

DEVICE AND METHOD FOR METERING A PARTICULATE SUBSTANCE AND APPARATUS COMPRISING A PLURALITY OF SUCH DEVICES

Background of the Invention

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The present invention relates to a device for and a method of metering a predetermined amount of a particulate substance, and to a metering apparatus comprising two or more such metering devices. More specifically, the present invention is directed to the metering or dosing of granular or spheronized substances having poor flowability. The present invention is especially, but not exclusively, adapted to meter pressure-sensitive particulate substances, such as in the metering of a predetermined amount of a particulate pharmaceutical substance for use in a dry powder inhaler.

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Finely divided powders having very small particle sizes (micronized powders) are commonly used in inhalation therapy. Such powders are often light and dusty, and therefore cause handling problems. Furthermore, such powders have very poor free-flowing properties which often make the handling and precise metering thereof problematic.

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It is known to form such powders into larger particles (agglomerates) in order to enhance flowability. WO-A-95/09615 discloses an example of a method of forming spheronized agglomerates capable of being broken down during inhalation to provide a fine powder medicament. Such agglomerates consisting of more dense and compact particles present, however, another disadvantage in that the agglomerates are relatively pressure-sensitive. This makes it difficult to meter the agglomerates without damaging the agglomerates and/or creating larger agglomerates, thereby reducing the flowability and thus the preconditions for exact metering.

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Thus, there is a need for a technique which permits a more exact metering of finely divided particulate substances, in particular agglomerates. Exact metering is especially important

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in the case of handling and distributing powder medicaments where stipulated volume or weight tolerances must be complied with. One example is the filling of dry powder inhalers, such as inhalers of the kind disclosed in EP-B-0237507.

5 GB-A-2113182 discloses a metering device for metering granular materials. The disclosed device is, however, adapted to meter free-flowing granular materials, such as granular fertilisers, and not finely divided powders having very small particle sizes with poor flowability. The disclosed metering device includes a reservoir in the form of an elongate tube, and, whilst suited to the delivery of free-flowing granular materials to the metering
10 mechanism, would be unable reliably to deliver finely divided powders to the metering mechanism, since the head of powder in the reservoir above the metering mechanism would result in physical bridges of the powder being formed in the reservoir, thereby preventing the free flow of powder to the metering mechanism.

15 It is thus a general aim of the present invention to provide a device for and a method of metering a particulate substance in a reliable and exact manner.

A further aim of the present invention is to provide a device for and a method of metering pressure-sensitive particulate substances, such as agglomerates, in a manner which avoids
20 damaging the particulate substances.

Another aim of the present invention is to provide a device for and a method of metering particulate substances which can be performed at high speed.

25 Summary of the Invention

Accordingly, the present invention provides a metering device for metering a predetermined amount of a particulate substance, comprising: a body member defining a metering chamber; an unbroken inflow path having an inlet and leading to the metering
30 chamber, wherein the inflow path is rotatable about an axis inclined relative to the vertical



such that at least a part of the inflow path is inclined downwards in a loading state and upwards in an emptying state, whereby the inflow path in use guides a gravity-induced flow of particulate substance into the metering chamber in the loading state and provides a gravitational inlet lock which prevents the flow of particulate substance into the metering chamber in the emptying state; an outflow path having an outlet and leading from the metering chamber, the outflow path including means which prevents the flow of particulate substance out of the metering chamber in the loading state, but admits the flow of particulate substance out of the metering chamber in the emptying state; and a reservoir connected to the inflow path so as in use to rotate therewith and being adapted, when containing any volume of particulate substance, so as on rotation to provide movement of the contained particulate substance at the inlet and thereby ensure the flow of particulate substance to the metering chamber.

The metering device is adapted to meter a predetermined amount of a particulate substance, either as a predetermined volume or a predetermined weight. In this application, it will be understood that the term state transition encompasses both a transition from the loading state to the emptying state and from the emptying state to the loading state.

An important feature of the metering device is that the inflow path to the metering chamber is unbroken. In this application, it will be understood that the term unbroken is used to mean that no mechanical valve members or the like are disposed in the inflow path. Thus, damage to the particulate substance present in the inflow path can be avoided, and the metering device is particularly suited to the metering of pressure-sensitive particulate substances such as powder agglomerates. The use of mechanical valve members downstream of the metering chamber is, however, not excluded so long as such valve members do not block or disrupt the outflow path. An example thereof will be described hereinbelow.

Another important feature of the metering device is the provision of a gravitational inlet lock upstream of the metering chamber; that is, a locking function which results from the





gravitational force acting on the particulate substance present in the inflow path. As a result, it is possible, even after filling of the metering chamber has been completed, to maintain unbroken contact between the particulate substance present in the inflow path and the metered amount of particulate substance present within the metering chamber. Thus, no mechanical valve member or the like is required at the inlet to the metering chamber to prevent the further inflow of particulate substance after filling has been completed.

In addition to the above-described gravitational inlet lock, the outflow path also includes means which prevents the flow of particulate substance from the metering chamber in the loading state, but admits such outflow in the emptying state. As a consequence of the fact that the metering chamber, and the outflow path downstream of the metering chamber, will normally be empty during the filling step, the means downstream of the metering chamber may, in contrast to the inlet lock, be in the form of a movable mechanical valve member or the like, the operation of which is controlled in a suitable manner in response to each state transition. However, in a preferred embodiment the metering device of the present invention includes a gravitational outlet lock downstream of the metering chamber. In order to provide a gravitational outlet lock, the state transition further involves a rotation of the outflow path so as to prevent the flow of particulate substance from the metering chamber in the loading state, but admit such outflow in the emptying state.

The flow paths preferably define a channel which extends through the body member. However, the flow paths may also be in the form of non-closed surfaces which support and guide the particulate substance, provided that such surfaces can be inclination-shifted for accomplishing the gravitational locking.

The present invention also provides a method of metering a predetermined amount of a particulate substance, comprising the steps of: providing a metering device for metering a predetermined amount of a particulate substance, the metering device comprising a metering chamber, an unbroken inflow path having an inlet and leading to the metering chamber, an outflow path leading from the metering chamber and a reservoir connected to

the inflow path, the reservoir being adapted, when containing any volume of particulate substance, so as on rotation to provide movement of the contained particulate substance at the inlet and thereby ensure the flow of particulate substance to the metering chamber; providing particulate substance in the reservoir; filling the metering chamber by guiding a gravity-induced flow of the particulate substance through the inflow path; preventing a gravity-induced flow of the particulate substance out of the metering chamber during the filling step; rotating the inflow path about an axis inclined relative to the vertical such that at least a part of the inflow path is inclined upwards and thereby provides a gravitational inlet lock which prevents the further flow of particulate substance into the metering chamber; emptying the metering chamber while the gravitational inlet lock prevents the further flow of particulate substance into the metering chamber; and rotating the inflow path about the rotational axis so as to remove the gravitational inlet lock and allow the filling step to be repeated.

The present invention further provides a metering apparatus for metering a predetermined amount of a particulate substance, comprising a rotatable wheel having two or more metering devices mounted thereon in circumferentially spaced positions with a common rotational axis, each metering device comprising a body member defining a metering chamber, an unbroken inflow path having an inlet and leading to the metering chamber, wherein the inflow path is rotatable about an axis inclined relative to the vertical such that at least a part of the inflow path is inclined downwards in a loading state and upwards in an emptying state, the inflow path thereby guiding a gravity-induced flow of particulate substance into the metering chamber in the loading state and providing a gravitational inlet lock which prevents the flow of particulate substance into the metering chamber in the emptying state, and an outflow path having an outlet and including means which prevents the flow of particulate substance out of the metering chamber in the loading state, but admits the flow of particulate substance out of the metering chamber in the emptying state.

An advantage of disposing a plurality of metering devices on a rotatable wheel is that one metering device can be loaded at a loading station, while another, previously filled



metering device can be emptied simultaneously at an emptying station. In a preferred embodiment the metering apparatus comprises at least two metering devices disposed diametrically opposite each other on the rotating wheel, such that when one of the at least two metering devices is in the loading state another is in the emptying state.

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When using only one metering device, the outlet thereof can be held in a substantially fixed position in a horizontal plane during a state transition. As a result, the flow of particulate substance from the device is focused. In contrast, in the case of a rotating wheel provided with a plurality of metering devices which follow a circular path, the outlet of each metering device is not stationary during a state transition. In order to avoid the premature flow of particulate substance from the outlets during rotation from the loading state to the emptying state, each metering device preferably comprises an individually controllable valve member, which is movable between a closed position for closing the outlet of the metering device in the loading state and an open position for opening the outlet of the metering device in the emptying state. The operation of such valve members may be controlled by a cam-type arrangement which is configured to operate in response to the rotation of the rotatable wheel.

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Brief Description of the Drawings

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Preferred embodiments of the present invention will now be described hereinbelow by way of example only with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view of a metering device, shown in the loading state, in accordance with a preferred embodiment of the present invention;

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Figure 2 is a cross-sectional view of the metering device of Figure 1 in the emptying state; and

Figure 3 is a schematic, cross-sectional lateral view of a metering apparatus in accordance

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with another embodiment of the present invention, shown with one metering device in the loading state and another metering device in the emptying state.

Description of the Preferred Embodiments

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Figures 1 and 2 illustrate a metering device in accordance with a preferred embodiment of the present invention. This metering device is typically used for the filling of dry powder inhalers with a predetermined amount (referred to as a "dose" hereinbelow) of a pharmaceutical substance in granular or spheronized form. The metering device is
10 preferably made of stainless steel.

The metering device comprises a body member 2 which in use is reciprocatingly rotated through 180° about an inclined rotational axis 4 (A-A) between a loading state as illustrated in Figure 1, and an emptying state as illustrated in Figure 2. The rotational axis
15 4 is inclined by an angle α of about 45° relative to the vertical V, but it will be understood that other inclinations could be employed. Although the body member 2 is reciprocatingly rotated in this preferred embodiment, it will be understood that the metering device could also equally be operated by rotating the body member 2 in a single sense.

20 A flow path extending through the body member 2 from an inlet 6 to an outlet 8 is formed by three bored channels, namely a first channel 10, a second, intermediate channel 12 and a third channel 14. The three channels 10, 12 and 14 are always interconnected; that is, no valve member or the like obturates the particulate substance guided inside the flow path.

25 The first and second channels 10, 12 together form an inflow path from the inlet 6 to a metering chamber 20, and the third channel 14 forms an outflow path from the metering chamber 20 to the outlet 8. In this embodiment, the metering chamber 20 forms part of the third channel 14.

30 The first channel 10 extends downwards from the inlet 6 and is co-axial with the rotational



axis 4. Thus, the inclination of the first channel 10 is constant in time and unaffected by a state transition.

The second channel 12 forms a gravitational lock upstream of the metering chamber 20, and extends from a lower portion 16 of the first channel 10 to an opening 18 to the metering chamber 20. The second channel 12 extends at an angle β relative to the rotational axis 4. The angles α and β are so chosen that the second channel 12 is not directed in a horizontal plane in either the loading or emptying states as illustrated in Figures 1 and 2. More specifically, the second channel 12 is inclined downwards in the loading state for permitting gravitational flow into the metering chamber 20, and upwards in the emptying state for preventing gravitational flow into the metering chamber 20. Reference numeral 22 designates a seal inserted in an outer end of the second channel 12.

The third channel 14 forms a gravitational lock downstream of the metering chamber 20, and extends from the metering chamber 20 to the outlet 8. The third channel 14 extends at an angle ϕ relative to the rotational axis 4. The angles α and ϕ are so chosen that in the loading state as illustrated in Figure 1 the outflow path defined by the third channel 14 is directed upwards so as to prevent gravitational flow from the metering chamber 20 during the filling thereof, and in the emptying state as illustrated in Figure 2 the outflow path defined by the third channel 14 is directed downwards for admitting and assisting gravitational flow from the metering chamber 20 of a dose of the particulate substance.

An adjustable plunger 24 is arranged inside the third channel 14 on the side of the metering chamber 20 facing away from the outlet 8 so as to provide for volume adjustment of the metering chamber 20. The plunger 24 is longitudinally positionable by an adjustment means 26 in order to set the internal volume of the metering chamber 20, and thus the volume to be filled in the loading state. The position of the plunger 24 may be manually adjustable by a nut and thread arrangement as illustrated in Figures 1 and 2, or optionally by a stepper motor or the like (not shown). In a preferred embodiment, a feedback-type control arrangement could be incorporated, wherein the weight of a dose dispensed from



the outlet 8 is measured, and a corresponding signal is used as a feedback signal for setting the internal volume of the metering chamber 20 at a desired value.

In use, in the loading state as illustrated in Figure 1, particulate substance flows through the inflow path formed by the first and second channels 10, 12 under the action of gravity and fills up the volume of the metering chamber 20. The extent to which the third channel 14 is filled during the filling step is dependent upon the inclination and the length of the third channel 14, the flowability of the particulate substance, and the pressure resulting from the weight of the particulate substance present within the flow path upstream of the metering chamber 20. Preferably, these parameters are so chosen that no overflow will take place from the outlet 8 during the loading step.

When the body member 2 is subsequently rotated through 180° to the emptying state as illustrated in Figure 2, the dose present within the metering chamber 20 and the now downwardly-inclined third channel 14 flows out through the outlet 8 under the action of gravity. During the emptying step, particulate substance is prevented from flowing into the metering chamber 20 because the second channel 12 is inclined upwards in the emptying state; that is, the inflow path is gravitationally locked. It is important to note that no valve member or the like which could damage the particulate substance obturates the flow path.

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As will be seen from Figures 1 and 2, the position of the outlet 8 in a horizontal plane is substantially unaffected by a state transition. This is due to the fact that the outlet 8 is co-axial with the rotational axis 4. In order to guide the outflow essentially in a vertical direction, for example into an inhaler (not shown) located below the outlet 8, the body member 2 is provided with a lug-shaped guide member 28.

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The metering device further comprises a reservoir 30 having a flow-guiding surface 32 at the inlet 6. In this embodiment, the reservoir 30 takes the form of a hollow, truncated cone which is co-axial with the rotational axis 4 and is fixedly attached to the body member 2 in order to rotate therewith. The particulate substance to be metered is fed into the reservoir

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30, preferably intermittently, so as to maintain a predetermined level within the reservoir 30. Rotation of the reservoir 30 accomplishes a tumbling effect, that is, a translational movement, of the particulate substance therein, thereby preventing the particulate substance from forming a physical bridge which could disturb or block the flow into the metering chamber 20.

Figure 3 illustrates a metering apparatus provided with a plurality of metering devices A, B of the kind as illustrated in Figures 1 and 2. Components of the metering devices A, B which have already been described in connection with the metering device of Figures 1 and 2 will be designated with the same reference signs, and a description of the construction and operation thereof will not be repeated.

The metering apparatus comprises a rotatable wheel 50 which is supported by a hub 52 and which is arranged to perform a stepwise, one-directional rotational movement about a rotational axis 54 (B-B). The rotational axis 54 is inclined by an angle ϕ of about 45° relative to the vertical V, but it will be understood that other inclinations could be employed. The rotatable wheel 50 comprises two opposite main walls 56, 58 which are interconnected by a peripheral wall 60. The walls 56, 58, 60 define an internal volume 62 for receiving particulate substance S, which substance S is fed in through an opening 64 provided in the upper main wall 56.

First and second metering devices A, B of the kind described with reference to Figures 1 and 2 are mounted on the rotatable wheel 50 in diametrically opposite positions. In Figure 3, the rotatable wheel 50 is illustrated in a position where the first metering device A is in a loading state and the second metering device B is in an emptying state. The operation of the metering devices A, B is essentially the same as the operation of the metering device described in relation to Figures 1 and 2. Thus, the metering devices A, B are repeatedly shifted between a loading state and an emptying state, without requiring any valve members which could damage the particulate substance within the metering device.

However, whereas in the metering device of Figures 1 and 2 the rotational axis 4 extends



through the metering device and is co-axial with the first channel 10, the metering devices A, B of Figure 3 have a common rotational axis, namely the rotational axis 54 of the rotatable wheel 50. In this regard, it will be apparent that the rotational axis 4 of the metering device of Figures 1 and 2 may be located outside the metering device.

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Although the metering apparatus of Figure 3 includes only two metering devices A, B, it will be appreciated that the rotatable wheel 50 may support additional metering devices.

Typically, the rotatable wheel 50 may support six circumferentially and symmetrically spaced metering devices, such that in a given rotational position of the rotatable wheel 50,

10 a first device is in the loading state at a loading station, second and third loaded devices are in the process of being rotated towards an emptying station, a fourth device is in the emptying state at the emptying station, and fifth and sixth empty devices are in the process of being rotated towards the loading station.

15 There is a further difference between the metering device as illustrated in Figures 1 and 2, and the metering devices A, B of the metering apparatus as illustrated in Figure 3. In the former, the position of the outlet 8 is substantially unaffected by a state transition, whereas in the latter the outlet 8 is moved along a circular path during a state transition. Therefore, the particulate substance present in a filled metering chamber 20 of one of the metering
20 devices A, B of Figure 3 leaving the loading station may fall out through the outlet 8, in part or completely before the metering device has reached the emptying station. In order to prevent such premature emptying of the metering devices A, B, the metering devices A, B are each provided with a mechanical outlet locking member in the form of a controllable valve arrangement. Each valve arrangement comprises a pivotable arm 66 having a valve
25 member 70 at one end and a cam follower 72 in the form of a roller at the other end. The pivot axis of the arm 66 is designated by reference sign 68. Each cam follower 72 is guided along a circumferential groove 74 formed in a stationary ring 76 and provides a guiding cam surface for the cam follower 72. As illustrated in Figure 3, the radius of the circumferential groove 74 is somewhat larger in the loading state than in the emptying
30 state. As a result, the angular position of the arms 66 will be shifted during a state



transition. More specifically, the radius of the cam groove 74 is chosen such that the valve member 70 will be in its closed position in the loading state and along the path towards the emptying state, in order to close the outlet 8, as illustrated by metering device A. In the emptying state, the valve member 70 will be in its opened position, admitting the flow of
5 particulate substance from the outlet 8, as illustrated by metering device B.

It will be understood that a mechanical valve member may be used in the metering device of Figures 1 and 2. In fact, it will be appreciated that the gravitational outlet lock formed by the third channel 14 in the metering device of Figures 1 and 2 may be replaced by a
10 mechanical valve mechanism which repeatedly opens and closes the outlet 8.

Finally, it will be appreciated by a person skilled in the art that the present invention is not limited to the described embodiments but may be modified in many different ways within the scope of the invention as defined in the appended claims.

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CLAIMS

1. A metering device for metering a predetermined amount of a particulate substance, comprising:

a body member (2) defining a metering chamber (20);

5 an unbroken inflow path having an inlet (6) and leading to the metering chamber (20), wherein the inflow path is rotatable about an axis (4) inclined (α) relative to the vertical (V) such that at least a part of the inflow path is inclined downwards in a loading state and upwards in an emptying state, whereby the inflow path in use guides a gravity-induced flow of particulate substance into the metering chamber (20) in the loading state
10 and provides a gravitational inlet lock which prevents the flow of particulate substance into the metering chamber (20) in the emptying state;

an outflow path having an outlet (8) and leading from the metering chamber (20), the outflow path including means which prevents the flow of particulate substance out of the metering chamber (20) in the loading state, but admits the flow of particulate substance
15 out of the metering chamber (20) in the emptying state; and

a reservoir (30) connected to the inflow path so as in use to rotate therewith and being adapted, when containing any volume of particulate substance, so as on rotation to provide movement of the contained particulate substance at the inlet (6) and thereby ensure the flow of particulate substance to the metering chamber (20).

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2. The metering device as claimed in claim 1, wherein the outflow path is adapted to rotate together with the inflow path about the rotational axis (4) such that at least a part of the outflow path is inclined upwards in the loading state and downwards in the emptying state, whereby the outflow path provides a gravitational outlet lock which prevents the flow
25 of particulate substance out of the metering chamber (20) in the loading state and guides a gravity-induced flow of particulate substance out of the metering chamber (20) in the emptying state.





3. The metering device as claimed in claim 1 or 2, wherein the metering chamber (20) has a variable internal volume.
4. The metering device as claimed in claim 3, further comprising control means (24,
5 26) for adjusting the internal volume of the metering chamber (20).
5. The metering device as claimed in any of claims 1 to 4, wherein the flow paths define a channel (10, 12, 14) which extends through the body member (2).
- 10 6. The metering device as claimed in any of claims 1 to 5, wherein the flow paths define a channel (10, 12, 14) which has a cross section that is substantially unaffected by a state transition.
7. The metering device as claimed in any of claims 1 to 6, wherein the reservoir (30) is
15 co-axial with the inlet (6) of the inflow path.
8. The metering device as claimed in any of claims 1 to 7, wherein the reservoir (30) is substantially conical in shape and tapers towards the inlet (6) of the inflow path.
- 20 9. The metering device as claimed in any of claims 1 to 8, wherein the angle (α) of inclination of the rotational axis (4) is unaffected by a state transition.
10. The metering device as claimed in any of claims 1 to 9, wherein the rotation is one-directional.
- 25 11. The metering device as claimed in any of claims 1 to 9, wherein consecutive state transitions involve a reciprocating rotational movement.





12. The metering device as claimed any of claims 1 to 11, wherein the outlet (8) of the outflow path is located adjacent to the rotational axis (4), whereby the position of the outlet (8) in a horizontal plane is substantially unaffected by a state transition.

5 13. The metering device as claimed in any of claims 1 to 12, wherein the inlet (6) of the inflow path is located adjacent to the rotational axis (4), whereby the position of the inlet (6) in a horizontal plane is substantially unaffected by a state transition.

14. A method of metering a predetermined amount of a particulate substance,
10 comprising the steps of:

providing a metering device for metering a predetermined amount of a particulate substance, the metering device comprising a metering chamber (20), an unbroken inflow path having an inlet (6) and leading to the metering chamber (20), an outflow path leading from the metering chamber (20) and a reservoir (30) connected to the inflow path, the
15 reservoir (30) being adapted, when containing any volume of particulate substance, so as on rotation to provide movement of the contained particulate substance at the inlet (6) and thereby ensure the flow of particulate substance to the metering chamber (20);

providing particulate substance in the reservoir (30);

filling the metering chamber (20) by guiding a gravity-induced flow of the
20 particulate substance through the inflow path;

preventing a gravity-induced flow of the particulate substance out of the metering chamber (20) during the filling step;

rotating the inflow path about an axis (4) inclined (α) relative to the vertical (V) such that at least a part of the inflow path is inclined upwards and thereby provides a
25 gravitational inlet lock which prevents the further flow of particulate substance into the metering chamber (20);

emptying the metering chamber (20) while the gravitational inlet lock prevents the further flow of particulate substance into the metering chamber (20); and

rotating the inflow path about the rotational axis (4) so as to remove the
30 gravitational inlet lock and allow the filling step to be repeated.





15. The method as claimed in claim 14, further comprising the step of feeding the particulate substance intermittently to the reservoir (30).

5 16. The method as claimed in claim 14 or 15, further comprising the step of determining the weight of a metered amount of the particulate substance dispensed from the metering chamber (20) in the emptying step, and adjusting the internal volume of the metering chamber (20) in response thereto.

10 17. A metering apparatus for metering a predetermined amount of a particulate substance, comprising a rotatable wheel (50) having two or more metering devices (A, B) mounted thereon in circumferentially spaced positions with a common rotational axis (54), each metering device (A, B) comprising a body member (2) defining a metering chamber (20), an unbroken inflow path having an inlet (6) and leading to the metering chamber (20),
15 wherein the inflow path is rotatable about an axis (4) inclined (ϕ) relative to the vertical (V) such that at least a part of the inflow path is inclined downwards in a loading state and upwards in an emptying state, the inflow path thereby guiding a gravity-induced flow of particulate substance into the metering chamber (20) in the loading state and providing a gravitational inlet lock which prevents the flow of particulate substance into the metering
20 chamber (20) in the emptying state, and an outflow path having an outlet (8) and including means which prevents the flow of particulate substance out of the metering chamber (20) in the loading state, but admits the flow of particulate substance out of the metering chamber (20) in the emptying state.

25 18. The metering apparatus as claimed in claim 17, comprising at least two metering devices (A, B) disposed diametrically opposite each other on the rotatable wheel (50), such that when one of the at least two metering devices (A, B) is in the loading state another is in the emptying state.





19. The metering apparatus as claimed in claim 17 or 18, wherein each of the metering devices (A, B) comprises a valve mechanism for opening and closing the outlet (8) of the outflow path of the respective metering device (A, B), each valve mechanism comprising a valve member (70), which is movable between a closed position for closing the outlet (8) of the respective metering device (A, B) in the loading state and an open position for opening the outlet (8) of the respective metering device (A, B) in the emptying state, and a cam-type arrangement (72, 74) for mechanically operating the valve member (70) during rotation of the rotatable wheel (50).

