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(54) EJECTION OF A COOLANT

(57) Method for ejecting a coolant (2), comprising:
a) providing the coolant (2) within a storage tank (5), wherein the coolant (2) comprises a liquid phase (3),
b) determining a filling level (8) of the liquid phase (3) of the coolant (2) within the storage tank (5),
cl) ejecting the coolant (2) from the storage tank (5) via a first ejection installation (6) if the filling level (8) determined in step b) is above a predetermined threshold, and
c2) ejecting the coolant (2) from the storage tank (5) via a second ejection installation (7) if the filling level (8) determined in step b) is below the predetermined threshold.

With the described method and device (1), a coolant (2) can be ejected such that a particularly constant cooling power can be achieved. Thereby, a decrease in the cooling power due to an increase in the gas fraction of the coolant (2) can be compensated by switching from the first ejection installation (6) to the second ejection installation (7) allowing a higher flow rate.

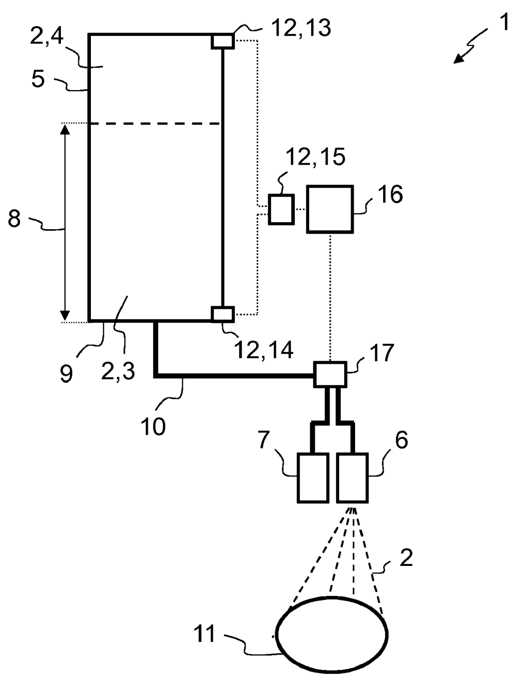

Fig. 1

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Description

[0001] The invention is directed to a method and a device for ejecting a coolant. Further, the invention is directed to a method for cooling an object by the coolant, in particular a food product. In particular, liquid nitrogen is used as the coolant.

[0002] Coolants such a nitrogen can be used to cool objects such as food products. In order to achieve a predictable cooling effect, the cooling power provided by the coolant is desired to be constant. However, if liquid nitrogen from a storage tank is used for cooling, the cooling power usually decreases over time. This is due to the fact that the cooling power depends on the gas fraction of the nitrogen. With the filling level of the liquid nitrogen decreasing, the gas fraction increases and the cooling power decreases.

[0003] This effect is particularly disadvantageous if the coolant is ejected in a constant manner. In such a process it is assumed that the cooling power is proportional to the flow rate. In fact, however, the cooling power also depends on the gas fraction of the coolant.

[0004] From the prior art methods are known in which the flow rate of the coolant is controlled in order to achieve a constant cooling power. Such methods however, cannot sufficiently compensate the described influence of the gas fraction of the coolant. This can reduce the production capacity.

[0005] It is, therefore, an object of the present invention to overcome at least in part the disadvantages known from prior art and, in particular, to provide a method and a device for ejecting a coolant such that a particularly constant cooling power can be achieved.

[0006] These objects are solved by the features of the independent claims. Dependent claims are directed to preferred embodiments of the present invention.

[0007] According to the invention a method for ejecting a coolant is presented. The method comprises:

a) providing the coolant within a storage tank, wherein the coolant comprises a liquid phase,
b) determining a filling level of the liquid phase of the coolant within the storage tank,
c1) ejecting the coolant from the storage tank via a first ejection installation if the filling level determined in step b) is above a predetermined threshold, and
c2) ejecting the coolant from the storage tank via a second ejection installation if the filling level determined in step b) is below the predetermined threshold.

[0008] By means of the described method a coolant can be ejected. In particular, the coolant can be ejected form one or more nozzles. Thus, the first ejection installation and/or the second ejection installation comprise at least one respective nozzle. The ejected coolant can be used for a further process. For example, the coolant can be ejected such that an object can be cooled by the coolant. In particular, the coolant can be ejected in order to cool a food product as the object. The method can be applied, in particular, to a freezer for cooling objects. That is, by the described method the coolant can be ejected from the ejection installations and thereby introduced into the freezer. The ejection installations are thus preferably arranged within a cooling chamber of a freezer, in particular of a freezer for cooling food products.

[0009] The coolant is a substance that can be used for cooling. Preferably, the coolant is gaseous at standard conditions. Preferably, the coolant is a cryogenic substance. With the described method the coolant can be ejected such that a particularly constant cooling power can be achieved. This is due to the fact that the coolant is ejected via different ejection installations depending on the filling level. The first filling installation can be adapted to properties of the coolant at relatively high filling levels, the second filling installation can be adapted to properties of the coolant a relatively low filling levels. The first filling installation and the second filling installation are separate elements. The first filling installation is configured differently from the second filling installation. Preferably, the first ejection installation is adapted to ejecting the coolant having a first gas fraction and the second ejection installation is adapted to ejecting the coolant having a second gas fraction, wherein the first gas fraction is lower than the second gas fraction, in particular by a factor in the range of 5 to 20.

[0010] By using separate filling installations with different properties, the cooling power can be maintained constant particularly well, in particular compared to a mere flow rate control. With a single ejection installation the flow rate could be controlled only within an insufficiently small range. In contrast to such a mere flow rate control, the described method adds a further degree of freedom to the control.

[0011] In step a) the coolant is provided within the storage tank. The storage tank can be any enclosed volume in which the coolant can be stored. The coolant can be provided such that the storage tank is filled prior to the beginning of the method, wherein the filled storage tank is provided as step a). Alternatively, the coolant can be provided in step a) by filling the coolant into the storage tank. Preferably, the coolant is provided in step a) such that the storage tank is filled up to a maximum filling level. The maximum filling level corresponds to the maximum amount of the coolant that is supposed to be filled into the storage tank.

[0012] The coolant within the storage tank is provided such that the coolant in the storage tank comprises a liquid phase and, preferably, also a gaseous phase. Naturally, the gaseous phase is arranged on top of the liquid phase. Within the storage tank the liquid phase and the gaseous phase are preferably in thermal equilibrium with each other. That is, the pressure within the storage tank is the equilibrium vapor pressure.

[0013] In step b) the filling level of the liquid phase of the coolant within the storage tank is determined. This can be done, for example, by means of a differential pressure measurement.

[0014] The filling level is a measure for the distance from the lowest point of the storage tank to where the gaseous phase and the liquid phase adjoin each other. The latter can be referred to as the dividing line between the gaseous phase and the liquid phase.

[0015] It is not required to determine the absolute filling level, that is the distance from the lowest point of the storage tank to the dividing line between the liquid phase and the gaseous phase of the coolant. It is sufficient to determine the filling level with respect to a fixed reference point, that is the distance from the reference point to the dividing line between the liquid and gaseous phases of the coolant. If the reference point is not the lowest point of the storage tank, the determined filling level deviates from the absolute filling level by a constant offset. Such a constant offset, however, is irrelevant for the described method.

[0016] Depending on the result of step b), the coolant is ejected either via the first ejection installation (step c1)) or via the second ejection installation (step c2)). That is, steps c1) and c2) are alternatives, of which one is performed at a time. However, the methods comprises both steps. That is, during a first period of time the coolant is ejected via the first ejection installation according to step c1) and during a second period of time, the coolant is ejected via the second ejection installation according to step c2). The first period of time can be before or after the second period of time. The first and second periods of time follow each other preferably, but not necessarily, without a time gap in between.

[0017] If the filling level is higher than the predetermined threshold, the coolant is ejected via the first ejection installation (step c1)). If the filling level is lower than the predetermined threshold, the coolant is ejected via the second ejection installation (step c2)). Starting from a storage tank filled to the maximum filling level the coolant is first ejected via the first filling installation (step c1)). Over time, the filling level decreases. Once the filling level is lower than the threshold, the coolant is ejected via the second filling installation (step c2)).

[0018] The threshold is preferably between 30 and 60 % of the maximum filling level. Preferably, the threshold is set according to a set of initial tests.

[0019] According to a preferred embodiment of the method the coolant is nitrogen.

[0020] Nitrogen is a cryogenic substance with a boiling point of 77 K. The method according to the present embodiment is thus applicable to processes, in which correspondingly low temperatures are desired. The fact that nitrogen is the coolant thus defines the technical field of the presented method.

[0021] Further, in particular nitrogen shows the described effect that the achievable cooling power depends on the gas fraction of the coolant. Thus, the described advantages of the presented method are achievable in a particularly pronounced manner if nitrogen is the coolant.

[0022] According to a further preferred embodiment of the method in steps c1) and c2) the coolant is extracted from a bottom of the storage tank.

[0023] If the storage tank is filled with the coolant, initially the temperature within the storage tank is low. The density of the coolant is highest at the bottom of the storage tank. Accordingly, the temperature of the coolant is lowest at the bottom of the storage tank. Thus, the gas fraction of the coolant extracted at the bottom of the storage tank is low and the cooling power is high. However, over time the gas fraction of the coolant extracted from the storage tank increases. This is due to the fact that the temperature of the coolant is higher at the top of the liquid phase than at the bottom of the liquid phase. The more coolant is consumed, the more coolant from an upper layer of the liquid phase is extracted at the bottom of the storage tank. This effect is also enhanced by heat intake into the storage tank.

[0024] That is, the described advantages of having two different ejection installations are achievable in a particularly pronounced manner if the coolant is extracted at the bottom of the storage tank.

[0025] The bottom of the storage tank is the lower side of the storage tank. If the storage tank has a cylindrical shape, the bottom of the storage tank is the lower end face of the cylinder. If the storage tank has a shape that deviates from a cylindrical shape, a corresponding definition applies.

[0026] According to a further preferred embodiment of the method the coolant is ejected at a first flow rate in step c1), wherein the coolant is ejected at a second flow rate in step c2), and wherein the first flow rate is lower than the second flow rate.

[0027] Step c1) is performed if the filling level is high and, correspondingly, the gas fraction of the coolant is low and the achievable cooling power is high. Thus, the comparatively low flow rate is sufficient. Step c2) is performed if the filling level is low and, correspondingly, the gas fraction of the coolant is high and the achievable cooling power is low. The lower cooling power can be compensated by using a higher flow rate.

[0028] According to a further preferred embodiment of the method the first flow rate is between 5 and 20 times lower than the second flow rate.

[0029] It was found that increasing the flow rate by a factor of 5 to 20 can particularly well compensate the loss in cooling power due to an increase in the gas fraction of the coolant.

[0030] According to a further preferred embodiment of the method the coolant is ejected only via one of the ejection installations at a time.

[0031] In the present embodiment the coolant is ejected only via the first ejection installation in step c1) and only via the second ejection installation in step c2). Steps c1) and c2) are not performed simultaneously.

[0032] According to a further aspect of the invention, a method for cooling an object is presented, wherein a coolant is ejected by the described method such that the object is cooled by the coolant.

[0033] The details and advantages disclosed for the method for ejecting a coolant can be applied to the method for cooling an object, and vice versa.

[0034] According to a preferred embodiment of the method the object is a food product.

[0035] In the present embodiment the technical field of the method is defined by the fact that food products are cooled. In particular in this technical field a constant cooling power is desirable.

[0036] According to a further aspect of the invention, a device for ejecting a coolant is presented. The device comprises:

- a storage tank for the coolant
- a first ejection installation connected to the storage tank,
- a second ejection installation connected to the storage tank,
- a level meter for determining a filling level of a liquid phase of the coolant within the storage tank and
- a control unit configured such that the coolant can be ejected from the storage tank via the first ejection installation if the filling level determined by the level meter is above a predetermined threshold, and via the second ejection installation if the filling level determined by the level meter is below the predetermined threshold.

[0037] The details and advantages disclosed for the described methods can be applied to the device, and vice versa. The described methods are preferably performed using the device. The device is preferably configured for ejecting the coolant according to the method for ejecting a coolant. The device is preferably configured for cooling an object according to the method for cooling an object.

[0038] The device is preferably a freezer, in particular for cooling food products.

[0039] The level meter is preferably configured for measuring the filling level as a differential pressure measurement. Therefore, the level meter preferably comprises an upper pressure sensor for measuring the pressure at the top of the storage tank, a lower pressure sensor for measuring the pressure at the bottom of the storage tank and a calculation element for calculating the filling level based on measurement results obtained from the upper pressure sensor and the lower pressure sensor.

[0040] The control unit is preferably configured to control the device such that steps c1) and c2) can be performed.

[0041] According to a preferred embodiment of the device the first ejection installation is configured for ejecting the coolant with a first flow cross section, wherein the second ejection installation is configured for ejecting the coolant with a second flow cross section, and wherein the first flow cross section is smaller than the second flow cross section.

[0042] At a given pressure, a certain flow cross section corresponds to a respective flow rate. To this end, the above description of the flow rates applies to the flow cross sections. Due to the different flow cross sections the first ejection installation is better suitable for high filling levels and the second ejection installation is better suitable for low filling levels.

[0043] According to a further preferred embodiment of the device the first flow cross section is between 5 and 20 times smaller than the second flow cross section.

[0044] It should be noted that the individual features specified in the claims may be combined with one another in any desired technologically reasonable manner and form further embodiments of the invention. The specification, in particular taken together with the figures, explains the invention further and specifies particularly preferred embodiments of the invention. Particularly preferred variants of the invention and the technical field will now be explained in more detail with reference to the enclosed figures. It should be noted that the exemplary embodiments shown in the figures are not intended to restrict the invention. The figures are schematic and may not be to scale. The figures display:

Fig. 1: a schematic view of a device for ejecting a coolant according to the invention, and

Fig. 2: a flow diagram of a method for ejecting a coolant according to the invention, applicable to the device of Fig. 1.

[0045] Fig. 1 shows a device 1 for ejecting a coolant 2. The device 1 comprises a storage tank 5 for the coolant 2. The coolant 2 can be extracted for ejection at a bottom 9 of the storage tank 5.

[0046] The coolant 2 within the storage tank 5 comprises a liquid phase 3 and a gaseous phase 4. A dashed dividing line indicates where the liquid phase 3 and the gaseous phase 4 adjoin one another. The distance of the dashed dividing line from the bottom 9 of the storage tank 5 is a filling level 8 of the liquid phase 3 of the coolant 2 within the storage tank 5.

[0047] A high filling level 8 results in a low gas fraction of the ejected coolant 2 and in a high cooling power. A lower filling level 8 results in a higher gas fraction of the ejected coolant 2 and in a lower cooling power. In order to compensate the loss of cooling power due to a decrease of the filling level 8, the flow rate can be increased. Therefore, the coolant 2 can be ejected from the storage tank 5 via a first ejection installation 6 or via a second ejection installation 7. The first ejection installation 6 is configured for ejecting the coolant 2 with a first flow cross section, the second ejection installation 7 is configured for ejecting the coolant 2 with a second flow cross section. The first flow cross section is between 5 and 20 times lower than the second flow cross section. At a given pressure of the coolant 2, a certain flow cross section corresponds to a respective flow rate. The first ejection installation 6 is better suitable for high filling levels 8, the second ejection installation 7 is better suitable for low filling levels 8.

[0048] The device comprises a switch vale 17 within a piping 10 between the storage tank 5, the first ejection installation 6 and the second ejection installation 7. By means of the switch valve 17 the first ejection installation 6 and the second ejection installation 7 can be switched between. The switch valve 17 is connected to a control unit 16. The control unit 16 is configured such that the switch valve 17 is operated depending on the filling level 8: The coolant 2 is ejected from the storage tank 5 via the first ejection installation 6 if the filling level 8 is above a predetermined threshold, and via the second ejection installation 7 if the filling level 8 is below the predetermined threshold.

[0049] The filling level 8 can be determined as a differential pressure measurement by means of a level meter 12. The level meter 12 comprises an upper pressure sensor 13 for measuring the pressure at the top of the storage tank 5 and a lower pressure sensor 14 for measuring the pressure at the bottom 9 of the storage tank 5. The measurement values obtained by the upper pressure sensor 13 and the lower pressure sensor 14 are supplied to a calculation element 15 of the level meter 12, wherein the filling level 8 is determined. The filling level 8 determined by the level meter 12 is supplied to a control unit 16. The calculation element 15 and the control unit 15 are shown as separate elements in order to point out that the upper pressure sensor 13, the lower pressure sensor 14 and the calculation element 15 for the level meter 12. However, it is also possible and even preferred that the filling level 8 is calculated in the control unit 16. Therefore, the upper pressure sensor 13 and the lower pressure sensor 14 can be connected directly to the control unit 16. In that case the calculation element 15 can be considered part of the control unit 16.

[0050] The device 1 can be used, in particular, for cooling an object 11. Thereby, the coolant 2 is ejected such that the object 11 is cooled by the coolant 2. The object 11 is preferably a food product.

[0051] Fig. 2 is a flow diagram of a method for ejecting a coolant 2, in particular nitrogen. The method can be performed with the device 1 of Fig. 1. Thus, the method is described using the reference numerals of Fig. 1. The method comprises:

a) providing the coolant 2 within a storage tank 5, wherein the coolant 2 comprises a liquid phase 3,
b) determining a filling level 8 of the liquid phase 3 of the coolant 2 within the storage tank 5,
c1) ejecting the coolant 2 from the storage tank 5 via a first ejection installation 6 if the filling level 8 determined in step b) is above a predetermined threshold, and
c2) ejecting the coolant 2 from the storage tank 5 via a second ejection installation 7 if the filling level 8 determined in step b) is below the predetermined threshold.

[0052] The coolant 2 is ejected only via one of the ejection installations 6,7 at a time. This is indicated in that the boxes representing steps c1) and c2) are arranged on top of each other. Steps c1) and c2) are not performed simultaneously. After the storage tank 5 has been filled, usually step c1) is performed. Due to consumption of the coolant 2, the filling level 8 can decrease. Once the threshold has been passed, step c2) is performed instead of step c1).

[0053] With the described method and device 1, a coolant 2 can be ejected such that a particularly constant cooling power can be achieved. Thereby, a decrease in the cooling power due to an increase in the gas fraction of the coolant 2 can be compensated by switching from the first ejection installation 6 to the second ejection installation 7 allowing a higher flow rate.

List of reference numerals

[0054]

1	device
2	coolant
3	liquid phase
4	gaseous phase
5	storage tank
6	first ejection installation
7	second ejection installation
8	filling level
9	bottom
10	piping
11	object
12	level meter
13	upper pressure sensor
14	lower pressure sensor
15	calculation element
16	control unit
17	switch valve

Claims

1. Method for ejecting a coolant (2), comprising:

a) providing the coolant (2) within a storage tank (5), wherein the coolant (2) comprises a liquid phase (3),
b) determining a filling level (8) of the liquid phase (3) of the coolant (2) within the storage tank (5),
c1) ejecting the coolant (2) from the storage tank (5) via a first ejection installation (6) if the filling level (8) determined in step b) is above a predetermined threshold, and
c2) ejecting the coolant (2) from the storage tank (5) via a second ejection installation (7) if the

filling level (8) determined in step b) is below the predetermined threshold.

2. Method according to claim 1, wherein the coolant (2) is nitrogen.

3. Method according to any of the preceding claims, wherein in steps c1) and c2) the coolant (2) is extracted from a bottom (9) of the storage tank (5).

4. Method according to any of the preceding claims, wherein the coolant (2) is ejected at a first flow rate in step c1), wherein the coolant is ejected at a second flow rate in step c2), and wherein the first flow rate is lower than the second flow rate.

5. Method according to claim 4, wherein the first flow rate is between 5 and 20 times lower than the second flow rate.

6. Method according to any of the preceding claims, wherein the coolant (2) is ejected only via one of the ejection installations (6,7) at a time.

7. Method for cooling an object (11), wherein a coolant (2) is ejected by a method according to any of the preceding claims such that the object (11) is cooled by the coolant (2).

8. Method according to claim 7, wherein the object (11) is a food product.

9. Device (1) for ejecting a coolant (2), comprising:

- a storage tank (5) for the coolant (2),
- a first ejection installation (6) connected to the storage tank (5),
- a second ejection installation (7) connected to the storage tank (5),
- a level meter (12) for determining a filling level (8) of a liquid phase (3) of the coolant (2) within the storage tank (5), and
- a control unit (16) configured such that the coolant (2) can be ejected from the storage tank (5) via the first ejection installation (6) if the filling level (8) determined by the level meter (12) is above a predetermined threshold, and via the second ejection installation (7) if the filling level (8) determined by the level meter (12) is below the predetermined threshold.

10. Device (1) according to claim 9, wherein the first ejection installation (6) is configured for ejecting the coolant (2) with a first flow cross section, wherein the second ejection installation (7) is configured for ejecting the coolant (2) with a second flow cross section, and wherein the first flow cross section is smaller than the second flow cross section.

11. Device (1) according to claim 10, wherein the first flow cross section is between 5 and 20 times smaller than the second flow cross section.

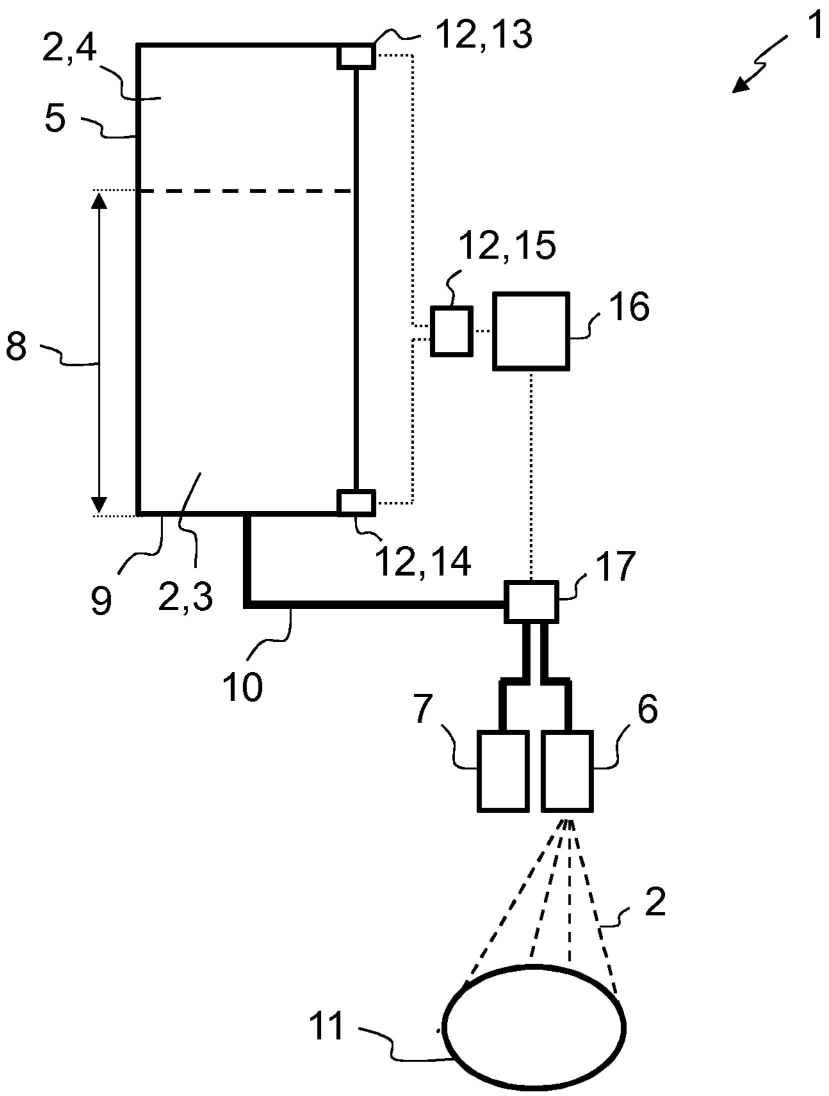

Fig. 1

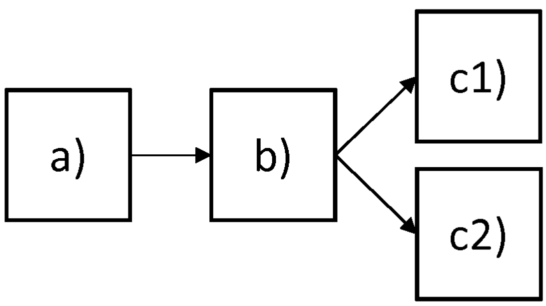

Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 19 21 1531

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TECHNICAL FIELDS SEARCHED (IPC)

F25D
F25B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	27 May 2020	Léandre, Arnaud

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 19 21 1531

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