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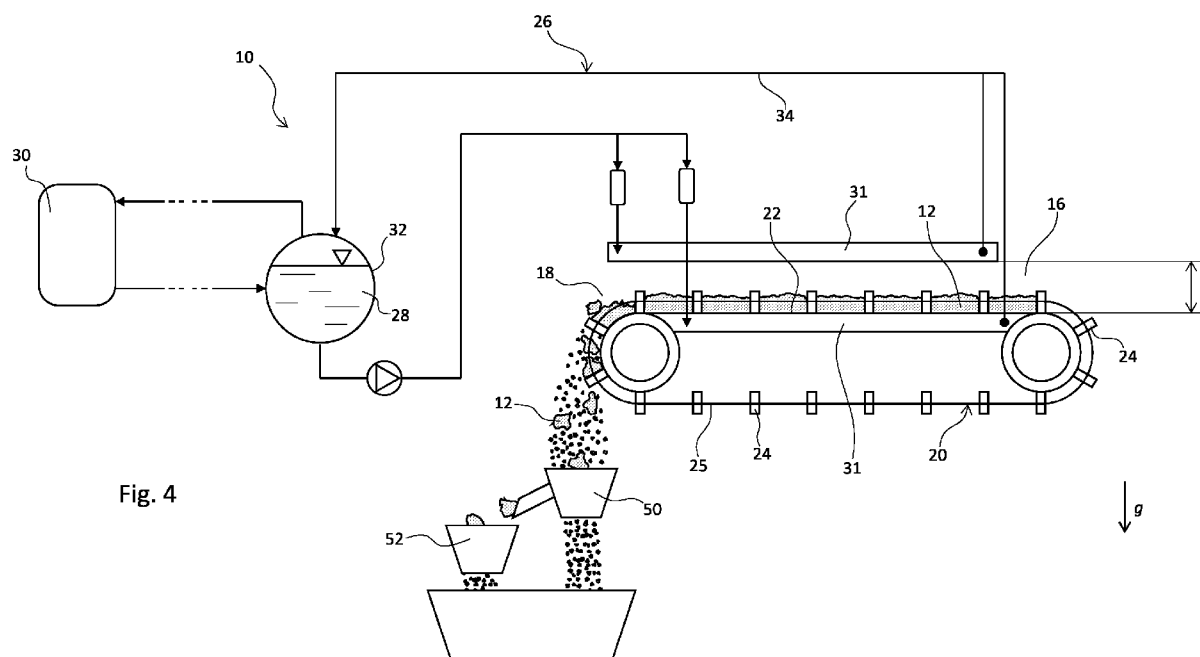


Fig. 4

(57) Abstract: The invention relates to a device for removing the slag from the deslagging area of a furnace and for recovering thermal energy from the slag. The device comprises: - a loading zone, which receives the hot liquid slag; - an unloading zone, which releases the cooled solid slag; - a dragging conveyor extending from the loading zone to the unloading zone and which comprises: - a support surface supporting the slag; and - a plurality of dragging elements dragging the slag; - a thermal exchange circuit which extends along the dragging conveyor and which comprises a thermal carrier fluid suitable for absorbing part of the heat in the slag and to render it available for a user device. In accordance with a second aspect, the invention relates to a steelmaking plant comprising a furnace and a device according to the invention. In accordance with a third aspect, the invention relates to a method for removing the slag and for recovering thermal energy from the slag.



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DEVICE AND METHOD FOR RECOVERING THERMAL ENERGY FROM STEELMAKING SLAG

The present invention relates to a device and a method for recovering thermal energy from steelmaking slag.

The following discussion refers in particular to the steelmaking cycle, even more particularly to the production cycle using Electric Arc Furnaces, or EAF. However, the intention is to clarify that this reference is purely by way of a non-limiting example. The invention can in fact be used in a similar way in other fields with similar characteristics. For example, the invention could be used downstream of the waste-to-energy cycle, where the removal of high temperature ashes is required. Furthermore, the invention could be used in steelmaking through the integrated blast furnace route, where high temperature blast furnace slag is produced.

In a manner widely known *per se*, steelmaking in the EAF furnace results in the production of slag which is found to float above the molten steel bath. The furnace itself is designed for expelling the slag (or deslagging) which must then be removed and disposed of. The following table shows the typical composition of the slag coming from an EAF plant.

Components	Min-max interval [%]
Iron – FeO	24-42
Calcium – CaO	30-36
Silicon – SiO ₂	10-18
Aluminium – Al ₂ O ₃	4-10
Magnesium – MgO	1-9
Manganese - MnO	4-8
Other	traces

Given the discontinuous nature of steelmaking in EAF plants, the slag must be disposed of at regular intervals, at each cycle time, in the form of large batches. Indicatively, the flow rate of the slag to be disposed of can

be considered in the order of a few tens of tons per hour. Traditionally, once the slag has been discharged in the liquid state from the furnace into a special container or tank, it is simply taken outside the foundry and discharged into special pits or yards where it is left to cool in the open air for the necessary time. This way of treating the slag only allows to recover the latter as an inert material. In fact, the solid slag, properly ground, can be usefully used as a filling material in civil works, such as road foundations, for example.

However, as the skilled person may well understand, the cooling of the slag in the open air is by no means an optimal procedure, neither from an energy point of view, nor from an environmental point of view. In fact, when discharged, the liquid slag includes a large amount of thermal energy, reaching temperatures above 1400 °C. In this regard, it is estimated that the slag contains in itself as much as 6% of the total thermal energy introduced into the steelmaking cycle through EAF. Furthermore, while cooling in the open air, the slag releases off-gases and vapours into the environment which not only dissipate thermal energy themselves, but are also polluting.

By virtue of the amount of energy involved, it can be well understood how the treatment of slag can represent an extremely interesting area of intervention to adapt steel mills to the most recent regulations on energy efficiency. At the same time, it is of fundamental importance to limit as much as possible, or cancel, the emission of pollutants, thereby obtaining also great results in terms of environmental protection.

A partial solution to this order of problems has been proposed by one of the two current proprietors, in the patent application published as WO 2013/186664. In this document, a cooling yard is described, into which the liquid slag can be discharged in the conventional way. The yard, outside the steel mill, is covered by a hood suitable for extracting the off-gases and vapours emitted by the slag, thereby solving the environmental problem. Furthermore, the bottom of the yard, the side walls, and the hood

itself include circuits for the circulation of cooling fluids suitable for removing the heat released by the slag and the related off-gases, thus recovering a share thereof.

This solution, even moving in the correct direction, is not able to fully solve
5 the problem of recovering thermal energy. In fact, in the cycle time that is available for the treatment of the slag, it cannot cool down, whether completely, or evenly. Due to its large volume, when the liquid slag is poured into the cooling yard described in WO 2013/186664, it is arranged in a layer of considerable thickness. The external portions of the slag
10 which are directly cooled by the ambient air flow or by the walls of the yard solidify relatively quickly. This way, an external shell of solid slag is quickly obtained, which encloses the remaining part of the slag, which inside is still in the liquid state and at high temperatures. However, the solid slag has an extremely low thermal conductivity which effectively prevents the
15 heat contained in the solid shell from being extracted in the cycle time.

Therefore, the object of the present invention is to overcome the drawbacks underlined before with respect to the prior art.

In particular, a purpose of the present invention is to make available a device and a method for removing the slag, which allow to recover most of
20 the thermal energy contained therein.

Furthermore, a purpose of the present invention is to make available a device and a method for removing the slag, which at the same time allow an adequate recovery of the off-gases, in order to limit the environmental impact of the process.

25 Furthermore, a purpose of the present invention is to make available a device and a method for removing the slag, which at the same time allow to obtain solid slag having mechanical characteristics suitable for the reuse thereof.

Finally, a purpose of the present invention is to make available a device
30 and a method for removing the slag, which allow to maintain at least partially the advantages already achieved in this field by the known

solutions.

This object and these purposes are achieved by a device according to claim 1, and by a method according to claim 12. Further advantages can be obtained by the optional features set forth in the dependent claims.

5 To better understand the invention and appreciate its advantages, some of its exemplifying and non-limiting embodiments are described below with reference to the accompanying drawings, wherein:

- Figure 1 shows a partially sectional schematic side view of a steelmaking plant comprising an electric arc furnace and a device for removing the slag
10 according to the prior art;
- Figure 2 shows a partially sectional schematic side view of a steelmaking plant comprising an electric arc furnace and a device for removing the slag according to the invention;
- Figure 3 shows a variation of the steelmaking plant according to the
15 invention;
- Figure 4 shows a schematic side view of the device for removing the slag according to the invention.

In accordance with a first aspect, the invention relates to a device 10 for removing the slag 12 from the deslagging area 15 of a furnace 14 and for
20 recovering thermal energy from the slag 12. The device 10 according to the invention comprises:

- a loading zone 16, suitable for receiving the hot slag 12 in an at least partially liquid state;
- an unloading zone 18, suitable for releasing the cooled slag 12 in an at
25 least partially solid state;
- a dragging conveyor 20 extending from the loading zone 16 to the unloading zone 18 and which comprises:
 - a support surface 22 suitable for supporting the slag 12; and
 - at least one dragging element 24 suitable for dragging the slag 12
30 along the support surface 22;
- at least one thermal exchange circuit 26 which extends at least partially

along the dragging conveyor 20 and which comprises a thermal carrier fluid 28 suitable for absorbing part of the heat contained in the slag 12 and to render it available for a user device 30.

In the context of the present discussion, some terminological conventions
5 have been adopted in order to make reading easier and smoother. Such terminological conventions are clarified below, also with reference to the accompanying figures.

Since the invention is designed to be used in presence of gravitational acceleration g , it is intended that the latter uniquely defines the vertical
10 direction. Likewise, it is understood that, based on gravity acceleration g , the terms “high”, “higher”, “above” and the like are defined unequivocally, with respect to the terms “low”, “lower”, “below” and the like.

“Cycle time” refers to the time which, when the EAF furnace works at full speed, elapses between two similar and subsequent steps. For example,
15 the cycle time is the one elapsing between the deslagging of the cycle n and the deslagging of the next cycle $n+1$. By way of example, an average cycle time could be considered to be approximately 50 minutes.

“Hot slag” refers to the slag 12 just removed from the Electric Arc Furnace 14 (EAF). Inside the furnace 14, in order to achieve the melting of the steel
20 40, the temperature must be higher than 1400 °C, preferably higher than 1500 °C. Therefore, it can be considered that the temperature of the hot slag is at least 1300 °C. Due to its variable and irregular composition, it is not possible to accurately characterize the state of the slag 12 as a function of the temperature, although at these temperatures the slag 12
25 behaves like a very viscous liquid.

“Cooled slag” refers to the slag 12 at the end of the heat recovery treatment performed using the invention. Following a number of considerations, relating for example to the advantageous temperature levels for the thermal carrier fluids 28 and for the user devices 30, to the
30 size of the device 10 in relation to the remaining parts of the steelmaking plant 32, and to the extent of the thermal exchange possible in the cycle

time, the Applicants have identified the temperature of 500 °C as a suitable threshold for defining an appropriate cooling of the slag 12. Furthermore, the Applicants have identified the temperature of 300 °C as a suitable threshold for defining an optimal cooling of the slag 12. Obviously, a more intense cooling is also possible, which would allow a greater amount of heat to be recovered; however, it would lead to times that are difficult to match with the cycle time and/or to sizes of the device 10 that are difficult to match with normal steelmaking plants 32. It should also be considered that the additional heat share would be made available using rather low temperatures of the thermal carrier fluid 28, which low temperatures are difficult to exploit industrially. For the purposes of the present discussion, it is therefore considered that the cooled slag has a temperature equal to or lower than 500 °C, preferably equal to or lower than 300 °C. Due to its variable and irregular composition, it is not possible to accurately characterize the state of the slag 12 as a function of the temperature, although at these temperatures the slag 12 is solid and friable.

The dragging conveyors 20 or drag chain conveyors are devices known in the industrial field, for example for the transport of minerals or inert materials. In general, these dragging conveyors 20 comprise a support surface 22, usually delimited by longitudinal side walls to form a channel. Along the support surface 22, dragging elements 24 move, for example mounted at regular intervals along one or more drag chains 25. The dragging elements 24 usually take the form of bulkheads extending through the channel formed by the support surface 22 and the longitudinal side walls. The motion of the chains 25 drags the dragging elements 24, thereby imposing the same motion along the support surface 22 also to the material comprised between two subsequent dragging elements 24.

As regards the device 10 of the invention, some construction choices, although not strictly necessary, are particularly advantageous for making the dragging conveyor 20 suitable for the specific conditions of use. It

should be noted that the representations of the dragging conveyor 20 in the accompanying figures are schematic and, being not to scale, they do not correctly represent the proportions between the different parts and dimensions of the dragging conveyor 20.

- 5 It is preferable that the dragging conveyor 20 comprises two drag chains 25, arranged on the sides of the support surface 22, so that there are no moving parts along the centre line of the dragging conveyor 20, *i.e.* where the slag 12 remains for a long time at a higher temperature.

It is also preferable that the dragging conveyor 20 has a limited width. In
10 fact, due to the lateral arrangement of the two drag chains 25, it is preferable to limit the size of the dragging elements 24, so that they are not subjected to excessive stresses.

Furthermore, a not too large width of the dragging conveyor 20 makes it easier to achieve an even distribution of the slag 12 on the support surface
15 22.

The area of the dragging conveyor 20 must be defined considering the typical parameters of thermal exchange phenomena occurring in the device 10, the flow rate of the slag 12 to be disposed of over the cycle time, and the need to cool the slag 12 down to at least 500 °C, preferably
20 down to 300 °C. As a result, once the width to limit the stresses imposed on the dragging elements 24 has been defined, it is possible to define the length of the dragging conveyor 20.

Advantageously, the support surface 22 is made of materials resistant to wear and high temperatures. Preferably, the initial part of the support
25 surface 22, *i.e.* the one near the loading zone 16, is at least partially made of or covered by a ceramic material (*e.g.*, alumina Al_2O_3). The part of the support surface 22 made of or covered by a ceramic material can extend, for example, for the first 5 m, or for the first 10 m from the loading zone 16 towards the unloading zone 18. As mentioned above, the liquid slag 12 is
30 collected in this zone at temperatures approaching 1300-1500 °C. Alumina is particularly suitable for use in this zone of the support surface 22

because of its high thermal conductivity, comparable to that of steel, and its high resistance, both to high temperatures and abrasion.

Furthermore, during the deslagging it is probable that, in addition to the slag 12, also a small amount of molten steel, which by gravity remains
5 below the slag, will come out of the furnace. The molten steel thus comes into direct contact with the support surface 22. If the latter were made of steel, adhesion phenomena or actual welding between the liquid steel and the support surface 22 at high temperature would easily occur. This would lead to the accumulation of unwanted metal masses on the support
10 surface 22. As the work cycles increase, it would be at first difficult, and then impossible to make the slag 12 slide smoothly on the support surface 22. The presence of alumina near the loading zone 16 prevents any adhesion or welding from occurring, maintaining the efficiency of the support surface 22.

15 Advantageously, the remaining part of the support surface 22 can be made of a steel resistant to high temperatures, such as stainless steel (e.g. AISI 430). In fact, on the remaining part of the support surface 22, any steel that was interspersed with the slag would have reached a temperature too low to cause phenomena of welding, or even just of
20 adhesion.

In some embodiments, if the thermal recovery is particularly pushed so as to obtain a particularly low final temperature of the slag 12, the final section of the support surface 22, *i.e.* the one near the unloading zone 18, can be made of common steel (construction steel). This choice proves to
25 be advantageous if the temperature of the slag 12 falls below 400 °C.

The speed with which the dragging elements 24 of the dragging conveyor 20 move along the support surface 22, and consequently the moving speed of the slag 12, must be determined as a function of the width of the dragging conveyor 20, in order to guarantee an appropriate flow rate to
30 dispose of the entire batch of slag 12 produced in each cycle time.

Preferably, the dragging conveyor 20 is arranged in such a way that the

support surface 22 is arranged horizontally, as can be seen from the accompanying figures. Alternatively, to meet specific needs, the support surface 22 can be arranged with a predetermined slope, so that the loading zone 16 is higher than the unloading zone 18.

5 As already reported above, the dragging conveyor 20 of the device 10 according to the invention also comprises a thermal exchange circuit 26. The thermal exchange circuit 26 extends over a significant portion of the area of the dragging conveyor 20. As the skilled person can well understand, the fact that the thermal exchange circuit 26 extends over a
10 significant portion of the area of the dragging conveyor 20 is a feature which helps to maximize the passage of heat from the slag 12 to the thermal carrier fluid 28.

The thermal carrier fluid 28, in turn, is suitable for absorbing a substantial part of the heat released by the slag 12 and for transporting it elsewhere to
15 make it available to one or more user devices 30. Some user devices 30 suitable for being powered by the thermal exchange circuit 26 of the invention will be described in greater detail below.

Among the various thermal carrier fluids 28 commonly used industrially for cooling parts at high temperature, the studies conducted by the Applicants
20 have led to believe that the boiling overheated water under pressure is the most suitable one. Notably, the use of water having a temperature and pressure at which the liquid phase and the vapour phase are in equilibrium has proved to be particularly advantageous. The only disadvantage of using water as the thermal carrier fluid 28 is related to the measures that
25 are necessary to guarantee the safety of the plant. However, the long experience gathered in the field of pressure plants allows to easily avoid, with wide safety margins, any loss of water/steam under pressure. Notably, it is necessary to pay attention on preventing water from coming into direct contact with the slag 12. Other thermal carrier fluids 28,
30 although less advantageous, can be used, *e.g.* diathermic oil, air, and air under pressure.

Preferably, the thermal exchange circuit 26 comprises at least one heat absorption portion 31, a heat storage 32 and specific ducts 34 suitable for circulating the thermal carrier fluid 28 from the at least one heat absorption portion 31 to the heat storage 32 and vice versa. The heat absorption portion 31 may advantageously comprise one or more coils and/or one or more arrays of pipes.

In some embodiments, a heat absorption portion 31 is arranged below the support surface 22, in contact therewith, and extends over a significant portion of the area of the support surface 22 itself. The various sections of pipe, coils or arrays of pipes are preferably arranged at a distance from each other such as to remove the heat substantially evenly. This allows to prevent the formation of excessively hot spots on the support surface 22.

The heat absorption portion 31 arranged under the support surface 22 receives a large amount of heat from the slag 12, transmitted mainly by conduction through the material the support surface 22 is made of and/or is covered by.

In some embodiments, a heat absorption portion 31 is arranged above the support surface 22, placed at a distance d therefrom, and extends over a significant portion of the area of the support surface 22 itself. The distance d between the support surface 22 and the heat absorption portion 31 placed above it must be such as to allow an appropriate heat transmission and, at the same time, to avoid any possible interference with the dragging conveyor 20. By way of example, the distance d can be comprised between 0.5 m and 1.5 m. Also in this case, the heat absorption portion 31 can advantageously comprise a coil or an array of pipes. The various pipe sections are preferably arranged at a distance from each other such as to remove the heat substantially evenly.

The heat absorption portion 31 arranged over the support surface 22 receives a large amount of heat from the slag 12, transmitted mainly by radiation and by convection.

Preferably, the thermal exchange circuit 26 comprises two heat absorption

portions 31: a first heat absorption portion 31 arranged below the support surface 22 in contact therewith, and a second heat absorption portion 31 arranged above the support surface 22 at a distance d therefrom.

The thermal exchange circuit 26 preferably comprises a heat storage 32.

5 The thermal carrier fluid 28, which carries with it the heat extracted from the slag 12, arrives into the heat storage 32 through the ducts 34. Especially in the case where the thermal carrier fluid 28 is boiling overheated water under pressure, the heat storage 32 may advantageously comprise a steam drum, widely known *per se*. In other
10 cases, the heat storage 32 can take different forms. For example, if the thermal carrier fluid 28 is diathermic oil, the heat storage 32 may advantageously comprise one or more reservoirs, *e.g.* a plurality of reservoirs at different temperatures from each other, or a single reservoir with thermocline.

15 A power supply circuit for one or more user devices 30 advantageously departs from the heat storage 32.

A user device 30 may be, for example, a system for the exploitation of heat for the purpose of air-conditioning rooms, both directly to obtain the heating thereof, and to obtain the cooling thereof by means of an
20 absorption-type refrigeration cycle.

A particularly useful use of the heat collected in the heat storage 32 is the one intended for preheating the ferrous scrap destined to be fed into the furnace 14. An efficient step of preheating the scrap can significantly reduce the amount of energy that must be introduced into the furnace 14,
25 in the form of electricity or fuel, to bring the steel charge to melting. It is thus possible to obtain a containment of costs, energy consumption and emissions associated with the processing cycle. This use of heat is particularly advantageous because it occurs within the same industrial plant, avoiding the losses inevitably associated with the transport and
30 transformation of energy.

Furthermore, a particularly advantageous user device 30 is a turbine plant

of the organic fluid Rankine cycle type (Organic Rankine Cycle, or ORC). This type of system is particularly suitable considering the temperature level at which the recovered heat is made available and the resulting relatively limited available enthalpy jump. As known, an ORC turbine plant works with a cycle similar to a classic water vapour cycle in which, however, the working fluid is one of the so-called "organic fluids", typically hydrocarbons (HC), hydrofluorocarbons (HFC), or fluorocarbons (FC). The ORC turbine plant may be advantageously used for the production of electricity. In the working conditions considered for the device 10 of the invention, the ORC turbine plant can reach an electrical efficiency of about 20%. In turn, the ORC cycle further requires its own cooling circuit which can make water available at around 80-90 °C or, if a maximization of the production of electricity is desired, at lower temperatures, of around 30-40 °C. The water at these temperatures may still be used for room heating, in an industrial or civil environment, and/or for the production of sanitary hot water.

Furthermore, another particularly advantageous user device 30 is a turbine of the steam Rankine cycle type, operating directly with the steam which can be withdrawn from the heat storage 32. This type of plant also requires its own cooling circuit with features similar to the previous one.

In accordance with another aspect, the invention relates to a steelmaking plant 32 comprising a furnace 14 and a device 10 for removing the slag 12 from the deslagging area 15 of the furnace 14 and for recovering thermal energy from the slag 12 itself, as described above.

Preferably, the device 10 is placed in proximity of the furnace 14.

Preferably, the furnace 14 is an electric arc furnace, or EAF. In a way known *per se*, the furnace 14 comprises a deslagging mouth 36 from which the slag 12 is poured to remove it from the molten steel bath 40. In steelmaking plants of the known type (see, for example, the diagram in Figure 1), a bucket 38 (or other similar device) suitable for receiving the slag 12 and transporting it to the cooling zone outside the plant may be

placed below the deslagging mouth 36, in the deslagging area 15. Therefore, in a known way, by tilting the furnace 14, it is possible to unload the slag 12 floating over the molten steel bath 40 into the bucket 38.

In accordance with some embodiments of the steelmaking plant 32 according to the invention, the loading zone 16 of the device 10 is located under the deslagging mouth 36, in the deslagging area 15, where the bucket 38 is located in the common plants. Therefore, in this type of steelmaking plant 32 according to the invention, by tilting the furnace 14, it is possible to unload the slag 12 directly into the loading zone 16 of the device 10.

In accordance with some embodiments, the steelmaking plant 32 according to the invention further comprises a metering pot 42, located in the deslagging area 15, between the furnace 14 and the device 10. The metering pot 42 is suitable for receiving the entire batch of slag 12 unloaded from the furnace 14 all at once and pouring it in a controlled manner into the loading zone 16 of the device 10. The importance of pouring the slag 12 in a controlled manner will be better explained below, referring to the method according to the invention. However, the skilled person can already well understand how difficult it can be to pour in a controlled manner the slag 12 directly from the deslagging mouth 36 of the furnace 14. The furnace 14 is, in fact, designed and built to quickly deslag, *i.e.* to expel the slag 12 all at once and in an uncontrolled manner. By contrast, the metering pot 42 is designed and built so as to be able to easily pour the slag 12 according to a controlled flow rate. Furthermore, the metering pot 42 is preferably designed and built so as to pour the slag 12 evenly along the entire width of the device 10. For example, the metering pot 42 is preferably designed and built so as to pour a slag blade having a width slightly less than the width of the dragging conveyor 20 and having a nearly even thickness along such width.

Preferably, the steelmaking plant 32 further comprises a suction system 44 for removing the off-gases deriving from deslagging and slag cooling

operations. In a manner known *per se*, each furnace 14 comprises its own suction system 44. The suction systems 44 may comprise, in a known manner *per se*, a hood 46, conduits 48, ventilation means and off-gas treatment systems (the latter not shown in the accompanying figures).

- 5 The fact that in the steelmaking plant 32 according to the invention, the device 10 is placed in proximity of the furnace 14, allows to provide the suction system 44 of the device 10 in an extremely simple way. In fact, the suction system 44 of the device 10 may easily merge into the similar suction system 44 already arranged for the furnace 14 and located in
- 10 close proximity. For example, the suction system of the device 10 may comprise a tunnel 47 enclosing the entire dragging conveyor 20. Preferably, the circulation of air inside the tunnel 47 is forced, which helps cooling the slag 12 and removing off-gases therefrom. The air filled with off-gases is then removed through a conduit 48 merging into the conduit
- 15 48 of the suction system 44 of the furnace 14. This possibility allows to exploit all the already arranged off-gas treatment systems, without the need of adding others, thereby limiting the complications and costs of the steelmaking plant 32 as a whole.

- In one embodiment, downstream of the unloading zone 18 of the device
- 20 10, the steelmaking plant 32 may further comprise means for treating the slag 12, such as typically a riddle 50 and a crusher 52. As already mentioned, the cooled slag 12 is solid and friable and takes the form of granules of various sizes. The riddle 50 is intended to separate the slag 12 based on the size of the granules and, preferably, it is suitable for feeding
- 25 into the crusher 52 the granules exceeding a predefined maximum size. The crusher 52 is therefore intended to crush the granules of slag 12 too large to make them suitable for the uses for which the slag 12 is intended. Once treated in this way, the slag 12 takes the form of an inert product having a controlled granulometry and can be usefully used, in a manner
- 30 known *per se*, in civil, construction or industrial uses.

In accordance with a further aspect, the invention relates to a method for

removing the slag 12 from the deslagging area 15 of a furnace 14 and for recovering thermal energy from the slag 12.

The method according to the invention comprises the following steps:

- providing a support surface 22;
- 5 - providing at least one thermal exchange circuit 26 which extends at least partially along the support surface 22 and which comprises a thermal carrier fluid 28;
- pouring the hot slag 12 in an at least partially liquid state on the support surface 22;
- 10 - controlling the pouring of the slag 12 so as to obtain a layer having a thickness smaller than 5 cm;
- absorbing part of the heat contained in the slag 12 by means of the thermal carrier fluid 28;
- rendering available the heat absorbed by the thermal carrier fluid 28 for a
15 user device 30;
- removing from the support surface 22 the cooled slag 12 in an at least partially solid state.

Preferably, in the method according to the invention, the thickness of the layer of slag 12 is smaller than 2.5 cm.

- 20 The studies conducted by the Applicants have highlighted the importance of arranging the slag 12 in a layer having a limited thickness. As already reported above referring to the prior art, in very thick deposits of slag 12, the relatively easy cooling of the external surfaces soon leads to the formation of a solid and substantially insulating shell. This way, the heat
25 contained within the slag 12 cannot be removed within the cycle time. The arrangement of the slag 12 in thin layers avoids this problem, allowing a nearly uniform, and therefore generally more efficient, cooling of the slag 12. Furthermore, it has been found that 5 cm represents the maximum thickness value which allows the temperature of the slag 12 to fall below a
30 predefined threshold, *e.g.* 500 °C, or even 300 °C, in a time compatible with an average cycle time.

- A first embodiment of the method could involve the steps of pouring all the slag 12 at once, to form a single layer having a small and controlled thickness, and allowing the slag 12 to cool down in the spot where it has been poured, recovering the heat thereof. Such solution would closely resemble the one known from WO 2013/186664, with an important difference in the control of the thickness of the layer of slag 12. In fact, in the known solution, the thickness was not subjected to any control, while, in the method of the present invention, it is important that the thickness of the layer of slag 12 is smaller than 5 cm, preferably smaller than 2.5 cm.
- However, as the skilled person may well understand, some tons of slag 12 arranged in a single layer having a thickness smaller than 5 cm or, especially, smaller than 2.5 cm, require a support surface 22 having huge size, certainly not suitable for being accommodated in a normal steelmaking plant 32. Furthermore, in this case, the problem arises of how to control the pouring of the liquid slag 12 over such a large area. Furthermore, the thermal exchange circuit 26 must extend over a significant part of the support surface 22 in order to be able to recover a significant part of the heat contained in the slag 12. In other words, the wider the support surface 22 is, the wider should be the thermal exchange circuit 26, or at least its heat absorption portion 31, with the resulting difficulties of realization.
- Finally, such a system would operate with temperatures of the materials cyclically oscillating at all spots between the maximum values when receiving the slag 12 and minimum values after unloading the slag 12. As the skilled person well understands, a cyclical thermal stress with such high temperature differences has a negative impact on the resistance of materials and structures over time. Such a system would therefore require the use of high-quality materials on the entire support surface 22, in order to withstand the strong cyclical thermal stresses.
- For the reasons briefly explained above, the method according to the invention preferably also comprises the step of providing a device 10 for

removing the slag 12 and for recovering thermal energy, as previously described. Notably, by arranging a device 10 according to the invention comprising a dragging conveyor 20, the method is simplified. In fact, the step of pouring the slag 12 can always be carried out in the same point,
5 *i.e.* in the loading zone 16 of the device 10. The poured slag 12 does not accumulate because the dragging conveyor 20 carries out the further step of dragging the slag 12 along the support surface 22.

Furthermore, when fully operating, the temperatures of the materials along the dragging conveyor 20 can become substantially constant over time, in
10 the presence of a continuous flow of the slag 12. This way, the cyclical thermal stresses described above are avoided, with significant advantages from the point of view of material strain and facility life time.

Preferably, the method according to the invention also comprises one or more of the following additional steps.

- 15 - Providing the device 10 near a furnace 14, so as to form a steelmaking plant 32 in accordance with what has been previously described.
- Providing, between the furnace 14 and the device 10, a metering pot 42 in accordance with what has been previously described.
- Pouring the slag 12 from the furnace 14 into the metering pot 42 all at
20 once, without any control.
- Pouring the slag 12 from the metering pot 42 into the loading zone 16 of the device 10, checking the thickness of the layer of slag 12 that forms on the support surface 22.
- Pouring the slag 12 from the metering pot 42 into the loading zone 16 of
25 the device 10, checking the width of the blade of poured slag 12 so that it is slightly smaller than the width of the dragging conveyor 20.
- Providing an off-gas suction system 44 comprising a tunnel 47 arranged around the dragging conveyor 20 in accordance with what has been described above.
- 30 - Providing a user device 30, such as, for example, an ORC turbine system.

- Providing the user device 30 with part of the heat absorbed by the thermal carrier fluid 28 included in the thermal exchange circuit 26.

- Providing, downstream of the unloading zone 18 of the device 10, a riddle 50 suitable for separating the slag 12 based on the size of the granules.

- Providing, downstream of the riddle 50, a crusher 52 suitable for crushing the granules of slag 12.

- Using the riddle 50, feeding the granules of slag 12 exceeding a predefined maximum size into the crusher 52.

10 EXAMPLE

Merely by way of example, the numerical data relating to a specific steelmaking plant 32 and to its device 10 for removing the slag 12 and for recovering thermal energy from the slag 12 in accordance with the invention are set forth below.

15 Furnace: electric arc or EAF

Cycle time: 30 minutes

Mass of the single batch of slag: 20 tons

Maximum thickness of the slag: 20 mm

Average thickness of the slag: 18 mm

20 Initial temperature of the slag 1500 °C

Final temperature of the slag 500 °C

Width of the dragging conveyor: 1.9 m

Length of the dragging conveyor: 27 m

Speed of the dragging conveyor: 0.1 m/s

25 Heat absorption portion: double, lower, and upper

Distance d : 1 m

Temperature of the cooling water: 224 °C

Pressure of the cooling water: 2.5 MPa (25 bar)

Thermal power recovered: about 12 MW

30 As the skilled person can easily understand, the invention allows to overcome the drawbacks highlighted previously with reference to the prior

art.

Notably, the present invention makes available a device 10 and a method for removing the slag 12, which allow to recover most of the thermal energy contained therein.

- 5 Furthermore, the present invention makes available a device 10 and a method for removing the slag 12, which at the same time allow an adequate recovery of the off-gases, in order to limit the environmental impact of the process.

- 10 Furthermore, the present invention makes available a device 10 and a method for removing the slag 12, which at the same time allow to obtain solid slag having uniform mechanical features suitable for the reuse thereof.

- 15 Finally, the present invention makes available a device 10 and a method for removing the slag 12, which allow to maintain at least partially the advantages already achieved in this field by the known solutions.

- It is understood that the specific features are described in relation to different embodiments of the invention by way of non-limiting examples. Obviously, one skilled in the art will be able to make further modifications and variations to the present invention, in order to satisfy contingent and specific needs. For example, the technical features described in relation to an embodiment of the invention may be extrapolated from it and applied to other embodiments of the invention. Such modifications and variations are also contained within the scope of the invention, as defined by the following claims.

CLAIMS

1. Device (10) for removing the slag (12) from a deslagging area (15) of a furnace (14) and for recovering thermal energy from the slag (12), comprising:
- 5 - a loading zone (16), suitable for receiving the hot slag (12) in an at least partially liquid state;
- an unloading zone (18), suitable for releasing the cooled slag (12) in an at least partially solid state;
- a dragging conveyor (20) extending from the loading zone (16) to the
- 10 unloading zone (18) and which comprises:
- a support surface (22) suitable for supporting the slag (12); and
- at least one dragging element (24) suitable for dragging the slag (12) along the support surface (22);
- at least one thermal exchange circuit (26) which extends at least partially
- 15 along the dragging conveyor (20) and which comprises a thermal carrier fluid (28) suitable for absorbing part of the heat contained in the slag (12) and to render it available for a user device (30).
2. Device (10) according to claim 1, wherein the portion of the support surface (22) near the loading zone (16) is at least partially made of or
- 20 covered by a ceramic material, preferably alumina (Al_2O_3).
3. Device (10) according to claim 1 or 2, wherein the thermal carrier fluid (28) is water and wherein the thermal exchange circuit (26) is suitable for containing boiling overheated water under pressure.
4. Device (10) according to one or more of the preceding claims, wherein
- 25 the thermal exchange circuit (26) comprises at least one heat absorption portion (31), a heat storage (32) and specific ducts (34) suitable for circulating the thermal carrier fluid (28) from the at least one heat absorption portion (31) to the heat storage (32) and vice versa.
5. Device (10) according to the preceding claim, wherein a heat absorption
- 30 portion (31) is provided under the support surface (22), in contact with it.
6. Device (10) according to claim 4 or 5, wherein a heat absorption portion

(31) is provided over the support surface (22), placed at a distance d from it, d being preferably comprised between 0.5 m and 1.5 m.

7. Steelmaking plant (32) comprising a furnace (14) and a device (10) according to one or more of the preceding claims.

5 8. Steelmaking plant (32) according to claim 7, wherein the device (10) is placed in proximity of the furnace (14).

9. Steelmaking plant (32) according to claim 7 or 8, further comprising a metering pot (42), placed between the furnace (14) and the device (10), suitable for receiving the entire batch of slag (12) discharged from the
10 furnace (14) and for pouring it in a controlled manner in the loading zone (16) of the device (10).

10. Steelmaking plant (32) according to one or more of claims 7 to 9, further comprising a system (44) for suction of off-gases deriving from deslagging and from slag cooling operations.

15 11. Steelmaking plant (32) according to one or more of claims 7 to 10, further comprising a riddle (50) downstream the unloading zone (18) of the device (10).

12. Steelmaking plant (32) according to claim 11, further comprising a crusher (52) downstream the riddle (50).

20 13. Method for removing slag (12) from a deslagging area (15) of a furnace (14) and for recovering thermal energy from the slag (12), the method comprising the steps of:

- providing a support surface (22);
- providing at least one thermal exchange circuit (26) which extends at
25 least partially along the support surface (22) and which comprises a thermal carrier fluid (28);
- pouring the hot slag (12) in an at least partially liquid state on the support surface (22);
- controlling the pouring of the slag (12) so as to obtain a layer having a
30 thickness smaller than 5 cm;
- absorbing part of the heat contained in the slag (12) by means of the

thermal carrier fluid (28);

- rendering available the heat absorbed by the thermal carrier fluid (28) for a user device (30); and

- removing from the support surface (22) the cooled slag (12) in an at least partially solid state.

14. Method according to claim 13, further comprising the step of controlling the pouring of the slag (12) so as to obtain a layer with a thickness smaller than 2.5 cm.

15. Method according to claim 14, wherein the step of controlling the pouring of the slag (12) comprises the use of a metering pot (42) placed between the furnace (14) and the support surface (22).

16. Method according to one or more of claims 13 to 15, further comprising the step of providing a device (10) according to one or more of claims 1 to 6.

17. Method according to one or more of claims 13 to 16, further comprising the step of providing a steelmaking plant (32) according to one or more of claims 7 to 12.

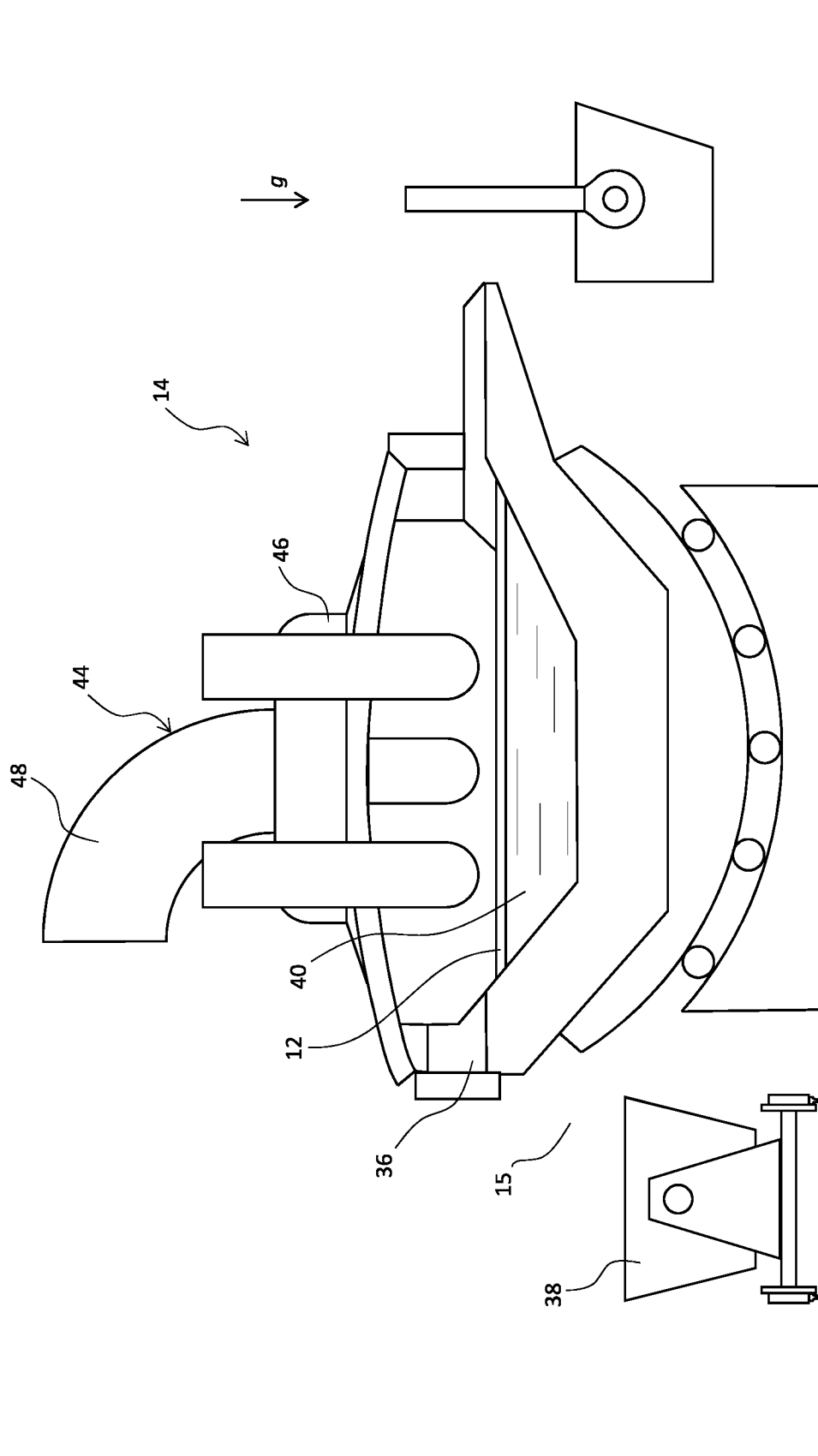


Fig. 1

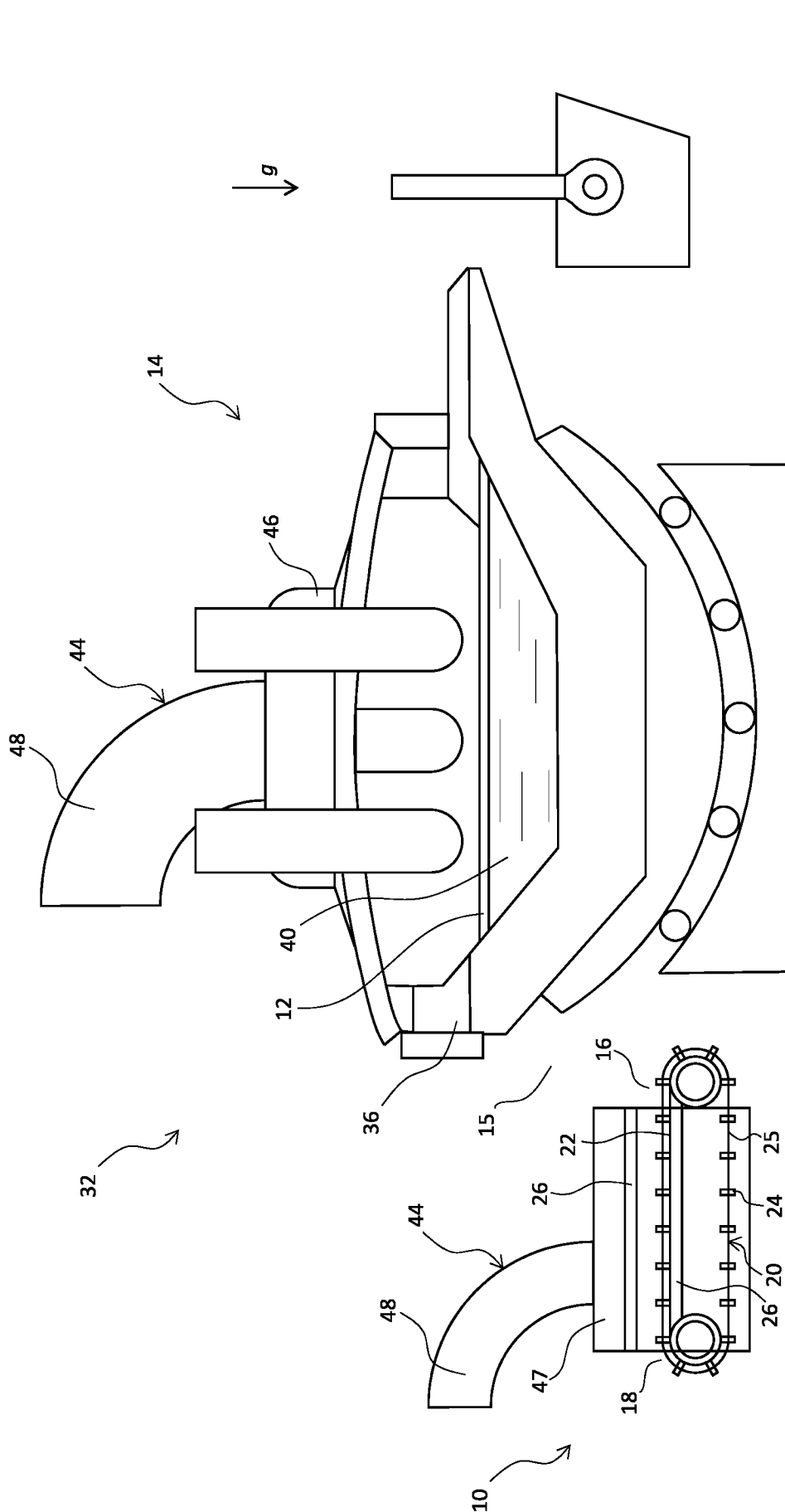


Fig. 2

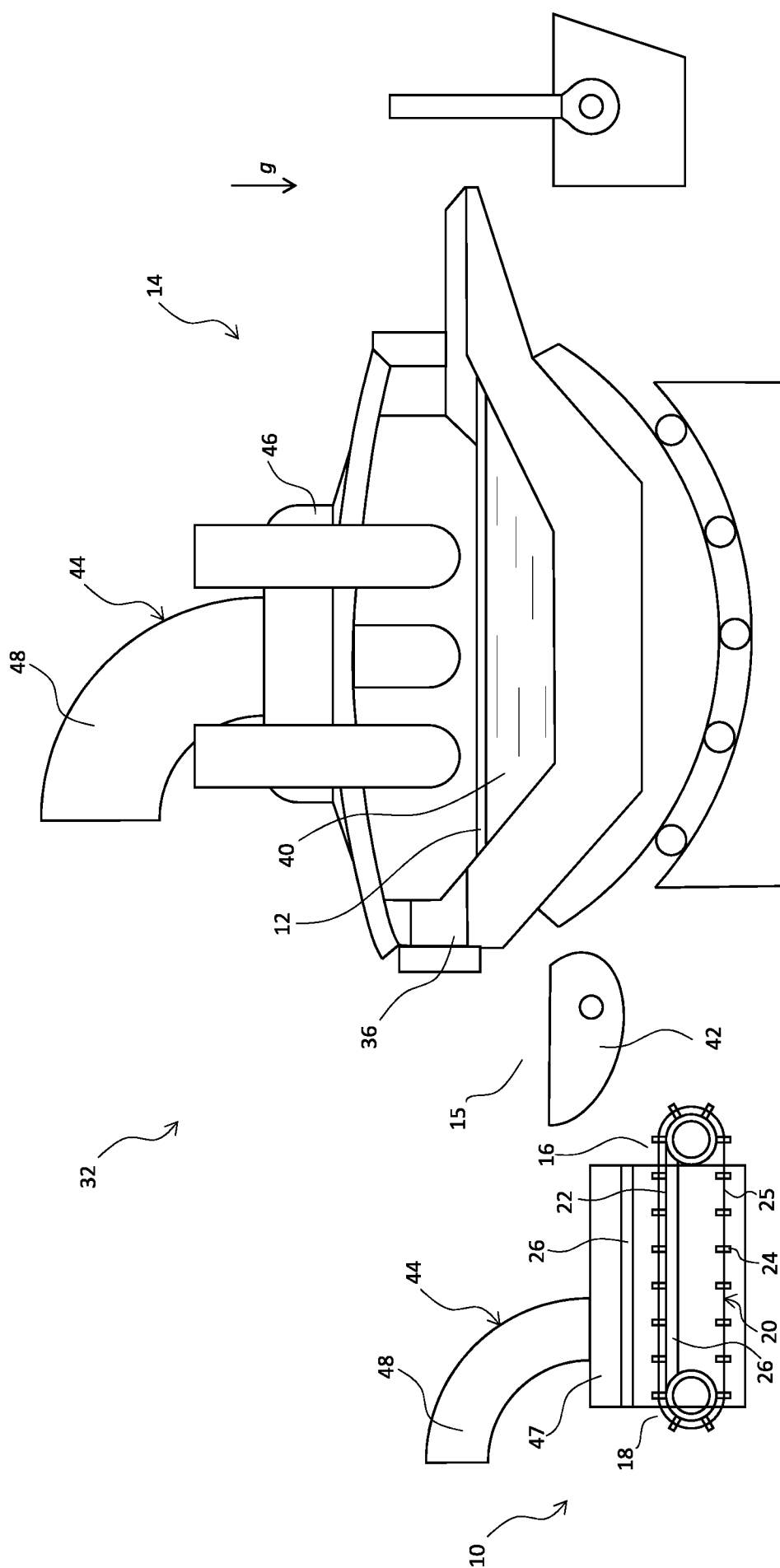


Fig. 3

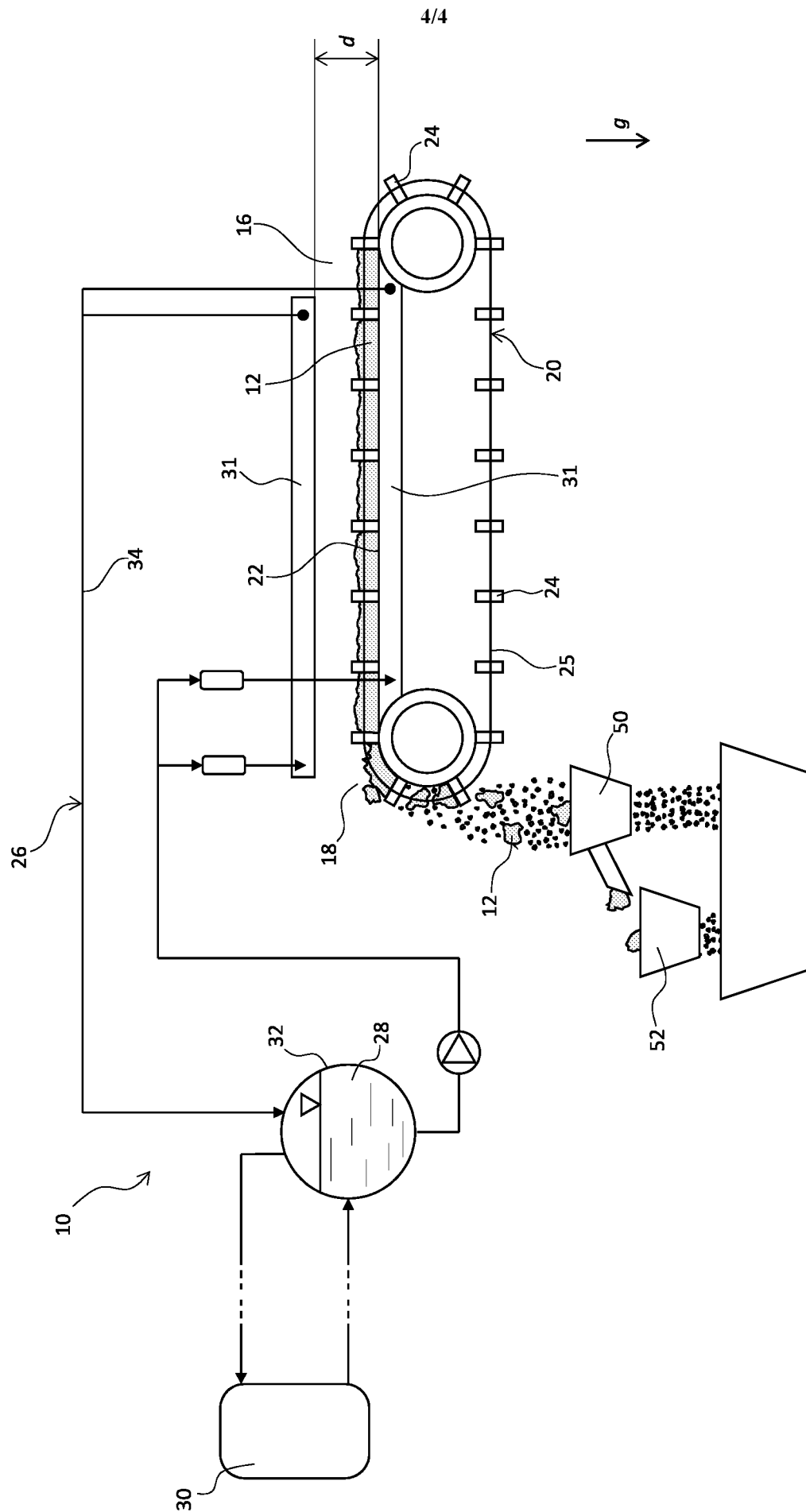


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/051431

A. CLASSIFICATION OF SUBJECT MATTER

INV. C21B3/08 F27D3/15 F27D15/02 F27D17/00
ADD.

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)

C21B F27D C21C

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)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 108 913 828 A (GUO JIN) 30 November 2018 (2018-11-30)	1-12
A	figures 1, 2 the whole document	13-17
X	DE 10 2012 010808 A1 (KME GERMANY GMBH & CO KG [DE]) 5 December 2013 (2013-12-05) figures 1, 2, 3, 5, 6 paragraph [0001] paragraph [0003] - paragraph [0004] paragraph [0006] - paragraph [0007] paragraph [0010] paragraph [0051] - paragraph [0058]	1-17
X	CN 108 411 117 A (UNIV ANHUI TECHNOLOGY) 17 August 2018 (2018-08-17)	1
A	figures 1, 4 the whole document	2-17

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"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)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search

12 May 2020

Date of mailing of the international search report

25/05/2020

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2020/051431

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 108913828 A	30-11-2018	NONE	

DE 102012010808 A1	05-12-2013	DE 102012010808 A1	05-12-2013
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