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(54) **COATING SYSTEM FOR COATING OBJECTS**

(57) A coating system for coating objects, particularly small objects, the coating system comprising:
a receiver element for receiving objects to be coated and for moving objects to be coated;
a provisioning element for providing coating material to objects within the receiver element;
a radiation element for emitting electromagnetic radiation to dry objects provided with coating material in the receiver element;
a sensor system for sensing a condition associated with an operating state of the radiation element;
a control device for controlling operation of the coating system based on the condition sensed by the sensor system.

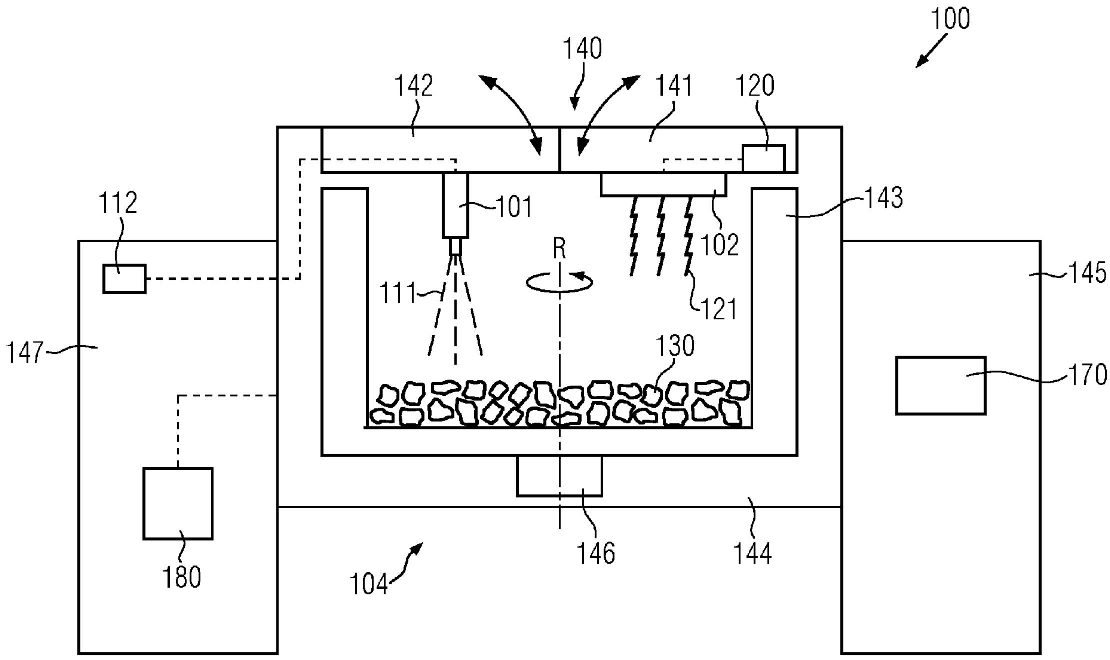

FIG. 1

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Description

[0001] The present invention relates to a coating system for coating objects according to independent claim 1 and a method for controlling the operation of a coating system according to claim 13.

Prior art

[0002] Coating systems for coating objects, particularly small objects like pieces of pens or keys or small components in the automotive industry or other industries, are known to the skilled person.

[0003] For example, from EP 1 916 905 B1, a device for coating small parts or objects is known that has a rotating drum and provides, to the parts inside of the drum, coating material which is then dried using a radiator emitting electromagnetic radiation. Using such coating materials that can be dried by, for example infrared radiation or other electromagnetic radiation provides advantages with respect to the amount of coating material that has to be used and reduced drying times.

[0004] However, proper quality of the coated parts strongly depends on the appropriate amount of energy being provided to the parts when drying them using the radiators.

Object

[0005] Starting from the known prior art, one object addressed by the present invention, thus is to provide a coating system for coating objects and a method for controlling operation of a coating system for coating objects which results in a reliable quality of the coated objects while ensuring reliable operation of the coating system.

Solution

[0006] This object is solved by the coating system according to claim 1 and the method for controlling operation of a coating system for coating objects according to claim 13. Preferred embodiments of the invention are provided in the dependent claims.

[0007] According to the invention, a coating system for coating objects, particularly small objects, is provided, the coating system comprising:

a receiver element for receiving objects to be coated and for moving objects to be coated;
a provisioning element for providing coating material to objects within the receiver element;
a radiation element for emitting electromagnetic radiation to dry objects provided with coating material in the receiver element;
a sensor system for sensing a condition associated with an operating state of the radiation element;
a control device for controlling operation of the coating system based on the condition sensed by the sensor system.

[0008] The receiver element is understood as a structure having a hollow portion into which the objects can be placed for treatment by the coating system. It can, for example, be or comprise a rotatable element, like a drum, that can be rotated about an axis and can accommodate the objects to be coated. The shape of the receiver element is not particularly restricted and other embodiments are possible as well. Preferably, the objects are moved within the receiver element without a particular order or orientation, for example in the form of bulk material. This can particularly comprise that the relative position of objects while moved within the receiver element changes with respect to the receiver element and/or relative to other objects.

[0009] The provisioning element can be or can comprise at least one dispenser that can dispense fluid coating material onto the objects while they are in the receiver element. The provisioning element is thus preferably arranged in order to output the coating material into the direction of the objects within the receiver element.

[0010] The radiation element can comprise an infrared radiator or other radiators emitting electromagnetic radiation (like, for example, UV radiation) with sufficient intensity so as to dry the coating material on the objects. In this respect, the radiation element is not particularly restricted but can, among other realizations, be provided as an inferred radiator that emits infrared radiation in a broad infrared spectrum, like for example, a heat emitter.

[0011] The sensor system can comprise at least one sensor for sensing a condition. It can, also comprise a plurality of sensors that do not need to be placed in the same position and can also be provided for measuring different conditions.

[0012] In this context, a condition is understood as a physical or chemical state associated with the operating state of the radiation element and can comprise, among others, for example a temperature of the radiation element or the surrounding or a temperature of a cooling fluid used for cooling the radiation element. Additionally or alternatively, the condition can also comprise a pressure that is sensed by the sensor system or binary states of components (for example whether they are turned on or off or the like). The invention is not particularly limited in regards to what condition the sensor system senses, and is also not limited with respect to what values of the condition are sensed by the sensor system.

[0013] The control device can be realized as a commonly known computing system or central control unit of the coating system. Controlling of the operation based on the conditions sensed by the sensor system is understood as comprising that, depending on the sensed condition (for example the temperature of the cooling liquid), a state of at least one component of the coating system or the whole coating system can be changed by the control device. For example, based on the temperature of the cooling liquid, the amount of cooling liquid flowing through the cooling system per amount of time can be changed to obtain a particular amount of cooling. Alternatively or additionally, the controlling operation of the coating system can comprise providing an output to an operator, for example in order to provide sufficient information on the operation of the coating system.

[0014] With the inventive coating system, it is ensured that the radiation element works properly and both reliable operation of the coating system as well as high quality of the coated objects is ensured.

[0015] The coating system can further comprise a cooling system for cooling the radiation element by providing an airflow to the radiation element, wherein the sensor system is adapted to sense, as the condition, an amount of airflow to the radiation element and/or an amount of airflow away from the radiation element, and/or wherein the sensor system is adapted to sense an amount of power consumed by the cooling system.

[0016] With this embodiment, it can be determined whether the radiation element is sufficiently cooled so that its' proper function is ensured. Likewise, it can be ensured (at least indirectly) that the radiation element does not consume too much power, thereby radiating too much energy to the objects. This can likewise ensure proper coating of the objects.

[0017] It can further be provided that the system comprises an exhaust ventilation system for removing air from an inside of the receiver element, wherein the exhaust ventilation system comprises a filter element through which air flows away from the inside of the receiver element, wherein the sensor system is adapted to sense, as the condition, a differential pressure at the filter element.

[0018] In this context, the inside of the receiver element may be the region of the receiver element that can accommodate the objects to be coated. This may be a hollow region of the receiver element. The exhaust ventilation system can comprise a flow channel through which air flows away from the inside of the receiver element. A ventilator or pump can be arranged in this flow channel so as to suck air from the inside of the receiver element. The filter element can be arranged downstream or upstream of the ventilator or pump. By determining the differential pressure, proper functioning of the filter element can be supervised, allowing for reliably determining whether the conditions inside the receiver element meet particular criteria (like for example air pressure or relative density of coating material in the air inside the receiver element). This can have impact on the operation of the device, particularly the radiation element because too high or too low pressure inside the receiver element or too much coating material inside the receiver element can result in risks when operating the radiation element. By using the determined differential pressure as a condition for controlling the operation of the system (for example shutting off the radiation element in cases where the density of coating material in the inside of the receiver element exceeds a particular threshold), operation of the system can be ensured.

[0019] In one embodiment, the cooling system comprises a heat exchanger arranged for removing heat from air flowing away from the radiation element and for providing heat to an interior of the receiver element.

[0020] With this, energy recycling is achieved which improves the ecological acceptability of the coating system.

[0021] The sensor system can be adapted to sense, as a condition, an amount of heat removed from the air flow by the heat exchanger and/or a temperature of the heat exchanger and/or a temperature of the air before and after passing the heat exchanger.

[0022] This embodiment allows for at least an indirect determination of whether the radiation element is over heating and/or the cooling system is properly functioning by providing sufficient airflow for cooling to the radiation element.

[0023] In one embodiment, the coating system comprises at least one movable cover for sealing the receiver element in a closed state, wherein the sensor system is adapted to sense, as the condition, whether the cover is in the closed state by sensing a position of the movable cover and/or by sensing a pressure inside a region bounded by the receiver element and the movable cover.

[0024] This embodiment allows for increasing the operation security of the coating system because if the cover is properly closed, a sufficient amount of coating material is indeed provided onto the objects to be coated while no energy is lost and drying of the object is not deteriorated.

[0025] The sensor system can be adapted to sense, as the condition, a temperature of the radiation element and/or a surrounding region of the radiation element. For example, if the radiation element overheats, the control device can, based on the sensed temperature, turn the radiation element off to prevent the objects or the coating material from being damaged. Likewise, negative impacts on the coating system can be avoided by measuring the temperature of the radiation element.

[0026] In a further embodiment, the coating system comprises a fluid cooling system comprising a fluid cycle inside the coating system, wherein the fluid cooling system comprises a pump for pumping the fluid through the fluid cycle and the sensor system is adapted to sense, as the condition, an amount of fluid flow through the fluid cycle and/or an amount of power consumed by the pump and/or a temperature difference at two points in the fluid cycle. In this context, the term "fluid" is to be understood as encompassing both gaseous and liquid mediums.

[0027] The fluid cooling cycle can either be the only cooling system for the radiation element or it can be provided as an additional cooling system in addition to another cooling system that uses, for example, air from the environment to cool the radiation system. The invention is not limited in this respect. The fluid cycle in this embodiment is a closed fluid cycle where the cooling fluid is not exchanged with the environment. By determining the amount of power consumed by the pump or the temperature difference at two points in the fluid cycle, it can be determined whether the fluid cooling system is properly working and thus sufficiently cooling the radiation element.

[0028] Particularly, the fluid cooling system can comprise a heat exchanger for exchanging heat between the fluid in the fluid cycle and the environment or an interior of the receiver element, and wherein the sensor system is adapted to sense, as the condition, a temperature of the heat exchanger and/or a temperature of the fluid before and after passing the heat exchanger.

[0029] By providing a heat exchanger, produced heat can be recycled in the process, thereby rendering the system ecologically more acceptable. Determining the temperature of the heat exchanger or the temperature of the fluid before and after passing the heat exchanger can be used to ensure that the proper removal of heat from the radiation element is maintained, thereby increasing the reliability of operation of the coating system.

[0030] The fluid can be a gaseous or liquid medium. A gaseous medium can be used if the amount of heat that needs to be transferred away from the radiation element is comparably small. The gaseous medium can, for example, be nitrogen or any other inert gas, thereby reducing the risk of incineration or damage to the coating system due to failure of the fluid cooling system (like leakages into the receiver element). A liquid medium, like, for example water, can be used if the amount of heat that needs to be removed from the radiation element is comparably high and could not reliably be ensured by only using gaseous mediums. Likewise, by using a liquid medium, the space required for providing the fluid cooling system is reduced as the amount of cooling medium can be kept comparably small.

[0031] It can be provided that the receiver element comprises a rotatable inner element for receiving objects. The rotatable inner element can, for example, have the shape of a drum with an open (but preferably closable) cover through which objects to be coated can be introduced into the interior of the rotatable inner element. This embodiment achieves highly reliable results of the coating of the objects while being easily controlled. Additionally, as the objects to be coated are moved inside the rotating inner element when coating the objects, even in case the radiation element does not work properly and for example emits too much radiation, damages to the objects can be reduced, thereby increasing the tolerance of the coating system against failure.

[0032] In one embodiment, the control device can control the operation of the coating system based on the condition by performing at least one of the following: stopping or releasing operation of a component of the coating system, pausing operation of a component of the coating system, changing an operation parameter of a component of the coating system, providing an output indicative of the condition on an output device of the coating system.

[0033] An operation parameter of a component of the operating system is understood as a physical or chemical parameter characterizing (and influencing) the operation of the component of the coating system. For example, the radiation system can have, as an operation parameter, the amount of power provided to the radiation system or its temperature. The amount of power can be changed depending on the sensed condition to, for example, reduce the amount of heat radiated by the radiation element. The output indicative of the condition on an output device can comprise, for example, providing on the output device, the value of the sensed condition (for example, the temperature of the radiation element or the amount of air flow flowing through the cooling system). Additionally or alternatively, an alarm may be triggered should the respective condition exceed a particular threshold value (for example, a particular temperature of the radiation element or the cooling fluids) or drop below such a threshold value. Outputting such information to the operator via an output device (like a display or an acoustic output device) allows the operator to take appropriate actions, thereby improving the operation security of the coating system.

[0034] According to the invention, a method for controlling operation of a coating system for coating objects, particularly small objects, is provided, the coating system comprising:

> a receiver element receiving objects to be coated and moving the objects to be coated;
> a provisioning element providing coating material to objects within the receiver element;
> a radiation element emitting electromagnetic radiation to dry objects provided with coating material in the receiver element;
> a sensor system sensing a condition associated with an operating state of the radiation element;
> a control device controlling operation of the coating system based on the condition sensed by the sensor system;
> the method comprising:
> while the radiation element emits electromagnetic radiation to dry the objects, sensing the condition associated with the operating state of the radiation element by the sensor system and controlling, by the control device, operation of the coating system based on the condition sensed by the sensor system.

[0035] Drying the objects in this context means drying the coating material provided on the objects.

[0036] With this method, reliable operation of the coating system is ensured while also improving the quality of the coated objects.

[0037] It can be provided that the sensor system senses, as a condition, at least one of the following: a temperature of an air flow or cooling liquid, a determination of whether there is an air flow or a flow of the cooling liquid, a temperature of the receiver element (and/or an inside of the receiver element where the objects are received) or a part of the receiver element or the radiation element, a power consumed by the radiation element, a power consumed by a cooling system and/or a liquid cooling system that cools the radiation element, a pressure inside a region bounded by the receiver element and a movable cover of the coating system, an amount of heat exchanged between a heat exchanger and an air flow or a cooling liquid.

[0038] Determining at least one of these conditions with the sensor system results in a reliable determination of whether or not the operation of the coating system or the coating of the objects is done with appropriate operation parameters. In this context, it can be provided that more than one condition is determined and operation of the system is only proceeded with by the control device if all determined conditions met particular characteristics, like, for example, are within a range of parameters (for example above and/or below particular thresholds) that is indicative of proper functioning of the system, particularly the radiation element. It further allows for reliably determining malfunctions of the coating system to thereby increase the operation accuracy and coating quality.

[0039] In one embodiment, the control device controls the operation of the coating system based on the condition sensed by the sensor system by performing at least one of the following: stopping or releasing operation of a component of the coating system, pausing operation of a component of the coating system, changing an operation parameter of a component of the coating system, providing an output indicative of the condition on an output device of the coating system. By controlling the operation of the coating system in this manner, the operation reliability and the quality of coating is furthered improved.

Brief description of the drawings

[0040]

Figure 1 shows a schematic depiction of a coating system for coating objects according to one embodiment.

Figure 2 shows an embodiment of a coating system comprising a cooling system for cool-ing the radiation element.

Figure 3 shows an embodiment of the coating system comprising a fluid cooling system comprising a fluid cycle.

Figure 4 shows an embodiment of a coating system comprising a movable cover.

Figure 5 shows a further embodiment of a coating system comprising an exhaust ventila-tion system

Detailed Description

[0041] Figure 1 shows a coating system 100 according to one embodiment. The coating system 100 is a coating system for coating objects 130, particularly small objects, preferably having maximum dimensions smaller than 20cm, and preferably smaller than 10cm in any direction. The aforementioned is not limiting with respect to what objects are coated and the coating system 100 is generally suitable for coating any small objects having sizes in the above-mentioned range, like, for example, components for pens, toys or mechanical components like sealing elements or components in the area of automotive engineering.

[0042] The coating system comprises a receiver element 104 that can receive objects 130 to be coated. The receiver element can for example, comprise a housing 144 that can generally be assumed to be in a fixed position and can additionally be comprised of a rotatable inner element 143, like a hollow drum, that is open to one side (in the depiction of Figure 1, the topside of the drum). The rotatable inner element 143 can be connected to a drive means 146, like an electric motor or a servo motor that can rotate the rotatable inner element 143 about a rotational axis R. The shape and size of the rotatable inner element 143 is not particularly restricted and any shape and size is possible. For example, the rotatable inner element 143 can also have a hexagonal base surface or a rectangular base surface.

[0043] Instead of a rotatable inner element 143, it is also possible to have a fixed inner element 143 or a hollow housing 144 into which the objects 130 to be coated are introduced. A mixing element (not shown in Figure 1) can be provided that is rotatably connected with the drive means 146 for mixing and thereby moving the objects 130 to be coated within the receiver element 104.

[0044] While, in Figure 1, the receiver element 104 and particularly the axis of rotation R is schematically shown to be parallel to the direction of gravity, it is preferred if the rotational axis R is inclined relative to the direction of gravity. Thereby, the objects to be coated will not only be rotated around the axis R when the rotatable inner element 143 rotates about the axis R, but, due to being lifted and dropping down, the objects 130 are also moved with respect to the rotatable inner element 143 while this is rotated about the rotational axis R. The inclination angle of the rotational axis R with respect to the direction of gravity is preferably between 0° and 90°, most preferably between 22.5°and 67.5°.

[0045] The coating system 100 further comprises a provisioning element 101, that can provide coating material 111 to the objects 130 to be coated while they are preferably within the receiver element 104. The provision of the coating material by the provisioning element 101 can be done continuously, i.e. throughout at least a given time frame like, for example, several seconds or minutes before or during the production cycle where the objects 130 are coated and dried or otherwise processed within the coating system 100. The provisioning element 101 can be or can comprise a dispenser for dispensing the coating material 111 onto the objects to be coated 130. The coating material can be provided to the provisioning element 101 by means of a coating material tank 112 that can, for example, be arranged in an exterior component 147 of the coating system 100 but can also be integrated into the receiver element 104.

[0046] Additionally, the coating system 100 comprises a radiation element 102 for emitting electromagnetic radiation 121 in the direction of objects 130 within the receiver element 104 so as to dry the coating material 111 on the objects 130. The radiation element 102 can be realised as an infrared radiator that emits infrared radiation over a wide spectral range and can particularly be realised as a heating element emitting heat radiation. Alternatively, the radiation element 102 may be or may comprise a UV-radiator for emitting ultraviolet radiation.

[0047] The particular realisation of the radiation element 102 is not restricted according to the invention and may be selected depending on what coating material 111 is used for coating the objects, 130. For example, if the coating material is water based or otherwise coating material that can be activated or dried by infrared radiation, the radiation element 102 may be realised as an infrared radiator. If UV ink or coating material is used, the radiation element 102 may be a UV radiator.

[0048] Instead of using radiation elements that emit electromagnetic radiation over a wide spectral range (more than 50nm spectral range), also radiation elements that emit (preferably diffuse) radiation in a small bandwidth of the electromagnetic spectrum (for example, having a spectral width of less than 50nm, preferably less than 30nm or less than 20nm) can be used. Such radiation elements can comprise one or more LEDs. Use of such LEDs can reduce the amount of energy necessary for drying the coating material.

[0049] According to the invention, the coating system 100 further comprises a sensor system 120 that is schematically shown here. The sensor system 120 is, according to the invention, adapted for sensing or determining a condition associated with an operating state of the radiation element. A condition in the context of the invention is understood as any numerical value of a physical or chemical property that is associated with the operating state of the radiation element. In this respect, the operating state of the radiation element does not only refer to whether the radiation element is properly functioning (for example, emitting a sufficient amount of radiation in a given time-frame) but also encompasses the operation of components associated with the radiation element and which may be necessary for proper functioning of the radiation element. This may, for example, also comprise conditions of one or more cooling systems associated with the radiation element (particularly for cooling the radiation element) and/or conditions relating to the pressure inside the receiver element 104 or whether the coating system 100 and particularly the receiver element 104 is closed so that the interior of the receiver element is not open to the outside environment.

[0050] The invention is thus not limited in regards to what condition is sensed by the sensor system as long as the condition sensed is associated with the operation of the radiation element.

[0051] For exemplary purposes, the embodiment of the coating system 100 is further depicted here as encompassing a cover 140 comprising components 141 and 142. The components 141 and 142 may both be provided as moveable covers 141 and 142 or only one of them may be moveable relative to the receiver element 104 to, for example, open the area defined by the cover 140 and the receiver element and allowing for extracting or introducing objects 130 into the receiver element 104. In the exemplary embodiment of Figure 1, the radiation element 102 and the provisioning element 101 are connected to one of the cover elements 141 and 142, respectively. This is not mandatory in the context of the invention and either one of the provisioning element 101 and the radiation element 102 may be fixedly arranged within or close to the receiver element 104 or both may be fixedly arranged in this sense.

[0052] Additionally, or alternatively, one of the cover elements 141 and 142 may not be moveable and either one or both of the provisioning element 101 and the radiation element 102 may be arranged at this not moveable cover element. Arranging one or both of the provisioning element 101 and the radiation element 102 at a cover element that is not moveable has the advantage that any conducts or connections to other components outside of the not moveable cover element can be rigid or fixed, because the not moveable cover element will not move relative to the components of the coating system. Arranging either one or both of the radiation element 102 and the provisioning element 101 at a moveable cover element (for example cover element 141), can provide the advantage of easier accessibility to the respective components, for example, for maintenance purposes.

[0053] It can further be provided that the cover comprises more than two cover elements (for example 3 cover elements) where at least one of the cover elements is fixed (i.e. not movable) and at least one cover element is movable. In one preferred embodiment, it can be provided that the radiation element 102 and/or the provisioning element 101 is/are arranged at the not movable cover element so as to reduce the number of conducts or connections that have to be movable. Further, in one embodiment, the cover 140 may only comprise a single cover element that is movable relative to the receiver element and the radiation element 102 and/or the provisioning element 101 may optionally be arranged at this single cover element.

[0054] According to the invention, the coating system 100 further comprises a control device 180 which may be realised as, for example, a suitable computer or a central control unit of the coating system. According to the invention, the control device 180 is at least connected to the sensor system 120 in a manner that allows the control device 180 to obtain the sensed condition from the sensor system 120. Furthermore, the control device 180 may be connected to one or more components of the coating system 100 (like, for example, the radiation element 102 or the rotatable inner element 143, if provided, or the drive means 146, if provided) or, for example, a display or interaction device 170 like a display screen or touch screen.

[0055] The control device 180 is, according to the invention, suitable to control the operation of the coating system 100 based on the condition sensed by the sensor system 120. This may encompass changing one or more operating parameters of the coating system 100 (or at least one component of the coating system) and/or stopping or reducing operation of the coating system or a component of the coating system 100 and /or displaying additional information on the display 170 to an operator or requesting the operator to provide input. The invention, is not limited in this respect and any control of any functionality of the coating system 100 based on the condition sensed by the sensor system 120 is encompassed.

[0056] The controlling based on the sensed condition may particularly comprise comparing the sensed condition (for example, the sensed value) to one or more threshold values for the respective condition and taking, by the control device 180, different actions depending on whether, for example, a threshold is exceeded or the value of the condition is below the respective threshold.

[0057] The coating system 100 may comprise further components 145 and 147 that may be connected to the receiver element 104 and may comprise additional components of the coating system 100, like, for example, the already previously described coating material tank 112 and the control device 180. It can also be provided that the receiver element 104 or at least the moveable inner element 143 is movable relative to these additional components 145 and 147.

[0058] Figure 2 shows an embodiment of a coating system 200 (at least partially). In this embodiment, in addition to the components discussed in regards to the embodiment of Figure 1, a cooling system 220 is provided for cooling the radiation element 202.

[0059] The cooling system 220 may comprise at least a flow channel 221 (also referred to as inflow channel) for providing air to the radiation element 202 and a flow channel 223 (also referred to as outflow channel) for removing air from the radiation element 202 and, for example, guide and/or release the air to the outside environment. The flow channels may completely be arranged within the cover 242 of the coating system 200, or they may alternatively or additionally also extend into other components, like the components 145 and/or 147 of the coating system 100.

[0060] If a flow channel 221 and/or 223 extends, into one of the components 145 and/or 147 and the receiver element 104 and particularly the radiation element 202 is arranged so as to be movable relative to the components 145 and/or 147, then the flow channel 221 and/or 223 may comprise connectors that allow for an air tight connection of a first part of the flow channel extending into the component 145 and/or 147 to a second part extending to the radiation element and not extending into the component 145 and/or 147. Insofar, the additional components 145 and/or 147 of the cooling system 220 described in the following may not necessarily be arranged in the cover 242 or the receiver element but may also be arranged outside the cover 242, for example, in one of the components 145 and 147.

[0061] The cooling system 220 is arranged so that it can cool the radiation element 202, preferably by exchanging heat between the radiation element 202 and the air flow being guided through or close to the radiation element. One or more heat exchangers (not shown) may be provided, that exchange heat between the radiation element 202 and the air flowing through the air flow channels 221 and/or 223. Particularly, it can be provided that the inflow channel 221 comprises a portion in close proximity to or indirect physical contact with the radiation element, the portion optionally having an increased surface area to allow for a larger amount of heat being transferred, compared to a region of the air flow channel 221 that has the same volume but smaller surface area. Thereby, a more efficient heat exchange is possible.

[0062] Within or associated with the air flow channels 221 and 223, there may be provided one or more ventilators 222 and 225 for actively streaming the air through the air flow channels.

[0063] In some embodiments, a heat exchanger 224 may be provided that can exchange heat between the air leaving the radiation element 202 (for example, within the outflow channel 223) and the interior of the coating system 200, particularly with the receiver element and more particularly with the inside of the receiver element 104 in which the objects 130 are arranged for coating. Thereby, the objects to be coated can additionally be heated by using excess energy obtained by cooling the radiation element. The amount of energy required to be emitted by the radiation element 202 for the drying of the coating material can thereby advantageously be reduced.

[0064] The sensor system described in regards to Figure 1 can comprise one or more sensors that can measure conditions associated with one or more of the previously described components.

[0065] For example, there may be provided a first and/or second sensor 231 and 235, that are associated with the respective ventilators 222 and 225 and can measure, for example, the amount of power consumed by the ventilators or generally the cooling system 220. If only one ventilator is provided, only one sensor 231 or 235 can be provided. If two ventilators 222 and 225 are provided, it may suffice if only one sensor 231 or 235 is provided for measuring the power consumed by at least one of the ventilators or if two sensors 231 and 235 are provided for measuring the power consumed by the ventilators. The same holds if more ventilators are provided and it can be preferred if, for each of the ventilators, a respective sensor for measuring the power consumed is provided. In this respect, it is noted that the sensors associated with the respective ventilators need not necessarily be separate physical entities (i.e. structurally separate sensors). They can also be realised as a single sensor that determines the overall amount of energy consumed by all ventilators. This can reduce the complexity of the coating system.

[0066] Additionally or alternatively, there may be provided one or more sensors 233 for measuring an amount of air flowing to and/or away from the radiation element 202. The amount of air flow is indicative of the amount of cooling that can be obtained with the cooling system and, for example, if one of the flow channels 221 and 223 leading air either to the radiation element or leading air away from the radiation element are somehow blocked, the cooling of the radiation element can fail.

[0067] The control device 280 can determine whether the amount of airflow detected by the sensor(s) is, for example, within a particular range that can either be preset or automatically determined based on, for example, the energy consumed by the radiation element 202. If the amount of airflow sensed by the sensor(s) is outside this range, the control device can control the display device 170 (see Figure 1) to output/trigger a warning or alarm and/or the control device can turn of the radiation element 202 to prevent the system from failing. Alternatively or additionally, the control device 280 may be adapted to adjust the amount of air flow by increasing or decreasing the power provided to the ventilator(s). If the amount of air flow is, for example, smaller than a minimum amount, the power provided to the ventilators can be increased until the amount of air flow is within the particular range. If the amount of air flow is too high or higher than a maximum amount, the power provided to the ventilator(s) can be reduced until the amount of air flow is within the particular range.

[0068] As previously mentioned, a heat exchanger 224 may be provided for exchanging heat between the air flowing away from the radiation element 202 and another component of the coating system 200. A further sensor 234 of the sensor system can be provided that can measure a temperature of the air before the air passes the heat exchanger 224 and after the air has passed the heat exchanger 224. The sensor 234 may comprise, for example, two temperature sensors, on being arranged upstream of the heat exchanger 224 and one being arranged downstream of the heat exchanger 224.

[0069] The drop in temperature of the air can indicate whether sufficient heat is removed from the radiation element 202 and/or whether the amount of air flow is sufficient for cooling the radiation element 202. The temperatures measured and/or the temperature difference can be provided by the sensor 234 to the control device 280 which can again compare the respective value to a threshold value and based on whether this threshold is exceeded or the obtained value is below the threshold value, control the coating system.

[0070] Alternatively or additionally, a sensor (not shown) of the sensor element can be provided that measures the temperature in the interior of the receiver element. If the temperature in the interior increases, this can be indicative of an insufficient cooling of the radiation element 202 or an optional cooling of the receiver element. Using this temperature of the interior of the receiver element as a condition, the control device 280 can, for example, stop operation of the radiation element 202 if the temperature in the interior of the receiver element exceeds a given threshold temperature that can be indicative of a proper amount of cooling of the radiation element 202.

[0071] In one embodiment, a sensor 232 can be provided that can measure a temperature of the radiation element 202 and/or a temperature of a surrounding region (for example, the cover 242) of the radiation element 202.

[0072] Based on the temperature of the radiation element 202 and /or the surrounding region of the radiation element 202, the control device 280 can, for example, increase or reduce an amount of air flowing to or from the radiation element 202 by increasing or decreasing the power provided to the ventilator(s) (see above) so as to, for example, maintain the temperature at a particular value or within a particular temperature range that is acceptable for operation of the radiation element 202. If, for example, the ventilators 222 and /or 225 are already at maximum power, but the temperature of the radiation element still exceeds, for example, a given temperature threshold, it can be provided that the control device 280 stops operation of the radiation element 202 or the whole coating system 200 and/or indicates a malfunction of the cooling system and/or the radiation element 202 to the operator, for example, via a corresponding alert on the display device 170.

[0073] It is noted that the described components of the cooling system 220 and the sensors can be provided in any combination and particularly only one of the respective components (ventilator(s), heat exchanger) can be provided together with their associated sensors or any combination of these components can be provided together with the associated sensors.

[0074] Figure 3 shows a further embodiment that can be combined with all previously mentioned embodiments. In this embodiment, the coating system 300 comprised a fluid cooling system 320.The cooling system discussed in relation to Figure 2 is an open cooling system where air from the exterior is used to cool the radiation element and the (heated) air is vented into the exterior environment.

[0075] In contrast to this, the fluid cooling system 320, according to the embodiment of Figure 3, is a "closed" cooling system in the sense that it has a closed cooling cycle 321, where the cooling medium inside the cooling cycle 321 is not exchanged.

[0076] The fluid cooling system 320 may, for example, be filled with a gaseous or liquid (for example, water) fluid cooling medium that is pumped through the fluid cycle or conduit 321 by a pump 322 or (particularly in the case of a gaseous cooling fluid) a ventilator 322. A heat exchanger 323 may be provided that can be adapted to remove heat from the fluid in the fluid cycle (particularly after the fluid has passed the radiation element 302) and provide the heat either to the exterior environment and/or to the interior of the receiver element (not shown) for additionally heating the objects to be coated. Alternatively or additionally, a cooling capacity for cooling the cooling medium after it has passed the radiation element 302 can be provided to reduce the temperature of the cooling medium again.

[0077] In this embodiment, a sensor 331 of the sensor system may be provided that can determine an amount of cooling fluid flowing from the pump 322 and/or flowing in to the pump 322 through the fluid cycle 321 or can otherwise determine the amount of cooling fluid flowing through a particular portion of the fluid cycle 321 within a particular time frame (for example per second or per minute). With this, it can be determined how much cooling capacity is available for cooling the radiation element. In case the amount of cooling fluid flow drops below a particular threshold value or there is no flow of cooling fluid from and/or to the pump, the control device 380 can, for example, stop operation in the coating system 300 and/or increase the power of an alternative cooling system (like, for example, the cooling system 220 discussed in relation to Figure 2) to compensate for a lack of cooling power provided by the fluid cooling system 320.

[0078] Alternatively, or additionally, the sensor 331 may be provided to measure a temperature of the cooling fluid before and/or after the radiation element to determine whether sufficient heat is removed from the radiation element 302. If the temperature difference is, for example, below a particular threshold, i.e. there is not much change in the temperature of the cooling fluid after passing the radiation element 302, this can indicate that either cooling is not properly functioning or the radiation element 302 is not working properly. In such a case, the control device 380 can control the display device 170 to output a warning or information indicative of the temperature of the cooling fluid not changing and can optionally instruct the operator of the coating system to, for example, check proper functioning of the radiation element 302.

[0079] Should the temperature difference exceed a given threshold that may be seen as indicative for the required amount of cooling at a given amount of heat emitted by the radiation element, then this can be indicative for the radiation element emitting too much heat and/or the cooling system not functioning properly. Based on determining that the threshold is exceeded, the control device can then control the display device 170 to output a warning or information that is indicative of the temperature of the cooling fluid changing too much and can optionally instruct the operator of the coating system to, for example, check proper functioning of the radiation element 302.

[0080] An additional sensor 332 may be provided (or may be provided instead of the sensor 331) that can measure a power consumed by the pump and/or ventilator 322 to determine whether it is properly functioning and there is sufficient circulation of cooling fluid in the fluid cycle 321. Should the amount of power consumed be below a particular threshold (that can either be pre-set or dynamically changed, for example, based on the power consumed by the radiation element 302), the control device 380 can either increase the power provided to the pump and/or ventilator 322 and/or the control device 380 can output information to an operator that the pump and/or ventilator 322 is not properly working. Alternatively or additionally, the control device may stop operation of the heating element 302 to avoid overheating.

[0081] If the heat exchanger 323 is provided, a sensor 333 may be provided that can determine either a temperature of the heat exchanger and/or an amount of heat transferred from the fluid and/or a temperature of the fluid before and after having passed the heat exchanger. This allows for determining how much heat is transferred from the radiation element to the fluid and how much heat, for example, is available for further heating the interior of the receiver element. If the heat transferred from the cooling fluid via the heat exchanger drops below a particular threshold, or if there is no temperature difference in the fluid before and after passing the heat exchanger, the control device 380 can determine that there is either insufficient or too much cooling of the radiation element 302 and can control the power provided to the fluid cooling system 320 (particularly the pump and/or the ventilator 322). Alternatively or additionally, if the obtained values indicate a failure of the cooling system, the control device can control the display device 170 (see Figure 1) to provide a warning or other output to the user and, for example, indicative of the failure of the cooling system, optionally prompting the operator to take further actions.

[0082] Figure 4 shows a further embodiment that can be combined with any of the previously described embodiments. In this embodiment, the coating system 400 comprises of at least one movable cover 443 as already previously described. It may be provided that the radiation element and/or the provisioning element of the previous embodiments (not shown in Figure 4) are connected with or provided at the movable cover 441 but this is not necessarily the case.

[0083] In this embodiment, a sensor 431 can be provided that can sense whether the movable cover 441 is in its closed position or opened (shown in dash lines with the position 443) moved away from the other cover element 442 so that the interior of the coating system or the receiver element is at least partially accessible. This would lead to a potential interruption of the cooling flow, as for example, the connection of the inflow of the cooling system for cooling the radiation element could be interrupted.

[0084] In such a case, the sensor can provide a signal to the control device 480 that is indicative of the movable cover 441 being opened and the control device 480 can stop the operation of the coating system 400. Alternatively, or additionally the sensor 431 can measure the pressure inside the receiver element (the region where the objects to be coated are placed) and, if there is a change in this pressure and/or if it exceeds a particular threshold that may for example be atmospheric pressure if coating is performed at a reduced pressure inside the receiver element, this can be indicative of an opening of the moveable element 441 (or generally the cover) and the control device can likewise stop operation of the coating system.

[0085] If the interior of the receiver element is connected to an air flow device comprising, for example, a ventilator to remove or filter air from the interior of the receiver element (see also Figure 5), the sensor 431, by measuring the pressure inside the receiver element, can likewise determine whether the respective air flow system is properly functioning. For example, it can be provided that the interior of the receiver element, if the moveable cover 441 is properly closed, is provided with a lower pressure compared to the outside atmospheric pressure. If this pressure is smaller than a given threshold value, the control device 480 can determine that the air flow device is sucking too much air from the interior of the receiver element and reduce, for example, the power consumption or the power provided to the air flow device.

[0086] If the air pressure inside the receiver element is above a threshold but still below atmospheric pressure, the control device can determine that the moveable cover 441 is still in the closed positon but the power provided to the airflow device has to be increased to reduce the pressure further.

[0087] Instead of comparing the pressure determined by the sensor 431 to a particular threshold, in one embodiment, a differential pressure to the outside environment can be determined. Like in the above examples and in analogy thereto, if the determined differential pressure is below a particular threshold (that, for example, can indicate an intended pressure difference to the outside environment), the control device can determine that the air flow device does not suck enough air from the interior of the receiver element and can, for example, increase the power provided to the air flow device (like a ventilator). If the differential pressure is above a particular threshold, the control device can reduce the amount of power provided to the air flow device as too much air is sucked from the interior of the receiver element in this case.

[0088] It can also be provided that the interior of the receiver element is connected to the inflow and/or outflow channel of the cooling system described in relation to Figure 2. In such a case, the sensor 431, by measuring the pressure inside the receiver element, can likewise provide a condition or value of the condition of the interior of the receiver element that is used by the control device for controlling the operation the coating system based on this sensed condition.

[0089] Figure 5 shows a further embodiment where the system 500, an exhaust ventilation system 501 for removing air from the inside (or interior, as mentioned previously) 541 of the receiver element 504 at least while the inside 541 is closed by a cover 521.

[0090] The exhaust ventilation system 501 may comprise an air flow channel 515 that is, on the one end, connected to the inside 541 of the receiver element 504 and, on the other end, connected to the outside 542 (for example free space around the system). Within the air flow channel, a ventilator or pump 512 may be arranged so that it can vent or pump air from the inside 541 of the receiver element 504 through the air flow channel and to the outside (or environment) 542. In one embodiment, it can be provided that the exhaust ventilation system 501 is adapted or controlled by the control device 580 to maintain an underpressure (or overpressure) in the inside compared to the outside. For example, the ventilator or pump 512 may be controlled in order to maintain the pressure in the inside 541 at 0.9bar or 0.95bar or 0.8bar. This, however, is not necessarily the case and in one embodiment the same pressure as in the outside 542 can be maintained in the inside 541.

[0091] Though not shown, the exhaust ventilation system 501 can comprise an inflow channel via which air can flow into the inside 541 of the receiver element 504. A ventilator or pump can be arranged in this inflow channel to control the amount of air flowing into the inside 541. This control can be provided in order to maintain an underpressure (or overpressure) compared to the outside 542 in the inside 541.

[0092] Furthermore, the exhaust ventilation system 501 may comprise, for example within the air flow channel 515, a filter element 511 for filtering air from the inside 541 of the receiver element before it is released to the environment 542. The filter element 511 may be arranged downstream of the ventilator or pump 512 (as shown) or upstream of the ventilator or pump 512 in the direction of air flow through the air flow channel 515. The filter 511 element may comprise a porous filter region through which air can flow but particles having a size larger than the size of the pores of the porous substrate cannot flow. The porous filter region may, for example, comprise activated carbon and/or a fibrous material having pores of a diameter of 50μm or less for filtering the air flowing through the filter region. This may be advantageous because particles of the coating material can be removed from the air flow before the air flow is released to the environment, thereby avoiding pollutions.

[0093] In one embodiment, the sensor system comprises a sensor 513 for sensing a pressure difference between the pressure upstream and downstream of the filter element. The sensor may comprise two sensor units, one arranged upstream and one arranged downstream of the filter element 511 (not shown explicitly).

Each sensor element can determine the pressure and, from these two pressure values, a pressure difference can be determined.

[0094] Alternatively, the sensor 513 may be realized as a differential pressure sensor for determining the differential pressure at the filter element as is known in the art.

[0095] The pressure difference or differential pressure can then be used by the control device 580 as a condition for controlling operation of the system 500 and/or the radiation element 502. For example, the pressure difference or differential pressure may be indicative of the condition of the filter element, particularly whether the filter element is blocked. If the differential pressure exceeds a given threshold that can be indicative for the filter element being blocked, the control device 580 can shut down the radiation element 502 or the complete operation of the system. This can be advantageous since a blocked filter element 511 could result in coating material accumulating in the inside 541 of the receiver element to a degree that can have impact on the coating quality or even security risks.

[0096] Alternatively or additionally, if the differential pressure exceeds a particular threshold or drops below such threshold as explained above, the control device 580 can control a display device (like the display device 170 in Figure 1) to provide a warning or alarm or instruction to change the filter element or part of the filter element 511.

[0097] Alternatively or additionally, the sensor system can comprise a sensor 514 for determining, for example, an amount of power consumed by the ventilator or pump 512 and/or for determining an amount of air flow flowing through the air flow channel 515, as was already explained in the above embodiments.

[0098] The values determined by the sensor 514 can then be used as a condition by the control device 580 to control operation of the system 500 and/or the radiation element 502. If the amount of air flow is, for example, too low, this can indicate a malfunction resulting in an accumulation of coating material in the inside 541 with the respective negative impacts as mentioned above already. If the amount of air flow is below a particular threshold level, the control device may either control the energy supply of the ventilator or pump 512 so as to increase the amount of air flow and/or the control device may stop operation of the radiation element 502 and/or the system 500.

Claims

1. A coating system for coating objects, particularly small objects, the coating system comprising:

   a receiver element for receiving objects to be coated and for moving objects to be coated;
   a provisioning element for providing coating material to objects within the receiver element;
   a radiation element for emitting electromagnetic radiation to dry objects provided with coating material in the receiver element;
   a sensor system for sensing a condition associated with an operating state of the radiation element;
   a control device for controlling operation of the coating system based on the condition sensed by the sensor system.

2. The coating system according to claim 1, further comprising a cooling system for cooling the radiation element by providing an airflow to the radiation element, wherein the sensor system is adapted to sense, as the condition, an amount of airflow to the radiation element and/or an amount of airflow away from the radiation element, and/or wherein the sensor system is adapted to sense an amount of power consumed by the cooling system.

3. The coating system according to claim 1 or 2, wherein the system comprises an exhaust ventilation system for removing air from an inside of the receiver element, wherein the exhaust ventilation system comprises a filter element through which air flows away from the inside of the receiver element, wherein the sensor system is adapted to sense, as the condition, a differential pressure at the filter element.

4. The coating system according to claim 2, wherein the cooling system comprises a heat exchanger arranged for removing heat from air flowing away from the radiation element and for providing heat to an interior of the receiver element.

5. The coating system according to claim 4, wherein the sensor system is adapted to sense, as a condition, an amount of heat removed from the air flow by the heat exchanger and/or a temperature of the heat exchanger and/or a temperature of the air before and after passing the heat exchanger.

6. The coating system according to any of claims 1 to 5, wherein the coating system comprises at least one movable cover for sealing the receiver element in a closed state, wherein the sensor system is adapted to sense, as the condition, whether the cover is in the closed state by sensing a position of the movable cover and/or by sensing a pressure inside a region bounded by the receiver element and the movable cover.

7. The coating system according to any of claims 1 to 6, wherein the sensor system is adapted to sense, as the condition, a temperature of the radiation element and/or a surrounding region of the radiation element.

8. The coating system according to any of claims 1 to 7,

wherein the coating system comprises a fluid cooling system comprising a fluid cycle inside the coating system, wherein the fluid cooling system comprises a pump for pumping the fluid through the fluid cycle and the sensor system is adapted to sense, as the condition, an amount of fluid flow through the fluid cycle and/or an amount of power consumed by the pump and/or a temperature difference at two points in the fluid cycle.

9. The coating system of claim 8, wherein the fluid cooling system comprises a heat exchanger for exchanging heat between the fluid in the fluid cycle and the environment or an interior of the receiver element, and wherein the sensor system is adapted to sense, as the condition, a temperature of the heat exchanger and/or a temperature of the fluid before and after passing the heat exchanger.

10. The coating system according to claim 8 or 9, wherein the fluid is a gaseous or liquid medium.

11. The coating system according to any of claims 1 to 10, wherein the receiver element comprises a rotatable inner element for receiving objects.

12. The coating system according to any of claims 1 to 11, wherein the control device can control the operation of the coating system based on the condition by performing at least one of: stopping or releasing operation of a component of the coating system, pausing operation of a component of the coating system, changing an operation parameter of a component of the coating system, providing an output indicative of the condition on an output device of the coating system.

13. A method for controlling operation of a coating system for coating objects, particularly small objects, the coating system comprising:

a receiver element receiving objects to be coated and moving the objects to be coated;
a provisioning element providing coating material to objects within the receiver element;
a radiation element emitting electromagnetic radiation to dry objects provided with coating material in the receiver element;
a sensor system sensing a condition associated with an operating state of the radiation element;
a control device controlling operation of the coating system based on the condition sensed by the sensor system;
the method comprising:
while the radiation element emits electromagnetic radiation to dry the objects, sensing the condition associated with the operating state of the radiation element by the sensor system and controlling, by the control device, operation of the coating system based on the condition sensed by the sensor system.

14. The method according to claim 13, wherein the sensor system senses, as a condition, at least one of: a temperature of an air flow or cooling liquid, a power consumed by the radiation element, a power consumed by a cooling system and/or a liquid cooling system that cools the radiation element, a pressure inside a region bounded by the receiver element and a movable cover of the coating system, an amount of heat exchanged between a heat exchanger and an air flow or a cooling liquid.

15. The method according to claim 13 or 14, wherein the control device controls the operation of the coating system based on the condition sensed by the sensor system by performing at least one of: stopping or releasing operation of a component of the coating system, pausing operation of a component of the coating system, changing an operation parameter of a component of the coating system, providing an output indicative of the condition on an output device of the coating system.

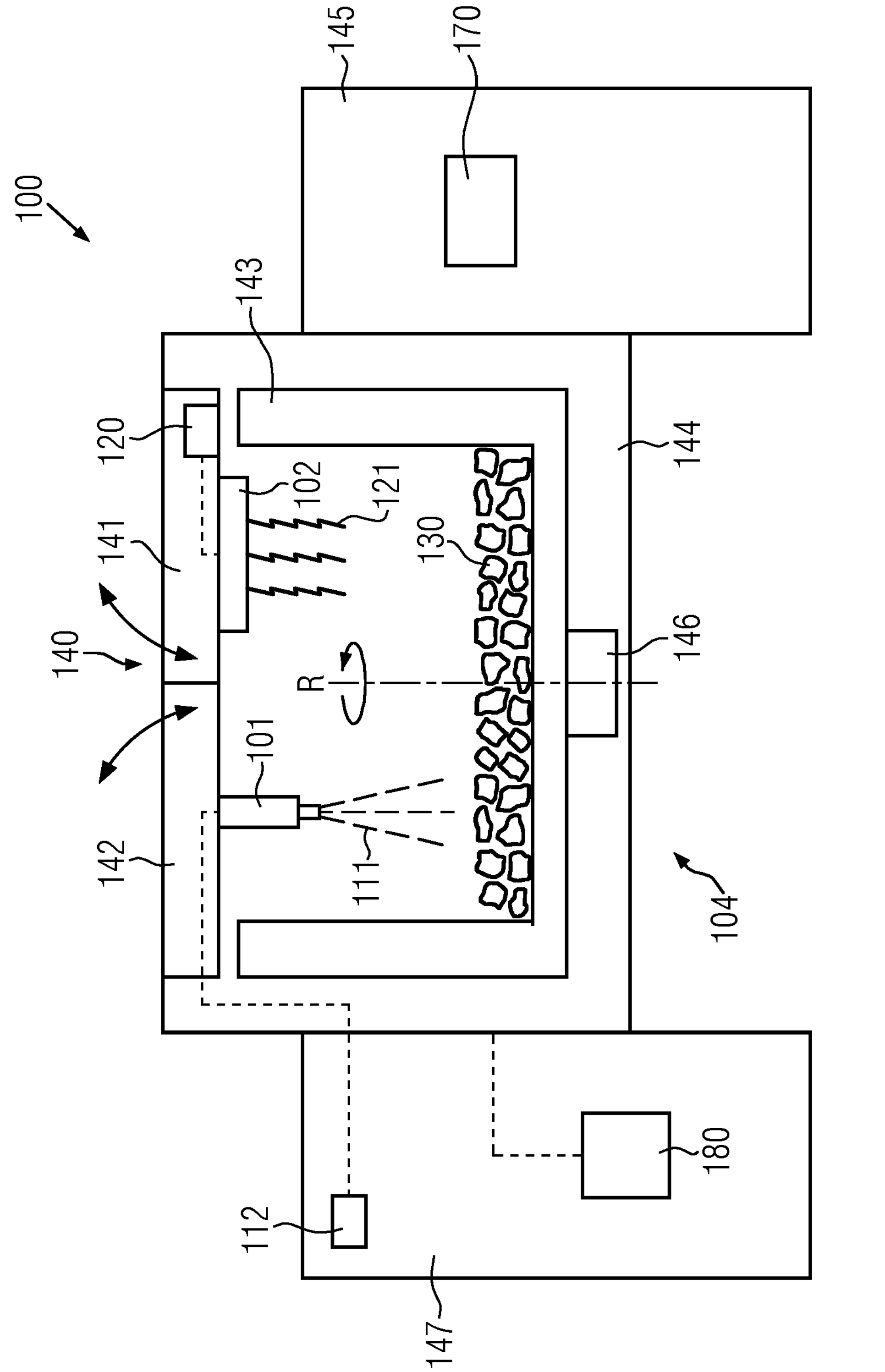
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FIG. 1

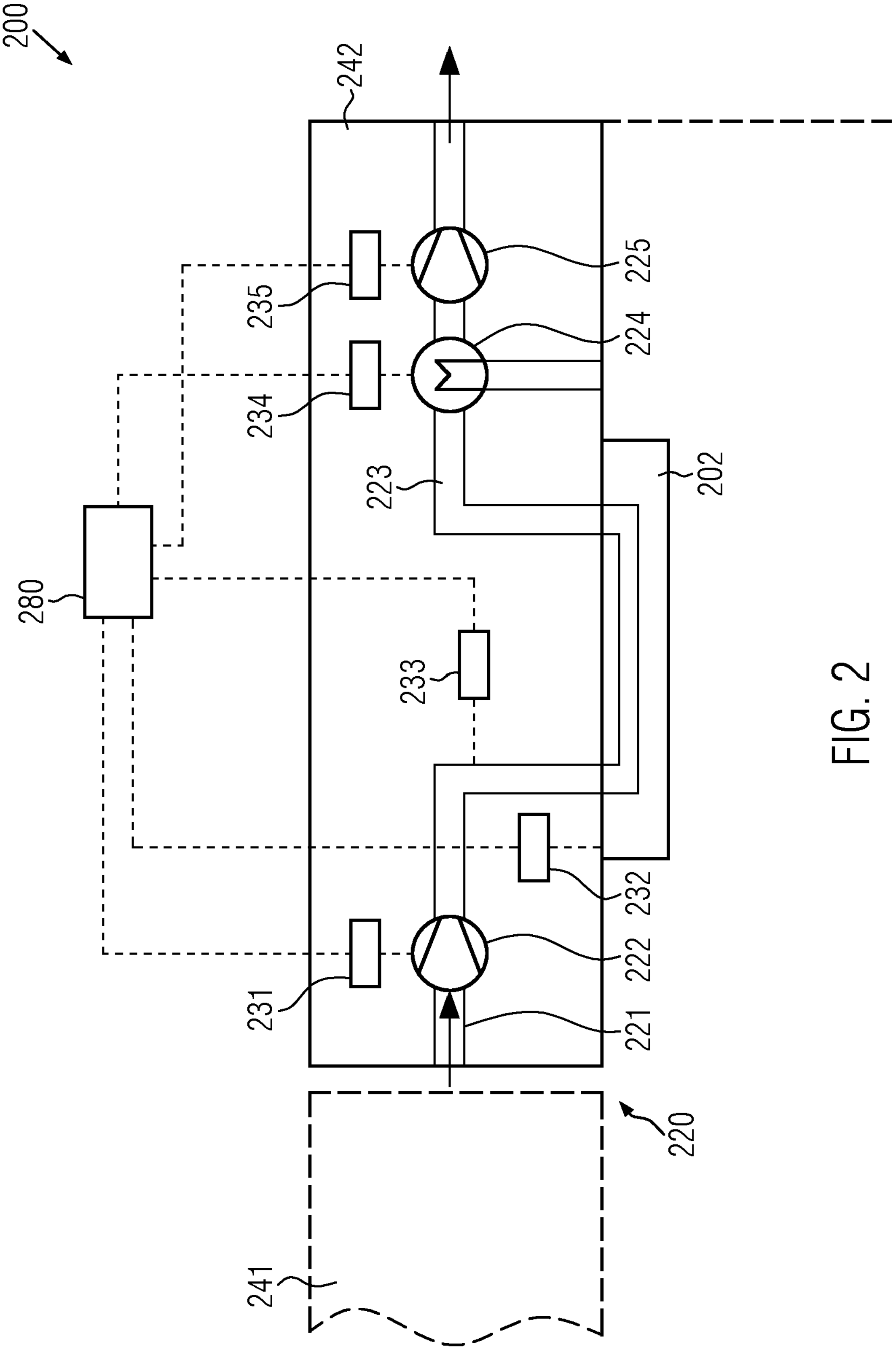

FIG. 2

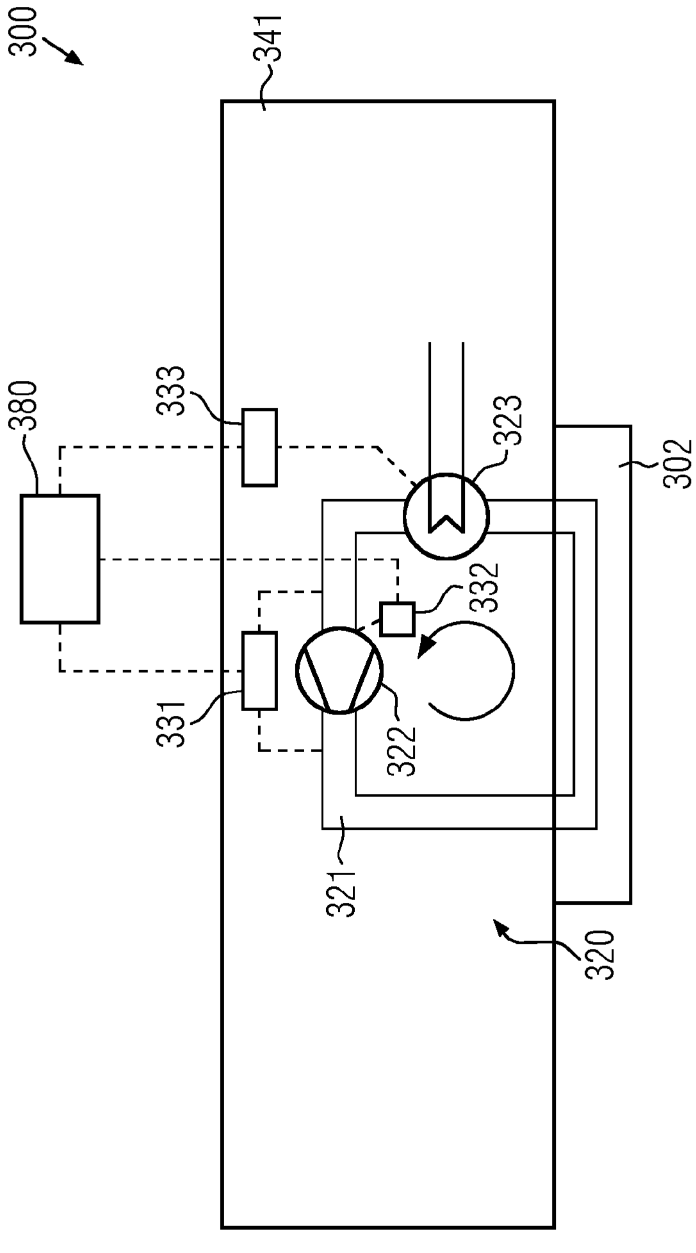
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FIG. 3

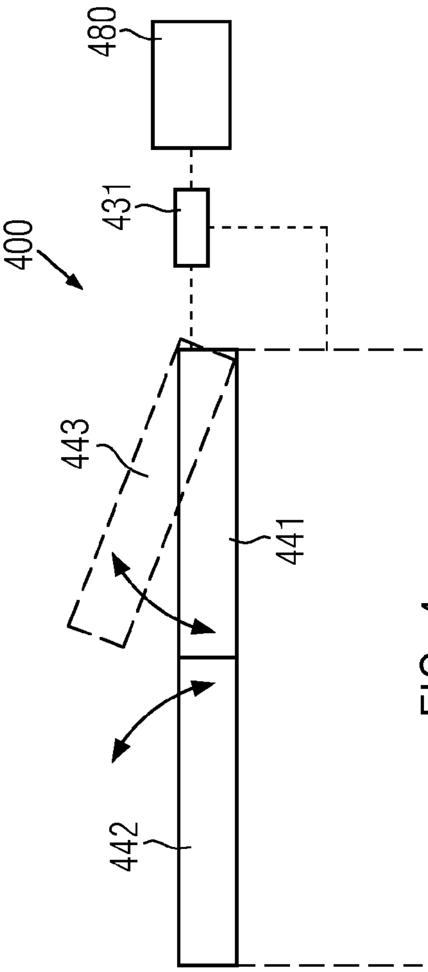
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FIG. 4

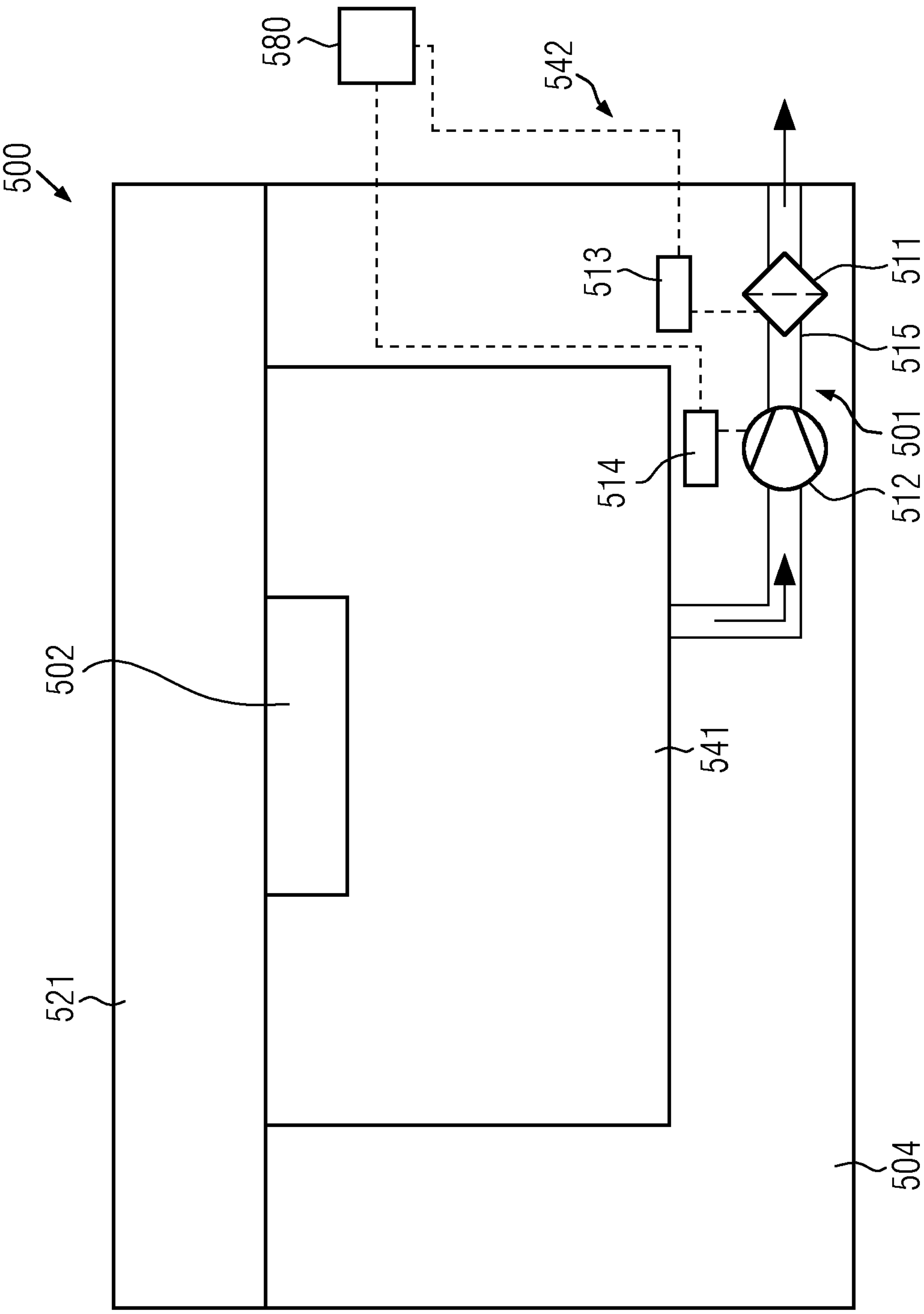

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 4316

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F26B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	21 March 2024	Makúch, Milan

CATEGORY OF CITED DOCUMENTS

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