method of any one of claims 1 to 4, wherein the finer particles are also particles of the mined material.

12. The method of any one of the preceding claims, wherein the method comprises providing third particles that have a P80 diameter that is smaller than that of the coarser particles and different to that of the finer particles and forming a blend of the coarser, finer and third particles.

13. The method of any one of the preceding claims, wherein the electromagnetic radiation is microwave radiation.

14. The method of any one of the preceding claims, wherein the method is conducted such that a power-density in an electromagnetic radiation absorbing phase of at least some of the coarser particles of the mined material is of the order of $1 \times 10^7 \text{ W/m}^3$ to $1 \times 10^{13} \text{ W/m}^3$.

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15. The method of claim 14, wherein the power-density is at least 1×10^{11} W/cm³.

16. The method of any one of the preceding claims,
5 comprising a step of feeding the blend of the distributions of the coarser and finer particles into a conduit and through the treatment region by virtue of gravity.

10 17. The method of any one of the preceding claims, wherein the finer particles have a P80 diameter that is less than 20, 15, 10, 5, 2 or 1mm.

18. The method of any one of the preceding claims,
15 wherein the coarser particles have a P80 diameter that is at least 10, 15, 20 30 or 50mm larger than that of the finer particles.

19. An apparatus for treatment of mined material, the
20 apparatus comprising:

a blending portion for forming a blend of a distribution of coarser particles and a distribution of finer particles of the mined material;

a source for generating electromagnetic radiation;
25 and

a conduit for throughput of the blend of the distributions of the coarser and finer particles of the mined material and comprising a treatment region for exposing the blend to the electromagnetic radiation
30 generated by the source.

20. The apparatus of claim 19, wherein the blending portion is arranged so as to form the blend of the

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distribution of particles such that a bulk density of the formed blend is greater than 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, or 95% of a solid density of the coarser particles.

5

21. The apparatus of claim 19 or 20, wherein the blending portion comprises a first chute portion for receiving the distribution of the coarser particles of the mined material and a second chute portion for receiving the
10 distribution of the finer particles of the mined material.

22. The apparatus of claim 19 or 20, wherein the blending portion comprises a particle size reducing system arranged to:

15 receive particles of the mined material; and
reduce a size of at least some particles of the mined material to form the blend of the distribution of coarser and finer particles.

20 23. The apparatus of claim 19 to 20, wherein the blending portion comprises a particle size reducing apparatus arranged to:

receive a distribution of coarser particles of the mined material; and
25 reduce a size of at least some particles of the distribution of coarser particles of the mined material so as to provide the distribution of finer particles.

24. The apparatus of claim 23, wherein the blending
30 portion further comprises a sorting apparatus arranged to remove particles below a predefined size after a size of at least some particles of the mined material has been reduced.

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25. The apparatus of any one of claims 19 to 25, wherein the source is arranged to generate microwave radiation.

5 26. The apparatus of any one of claims 19 to 25, further comprising a separator arranged for separating the coarser particles of the mined material from the finer particles.

27. The apparatus of any one of claims 20 to 26, wherein
10 the apparatus is arranged such that the mined material passes through the conduit and the treatment region by gravity.

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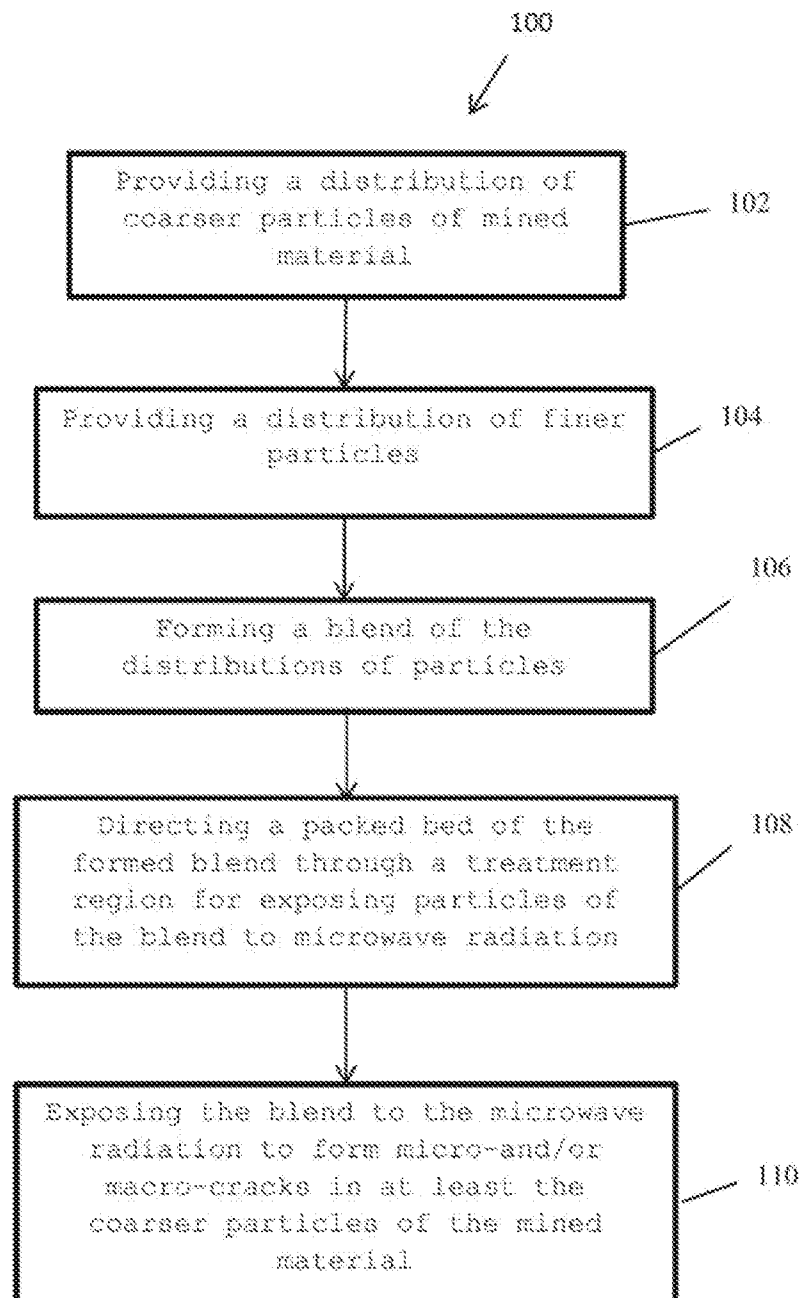


Fig. 1

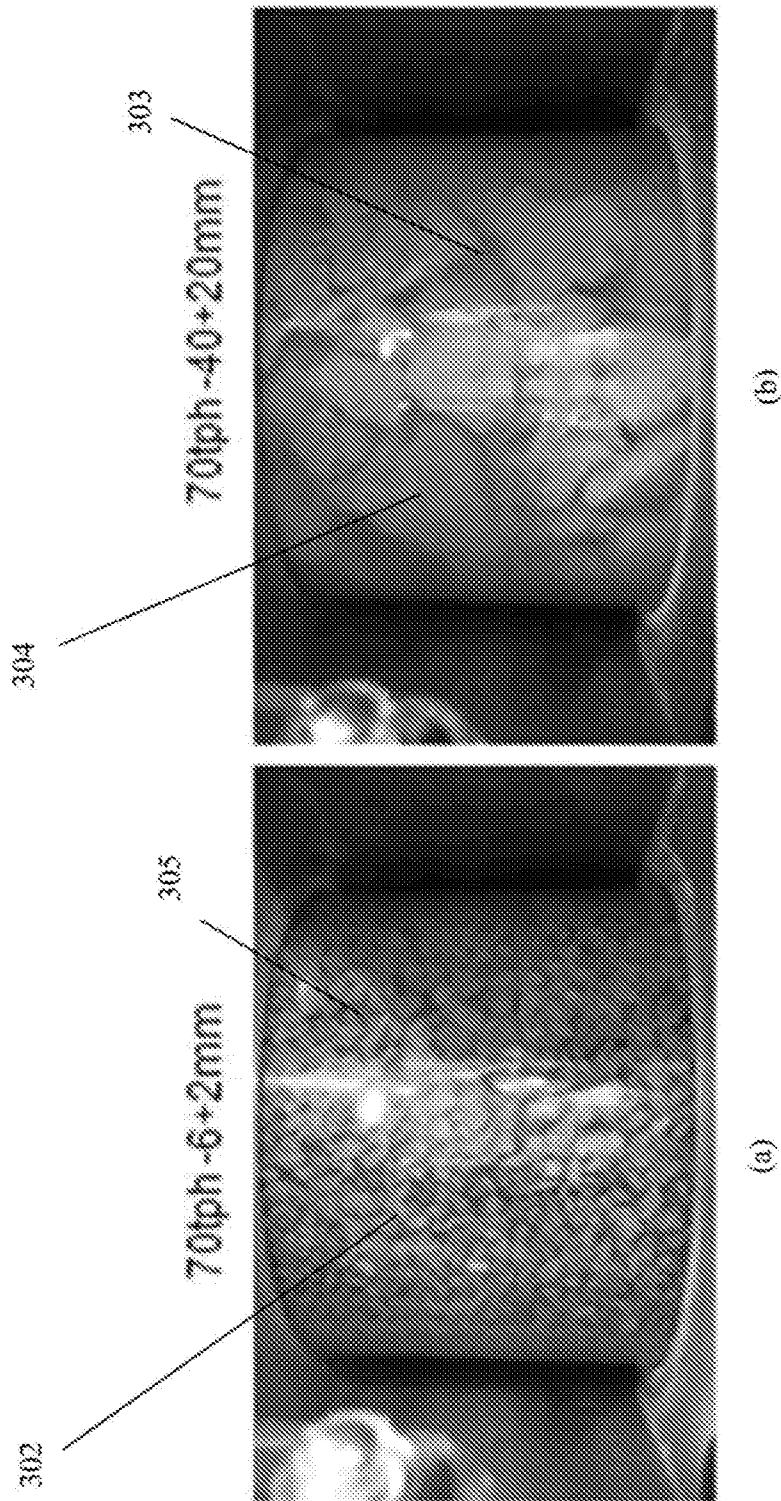


Fig. 2

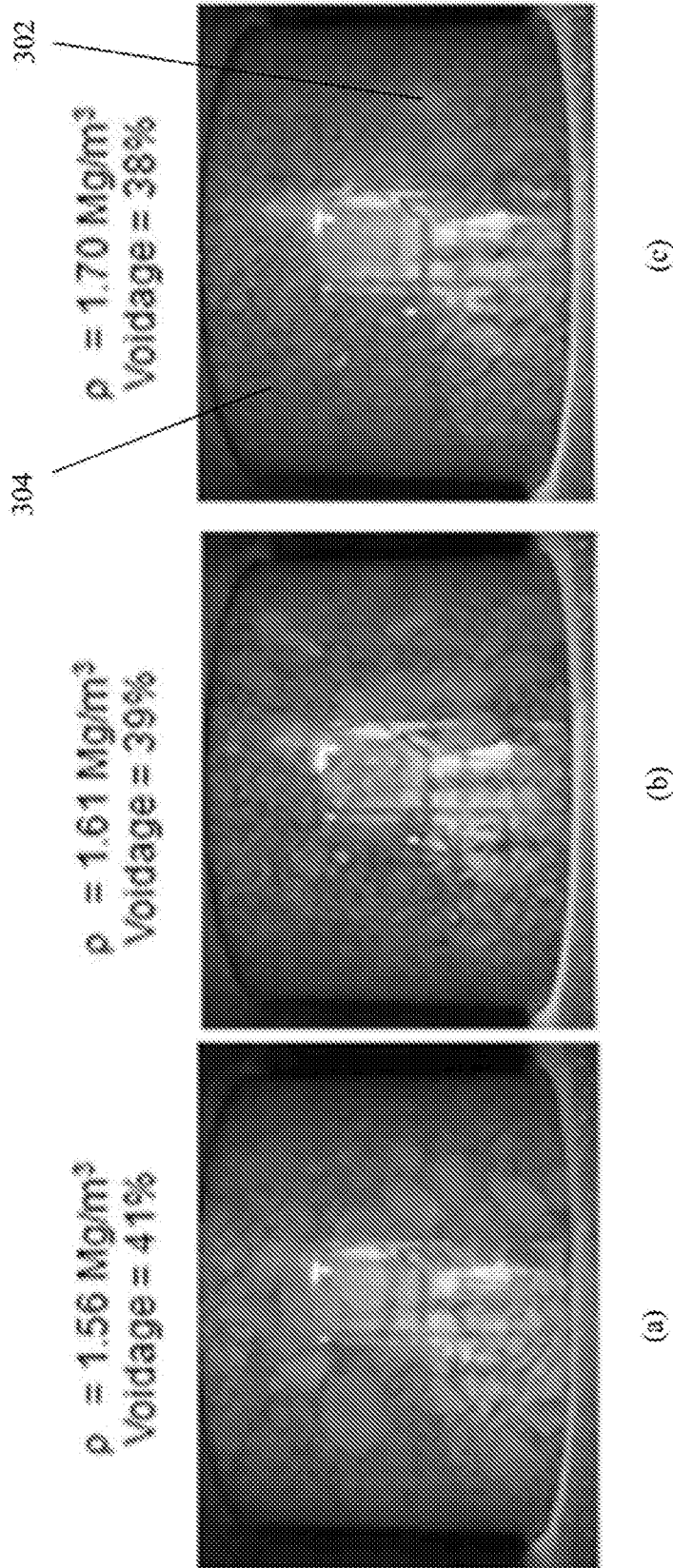


Fig. 3

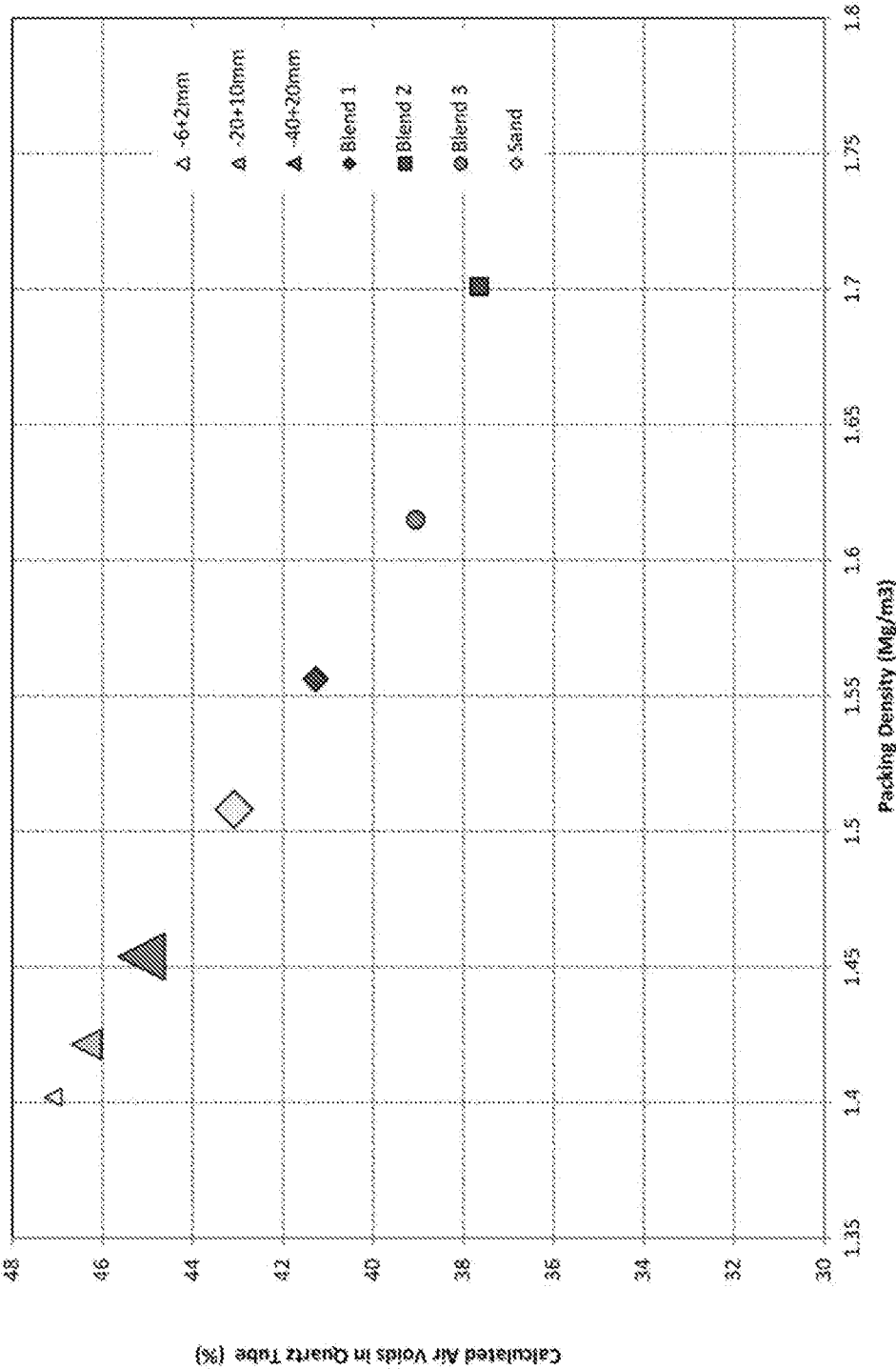


Fig. 4

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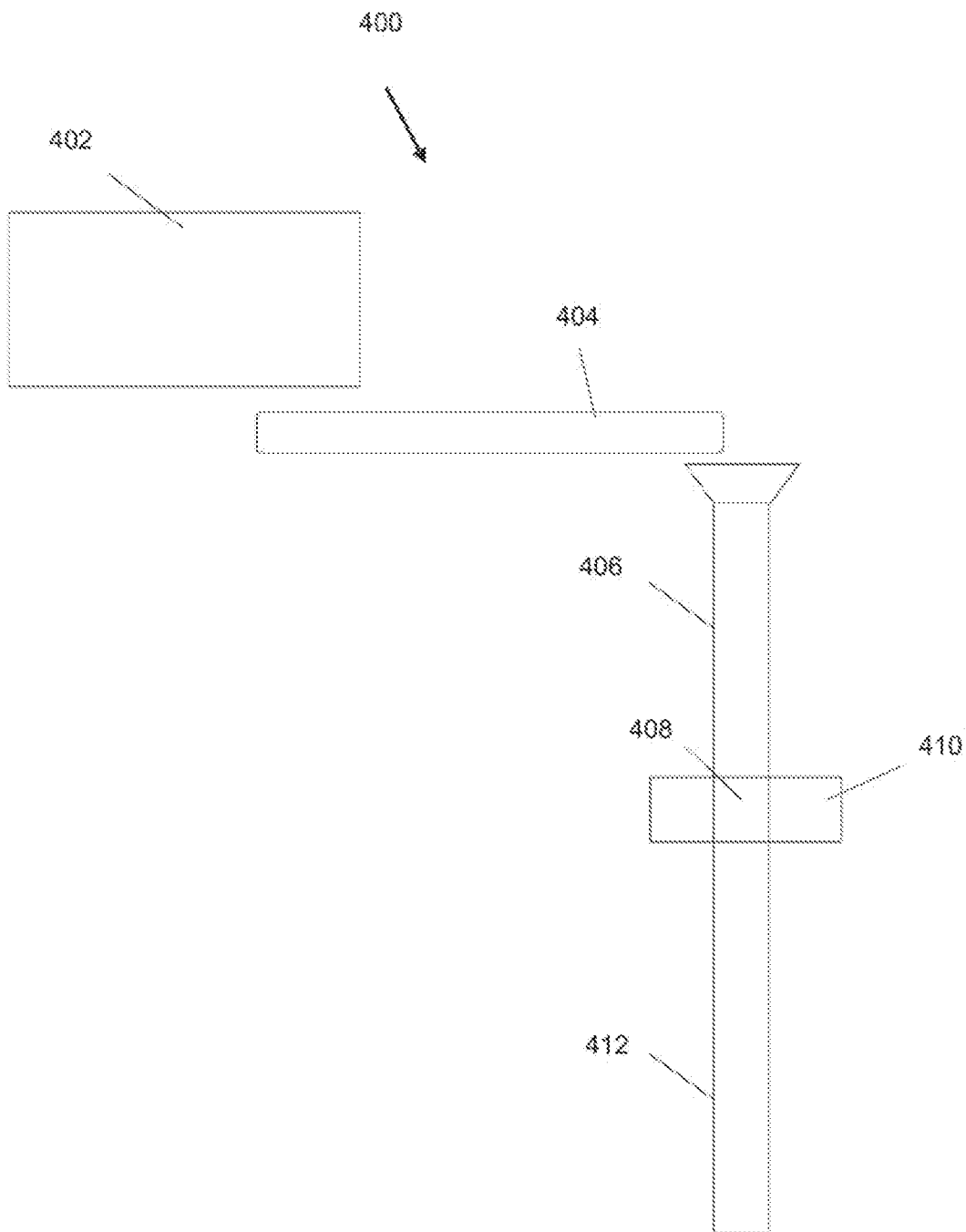


Fig. 5

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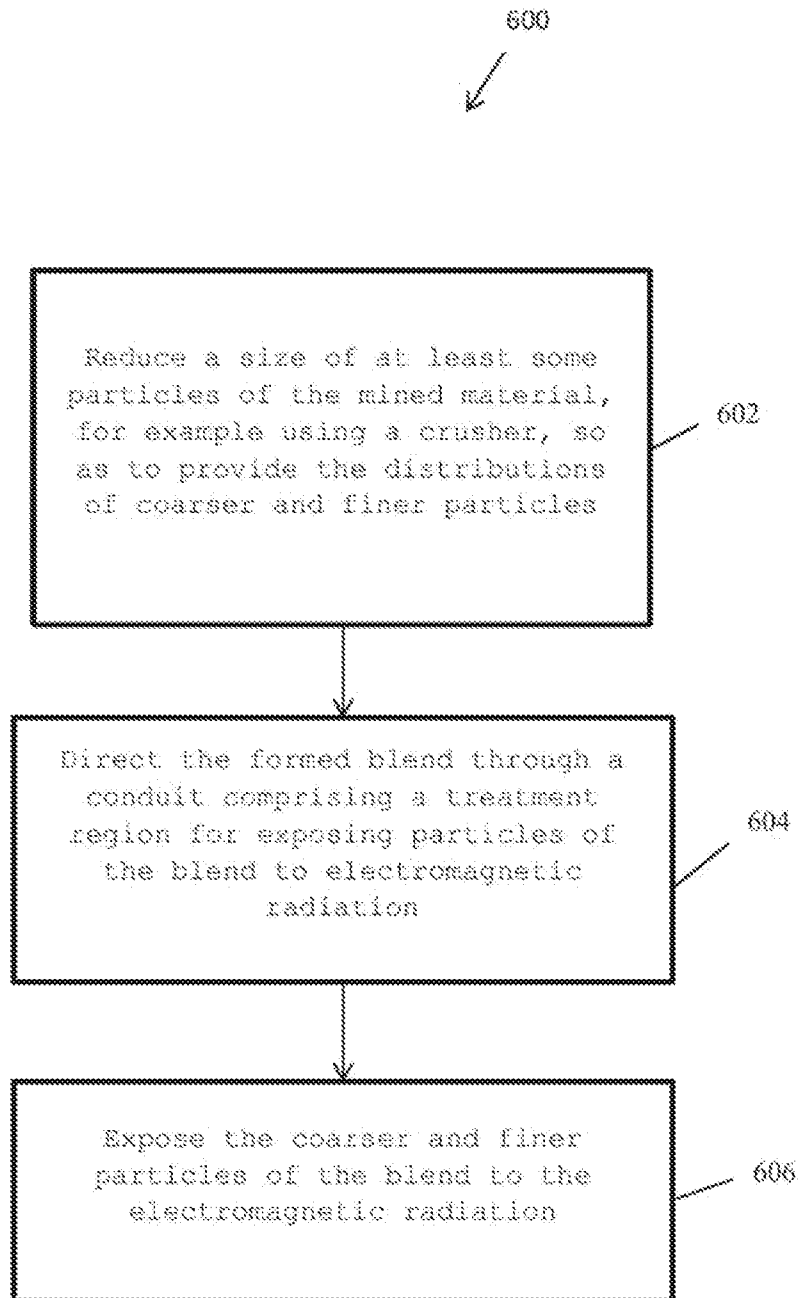


Fig. 6

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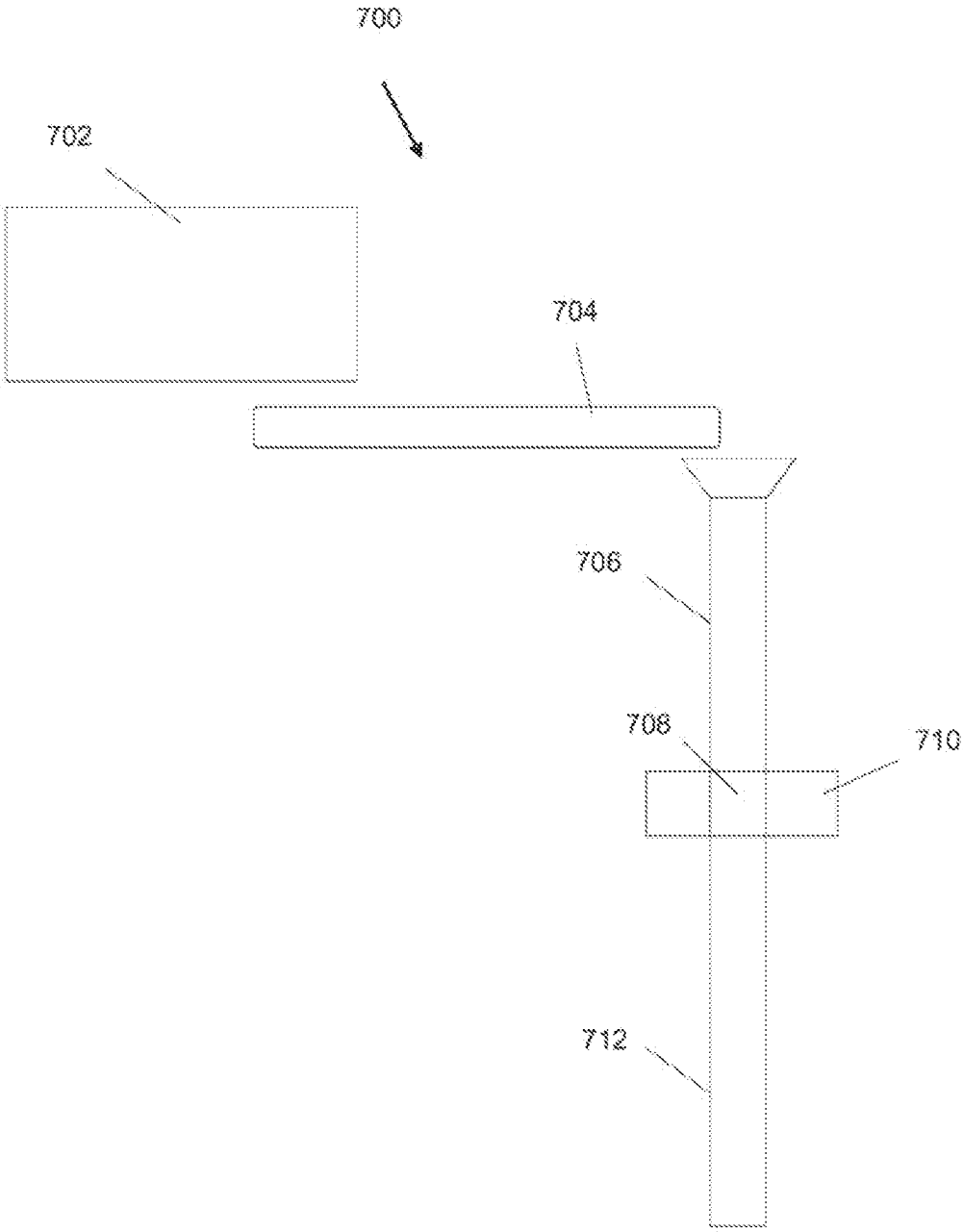


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2014/001044

A. CLASSIFICATION OF SUBJECT MATTER

B02C 19/18 (2006.01) B01J 19/12 (2006.01) B01J 19/08 (2006.01) C22B 1/14 (2006.01) B02C 23/08 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI and EPODOC; IPC and CPC marks: B02C19/18, B02C23/LOW, B02C21/00, B01J19/12, B01J19/08, C22B1/14/LOW, C22B9/14, H05B6/70, H05B6/78, H05B6/80, H05B6/784 with keywords such as: electromagnetic, particle, blend, mine, fine, coarse, conduit, bi-modal and their similar keywords. Also, searched in the Google Patents and Esp@cenet using keywords such as: fragment, ore, microwave, mixing, fine, coarse, conduit and their similar words; Also searched Auspat, Esp@cenet for applicant :Technological Resources.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

☒ Further documents are listed in the continuation of Box C ☒ See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search 3 February 2015		Date of mailing of the international search report 03 February 2015	
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustalia.gov.au		Authorised officer Abdulla Al-Motin AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0262837965	

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2014/001044
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/0043314 A1 (LIUBAKKA et al.) 23 February 2012 (Abstract, figures 1-2, paragraph [0019-0020, 0029-0030,0051], claims)	1-27
A	US 2013/0020420 A1 (SHAW et al.) 24 January 2013 (Abstract; Figure 3)	1-27
A	US 7571814 B2 (BIRKEN) 11 August 2009 (Abstract, Figures 1-9)	1-27

Form PCT/ISA/210 (fifth sheet) (July 2009)

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2014/001044	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

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INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/AU2014/001044	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
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		US 6923328 B2	02 Aug 2005
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		US 2013284643 A1	31 Oct 2013
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		WO 2006037120 A2	06 Apr 2006
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End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			