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(54) **Title:** POWDER FEEDING METHOD, POWDER FEEDING APPARATUS AND ELECTROSTATICAL POWDER SPRAY COATING APPARATUS

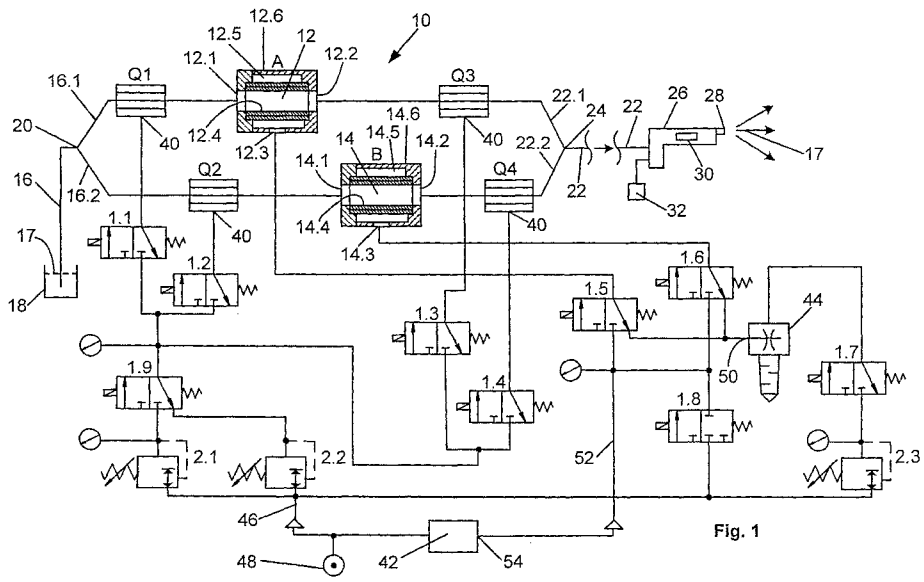


Fig. 1

(57) **Abstract:** A coating powder feed method, coating powder feeding device, electrostatic powder spraycoating apparatus containing such a coating powder feeding device. The invention includes a dense phase powder pump (10) fitted with at least one feed chamber (12, 14). A control signal to create a partial vacuum in the feed chamber (12, 14) is generated no earlier than simultaneously with, preferably by a predetermined delay time after, a control signal opening a powder intake valve (Q1, Q2) of the feed chamber (12, 14), as a result of which the beginning of partial vacuum buildup in the feed chamber (12, 14) shall take place no earlier than simultaneously with the initial opening of the powder intake valve (Q1, Q2) or by a defined time delay after the opening of the powder intake valve (Q1, Q2).

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POWDER FEEDING METHOD, POWDER FEEDING APPARATUS AND ELECTROSTATICAL POWDER SPRAY COATING APPARATUS

In accordance with the pending claims, the present invention relates to a powder feeding method, to a powder feeding device and to an electrostatical powder spraycoating apparatus comprising a powder feeding device.

In particular, the present invention relates to methods and apparatus/equipment containing a dense phase powder pump. Dense phase powder pumps comprise at least one feed chamber fitted with a powder intake valve and a powder outlet valve. The chamber may be connected alternatively to a vacuum source to aspirate powder, through its open powder intake valve while the powder outlet valve is closed, into the feed chamber, or subsequently thereto to a source of compressed gas, usually compressed air, in order to expel the coating powder from the feed chamber through the open powder outlet valve while the powder intake valve is closed. When two feed chambers are configured in parallel, powder will be aspirated into one chamber while powder is discharged from the other, whereupon powder will be discharged from the first chamber and new powder is aspirated into the other. When two or more feed chambers are configured in parallel, a continuous flow of powder may be implemented in a powder discharge conduit into which issue the powder outlet valves of all feed chambers.

As regards another kind of pump not object of the present invention, injectors aspirate coating powder into a flow of feeding air where said powder mixed with this flow and is fed through a discharge conduit to a powder spraycoating tool. Such powder spraycoating equipment is known for instance from the European patent document EP 0606577 B1.

CONFIRMATION COPY

Illustratively the following documents disclose a variety of coating powder feeding device containing a dense phase powder pump: JP 09/071325 A, DE 196 11 533 B4, US 2006/0193704 A1 (= EP 1 644 131A2), US 7,150,585 B2 (= WO 2004/087331 A1) and US 2005/0178325 A1 (= EP 1 566 352 A2). The dense phase powder pumps are fitted with at least one, usually two feed chambers. A vacuum intake of the feed chamber -- in some designs also a compressed air intake in the feed chamber -- is fitted with a filter permeable to air but not to coating powder. For decades the filter material has conventionally been a sintered material. Typically the powder intake and outlet valves are pinch valves that have already been successfully used with injector pumps in feeding thin phase powders because being less susceptible to aggregating powder within them and being more easily cleansed by the gas flow through them than are other types of valves.

The patent document US 2005/0178325 A1 (= EP 1 566 352 A2) cited above proposes increasing the partial vacuum in the feed chamber at least in part before opening the feed chamber's intake valve.

The object of the present invention is to increase the pumping rate without incurring thereby complex or costly steps.

The object of the present invention is attained by means of the appended claims,

Further features of the present invention are contained in the dependent claims.

The invention allows raising the pumping rate in simple manner.

Moreover the present invention allows more accurately metering the powder feed volume rates.

According to the present invention, a control signal is generated to produce the partial vacuum in the feed chamber, no earlier than simultaneously

with, or preferably by a predetermined delay after a control signal opening the powder intake valve was generated, as a result of which the partial vacuum begins increasing in the feed chamber, no earlier than simultaneously with opening the powder intake valve, preferably however after the above cited delay time beyond opening the powder intake valve. The predetermined delay time preferably shall be in the range of 0 to 50 ms for a feed-cycle period of about 200 ms of the feed chamber. However this embodiment mode does not preclude applying the present invention to other delay times and cycle-periods.

The present invention attains that the partial vacuum in the feed chamber shall oppose an opening displacement of the powder intake valve -- especially it is a pinch valve -- at least at the time the powder intake valve starts opening, than is the case in the state of the art.

The present invention is illustratively discussed below in relation to the appended drawings by means of a preferred embodiment mode.

Fig. 1 schematically shows a coating powder feeding device of the invention which is part of an electrostatic powder spraycoating apparatus.

Fig. 2 schematically shows a longitudinal section of a pinch valve of Fig. 1 in its open state, and

Fig. 3 schematically shows a longitudinal section of the pinch valve of Fig. 2 in its closed state.

Fig. 1 schematically shows a coating powder feeding device of the invention containing a dense phase powder pump 10 illustratively fitted with two feed chambers 12 and 14 configured in parallel each in a pump cylinder A respectively B each fitted with a powder intake valve Q1 and Q2 at a powder intake 12.1 and 14.1 and with a powder outlet valve Q3 and Q4 respectively at a powder outlet 12.2 and 12. 4. For clarity, the powder intake valves Q1 and Q2 are shown away from the powder intakes 12.1 respectively 14.1, though in fact

they are configured preferably immediately at the powder intakes 12.1 and 14.1. The powder outlet valves Q3 and Q4 respectively are shown away from the powder outlets 12.2 and 14.2 for clarity, though practically they are preferably mounted immediately at the powder outlets 12.2 and 14.2.

The pump cylinders A and B and their feed chambers 12 and 14 may be arbitrary. In the preferred embodiment mode of the present invention, each feed chamber 12 and 14 is constituted -- at least over part of its straight length between its powder intake valve Q1 respectively Q2 and its powder outlet valve Q3 and Q4 -- by a filter 12.4 and 14.4 enclosing the feed chamber 12 and 14 and separating it from an intermediate chamber 12.5 and 14.5. The intermediate chamber 12.5 and 14.5 encloses the filter 12.4 and 14. 4 and is situated in a pump housing 12.6 and 14.6. A gas hookup port 12.3 respectively 14.3 is constituted in the pump housing 12.6 and 14. 6 and issues into the intermediate chamber 12.5 and 14.5 and is connected to a connector of a control valve 1.5 and 1.6. This hookup port of the control valve 1.5 respectively 1.6 can be loaded alternatively with a partial vacuum or with compressed air by switching this control valve 1.5 or 1.6. The filter 12.4 and 14.4 is permeable to gas but impermeable to coating powder. Preferably it is porous and made of a sintered material.

A powder moving conduit 16 is fitted with a preferably Y-shaped branch 20 with feed conduit branches 16.1 respectively 16.2 to move coating powder 17 out of a powder bin 18 and is connected to allow flow with the powder intake sides of the two powder intake valves Q1 and Q2. The powder outlet sides of the two powder outlet valves Q3 and Q4 each are connected by a discharge branch 22.1 respectively 22.2, preferably by a Y-shaped branch 24, to a powder discharge conduit 22.

The powder discharge conduit 22 may lead to a powder receiving bin or to a powder coating tool 26. The manual or automatic spray tool 26 is fitted

preferably to at least one high voltage (hv) electrode 28 to electrostatically charge the coating powder 17. Illustratively the hv may be generated by a hv generator 30 integrated into the powder spray tool 26 and supplied from a current or voltage source 32 with electric power.

The powder intake valves Q1 and Q2 and the powder outlet valves Q3 and Q4 preferably are pinch valves. Their designs may be identical. Using the powder intake valve Q1 as a model, Figs. 2 and 3 schematically show a preferred embodiment mode used also for all other valves Q2, Q3 and Q4. Their valve duct 34 is subtended by the inner surface of a flexible hose 36 separating the valve duct 34 from a pressure chamber 38 on the hose outer side in a housing 39. The valve duct 34 is the hose transmission aperture and is kept open by the tension in the hose 36 as shown in Fig. 2. When introducing a compressed gas, preferably air, into the pressure chamber 38 through a gas hookup 40, the hose is radially compressed and in this manner the valve duct 34 can be kept closed as shown in Fig. 3. When the compressed air is then removed from the pressure chamber 38, the hose 36 resumes its initial shape shown in Fig. 2, wherein said valve duct 34 is open again.

Fig. 1 shows nine control valves 1.1, 1.2, 1.3, 1.4, 1.5. 1.6, 1.7, 1.8 and 1.9 which may be driven independently from each other by an electronic control 42.

Fig. 1 also shows three pressure regulators 2.1, 2.2 and 2.3 and a vacuum source 44. The vacuum source 44 preferably is a vacuum injector.

The control valve 1.1 is connected to the powder intake valve Q1 and may alternatively may connect latter's pressure chamber 38 to a source of compressed air 46 or vent it. The control valve 1.2 is connected to the other powder intake valve Q2 and is able to alternatively connect its pressure chamber 38 to the compressed air feed conduit 46 or to vent it. The control

valve 1.3 is connected the powder outlet valve Q3 and is able to alternatively connect its pressure chamber 38 to the compressed air feed conduit 46 or to vent it. The control valve 1.4 is connected to the other powder outlet valve Q4 and is able to alternatively connect its pressure chamber 38 to the compressed air feed conduit 46 or to vent it.

The compressed air feed conduit 46 and the control 42 may be connected to a source of compressed air 48 either directly or by means of pressure regulators.

Preferably one of the pressure regulators, namely 2.2, is configured between the control valves 1.1, 1.2, 1.3 and 1.4 on one hand and on the other hand the compressed air feed conduit 46, the closing pressure of the pinch valves Q1, Q2, Q3 and Q4 for powder feed operation being adjustable at said pressure regulator 2.2.

According to the embodiment of the present invention shown in Fig. 1, an additional pressure regulator 2.1 may be used in addition to the pressure regulator 2.2, only one of the two pressure regulators 2.2 or 2.1 being connectable alternatively by means of the control valve 1.9 to the pressure intake side of the control valves 1.1, 1.2, 1.3 and 1.4. Consequently a different air pressure may be set at the second pressure regulator 2.1 than at the pressure regulator 2.2, for instance a higher pressure. Illustratively the higher pressure of the second pressure regulator 2.1 may serve to generate a higher closing pressure in the valves Q1, Q2, Q3 and Q4 designed as pinch valves whenever the feed chambers 12 and 14 are used not for power feeding, but for cleansing with cleansing air.

Each pump cylinder A and B is fitted with a gas hookup port 12.3 respectively 14.3 to which is connected one of the two control valves 1.5 and 1.6 in order to supply the two feed chambers 12 and 14 alternatingly with

compressed conveying air from the control 42 or to connect them to the vacuum source 44 and thereby to evacuate them.

Compressed air from the compressed air supply conduit 46 can be fed by means of the pressure regulator 2.3 and the control valve 1.7 to a vacuum injector 44 to generate in latter a partial vacuum which can be applied by means of the two independently driven control valves 1.5 and 1.6 alternatively to either of the feed chambers 12 and 14 respectively. The control valve 1.7 allows alternatively connecting the vacuum injector 44 in the manner discussed above to the compressed air supply conduit 46 or to vent it.

The feed chambers 12 and 14 can be connected by means of the control valves 1.5 and 1.6 alternatively to a partial vacuum hookup 50 of the vacuum injector 44 or by means of a compressed air conduit 52 to a compressed air outlet 54 of the control 42.

The preferred embodiment mode of Fig. 1 further comprises the control valve 1.8 by means of which the pressure side of the two control valves 1.5 and 1.6 of the feed chambers 12 and 14 alternatively can be connected to the compressed air supply conduit 46 of which the pressure exceeds that of the compressed feed air applied by the control 42 through the compressed air feed conduit 52. The higher pressure of the compressed air supply conduit 46 may be applied through the control valve 1.8 to the feed chambers 12 and 14 for instance when the feed chambers 12 and 14 and the powder conduits connected to them must be rinsed with compressed air.

The control 42 of the present invention is designed in a manner that it generates a control signal to the control valve 1.5 or 1.6 to generate the partial vacuum in the feed chamber 12 or the other feed chamber 14, no earlier than simultaneously with a control signal to the control valve 1.1 or 1.2 opening the related powder intake valve Q1 or Q2 in such a way that the partial vacuum in

the feed chamber 12 or 14 shall build up, no earlier than simultaneously with opening the powder intake valve Q1 respectively Q2 associated with this feed chamber 12 or 14.

According to the preferred embodiment mode of the present invention, the control 42 generates the control signal for the control valve 1.5 or 1.6 to generate a partial vacuum in the pertinent feed chamber 12 or 14 at a predetermined time delay after the control signal has been applied to the related control valve 1.1 or 1.2 to open the powder intake valve Q1 or Q2 of the related feed chamber 12 or 14, as a result of which the partial vacuum in the pertinent feed chamber 12 or 14 shall build up at the defined time delay after opening the powder intake valve Q1 respectively Q2.

The predetermined time delay may be stored in permanent or variable manner in the control 42 or be adjustable for any application of the feed apparatus. Preferably the predetermined delay time is in the range between 0 and 50 ms.

The present invention allows diverse cleansing procedures to cleanse the various components by passing compressed air through or over them, either by a feed of compressed air from the control 42 or a feed of compressed air at a higher pressure from the compressed air supply conduit 46. This compressed rinsing air may be guided either through both feed chambers 12 and 14 simultaneously in the same direction or in opposite directions. Both feed chambers 12 and 14 may be cleansed individually or jointly. The compressed cleansing air may pass from the feed chambers 12 and 14 toward the powder discharge conduit 22 or reversely in the direction to the powder feed conduit 16. When rinsing, the powder intake valve Q1 respectively Q2 and the powder outlet valve Q3 and Q4 one and/or the other feed chamber 12 and 14 may be opened simultaneously to generate two mutually oppositely directed flows of compressed rinsing air jointly flowing through the gas hookup port 12.3

respectively 14.3. The flow of compressed rinsing air may be continuous or in pulses.

Instead of the preferred embodiment modes of pinch valves Q1, Q2, Q3 and Q4 shown in Figs. 2 and 3, other pinch valves also may be used that are operated not by applying pneumatic pressure on the hose 36 to pinch it, but instead being operated by a mechanical element, for instance a plunger or the like. Such a mechanical element may be driven pneumatically, hydraulically or electrically.

The present invention is not restricted to the above described embodiment modes. Illustratively two gas hookup ports 12,3 and 14.3 may be used for each feed chamber 12 respectively 14, one of which being connectable to the vacuum source 44 and the other to the compressed feed air conduit 52.

CLAIMS

1. A coating powder feed method, including:

- using a dense phase powder pump (10) comprising at least one feed chamber (12, 14) fitted with a powder intake valve (Q1, Q2) and one powder outlet valve (Q3, Q4);
- performing the following operational cycles (a) through (d) at least once:
- (a) generating a partial vacuum in the feed chamber (12, 14) to aspirate coating powder into the feed chamber (12, 14) through the open powder intake valve (Q1, Q2) while the powder outlet valve (Q3, Q4) is closed;
- (b) closing the powder intake valve (Q1, Q2) and opening the powder outlet valve (Q3, Q4);
- (c) introducing a compressed gas into the feed chamber (12, 14) to discharge the coating powder from the feed chamber (12, 14) through the open powder outlet valve (Q3, Q4) while the powder intake valve (Q1, Q2) is closed; and
- (d) closing the powder outlet valve (Q3, Q4) and opening the powder intake valve (Q1, Q2),

characterized

in that during the cycle segment (a) or when passing from the cycle segment (d) to the cycle segment (a), a control signal generates the partial vacuum in the feed chamber (12, 14) no earlier than simultaneously with the generation of a control signal to open the powder intake valve (Q1, Q2), as a result of which the initial partial vacuum buildup in the feed chamber (12, 14) takes place no earlier than simultaneously with the beginning of opening the powder intake valve (Q1, Q2).

2. Coating powder feed method as claimed in claim 1, characterized in that during the cycle segment (a) or when passing from the cycle segment (d) to the cycle segment (a), the control signal generating the partial vacuum in the feed chamber (12, 14) is generated a predetermined delay time after the control signal opening the powder intake valve (Q1, Q2) was generated, as a result of which the partial vacuum buildup in the feed chamber (12, 14) begins a defined delay time after opening the powder intake valve (Q1, Q2).

3. Coating powder feed method as claimed in one of the above claims, characterized in that a pinch valve is always used as the powder intake valve (Q1, Q2) and as the powder outlet valve (Q3, Q4).

4. Coating powder feed method as claimed in claim 3, characterized in that pinch valves (Q1, Q2, Q3, Q4) are of a design such that a flexible hose (36) separates a valve duct (34) on the inner hose side from a pressure chamber (38) on the hose outside and in that the hose (36) can be pinched shut by the pressure of an applied compressed gas introduced into the pressure chamber (38), thereby closing the valve duct (34).

5. Coating powder feed method as claimed in one of the above claims, characterized in that the dense phase powder pump (10) used is such that it comprises at least two feed chambers (12, 14) running in parallel, each feed chamber (12, 14) being fitted with a powder intake valve (Q1, Q2) and a powder outlet valve (Q3, Q4) and in that powder is alternatingly aspirated into one (12) of the feed chambers (12, 14) by partial vacuum through its powder intake valve (Q1), and powder is discharged from another (14) of the feed chambers (12, 14) by means of a compressed gas through its powder outlet valve (Q4), and in that thereupon the powder is discharged by a compressed

gas from the one feed chamber (12) through its powder outlet valve (Q3) and powder is aspirated by a partial vacuum into the other feed chamber (14) through its powder intake valve (Q2).

6. Coating powder feed method as claimed in one of the above claims, characterized in that separate control valves (1.1, 1.2, 1.3. 1.4) are used for each feed chamber (12, 14) to control the powder intake valve (Q1, Q2) and the powder outlet valve (Q3, Q4) and that said control valves are driven separately, and in that a further separate control valve (1.5, 1.6) is used to load the feed chambers (12, 14) alternatively with a partial vacuum or a compressed gas, and that said further control valve (1.5, 1.6) is driven separately.

7. Coating powder feed method as claimed in one of the above claims, characterized by using a dense phase powder pump (10) wherein the chamber wall of the feed chamber (12, 14) is constituted at least over part of its length between its powder intake valve (Q1, Q2) and its powder outlet valve (Q3, Q4) by a filter (12.4, 14.4) enclosing the feed chamber (12, 14) and separating it from an intermediate chamber (12.5, 14.5) which encloses the filter (12.4, 14.4) and is constituted between the filter (12.4, 14.4) and a housing (12.6, 14.6), said filter (12.4, 14.4) being permeable to gas but impermeable to coating powder, and in that the partial vacuum and the compressed gas are transmitted through this pressure chamber (38) and through the filter (12.4, 14.4) into the feed chamber (12,14).

8. Coating powder feed method as claimed in one of the above claims, characterized in that the powder is moved by the dense phase powder pump (10) to a powder spray tool (26).

9. Coating powder feeding device containing:

- a dense phase powder pump (10) comprising at least one feed chamber (12, 14) fitted with a powder intake valve (Q1, Q2) and a powder outlet valve (Q3, Q4),
- a control (42) generating control signals to recurringly carry out the following operational cycles (a) through (d):
- (a) generating a partial vacuum in the feed chamber (12, 14) to aspirate coating powder into the feed chamber (12, 14) through the open powder intake valve (Q1, Q2) while the powder outlet valve (Q3, Q4) is closed;
- (b) closing the powder intake valve (Q1, Q2) and opening the outlet valve (Q3, Q4);
- (c) introducing a compressed gas into the feed chamber (12, 14) to discharge the coating powder from the feed chamber (12, 14) through the open powder outlet valve (Q3, Q4) while the powder intake valve (Q1, Q2) is closed;
- (d) closing the powder outlet valve (Q3, Q4) and opening the powder intake valve (Q1, Q2),

characterized

in that the control (42) is designed furthermore in a way that during the cycle segment (a) or when passing from the cycle segment (d) to the cycle segment (a), said control generates a control signal no earlier than simultaneously with a control signal to open the powder intake valve (Q1, Q2), as a result of which the start of partial vacuum buildup in the feed chamber (12, 14) takes place no earlier than simultaneously with the initial opening of the powder intake valve (Q1, Q2).

10. Coating powder feeding device as claimed in claim 9, characterized in that the control (42) is designed in a manner that during the cycle segment (a) or when passing from the cycle segment (d) into the cycle segment (a), said control shall generate the control signal generating the partial pressure in the feed chamber (12, 14) at a predetermined time delay after the control signal opens the powder intake valve (Q1, Q2), as a result of which the partial vacuum buildup in the feed chamber (12, 14) takes place at the defined time delay after opening the powder intake valve (Q1, Q2).

11. Coating powder feeding device as claimed in either of the above claims 9 and 10, characterized in that the powder intake valve (Q1, Q2) and the powder outlet valve (Q3, Q4) are pinch valves.

12. Coating powder feeding device as claimed in claim 11, characterized in that pinch valves (Q1, Q2, Q3, Q4) are of a design such that a flexible hose (36) separates a valve duct (34) on the inner hose side from a pressure chamber (38) on the hose outside and in that the hose (36) can be pinched shut by the pressure of an applied compressed gas introduced into the pressure chamber (38), thereby closing the valve duct (34).

13. Coating powder feeding device as claimed in one of the above claims 9 through 11, characterized in that the dense phase powder pump (10) comprises at least two feed chambers (12, 14) configured in parallel, of which each feed chamber (12, 14) is fitted with a powder intake valve (Q1, Q2) and a powder outlet valve (Q3, Q4) wherein powder controlled by the control (42) is alternatingly aspired by partial vacuum into one (12) of the feed chambers (12, 14) through its powder intake valve (Q1) and can be discharged from another (14) of the feed chambers (12, 14) by compressed air through its powder outlet

valve (Q4) and thereupon the powder can be discharged from the feed chamber (12) by means of compressed air through its powder outlet valve (Q3) and powder can be aspirated into the other feed chamber (14) by means of a partial vacuum through its powder intake valve (Q2).

14. Coating powder feeding device as claimed in one of the above claims 9 through 13, characterized in that separate control valves (1.1, 1.2, 1.3, 1.4) are used for each feed chamber (12, 14) to drive the powder intake valve (Q1, Q2) and the powder outlet valve (Q3, Q4) and that said control valves may be separately driven by the control (42) and in that at least one further control valve (1.5, 1.6) separately driven by the control (42) is provided to alternatively load the feed chambers (12, 14) with partial vacuum or compressed gas.

15. Coating powder feeding device as claimed in one of the above claims 9 through 14, characterized in that the minimum of one feed chamber (12, 14) of the dense phase powder pump (10) is constituted, over at least part of said pump's length between its powder intake valve (Q1, Q2) and its powder outlet valve (Q3, Q4, by a filter (12.4, 14.4) which encloses the feed chamber and separates it from an intermediate chamber (12.5, 14.5) enclosing the filter (12.4, 14.4) and is constituted between the filter (12.4, 14.4) and a housing (12.6, 14.6), where said filter (12.4, 14,4) is permeable to a gas but not to the coating powder, and in that the feed chamber (12, 14) is loaded alternatively through the filter (12.4, 14.4) with partial vacuum or a compressed gas.

16. An electrostatic powder spraycoating apparatus containing coating powder feeding device as claimed in one of claims 9 through 15, and a spray tool (26) designed for electrostatic spraycoating and connected to the powder discharge conduit (22) of the dense phase powder pump (10).

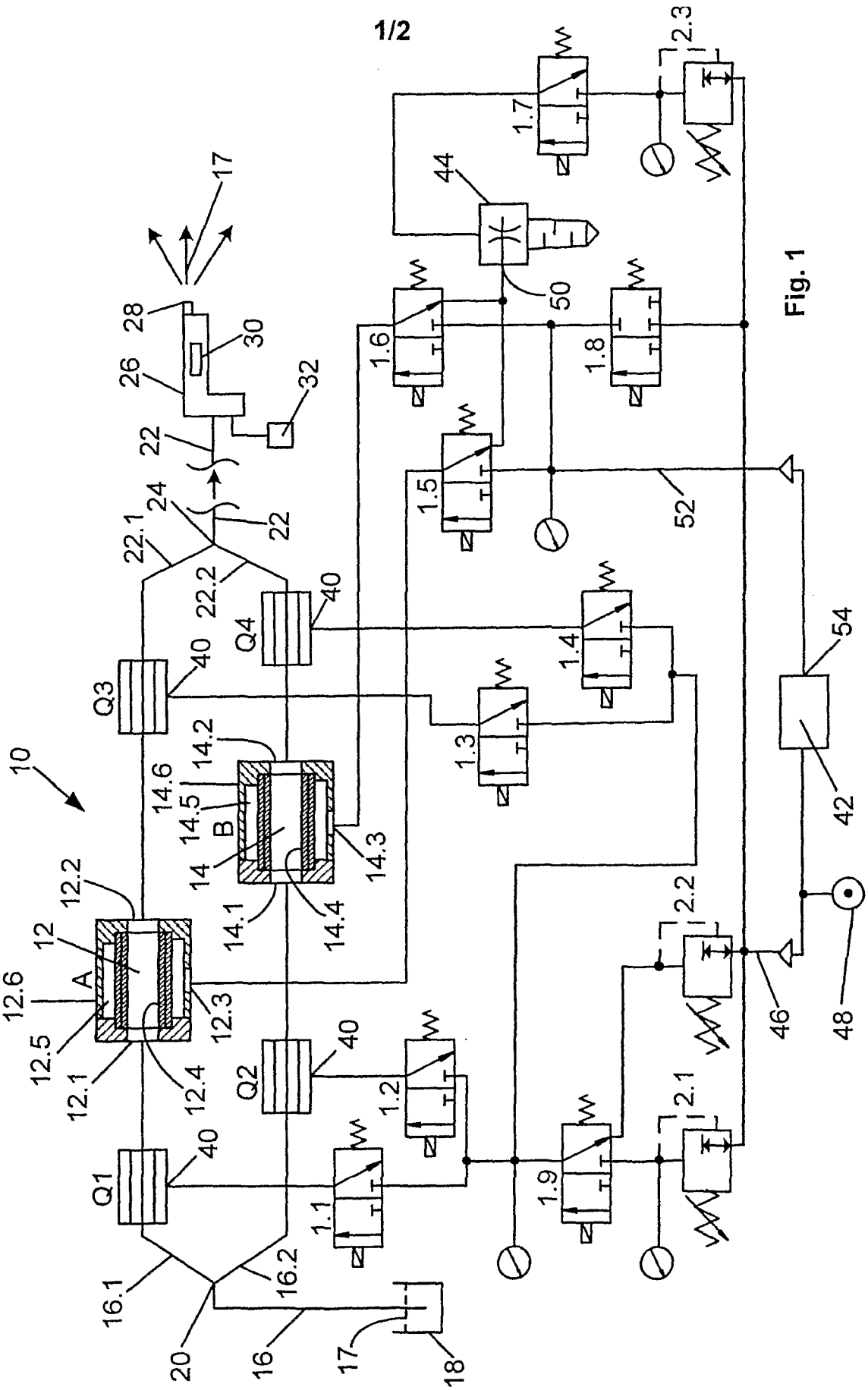

10
12
12.1
12.2
12.3
12.4
12.5
12.6
A
14
14.1
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14.4
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14.6
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16.1
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Fig. 1

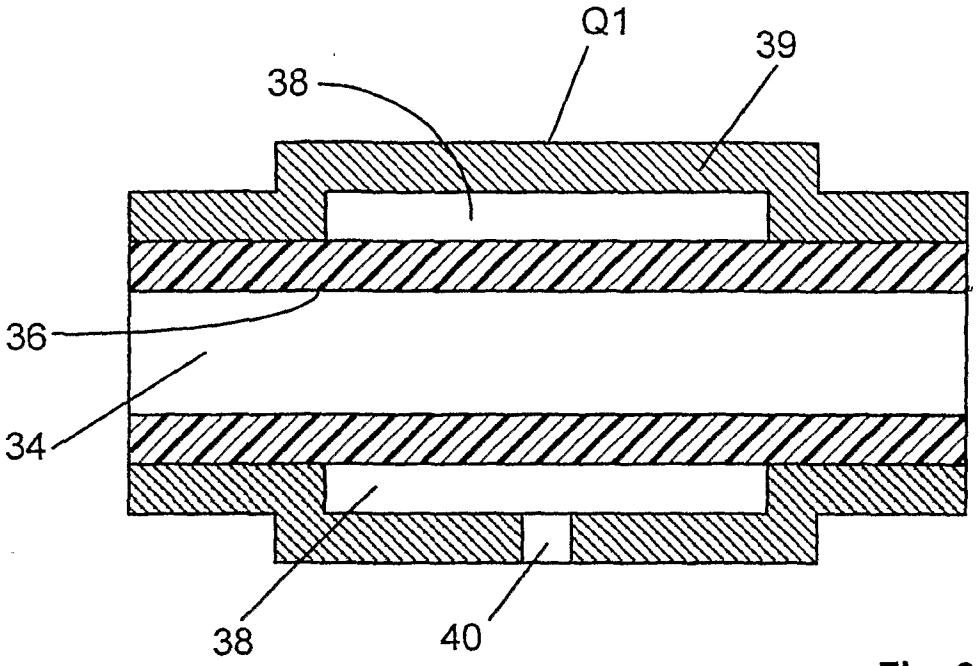


Fig. 2

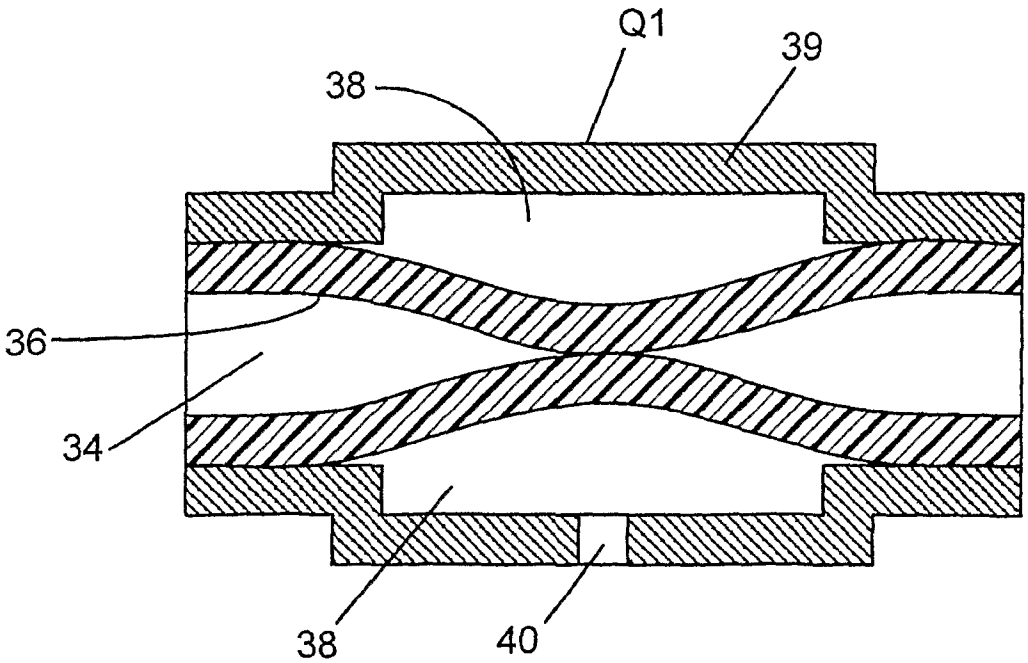


Fig. 3