



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
09.10.2013 Bulletin 2013/41

(51) Int Cl.:
F26B 3/14 (2006.01) **F26B 17/12** (2006.01)
F26B 21/04 (2006.01) **F26B 25/00** (2006.01)

(21) Application number: **12163049.5**

(22) Date of filing: **03.04.2012**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

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(54) **Grain drying arrangement and method for drying grain**

(57) The present invention relates to a grain drying arrangement (100), comprising a container (102), a drying zone (108), and a cooling zone (110), a first air inlet (116) and a first air outlet (122) which are in communication with said drying zone (108), a second air inlet (132) and a second air outlet (130) which are in communication with said cooling zone (110), a heating device (120), and a particle removal arrangement (400), wherein at least a portion of at least one of said first air outlet (122) and said second air outlet (130) is in communication with said

first air inlet (116) so that at least a portion of said air discharged from said drying zone (108) and/or said cooling zone (110) is provided to said first air inlet (116), and wherein said particle removal arrangement (400) is provided between at least one of said first (122) and said second (130) air outlets and said first air inlet (116), such that said portion of said air discharged from said drying zone (108) and/or said cooling zone (110) will pass said particle removal arrangement (400) prior to being provided to said first air inlet (116).

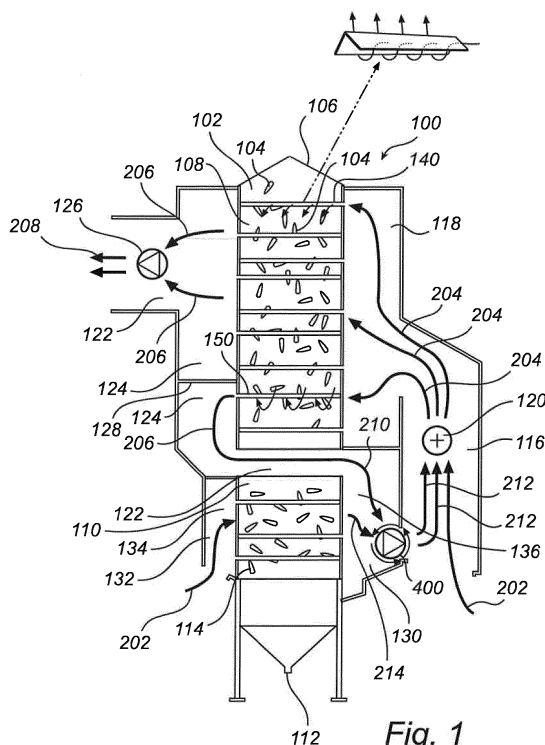


Fig. 1

Description

Field of the Invention

[0001] The present invention relates to the field of grain drying, and more specifically to an arrangement adapted for using utilized air when drying grain. The present invention also relates to a method of drying grain using the above arrangement.

Background of the Invention

[0002] In order to be able to store grain received from the harvest work, it is most often necessary to reduce the water content of the grain before storing it, in order to minimize the risk of e.g. mould formation in the grain. By drying the grain prior to storing it, the content of water in the grain can be reduced to such an amount that the grain can be stored safely without the risk of e.g. mould formation being produced.

[0003] A typical arrangement for drying grain comprises a container, where the wet and un-dried grain is provided through an inlet at an upper end of the container. The grain is thereafter intermittently transported downwardly inside the container while being dried and thereafter outputted through an outlet at a lower end of the container. Heated air is transported through the grain which at the moment resides in a drying zone of the container. The heated air can be transported through the grain in the drying zone by means of e.g. hot air inlet laterals and wet air outlet laterals arranged in the drying zone. Hence, the heated air transported to the grain via the hot air inlet laterals and away from the grain via the wet air outlet laterals dries the grain while passing through the grain in the drying zone. The heated air can, for example, be ambient air which is provided through a heater in order to increase its temperature and decrease its relative humidity to such levels that the grain is dried when the air is passing through the drying zone. Due to the difference in temperature and steam pressure between the heated air and the un-dried grain, the heated air is cooled off and humidified when being transported through the un-dried grain and outputted from the container as utilized air. A typical arrangement also comprises a cooling zone at a lower portion of the container where dried grain from the drying zone is cooled off by providing unheated air through the lower portion of the container so that the dried grain outputted through the outlet of the container is sufficiently cooled off before being stored. The air outputted through the cooling zone is hence warmed up and also outputted from the container as utilized air.

[0004] In order to e.g. reduce the energy consumption of the drying arrangement, some of the utilized air may be re-circulated and reused as partially heated drying air provided downstream of the heater and mixed with heated air from the heater, thus forming heated air to be provided through the drying zone of the container for drying

new wet and un-dried grain.

[0005] Although the use of re-circulated utilized air improves the energy efficiency of the grain drying arrangement, there is still a need of further improvements to grain drying arrangements and methods for drying grain in terms of e.g. energy and cost efficiency.

Summary of the Invention

[0006] In view of the above mentioned, an object of the present invention is to provide an improved arrangement and method for drying grain in a grain drying arrangement.

[0007] According to a first aspect of the present invention, a grain drying arrangement is provided. The grain drying arrangement comprises: a container comprising a grain receiving portion, a grain output portion, a drying zone for drying grain, and a cooling zone arranged downstream of the drying zone and adapted to cool grain dried in the drying zone, a first air inlet and a first air outlet which are in communication with the drying zone of the container, a second air inlet and a second air outlet which are in communication with the cooling zone of the container, a heating device in communication with the first air inlet for heating air, and a particle removal arrangement, wherein the first air inlet is adapted to receive air and the heating device is configured to heat air such that heated air is provided into the drying zone of the container, wherein the second air inlet is arranged to direct unheated air into the cooling zone of the container, wherein the first air outlet is adapted to discharge air provided from the drying zone and the second air outlet is arranged to discharge air provided from the cooling zone, wherein at least a portion of at least one of the first air outlet and the second air outlet is in communication with the first air inlet so that at least a portion of the air discharged from the drying zone and/or the cooling zone is provided to the first air inlet, and wherein the particle removal arrangement is provided between at least one of the first and the second air outlets and the first air inlet, such that the portion of the air discharged from the drying zone and/or the cooling zone will pass the particle removal arrangement prior to being provided to the first air inlet.

[0008] An advantage of the present invention is, at least, that a particle removal arrangement allows for providing the discharged air from the drying zone and/or the cooling zone to the first air inlet in the grain drying arrangement, substantially without the risk that particles being released from the grain in the drying zone and/or the cooling zone are being re-directed into the first air inlet. An advantage of redirecting the discharged air into the drying zone is, at least, that a reduced energy consumption may be provided for the grain drying arrangement. By mixing the relatively warm discharged air from the drying zone and/or the cooling zone with the ambient air heated by the heating device, the heating device does not have to heat the ambient air as much as compared to if only heated ambient air is utilized for drying the grain

in the drying zone.

[0009] Moreover, a further advantage of providing the above described particle removal arrangement is, at least, that the risk of having accumulation of particles at, for example, lee sides within the grain drying arrangement may be reduced. Such accumulation of particles may increase the risk of e.g. clogging the grain drying arrangement, thereby reducing its drying capabilities. Also, accumulation of particles may increase the risk of fire in the grain drying arrangement when heated air is transported passed e.g. a pile of particles since heated air in a drying arrangement without a particle removal arrangement may contain glowing particles.

[0010] Furthermore, by providing the particle removal arrangement to the grain drying arrangement, the particles may be taken care of in a controlled manner and the contamination of the environment may hence be reduced. Furthermore, the requirements of e.g. a purification plant or the like, which normally handles the contaminated discharged air from the grain drying arrangement, may be reduced, since the contamination of discharged air to a large degree is handled by the particle removal arrangement.

[0011] The wording "particle removal arrangement is provided between at least one of the first and the second air outlets and the first air inlet" should in the following and throughout the entire description be interpreted such that the particle removal arrangement is located at a position somewhere along the air communication from at least one of the first and second air outlets to the first air inlet. Accordingly, the present invention is not limited to providing the particle removal arrangement at a specific position between one of the first and second outlets and the first air outlet. Also, the present invention is not limited to a specific type of heating device; any suitable heating device fulfilling the purpose of providing heated air to the drying zone is applicable. According to some examples, the heating device may e.g. be a heat exchanger where the air is transported in connection with a surface which on its other side is heated by e.g. hot gas or hot liquid. The heating device may also be an oil- or gas burner whose combustion products, e.g. mainly water and carbon dioxide, are used in the heating process. Moreover, it should be realized that the positioning of the heating device is not limiting the scope of the present invention. For example, the heating device may be located within the first air inlet or it may be located outside the first air inlet.

[0012] Furthermore, it should be realized that the drying zone and the cooling zone described above may each be constituted by a plurality of zones. Hence, the drying zone may e.g. be constituted by a number of drying zones where the grain in each of the zones has been dried differently during the drying process. For example, a section of the drying zone located in proximity to the grain receiving portion may have a relatively low temperature and a relatively high humidity. The moisture is however relatively tightly bound to the seeds. Hereby, the air pass-

ing through this section of the drying zone is relatively more cooled off and relatively less humidified in comparison to a zone located further downstream the drying zone. Accordingly, further downstream the drying zone, the grain is heated to a larger extent and the moisture is less tightly bound to the seeds, such that the air passing through this section of the drying zone is less cooled off and relatively more humidified. Even further downstream the drying zone, the grain is relatively warm and having a relatively low humidity, so the air passing through this section will be even less cooled off and again relatively less humidified. Still further, as described above, the cooling zone may also be constituted by a plurality of zones. Moreover, the invention is not limited to the use of a distinct interface between the drying zone and the cooling zone, i.e. the grain may, for example, still be exposed to a drying process when received in the cooling zone.

[0013] Furthermore, the wording "air" may be mainly interpreted as relatively pure air. However, when the air has been provided through the heating device, drying zone and/or the cooling zone and discharged to its respective outlets, it may be contaminated with, for example, combustion products such as CO₂, H₂O, NO_x, SO_x, etc. Accordingly, when in the following description discussing "air" it should be readily understood that the air may contain e.g. any of the above combustion products and hence may not necessarily be pure air.

[0014] Moreover, by providing a particle removal arrangement which substantially removes all particles provided in the discharged air from the drying zone and/or the cooling zone, prior to the first air inlet, a continuous grain drying arrangement may be provided which utilize the discharged air from the drying zone and/or the cooling zone for drying the grain in the container. In a continuous grain drying arrangement, the grain is continuously transported downwardly in the container towards the grain output portion while simultaneously being aerated by heated air and/or unheated air. This may be accomplished by providing heated air into the drying zone, via e.g. hot air inlet laterals, and outputted from the drying zone, via e.g. wet air outlet laterals. The same procedure may also apply for the cooling zone. The discharged air from the drying zone and/or the cooling zone will be contaminated with particles that are transported out from the wet air outlet laterals. The size of the particles may vary depending on which phase of the process the grain is currently located in. Hereby, particles are released from the grain and drawn out from the container and released into the discharged air in the first and/or the second air outlets to a larger extent than e.g. in a batch drying arrangement or a grain drying arrangement with an intermittent grain flow. Hence, according to an example embodiment, the grain drying arrangement is a continuous grain drying arrangement. Accordingly, by providing the particle removal arrangement prior to the first air inlet, these particles may be substantially removed from the discharged air and thereby allowing the continuous grain drying ar-

rangement to utilize the discharged air from the drying zone and/or the cooling zone to dry grain.

[0015] Furthermore, the wording "continuous grain drying arrangement" should in the following and throughout the entire description be interpreted as an arrangement where the grain is in motion and being aerated simultaneously.

[0016] Moreover, another advantage of having a continuous grain drying arrangement as described above is, at least, that by being able to continuously transport the grain in a direction towards the grain output portion of the container while simultaneously aerating the grain, the heated air provided into the drying zone may have a higher temperature in comparison to e.g. the heated air of a batch drying arrangement or a grain drying arrangement with an intermittent grain flow, in which the grain is substantially stationary in the container when being aerated. In these types of grain drying arrangements, portions of the grain will be located in close proximity to the hot air inlet laterals and hence be exposed to relatively high temperatures, which in turn may e.g. damage the grain's fertility. In the continuous grain drying arrangement according to the present invention, the grain may however not suffer as much by the relatively high temperature since it is in substantially continuous motion downwardly, and not being stationary at the hot air inlet laterals. This allows for the provision of an increased drying temperature into the drying zone, which in turn increases the dehumidification rate of the grain in the container, i.e. an increased drying capacity of the grain drying arrangement is provided, which may also provide for improved germination of the grain.

[0017] Furthermore, since the drying capacity may be increased by the continuous grain drying arrangement, the size of the grain drying arrangement may be reduced if a substantially equal drying capacity is needed as for e.g. an intermittent grain drying arrangement. Still further, another advantage of the continuous grain drying arrangement is that the size and dimension of e.g. transportation equipments which transports the grain from the grain drying arrangement after the grain has been outputted through the grain output portion may be reduced in size. This may be achieved since the transportation equipment may be arranged to handle smaller amount of grain since grain is outputted nearly continuously, in comparison with a grain drying arrangement where the grain, when aerated, needs to be substantially stationary and hence, when not aerated, be outputted intermittently, and hence these types of grain drying arrangements have to output a large amount of grain at the grain output periods.

[0018] According to at least one example embodiment of the present invention, the particle removal arrangement may be arranged in upstream communication with the heating device, such that the portion of the air discharged from the drying zone and/or the cooling zone will pass the particle removal arrangement prior to being provided to the heating device.

[0019] An advantage of having a particle removal arrangement between at least one of the first and second air outlets and the heating device is, at least, that the utilized air from the drying zone and/or the cooling zone may be substantially free from particles before being received into the heating device. Any lot of grain contains contaminations in the form of e.g. broken seeds, parts of straw, chaff and dust of different origin. Accordingly, as also described above, in a continuous grain drying arrangement where grain, in the drying zone and/or in the cooling zone, is aerated simultaneously as it is flowing downwards towards the grain output portion, particles are released from the grain and drawn out from the container and released into the discharged air in the first and/or second air outlets. Hence, the discharged air may, in the described continuous grain drying arrangement, be contaminated with particles from the grain. These particles may be of different size and moisture depending on where in the drying process the discharged air is outputted. Hence, by providing a particle removal arrangement prior to the heating device, the grain drying arrangement may provide utilized relatively clean discharged air through the heating device, which may hence increase the drying capacity of the grain drying arrangement. Accordingly, by providing the discharged air to the particle removal arrangement prior to providing it to the heating device, the risk of e.g. accidental fire in the grain drying arrangement, caused by the particles being ignited by the heating device, may be reduced. Hereby, the heated discharged air may be allowed to be transported through positions within the grain drying arrangement which would otherwise be affected negatively if the air was containing glowing particles. Such positions of the grain drying arrangement may, for example, be the first fluid inlet, the drying zone, the cooling zone, etc.

[0020] Furthermore, by providing utilized discharged air, which is relatively warm in comparison to ambient air, to the heating device, a relatively large amount of air, i.e. a mixture of warm utilized air and ambient air can be provided into the heating device. The heating device may hence not need to heat the mixture of air to such an amount as compared to only heating ambient air, where a smaller amount of ambient air has to be heated to a relatively high temperature in order to have a sufficiently high temperature and low humidity to dry grain. Accordingly, heating a relatively large amount of air from a relatively high temperature to a relatively low temperature reduces the demands on e.g. the material of the heating device in comparison to heating a relatively small amount of air from a relatively low temperature to a relatively high temperature. Also, the demands on other parts of the grain drying arrangement positioned adjacent the heating device may be reduced. Hereby, an increased durability of the heating device and its adjacent part may be provided.

[0021] According to at least one example embodiment, the utilized air from the lower portion of the container may be re-circulated to the particle removal arrangement and

thereafter to the heating device. Hereby, utilized air which may be relatively dry and warm is used as re-circulated air. An advantage is that the heating device is provided with utilized air that is relatively warm and the heating device may thus heat the mixture of utilized air and ambient air to a lesser degree in order to provide a sufficient drying temperature of the air downstream the heating device. Furthermore, the present invention is also applicable for re-circulating utilized air from both the drying zone as well as the cooling zone, or from only one of the zones. Accordingly, the present invention is not limited to re-circulating a specific portion of the utilized air from the drying zone and/or the cooling zone.

[0022] According to at least one example embodiment of the present invention, the particle removal arrangement may be a dust extracting fan unit.

[0023] According to at least one example embodiment of the present invention, the dust extracting fan unit may comprise an impeller, an inlet passage in communication with the impeller, an outlet passage in communication with the impeller and provided circumferentially of the inlet passage, and a primary particle separating unit located circumferentially of the outlet passage and at a distance from the impeller, wherein the inlet passage is arranged to transport the discharged air in a direction towards the impeller, wherein the impeller is adapted to redirect the discharged air into an at least partially radial and an at least partially tangential direction and output the discharged air into the outlet passage in a direction away from the impeller, such that particles provided in the discharged air will be directed towards the periphery of the outlet passage and outputted into the primary particle separating unit.

[0024] Hereby, particles provided in the discharged air at the first and/or second air outlets may effectively be separated from the discharged air and provided into the primary particle separating unit, while the remaining portion of the discharged air, which is relatively free from particles can be outputted from the dust extracting fan unit and provided into e.g. the heating device together with ambient air or to the first air inlet downstream the heating device where it is mixed with e.g. heated ambient air. Hence, the discharged air provided into the inlet passage will, when entering the impeller, be redirected into an at least partially radial and an at least partially tangential direction into the outlet passage, such that the discharged air may have a counter-flow in the outlet passage in relation to the flow in the inlet passage. Also, the flow in the outlet passage will, due to the tangential velocity component of the discharged air, circulate around an outer wall of the inlet passage. Hereby, the particles provided in the discharged air will be directed towards the periphery of the outlet passage due to centrifugal forces acting on the particles which have generally higher density than the air. Furthermore, at a distance from the impeller, the particles that are directed towards the periphery of the outlet passage will hence be provided into the primary particle separating unit, while the remain-

ing, substantially "clean" discharged air will be provided to the first air inlet. The impeller may, for example, be a radial-flow impeller or a diagonal-flow impeller configured to, as described above, redirect the air from the inlet passage to the outlet passage in an at least partially radial and an at least partially tangential direction.

[0025] An advantage is, at least, that the particles may be collected in the primary particle separating unit such that they may easily be taken care of. Moreover, since the dust extracting fan unit uses an impeller to enable a rotational movement on the discharged air, so that the centrifugal forces acting on the particles will provide them towards the periphery of the outlet passage, the dust extracting fan unit may be arranged in substantially any desirable position. Accordingly, the dust extracting fan unit may be positioned such that discharged air may flow in either a horizontally or vertically arranged inlet passage.

[0026] According to at least one example embodiment of the present invention, the primary particle separating unit may be in communication with a secondary particle separating unit, a particle container and a secondary air outlet, wherein the secondary air outlet is in communication with the inlet passage of the dust extracting fan unit, such that at least a portion of the particles outputted into the primary particle separating unit is provided to the particle container via the secondary particle separating unit, and at least a portion of the discharged air outputted into the primary particle separating unit is provided to the inlet passage of the dust extracting fan unit via the secondary particle separating unit.

[0027] Accordingly, the secondary air outlet should be interpreted as an outlet where air that contained particles is outputted to the inlet passage of the dust extracting fan unit. Hereby, the particle container may receive the particles from the discharged air, while the dust extracting fan unit may be provided with relatively "clean" air from the primary particle separating unit. This may be accomplished since the pressure is higher at the outlet passage than at the inlet passage, which thereby enables the discharged air provided to the primary particle separating unit to be outputted to the inlet passage of the dust extracting fan unit. An advantage is, at least, that the efficiency of the dust extracting fan unit may be increased and hence the energy consumption may be reduced.

[0028] According to a second aspect of the present invention, there is provided a method for drying grain in a grain drying arrangement. The grain drying arrangement comprises a container arranged to receive un-dried grain through a grain receiving portion and provide dried grain through a grain output portion, wherein the method comprises the steps of providing air through a heating device arranged in communication with a drying zone of the container, providing air, heated by the heating device, through the drying zone of the container, discharging air provided through the drying zone of the container, providing air through a cooling zone arranged downstream of the drying zone of the container, discharging air pro-

vided through the cooling zone of the container, providing at least a portion of the air discharged from the drying zone and/or the cooling zone to a particle removal arrangement, and providing the at least a portion of the discharged air from the particle removal arrangement to the drying zone of the container.

[0029] Advantages of this second aspect are largely analogous to those described in relation to the first aspect of the present invention.

[0030] According to at least one example embodiment of the present invention, the particle removal arrangement is arranged upstream of the heating device, such that the at least a portion of the discharged air provided from the particle removal arrangement is provided to the heating device prior to being provided to the drying zone of the container.

[0031] According to at least one example embodiment of the present invention, the grain in the drying zone and/or the cooling zone may be continuously transported downwardly towards the grain output portion.

[0032] An advantage is, as described above, that the grain drying arrangement may be efficiently utilized and hence e.g. the size of the grain drying arrangement may be reduced. Also, the size and dimension of e.g. transportation equipments which transports the grain from the grain drying arrangement after the grain has been outputted through the grain output portion may be reduced in size.

[0033] According to at least one example embodiment of the present invention, the dust removal arrangement is a dust extracting fan unit, wherein the method further comprises the steps of providing the discharged air through an inlet passage of the particle removal arrangement in a direction towards an impeller arranged in communication with the inlet passage, providing the discharged air in an at least partially radial and an at least partially tangential direction when transported through the impeller, outputting the discharged air through an outlet passage, located circumferentially from the inlet passage, in a direction away from the impeller.

[0034] According to at least one example embodiment of the present invention, the outlet passage comprises a primary particle separating unit located circumferentially of the outlet passage and at a distance from the impeller, wherein the method further comprises the step of providing a portion of the discharged air in the outlet passage to the primary particle separating unit and a remaining portion of the discharged air to the first air inlet.

[0035] According to at least one example embodiment of the present invention, the primary particle separating unit is in communication with a particle container and a secondary air outlet, wherein the secondary air outlet is in communication with the inlet passage of the dust extracting fan unit, wherein the method further comprises the steps of providing at least a portion of particles provided in the discharged air to the particle container, and outputting at least a portion of the discharged air into the inlet passage of the dust extracting fan unit.

[0036] Accordingly, the secondary air outlet should be interpreted as an outlet where air that previously contained particles is outputted to the inlet passage of the dust extracting fan unit.

[0037] Other effects and features of this second aspect are largely analogous to those described above in relation to the first aspect of the present invention.

Brief Description of the Drawings

[0038] The above, as well as additional objects, features and advantages of the present invention, will be better understood through the following illustrative and non-limiting detailed description of an exemplary embodiment of the present invention, with reference to the appended drawings, where the same reference numerals will be used for similar elements, wherein:

Fig. 1 illustrates a cross-sectional side view of an exemplary embodiment of a grain drying arrangement according to the present invention,

Fig. 2 illustrates an at least partly cross-sectional side view of an exemplary embodiment of a dust extracting fan unit according to the present invention, and

Fig. 3 illustrates a further exemplary embodiment of the grain drying arrangement according to the present invention.

Detailed Description of Exemplary Embodiments of the Invention

[0039] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided for thoroughness and completeness. Like reference character refer to like elements throughout the description.

[0040] In the following description, the present invention is described with reference to a grain drying arrangement 100 adapted to dry grain. Firstly, the structural features of the grain drying arrangement 100 will be described. Thereafter, the functionality and associated method of drying grain in the grain drying arrangement 100 will be described. Referring now to Fig. 1 there is depicted a cross-sectional side view of an exemplary embodiment of a grain drying arrangement according to the present invention. As is illustrated, the grain drying arrangement comprises a container 102 adapted to receive grain 104 at a grain receiving portion 106 located at an upper side of the container 102. Downstream of the grain receiving portion 106 in the container 102 is located a drying zone 108 adapted to dry grain located therein. The drying zone 108 is depicted as only one drying zone 108 but may of course be constituted by a plurality of drying

zones (not illustrated here), such that grain located in the various drying zones are or have been dried to a various amount. Furthermore, downstream of the drying zone 108 is arranged a cooling zone 110 adapted to cool grain that previously was dried in the drying zone 108. In a similar manner as described above in the relation to the drying zone 108, the cooling zone 110 may also be constituted by a plurality of cooling zones (not illustrated here), where the grain in the various cooling zones may be cooled to a various amount. Still further, downstream of the cooling zone 110 is arranged a grain output portion 112 adapted to output dried grain 114 to, for example, a transportation equipment to deliver the grain from the grain drying arrangement 100.

[0041] Furthermore, the grain drying arrangement 100 comprises a first air inlet 116 which is in upstream communication with the drying zone 108 of the container 102 and having a hot air plenum 118 located adjacent the drying zone 108. Also, in the illustrated embodiment, the first air inlet 116 comprises a heating device 120. The heating device 120 may, as illustrated in Fig. 1, be provided in the first air inlet 116, but may also be provided further upstream or downstream of the first air inlet 116, or even outside the first air inlet 116. Also, the heating device 120 may, for example, be a heat exchanger heated by hot gas or liquid, or a burner burning gas, liquid or solid fuel, etc. Still further, the grain drying arrangement 100 comprises a first air outlet 122 which is in downstream communication with the drying zone 108 of the container 102. The first air outlet 122 further comprises a wet air plenum 124 located adjacent the drying zone 108 of the container 102. Also, in the illustrated embodiment of Fig. 1, a portion of the first air outlet 122 comprises a fan unit 126 arranged to discharge at least a portion of air from the first air outlet 122 to e.g. the ambient air or a purification plant or the like. It should however be noted that the fan unit 126 may equally be replaced by a compressing arrangement in e.g. the heating device 120 and arranged to push the air out to the ambient air or the purification plant. Moreover, another portion of the first air outlet 122 is in communication with a particle removal arrangement 400, in the illustrated embodiment located at the circulated air plenum 136 of the grain drying arrangement 100. Although the first air outlet 122 is depicted as being divided by a wall 128, the present invention is just as applicable without the use of a wall 128, which mainly serves for illustrative purposes.

[0042] Moreover, in upstream communication with the cooling zone 110 is arranged a second air inlet 132 comprising a cooling air plenum 134 adjacent the cooling zone 110 of the container 102. The second air inlet 132 is arranged to direct e.g. ambient air into the cooling zone 110 of the container 102. Also, downstream of the cooling zone 110 is arranged a second air outlet 130 arranged in communication with the circulated air plenum 136.

[0043] Reference is now made to the drying zone 108 of the container 102. As described above, grain 104 is provided into the drying zone 108 via the grain input por-

tion 106 of the container 102. The grain 104 received through the grain receiving portion 106 has a high level of moisture and comprises particles of different size. Also, the temperature level of the grain 104 is relatively low at this stage of the drying process. As the grain 104 is provided in a downward direction of the drying zone 108 of the container 102, the moisture level of the grain 104 is gradually reduced and the temperature of the grain is gradually increased, so that the grain is getting dryer and dryer further down the drying zone 108. At a bottom portion of the drying zone 108 the moisture level of the grain has been reduced to such a level that the grain can be provided into the cooling zone 110 where it is being cooled off. It should be noted that the drying zone 108 and the cooling zone 110 of the container 102 may be in connection with each other. Accordingly, the illustrated portion of the first air outlet 122 does not necessarily separate the two zones from each other. The portion of the first air outlet 122 illustrated as separating the drying zone 108 from the cooling zone 110 may in reality, for example, be arranged as a bypass, around or through, the container 102 but the illustration serves for better understanding of the functionality and method for drying grain, which is further described below.

[0044] Now, reference is made to the description of the functionality and associated method for drying grain in the grain drying arrangement illustrated in Fig. 1. As described above, un-dried grain is continuously provided into the grain receiving portion 106 of the container 102. Hereby, grain having a relatively high level of moisture and a relatively low temperature is received in the upper parts of the container 102.

[0045] Furthermore, ambient air 202 is provided into the first air inlet 116 where it is received into the heating device 120 so that the ambient air 202 is heated and relatively dehumidified to levels sufficiently hot and dry to be able to dry grain received in the container 102. Accordingly the ambient air 202 is, after being provided through the heating device 120, heated and dried to such an amount that it can be utilized as drying air 204. The drying air 204 is thereafter directed through the first air inlet 116 and to the hot air plenum 118 of the grain drying arrangement 100 where it is further directed into the drying zone 108 of the container 102. The drying air 204 is provided into the drying zone 108 of the container 102 via, for example, a plurality of hot air inlet laterals 140 arranged inside the drying zone 108, each hot air inlet lateral having an inlet opening communicating with the hot air plenum 118 and an outlet opening communicating with the grain in the drying zone 108. The drying air 204 is then, after passing through the grain in the drying zone 108, outputted from the drying zone 108 via, for example, a plurality of wet air outlet laterals 150 also arranged in the drying zone 108, each wet air outlet lateral having an inlet opening communicating with the grain in the drying zone 108 and an outlet opening communicating with the wet air plenum 124. The drying air 204 is in Fig. 1 depicted as entering one of the hot air inlet laterals 140 and out-

putted through one of the wet air inlet laterals 150. The drying air 204 is of course entering a plurality of hot air inlet laterals 140 as well as being outputted through a plurality of wet air output laterals. Thereafter, since the grain 104 in the drying zone 108 is relatively wet and having a relatively low temperature, wet air 206 is outputted to the first air outlet 122. The wet air 206 has thus been humidified and cooled down in relation to the drying air 204 in the hot air plenum 118 by means of the wet and relatively low tempered grain 104 in the drying zone 108. Moreover, as described above, the grain located further down in the drying zone has been heated and dried to a larger amount than the grain located in an upper region of the drying zone. Hereby, the wet air 206 outputted from the drying zone 108 has a various characteristic depending on the lateral position where it was outputted. Accordingly, the wet air 206 in the upper region of the first air outlet 122 is more humidified and has a lower temperature than the wet air 206 in the lower region of the first air outlet 122, which is hence warmer and dryer.

[0046] Still further, as the grain drying arrangement in Fig. 1 is an arrangement where grain in the drying zone 108 and/or the cooling zone 110 is aerated simultaneously as it is transported downwardly in a direction towards the grain output portion 112, particles are hence released from the grain and outputted from the respective drying zone 108 and/or cooling zone 110 together with the discharged air. Accordingly, the discharged air is, in the depicted grain drying arrangement 100, contaminated with particles from the grain. Hence, the wet air 206 outputted to the first fluid outlet 122 will be more or less contaminated with particles, such as e.g. broken seeds, parts of straws, chaff, dust of different origin, etc.

[0047] Now, a portion of the wet air 206 in the first air outlet is outputted and directed away from the grain drying process as used air 208. Another portion of the wet air 206 is directed towards the particle removal arrangement 400 as re-circulated drying air 210. Preferably, the wet air 206 utilized as re-circulated drying air 210 is the portions of wet air 206 that has a relatively high temperature and is relatively dry. However, the invention is not limited to a specific temperature and dryness of the re-circulated drying air 210. Moreover, the re-circulated drying air 210 is thereafter provided into the particle removal arrangement 400 where the particles accommodated in the re-circulated drying air 210 is substantially removed, which will be further described below in relation to the description of Fig. 2. Finally, the re-circulated drying air 210 is provided, together with ambient air 202, into the heating device as relatively clean re-circulated air 212, so that a mixture of relatively clean re-circulated air 212 and ambient air 202 is provided into the heating device.

[0048] Reference is now made to the cooling zone 110 of the container 102. In order to cool the grain that was dried in the drying zone 108, ambient air 202 is provided into the second air inlet 132 which is in communication with the cooling zone 110 of the container 102. The am-

bient air 202 is thereafter provided into and through the cooling zone 110 via e.g. laterals in the same manner as described above in relation to the description of the laterals in the drying zone. Due to the relatively high temperature of the grain in the cooling zone 110, the ambient air 202 provided into the cooling zone will be heated and outputted to the second air outlet 130 as heated cooling air 214, which is also relatively dry. The heated cooling air 214 will, for the same reasons as the wet air 206, be at least partially contaminated with particles from the grain in the cooling zone 110. The heated cooling air 214 is thereafter, together with the re-circulated drying air 210, provided into the particle removal arrangement 400 in order to remove the particles from the heated cooling air 214. Finally, the heated cooling air is provided, together with the re-circulated drying air 210 and the ambient air 202, into the heating device as relatively clean re-circulated air 212.

[0049] Turning to Fig. 2, a further description is now made to the functionality of a dust extracting fan unit 300 which is configured to remove particles from re-circulated drying air and heated cooling air, and may suitably be used as a particle removal arrangement 400 in an arrangement according to Fig. 1. Fig. 2 illustrates an at least partial cross-sectional side view of a dust extracting fan unit 300 according to an example embodiment of the present invention. The dust extracting fan unit 300 comprises an inlet passage 302 extending towards an impeller 304. The impeller 304 is in the illustrated embodiment of Fig. 2 driven by a motor 306 located on an opposite side of the impeller 304 in relation to the inlet passage 302. Moreover, the dust extracting fan unit 300 further comprises an outlet passage 308. The outlet passage 308 is also in communication with the impeller 304 and located circumferentially of the inlet passage 302. Accordingly, the outlet passage 308 encloses the inlet passage 302 such that an outer wall 310 of the inlet passage 302 may thus act as inner wall for the outlet passage 308. The outlet passage 308 is further directed towards an output 312 arranged in communication with the first air inlet 116 as described above.

[0050] Furthermore, the dust extracting fan unit 300 comprises a primary particle separating unit 314. The primary particle separating unit 314 is in the depicted example embodiment of Fig. 2 located at the periphery of the outlet passage 308 and at an axial distance from the impeller 304. Moreover, the primary particle separating unit 314 is configured to receive particles 316 provided in the re-circulated drying air 210 and the heated cooling air 214, which will be further described below. Still further, a secondary particle separating unit 322, a particle container 318 and a secondary air outlet 320 is arranged in communication with the primary particle separating unit 314 and located downstream the primary particle separating unit 314, where the secondary air outlet 320 is in further communication with the inlet passage 302 of the dust extracting fan unit 300.

[0051] The functionality of the dust extracting fan unit

300 will now be described in more detail. Reference is again made to Fig. 2 illustrating the at least partially cross-sectional side view of the dust extracting fan unit. As described above in relation to Fig. 1, re-circulated drying air 210 and heated cooling air 214 is provided to the dust extracting fan unit 300. More specifically, the re-circulated drying air 210 and the heated cooling air 214 is provided into the inlet passage 302 of the dust extracting fan unit 300. The re-circulated drying air 210 and the heated cooling air 214 is thereafter directed towards the impeller 304 where it is redirected into an at least partially radial and an at least partially tangential direction and provided into the outlet passage 308. Due to the impeller 304, the re-circulated drying air 210 and the heated cooling air 214 will be given an opposite flow direction in the outlet passage 308 in comparison to the flow direction in the inlet passage 302. Also, the impeller 304 will provide the re-circulated drying air 210 and the heated cooling air 214 to circulate around the wall 310 separating the inlet passage 302 from the outlet passage 308. Hereby, particles 316 contained in the re-circulated drying air 210 and in the heated cooling air 214 and having higher density compared to the air will, due to centrifugal forces, gradually be concentrated towards the periphery of the outlet passage 308 and finally received in the primary particle separating unit 314. Moreover, the re-circulated drying air 210 and the heated cooling air 214, which at this stage is relatively free from particles, are outputted from the dust extracting fan unit 300 as relatively clean re-circulated air 212.

[0052] Furthermore, the particle contaminated air received by the primary particle separating unit 314 is directed towards the secondary particle separating unit 322 from which the particles are separated from the air and into the particle container 318. Hereby, the particles contained in the re-circulated drying air 210 and the heated cooling air 214 is collected in the particle container 318 and can thereafter be taken care of in an appropriate manner. Moreover, when the impeller 304 is rotating, a difference in pressure between the inlet passage 302 and the outlet passage 308 arises, i.e. there will be a lower pressure at the inlet passage 302 compared to the outlet passage 308. Hereby, the fraction of the re-circulated drying air 210 and the heated cooling air 214 provided into the primary particle separating unit 314 may, due to the described pressure difference, be directed via the secondary particle separating unit 322 and onwards to the inlet passage 302 of the dust extracting fan unit 300 and hence, together with new re-circulated drying air 210 and heated cooling air 214 from the container 102, be provided into the inlet passage 302.

[0053] Reference is now made to Fig. 3 illustrating yet another example embodiment of the grain drying arrangement 100 according to the present invention. The difference between the grain drying arrangement depicted in Fig. 3 and the example embodiment of the grain drying arrangement depicted in Fig. 1 is the positioning of the particle removal arrangement 400. As illustrated

in Fig. 3, the particle removal arrangement 400 is arranged such that the relatively clean re-circulated air 212 outputted from the particle removal arrangement 400 is provided into the first air inlet 116 downstream the heating device 120. Hereby, instead of mixing the relatively clean re-circulated air 212 with ambient air and provide the mixture into the heating device as described in relation to Fig. 1, the relatively clean re-circulated air 212 is mixed with the heated ambient air downstream the heater. The grain drying arrangement 100 depicted in Fig. 3 may of course also use the dust extracting fan unit 300 illustrated in Fig. 2 as particle removal arrangement 400.

[0054] Although two example embodiments of the present invention have been described herein, it should be apparent to those having ordinary skill in the art that a number of changes, modifications or alterations to the invention as described herein may be made. For example, the above description relates to simultaneously re-circulating both the drying air and the cooling air. It should however be noted that the present invention is equally applicable for re-circulating only one of the cooling air or the drying air. Moreover, the present invention is not limited to a single heating device as depicted in Fig. 1, a plurality of heating devices may just as well be used and the plurality of heating devices may, for example, be parallel to each other or provided in series.

[0055] Thus, the above description of the example embodiment of the present invention and the accompanying drawings are to be regarded as a non-limiting example of the invention and the scope of protection is defined by the appended claims. Any reference sign in the claims should not be construed as limiting the scope.

Claims

1. A grain drying arrangement (100), comprising:

- a container (102) comprising a grain receiving portion (106), a grain output portion (112), a drying zone (108) for drying grain, and a cooling zone (110) arranged downstream of said drying zone (108) and adapted to cool grain dried in said drying zone (108),
- a first air inlet (116) and a first air outlet (122) which are in communication with said drying zone (108) of said container (102),
- a second air inlet (132) and a second air outlet (130) which are in communication with said cooling zone (110) of said container (102),
- a heating device (120) in communication with said first inlet (116) for heating air, and
- a particle removal arrangement (400), wherein said first air inlet (116) is adapted to receive air and said heating device (120) is configured to heat air such that heated air is provided into said drying zone (108) of said container (102), wherein said second air inlet (132) is ar-

- ranged to direct unheated air into said cooling zone (110) of said container (102), wherein said first air outlet (122) is adapted to discharge air provided from said drying zone (108) and said second air outlet (130) is arranged to discharge air provided from said cooling zone (110), wherein at least a portion of at least one of said first air outlet (122) and said second air outlet (130) is in communication with said first air inlet (116) so that at least a portion of said air discharged from said drying zone (108) and/or said cooling zone (110) is provided to said first air inlet (116), and wherein said particle removal arrangement (400) is provided between at least one of said first (122) and said second (130) air outlets and said first air inlet (116), such that said portion of said air discharged from said drying zone (108) and/or said cooling zone (110) will pass said particle removal arrangement (400) prior to being provided to said first air inlet (116) .
2. The grain drying arrangement (100) according to claim 1, wherein said particle removal arrangement (400) is arranged in upstream communication with said heating device (120), such that said portion of said air discharged from said drying zone (108) and/or said cooling zone (110) will pass said particle removal arrangement (400) prior to being provided to the heating device (120).
 3. The grain drying arrangement (100) according to claim 1 or 2, wherein said particle removal arrangement (400) is a dust extracting fan unit (300).
 4. The grain drying arrangement (100) according to claim 3, wherein said dust extracting fan unit (300) comprises:
 - an impeller (304),
 - an inlet passage (302) in communication with said impeller (304),
 - an outlet passage (308) in communication with said impeller (304) and provided circumferentially of said inlet passage (302), and
 - a primary particle separating unit (314) located circumferentially of said outlet passage (308) and at a distance from said impeller (304), wherein said inlet passage (302) is arranged to transport said discharged air in a direction towards said impeller (304), wherein said impeller (304) is adapted to redirect said discharged air into an at least partially radial and an at least partially tangential direction and output said discharged air into said outlet passage (308) in a direction away from said impeller (304), such that particles provided in said discharged air will be directed towards the periphery of said outlet passage (308) and outputted into said primary particle separating unit (314) .
 5. The grain drying arrangement (100) according to claim 4, wherein said primary particle separating unit (314) is in communication with a secondary particle separating unit (322), a particle container (318) and a secondary air outlet (320), wherein said secondary air outlet (320) is in communication with said inlet passage (302) of said dust extracting fan unit (300), such that at least a portion of said particles (316) outputted into said primary particle separating unit (314) is provided to said particle container (318) via said secondary particle separating unit (322), and at least a portion of said discharged air outputted into said primary particle separating unit (314) is provided to said inlet passage (302) of said dust extracting fan unit (300) via said secondary particle separating unit (322).
 6. A method for drying grain in a grain drying arrangement, comprising a container (102) arranged to receive un-dried grain through a grain receiving portion (106) and output dried grain through a grain output portion (112), wherein the method comprises the steps of:
 - providing air (202) through a heating device (120) arranged in communication with a drying zone (108) of said container (102);
 - providing air (204), heated by said heating device (120), through said drying zone (108) of said container (102);
 - discharging air (206) provided through said drying zone (108) of said container (102);
 - providing air (202) through a cooling zone (110) arranged downstream of said drying zone (108) of said container (102),
 - discharging air (214) provided through said cooling zone (110) of said container (102),
 - providing at least a portion of said air discharged from said drying zone (108) and/or said cooling zone (110) to a particle removal arrangement (400), and
 - providing said at least a portion of said discharged air from said particle removal arrangement (400) to said drying zone (108) of said container (102).
 7. The method according to claim 6, wherein said particle removal arrangement (400) is arranged upstream of said heating device (120), such that said at least a portion of said discharged air provided from said particle removal arrangement (400) is provided to said heating device (120) prior to being provided to said drying zone (108) of said container (102).
 8. The method according to any one of claims 6 and 7,

wherein said grain in the drying zone (108) and/or the cooling zone (110) is continuously transported downwardly towards said grain output portion (112).

9. The method according to any one of claims 6 to 8, wherein said dust removal arrangement (400) is a dust extracting fan unit (300), wherein the method further comprises the steps of:

- providing said discharged air through an inlet passage (302) of said dust extracting fan unit (300) in a direction towards an impeller (304) arranged in communication with said inlet passage (302),
- providing said discharged air in an at least partially radial and an at least partially tangential direction when transported through said impeller (304);
- outputting said discharged air through an outlet passage (308), located circumferentially from said inlet passage (302), in a direction away from said impeller (304).

10. The method according to claim 9, wherein said outlet passage (308) comprises a primary particle separating unit (314) located circumferentially of said outlet passage (308) and at a distance from said impeller (304), wherein the method further comprises the step of:

- providing a portion of said discharged air in said outlet passage (308) to said primary particle separating unit (314) and a remaining portion of said discharged air to said first air inlet (116).

11. The method according to claim 10, wherein said primary particle separating unit (314) is in communication with a particle container (318) and a secondary air outlet (320), wherein said secondary air outlet (320) is in communication with said inlet passage (302) of said dust extracting fan unit (300), wherein the method further comprises the steps of:

- providing at least a portion of said particles (316) provided in said discharged air to said particle container (318), and
- outputting at least a portion of said discharged air into said inlet passage (302) of said dust extracting fan unit (300).

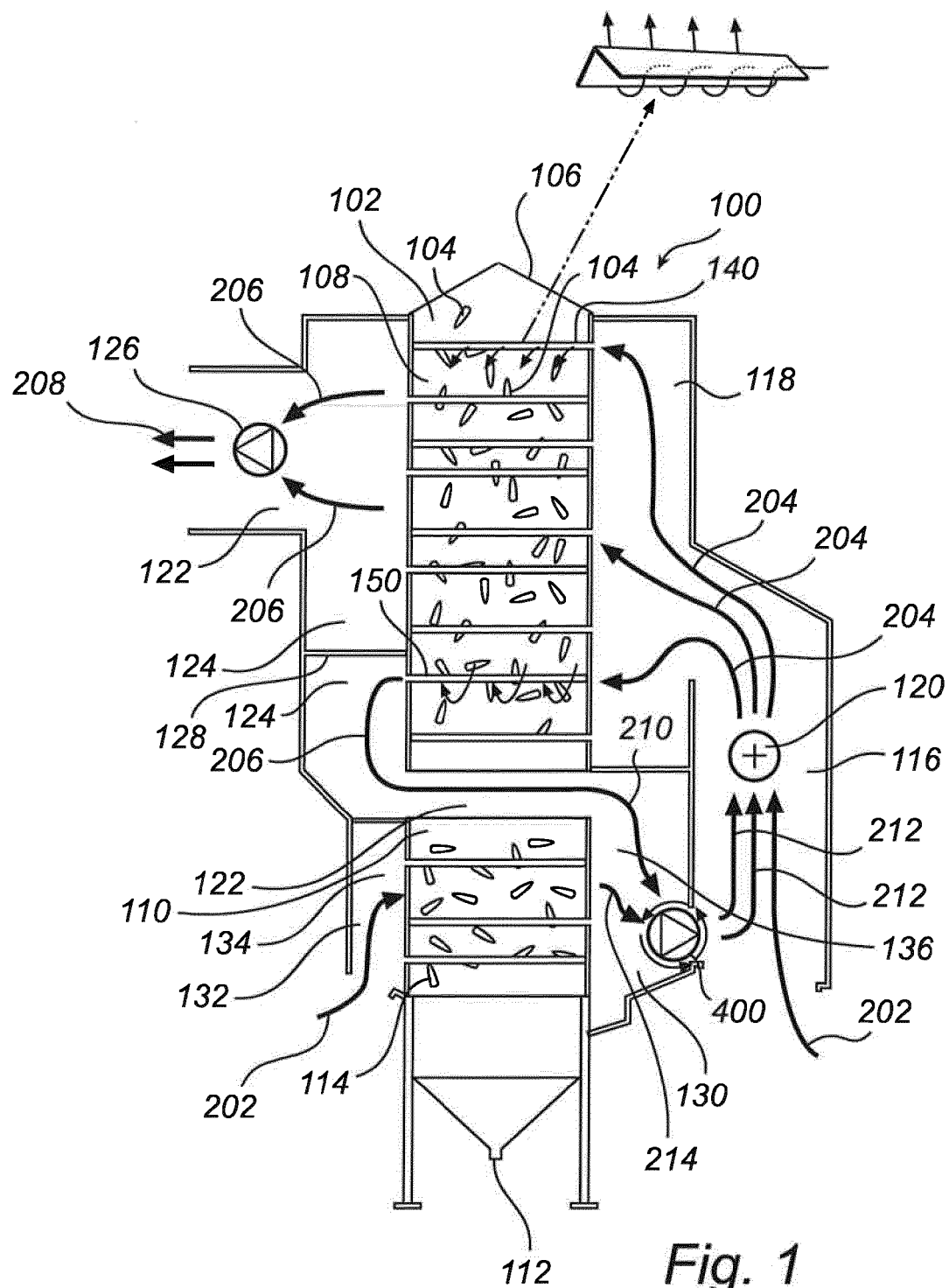


Fig. 1

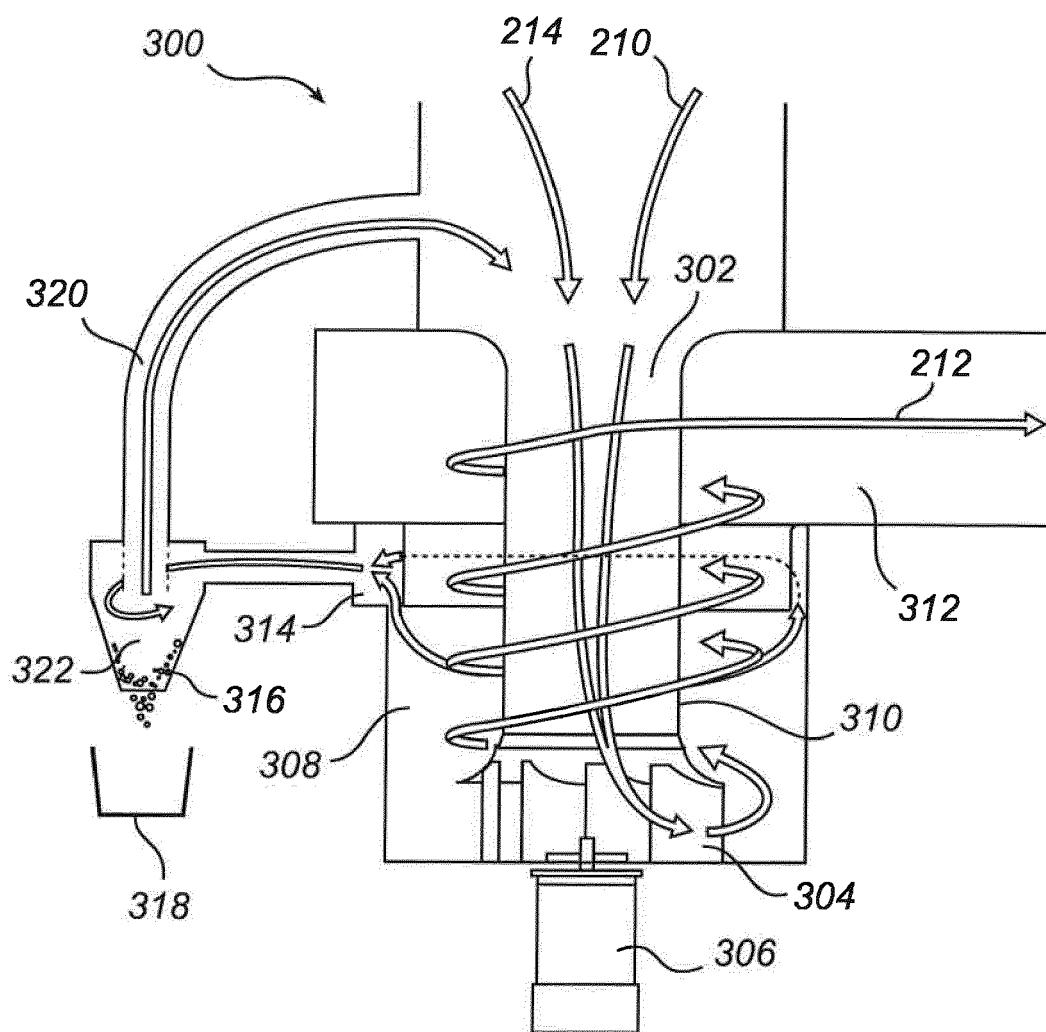


Fig. 2

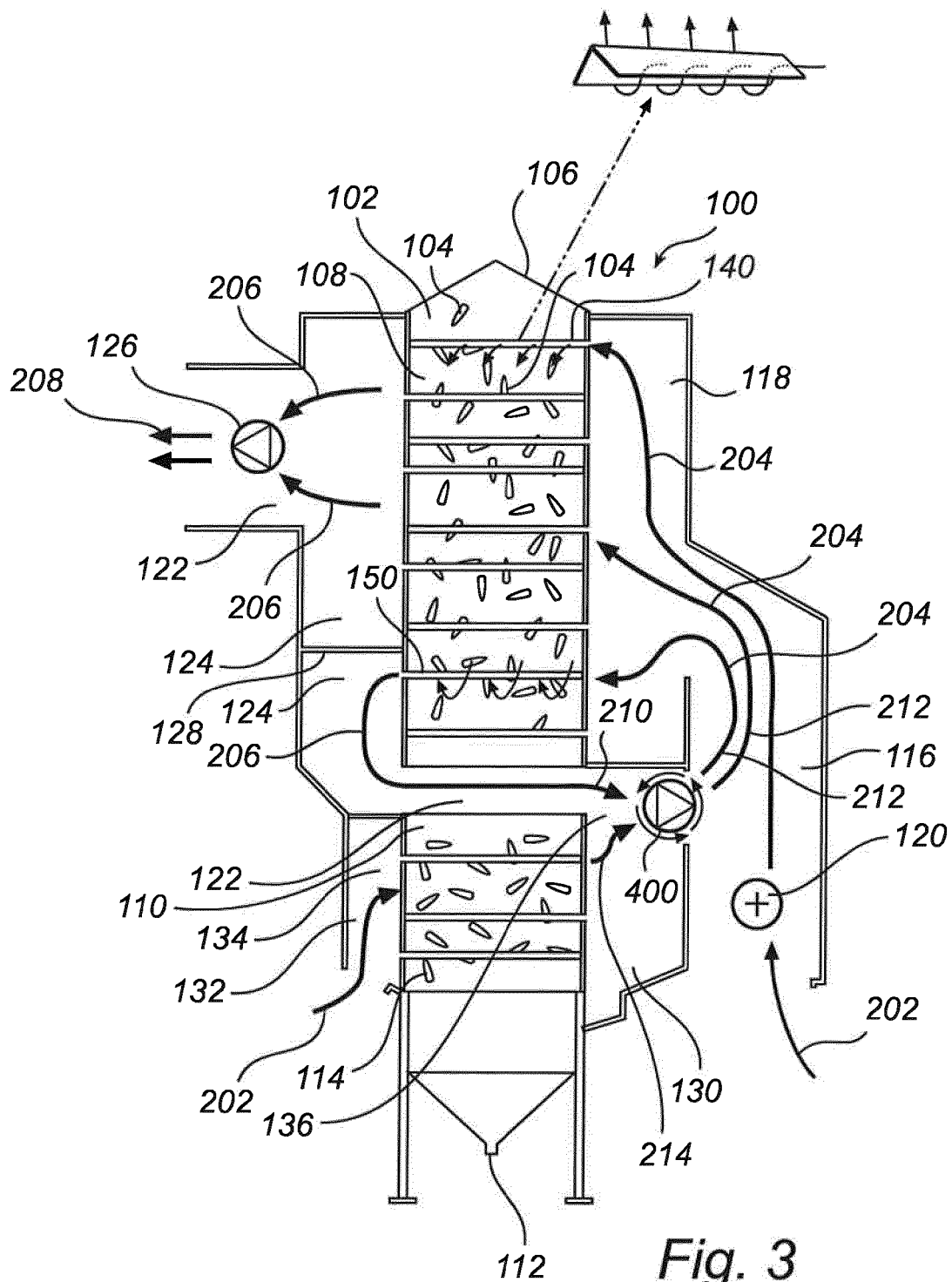


Fig. 3



EUROPEAN SEARCH REPORT

Application Number
EP 12 16 3049

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Place of search The Hague		Date of completion of the search 29 August 2012	Examiner Etienne, Nicolas
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