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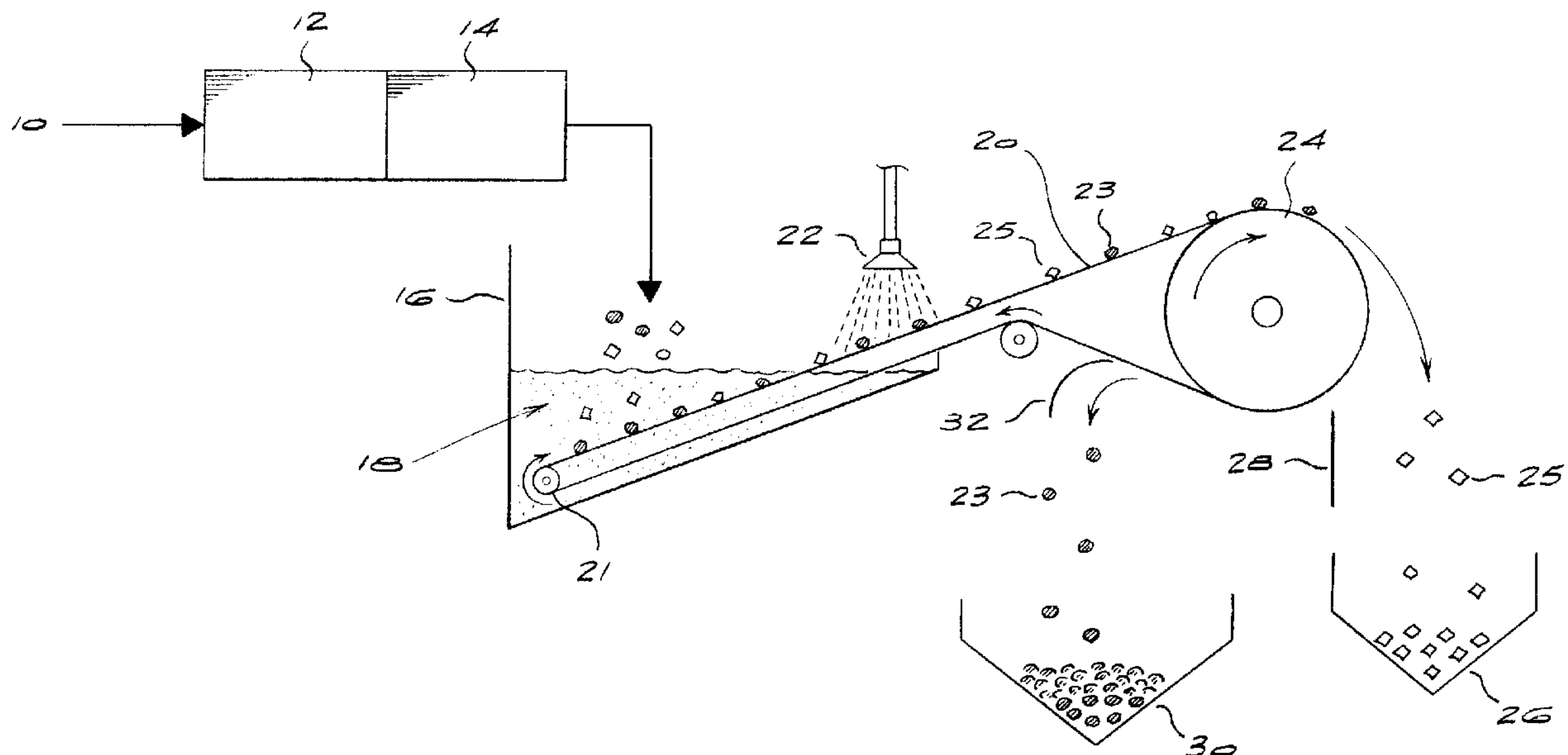
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(57) Abrégé/Abstract:

The invention is directed to the sorting of particles according to the thermal properties of the particles. The method comprises, as a first step, subjecting the particles to one or more thermal treatment steps so that particles with different intrinsic thermal properties are brought to different temperatures. In the next step, conducted either during or after the thermal treatment steps, the particles are subjected to a further, non-thermal treatment. This treatment is chosen to give selected particles that are distinguished from other particles by a difference in temperature a certain feature which is not an intrinsic feature of the particles prior to the thermal treatment step. The particles can then be sorted into a fraction having the certain feature after a predetermined time period has elapsed since the further treatment step and a fraction not having the certain feature after that time lapse.



ABSTRACT

The invention is directed to the sorting of particles according to the thermal properties of the particles. The method comprises, as a first step, subjecting the particles to one or more thermal treatment steps so that particles with different intrinsic thermal properties are brought to different temperatures. In the next step, conducted either during or after the thermal treatment steps, the particles are subjected to a further, non-thermal treatment. This treatment is chosen to give selected particles that are distinguished from other particles by a difference in temperature a certain feature which is not an intrinsic feature of the particles prior to the thermal treatment step. The particles can then be sorted into a fraction having the certain feature after a predetermined time period has elapsed since the further treatment step and a fraction not having the certain feature after that time lapse.

BACKGROUND TO THE INVENTION

THIS invention relates to a particle sorting method. In particular, the invention relates to a method for sorting particulate material on the basis of differences in thermal properties.

One application of the invention is in the recovery of diamonds from associated gangue particles in a diamond bearing gravel recovered in diamond mining or exploration activities.

SUMMARY OF THE INVENTION

According to this invention, there is provided a method of sorting particles according to the intrinsic thermal properties of the particles, the method comprising:

subjecting the particles to one or more thermal treatment steps so that particles with different intrinsic thermal properties are brought to different temperatures,

either during or after the thermal treatment steps, subjecting the particles to a further, non-thermal treatment chosen to endow selected particles that are distinguished from other particles by a difference in temperature with a certain feature which is not an intrinsic feature of the particles prior to the thermal treatment steps, and

sorting the particles into a fraction having the certain feature after a predetermined time period has elapsed since the further treatment step and a fraction not having the certain feature after that time lapse.

In a first version of the invention, the particles are exposed, in the further treatment step, to water vapour after at least some of them have been brought to a temperature below the freezing point of water, and the sort is made according to whether the particles exhibit a frosted appearance a predetermined time after such exposure.

In one embodiment of the first version of the invention, in which thermal treatment takes place before further treatment, the particles are initially thermally treated by cooling them to different temperatures above and below the freezing point of water, the temperature-distinguished particles are then exposed to water vapour so that particles at the lower temperature selectively acquire a frosted appearance, and the sort is then made on the basis of whether the particles exhibit a frosted appearance.

In another embodiment of the first version of the invention, in which the further treatment step takes place during thermal treatment, the particles are all cooled to a uniform low temperature below the freezing point of water and are then exposed to warmer air containing water vapour so that all particles acquire a frosted appearance, the sort being made according to whether the particles still exhibit the frosted appearance after a predetermined time lapse.

In a second version of the invention, the particles are thermally treated to bring them to different temperatures, the particles are exposed to a magnetic substance which selectively freezes onto particles at a lower temperature, and the particles are then magnetically sorted.

In a third version of the invention, the particles are thermally treated to bring them to different temperatures above and below the freezing point of a liquid and are then placed in a body of the liquid so that the liquid selectively freezes onto the cooler particles, the sort being made according to the buoyancy of the particles.

BRIEF DESCRIPTION OF THE DRAWINGS

Various versions of the invention will now be described in more detail and by way of example only, in some cases with reference to the accompanying drawings in which:

- Figure 1** diagrammatically illustrates one embodiment of a second version of the invention;
- Figure 2** diagrammatically illustrates one embodiment of a third version of the invention; and
- Figure 3** diagrammatically illustrates another embodiment of the third version of the invention.

SPECIFIC DESCRIPTION

Two non-illustrated embodiments of the first version of the invention will now be described in more detail. In both cases, the descriptions refer to the sorting of diamond particles from associated gangue, but it is to be appreciated that the principles of the invention are applicable to many other applications in which it is possible to make a distinction between particles with different intrinsic thermal properties.

In the first embodiment of this version of the invention, particulate diamondiferous material, containing a mixture of diamond particles and associated gangue particles, is initially thermally treated by depositing it

in a monolayer on the surface of a body or layer of ice at a temperature substantially below the freezing point of water. The fact that the diamonds have a higher coefficient of thermal conductivity and thermal diffusivity means that they will lose heat to the ice more quickly than the gangue particles which have a lower thermal diffusivity. Accordingly, the diamond particles will be brought more quickly to a temperature below the freezing point of water than the gangue particles.

After a period of time sufficient for the above temperature distinction to take place, the thermally treated particles are subjected to a further treatment step in which they are all exposed to ambient air containing water vapour in gaseous form. The air may be normal ambient air. Alternatively, the air may be specially prepared air with a water vapour content higher than normal ambient air.

Because the diamonds are now at a temperature sufficiently below the freezing point of water, water vapour in the air which contacts the diamond particles will be frozen on the surfaces of the diamond particles, forming a "frosted" layer on the diamond particles. The "frosted" layer will have the normal white colouration.

The associated gangue particles are, after the chosen time period, still at a temperature at which freezing of the water vapour cannot take place, because of their lower thermal conductivities and diffusivities. There will therefore be no formation of a frosted layer on the gangue particles.

It will be appreciated that the feature of a frosted appearance on the diamond particles is a non-intrinsic property of those particles. In other words, diamonds do not normally have a frosted appearance, such appearance in this case being given to the diamonds because of their lower temperature.

The presence or otherwise of the frosted layer on the diamond particles will be readily detectable, for instance by eye, enabling a sort to be made. As an alternative to eye distinction, an automatically operating apparatus may be used to distinguish and sort the relevant particles from one another. Since the diamond particles have a white, frosted appearance, and accordingly are lighter in colour than the associated, non-frosted gangue particles, an optical distinction can be made automatically merely on the basis of light and dark particles. It is anticipated that conventional photometric equipment currently used for distinguishing between relatively light and relatively dark particles will be able to make the necessary distinction in this case.

The actual sorting of the particles may be made manually on the basis of the visual determination referred to above. Alternatively, automatic sorting means, possibly employing gas blast ejectors or the like, could be arranged to separate the diamond particles from the gangue particles in response to the determinations made by the automatic optical detection equipment referred to above.

In the second embodiment of this version of the invention, all the particles are cooled down for a period of time sufficient for them all to come to a temperature below the freezing point of water. This could, for

instance be done by immersing all the particles in a liquid, such as liquid nitrogen, at a temperature substantially below the freezing point of water, and leaving the particles so immersed for a period of time long enough to enable all the particles to come to the required low temperature. Alternatively, the particles could be placed in a cold enclosure, or be exposed to a cold gaseous environment for the required time period.

Thereafter the particles are contacted with air at a temperature substantially above the freezing point of water. The air may contain normal amounts of water vapour or, preferably, has been moistened to a greater degree. The water vapour will freeze onto the surfaces of all the particles because of their uniform low temperature. Thus all the particles at this stage will have a frosted appearance.

Because the diamond particles have a high thermal diffusivity, they will accept heat from the relatively hot, ambient air at a faster rate than the gangue particles. The temperature of the diamond particles will therefore rise more rapidly to a level above the freezing point of water. Accordingly the frozen water vapour on the diamond particles will melt before melting of the water vapour on the gangue particles takes place. The diamond particles will therefore lose their frosted appearance before the gangue particles.

In this embodiment, it will be appreciated that the initial cooling of the particles to a uniform low temperature and the subsequent warming of the particles by exposing them to warmer air constitute the thermal treatment steps of the invention. It will also be appreciated that the

further treatment, i.e the exposure of the particles to the water vapour, takes place during the latter part of the thermal treatment.

Once again, an eye or automatic optical distinction can be made between the lighter, in this case gangue, and darker, in this case diamond, particles. Thereafter the particles can be separated from one another as described above for the first embodiment.

It will be appreciated that both embodiments of the invention as described above are time-dependent. In the first embodiment the particles must be cooled down for a period of time chosen for the diamond particles to gain a frosted appearance when they are then exposed to water vapour, but not the gangue particles. Thereafter the particles must be viewed at a time when the diamond particles still retain the frosted appearance, so that the necessary frosted/non-frosted distinction can be made.

In the second embodiment the initial cooling period is sufficiently long for all particles to drop to an appropriately low temperature, and viewing takes place after a time lapse chosen for the water vapour on the diamond particles to have melted, but not the water vapour on the gangue particles. In each case, the relevant time periods can be determined experimentally.

Reference is now made to Figure 1 of the drawings, which diagrammatically illustrates a first embodiment of the second version of the invention. In Figure 1, a feed stream of diamond-bearing gravel which is to be sorted into a diamond-rich fraction and a gangue fraction

is indicated with the numeral 10. The feed stream 10 may, for instance, be conveyed on a conveyor belt (not shown).

The feed stream 10 is passed through a cooling tunnel 12 and then through a bath 14 of liquid nitrogen. The residence time of the particles in the bath 14 is sufficient to bring the particles to a uniform low temperature, typically below -120°C .

The cooled particles are then fed into a tank 16 containing a suspension 18 of magnetic material, in this case magnetite, in water. The temperature of the suspension is maintained in the range 0°C to 25°C , and is typically around 7°C . The suspension 18 contains between 10% and 60% magnetite particles by mass, the particles themselves typically having a size of $-10 \times 10^{-6}\text{m}$.

As the particles gravitate through the suspension 18, the gangue particles, having a very much lower thermal diffusivity than the diamonds, gain heat relatively slowly from the suspension and remain at a temperature well below the freezing point of the suspension. They therefore acquire an at least partial frozen coating of the suspension.

The diamonds, on the other hand, gain heat more rapidly because of their higher thermal diffusivity, and rapidly come to a temperature at or near that of the suspension. At their relatively elevated temperature, the diamond particles are unable to acquire a frozen coating of the suspension.

The particles gravitate onto the upper run of an endless conveyor belt 20 moving around a submerged tail pulley 21 and a magnetised head pulley 24 located outside the bath 16. The belt 20 conveys the particles upwardly and out of the bath through a water spray 22 which washes away any free suspension 18.

The magnetically coated gangue particles 23 and uncoated diamonds 25 continue moving on the belt and pass over the head pulley 24. As the belt passes over the head pulley, the diamond particles, having no magnetic susceptibility, fall off into a collection bin 26. The magnetically coated gangue particles are held in contact with the belt by the magnetic attraction of the head pulley, and move further around beneath the head pulley, past a splitter plate 28. As they move further away from the head pulley, the magnetic attraction forces diminish and the gangue particles eventually fall off into a collection bin 30. A scraper 32 can, if necessary, be provided to ensure separation of the gangue particles from the belt.

In a mining exploration or prospecting operation, the method described above can be carried out batchwise to analyse small geological samples.

In the example described above and illustrated in Figure 1, the thermal treatment steps of the invention involve firstly cooling the particles and then heating them to bring them to substantially different temperatures at the lower of which selective freezing of the suspension 18 can take place. In the illustrated case, after initial cooling, heating to achieve a marked temperature distinction is performed by the suspension 18 itself.

Thus in the embodiment illustrated in Figure 1, it will also be appreciated that the further treatment step, namely the exposure of the particles to the magnetic liquid, takes place during the thermal treatment, since it is the exposure of the particles to the magnetic liquid which forms the second part of the thermal treatment procedure.

In a non-illustrated embodiment of this version, the thermal treatment steps of the invention could involve applying heat to the particles, after initial cooling to a uniform low temperature, by a flash heating process in which the diamond particles would gain heat far more rapidly than the gangue particles.

In a reversal of the above thermal treatment steps it would also be possible initially to heat the particles to a uniform high temperature. The particles would then be subjected to a cooling step, for instance by passing them through liquid nitrogen. The diamond particles would lose their heat far more rapidly than the gangue particles and would be brought to a low temperature at which freezing of the suspension could later take place. On the other hand, the gangue particles would remain at a relatively high temperature at which no such freezing could take place. Thus in this case, it would be the gangue particle which would fall first off the belt, with the attractive magnetic forces holding the diamond particles, which are coated with frozen suspension, on the belt for subsequent removal.

The methods described in relation to Figure 1 are believed to be particularly suitable for recovering diamond particles in the size range 3mm to 15mm.

Reference is now made to Figure 2 of the drawings, which diagrammatically illustrates a second embodiment of the second version of the invention. In Figure 2, a diamondiferous feed stream 100 is passed through a liquid nitrogen bath 102 which cools all the particles to a uniformly low temperature.

The cooled particles are dropped onto the upper run of an endless conveyor belt 104 which conveys them past a hot air blower 106 which applies heat to them. The diamond particles heat up much more rapidly than the gangue particles.

The conveyor belt 104 then conveys the cooled and subsequently heated particles through a spray 108 of a magnetic liquid, typically a magnetite suspension as described in relation to Figure 1. The time and temperature parameters are set such that the gangue particles, on reaching the spray 108, are at a temperature below the freezing point of the liquid, while the diamond particles have gained sufficient heat to be above that freezing point. Thus the gangue particles acquire at least a partial frozen coating of the magnetic liquid.

The conveyor belt passes around a magnetic head roller 110 which attracts the coated gangue particles but not the diamonds. The diamonds fall off the conveyor belt as they pass the head roll 110 and are collected to one side of a splitter plate 112. The gangue particles are kept, by magnetic attraction, in contact with the belt as they pass around the head roller. As the gangue particles move further from the head roll 110, the magnetic attraction decreases and these particles eventually fall off the belt on the opposite side of the splitter plate 112.

In a modified form of the Figure 2 embodiment, the upper run of the belt 104 could carry a film of water. The particles are initially cooled to a temperature low enough for them to freeze the water upon contacting the film. This adheres all the particles to the belt. When the particles are subsequently subjected to heating by the hot air blower, the diamond particles gain heat more quickly and melt the frozen water adhering them to the belt. The gangue particles remain adhered to the belt for a longer period of time.

Thus in this case, it is a combination of the adhering effects of the frozen water and the magnetic attraction between the frozen magnetic coatings and the head roll 110 which keeps the gangue particles in contact with the belt longer than the diamond particles. As before the diamond particles are able to fall off under gravity.

In yet another modification of the Figure 2 embodiment, the particles could be initially cooled and then flash-heated in such a manner as to bring the temperature of the diamonds above the freezing point of water while the gangue particles remain below such freezing point. In this case, only the gangue particles would be adhered to the surface of the belt by frozen water. This system would again be used in combination with application of a magnetic liquid as described above, so that the gangue particles selectively acquire a frozen coating of the magnetic material. Once again, it would be a combination of the adherence caused by freezing of a water film and magnetic attraction between the coatings of the gangue particles that would keep the gangue particles in contact with the belt after passage around the head pulley.

The magnetic attraction decreases as described above as the gangue particles move further from the head roll. The adhering effect of the ice can be broken by applying further heat to the underside of the belt, after the particles have passed the splitter plate, or by scrapers or warm water sprays. The combined magnetic attraction and ice adhesion may, it is believed, enhance the accuracy of the sort which is achieved.

Reference is now made to Figure 3 of the drawings which illustrates one embodiment of the third version of the invention. Figure 3 shows a feed stream 210 of diamond-bearing gravel derived, for instance, from diamond mining or prospecting activities. The feed stream 210 is conveyed, for instance on a conveyor belt, through a cooling apparatus 212. The cooling apparatus may, for instance, include a bath of liquid nitrogen. The residence time of the particles of the gravel in the cooling apparatus 212 is sufficient to bring all the particles to a uniform low temperature well below the freezing point of water.

Once all the particles are at the same uniform low temperature, they are conveyed through a flash heating station 214 at which heat is applied rapidly to them. The residence time and temperature in the flash heating station is chosen for those particles which have a relatively high thermal diffusivity, in this case diamonds, to heat up rapidly to a temperature above the freezing point of water. However, the time and temperature parameters are set such that the gangue particles in the gravel, being of lower thermal diffusivity, are unable to acquire sufficient heat to elevate their temperature above the freezing point of water.

In practice, the time and temperature parameters are set for the gangue particles to emerge from the flash heating station at a temperature still well below 0°C, typically about -40°C, with the diamonds emerging at a temperature of around 5°C.

The thermally treated particles are then dropped into a stream of water 216 which flows in the direction of the arrow 218 in a conduit 220. The water is maintained by cooling means (not shown) at a temperature slightly above 0°C.

Ice builds up on the low temperature gangue particles, but not on the diamonds. The diamonds 222 sink rapidly and are conveyed downstream a short distance only. The ice-covered gangue particles 224, on the other hand, are more buoyant than the diamonds and are thus conveyed further downstream by the water flow.

The diamond and gangue particles are at least roughly uniformly presized before the sorting operation commences. This would, in any event, normally be the case in diamond mining operations where all particles would have been subjected to a crushing operation before sorting. The greater buoyancy of the gangue particles is attributable in the first place to their greater volume as a result of ice build-up. Also, the iced gangue particles will have a lower overall density than the diamond particles because of the presence of the ice.

Figure 3 shows a splitter plate 226 upstream of which the diamond particles settle to the bottom of the conduit and downstream of which the gangue particles settle. The particles are then recovered separately.

In a slightly modified version of the Figure 3 embodiment, suitable for batch sorting, the thermally treated particles are merely dropped into a bath of low temperature water. Once again the diamond particles sink rapidly in the water, while ice builds up on the gangue particles. With the time and temperature parameters correctly set, sufficient ice will build up on the gangue particles to cause them to float in the water. In this case, the diamonds are recovered as a sunken fraction and the gangue particles are recovered as a floating fraction.

In either case, the ice on the gangue particles will, after a period of time, start to melt, and it will therefore be important for separation of the more and less buoyant particles to take place at the correct time.

Although specific reference has been made in this specification to the sorting of diamonds from associated gangue particles, it will be appreciated that the principles of the invention will be equally applicable to the sorting of other particles distinguished from one another by marked differences in intrinsic thermal properties. In each case, the difference in intrinsic thermal properties, notably thermal diffusivity, is used, with appropriate thermal treatment, to create a temperature differential. After the various further treatments described above and as a result of the temperature differential, one class of particles acquires or retains a specific feature on the basis of which a reliable sort can subsequently be made. It will be recognised that the feature, such as a frosted appearance, a frozen magnetic coating or a frozen coating affecting buoyancy, is not an intrinsic feature of any of the particles and is only acquired because of the thermal treatment to which the particles are subjected.

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Various proposals have previously been made for sorting particles on the basis of differences in intrinsic thermal properties. In the prior proposals it is the difference in intrinsic thermal properties of the particles alone which makes the eventual sort possible. The individual particles, or selected particles, are not caused to acquire a non-intrinsic feature on the basis of which the sort is eventually made, as proposed by the present invention.

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THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:-

1.

A method of sorting particles according to the thermal properties of the particles, the method comprising:

subjecting the particles to one or more thermal treatment steps so that particles with different intrinsic thermal properties are brought to different temperatures,

either during or after the thermal treatment steps, subjecting the particles to a further, non-thermal treatment chosen to endow selected particles that are distinguished from other particles by a difference in temperature with a certain feature which is not an intrinsic feature of the particles prior to the thermal treatment steps, and

sorting the particles into a fraction having the certain feature after a predetermined time period has elapsed since the further treatment step and a fraction not having the certain feature after that time lapse.

2.

A method according to claim 1 wherein the particles are exposed, in the further treatment step, to water vapour after at least some of them have been brought to a temperature below the freezing point of water, and the sort is made according to whether the particles exhibit a frosted appearance a predetermined time after such exposure.

3.

A method according to claim 2 wherein thermal treatment takes place before further treatment and wherein the particles are initially thermally treated by cooling them down so that different particles have different temperatures respectively above and below the freezing point of water, the particles are then exposed to water vapour so that those particles at a temperature below the freezing point of water selectively acquire a frosted appearance, and a sort is then made on the basis of whether or not the particles exhibit a frosted appearance.

4.

A method according to claim 2 wherein the further treatment step takes place during thermal treatment and wherein the particles are all cooled to a uniform low temperature below the freezing point of water and are then exposed to warmer air containing water vapour so that all particles acquire a frosted appearance, the sort being made according to whether the particles still exhibit the frosted appearance after a predetermined time lapse.

5.

A method according to claim 1 wherein the particles are thermally treated to bring them to different temperatures, the particles are exposed to a magnetic substance which selectively freezes onto particles at a lower temperature, and the particles are then magnetically sorted.

6.

A method according to claim 5 wherein the particles are cooled down to a uniform low temperature and are then dropped into a bath containing a suspension of a relatively warm magnetic material so that particles with a certain thermal diffusivity acquire a frozen coating of the magnetic material while other particles do not, and the particles are magnetically sorted.

7.

A method according to claim 6 wherein the particles are dropped onto a moving conveyor belt immersed in a magnetite suspension, the conveyor belt passing over a magnetised head pulley which performs a magnetic sort.

8.

A method according to claim 6 wherein the particles are flash-heated after being cooled down to a uniform low temperature and before being dropped into the bath.

9.

A method according to claim 5 wherein the particles are heated up to a uniformly high temperature and are then subjected to a rapid cooling step, whereafter the particles are dropped into a bath containing a suspension of a magnetic material so that particles with a certain thermal diffusivity acquire a frozen coating of the magnetic material while other particles do not, and the particles are magnetically sorted.

10.

A method according to claim 5 wherein the particles are cooled down to a uniform low temperature and are then conveyed in sequence through a heating station and through a spray of magnetic material so that particles with a certain thermal diffusivity acquire a frozen coating of the magnetic material while other particles do not, and the particles are magnetically sorted.

11.

A method according to claim 10 wherein the cooled particles are dropped onto a conveyor belt which conveys the particles in sequence beneath a hot air blower, through a magnetite spray and around a magnetised head pulley which magnetically sorts the particles.

12.

A method according to claim 11 wherein the conveyor belt carries a film of water which freezes around at least some of the cooled particles to adhere those to the belt.

13.

A method according to claim 1 wherein the particles are thermally treated to bring particles with different thermal properties to different temperatures above and below the freezing point of a liquid, the thermally treated particles are placed in a body of the liquid so that the liquid selectively freezes onto the cooler particles, and the particles are sorted according to their buoyancy.

14.

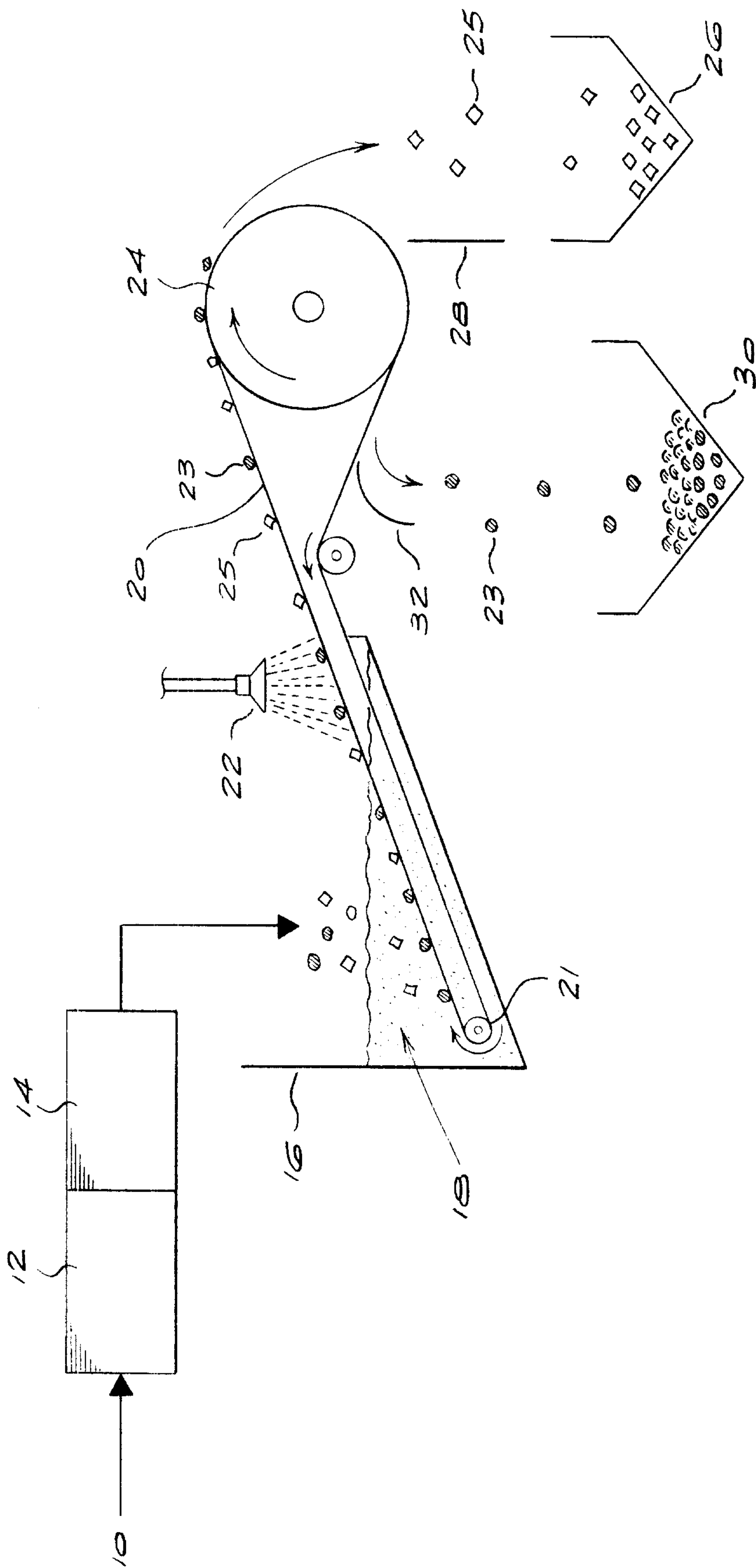
A method according to claim 13 wherein the thermally treated particles are dropped into a moving stream of water and are sorted according to how far downstream they are conveyed by the water.

15.

A method according to claim 13 wherein the thermally treated particles are dropped into water and the time and temperature parameters are such that those particles with a temperature below the freezing point of water acquire an ice coating which causes them to float, and the particles are sorted according to whether or not they float.

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Fig. 1



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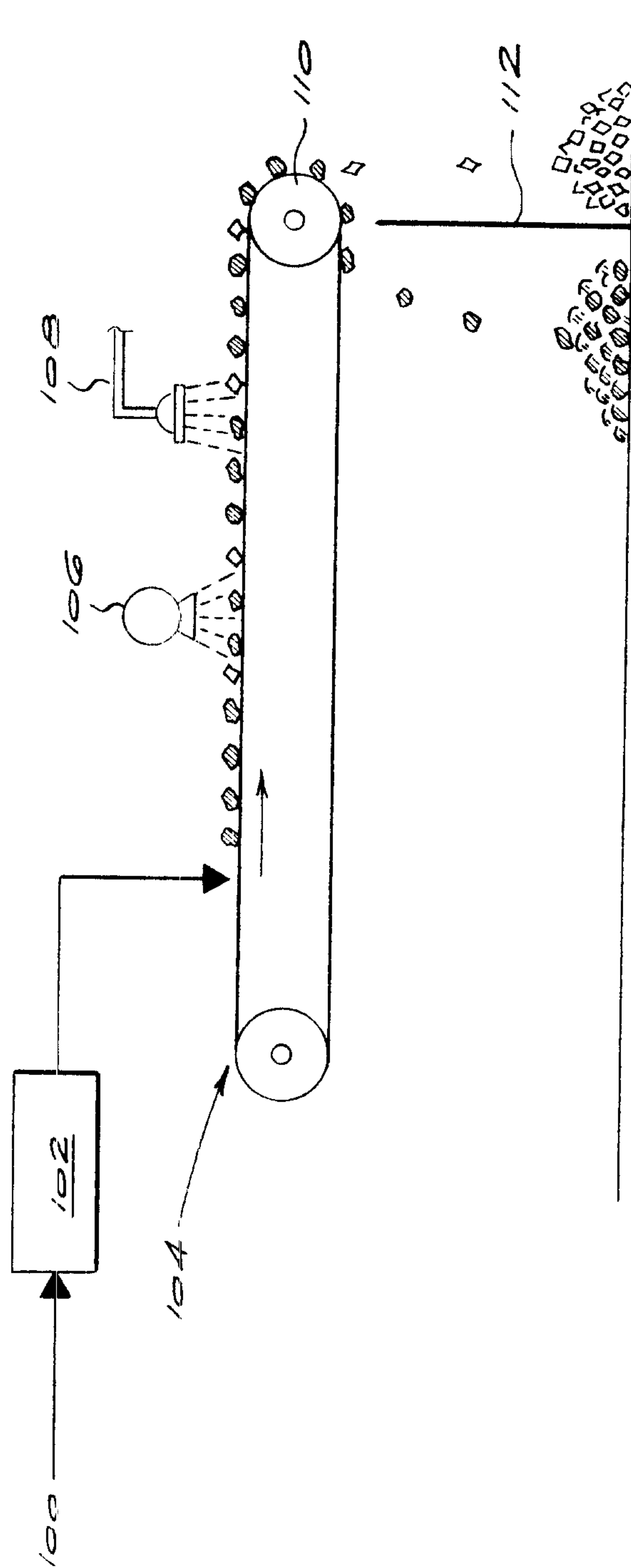


FIG 2

