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(71) Applicant (for all designated States except US): **BDT MEDIA AUTOMATION GMBH** [DE/DE]; Saline 29, 78628 Rottweil (DE).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **KEARNEY, Peter, Xavier** [DE/DE]; Hofgut Bronnen 3, 88637 Buchheim (DE). **WARDAK, Andreas** [DE/DE]; Hauptstrasse 15, 78628 Rottweil (DE). **SCHECH, Klaus** [DE/DE]; Schützstr. 4, 78647 Trossingen (DE).

(74) Agent: **WESTPHAL, MUSSGNUG & PARTNER**; Am Riettor 5, 78048 Villingen-Schwenningen (DE).

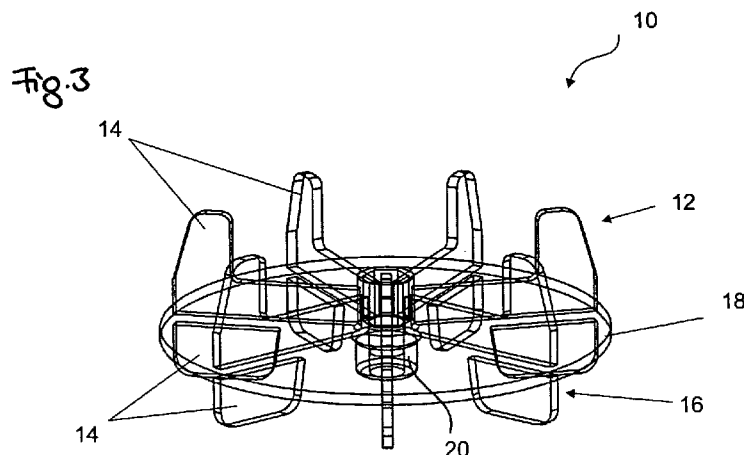
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(54) Title: THE PRESENT INVENTION RELATES TO A SUCTIONING AND CONVEYING SYSTEM FOR SUCTIONING AND CONVEYING AN OBJECT



(57) Abstract: The invention refers to a suctioning and conveying system for suctioning and conveying an object comprising first means for generating a low pressure induced by a whirlwind for sucking in the object, the whirlwind having an axis of rotation, wherein the system comprises second means for conveying the suctioned object along a transfer path transverse to the axis of rotation of the whirlwind.



Suctioning and conveying system

Description

5 The present invention relates to a suctioning and conveying system for suctioning and conveying an object.

Conveyance systems ordinarily rely on friction drives (i.e., belts or rollers) using gravity as a friction force to maintain an object being conveyed along a transfer path. However, when the object being transported is relatively flat and/or lightweight, ambient air streams can cause the object to get blown off from the conveyor. Additionally, when the conveyor is vertical or inclined, the object is likewise susceptible to sliding, rolling or flying away from the transfer path.

In the conveyance of paper, or other objects and substrates, often times the handling of stacks is required. When objects are stacked and a single object needs to be moved from the top of the stack, often times static and frictional adhering forces make it difficult to smoothly move the top object from the stack. This is particularly a problem when handling heavy or glossy media.

25 U.S. Patent No. 6,565,321 describes a vortex attractor. An impeller including a plurality of radial blades extending in a direction of the rotation axis is provided to generate a vortex flow. The vortex flow provides a central negative low pressure region which can be used to attract an object.

Further vortex generators are disclosed in U.S. Patent No. 6,497,553, U.S. Patent No. 6,960,063, U.S. Patent No. 6,595,753, U.S. Patent No. 6,811,678, U.S. Patent No. 6,802,881 and U.S. Patent No. 6,729,839.

GB 2 295 799 A discloses a device for increasing adhesion to a surface by suction force.

5 U.S. Patent No. 4,193,469 discloses a vehicle attachment for increasing adhesion to the supporting surface by a suction force.

U.S. Patent No. 7,204,672 describes a vortex device being able
10 to generate both an attractive force and a down or pushing force.

U.S. Patent Application No. 2001/0040062 discloses a lifting platform utilizing a propeller or impeller.

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U.S. Patent No. 6,402,843 describes a non-contact holder for substantially planar workpieces using a vortex device to attract the workpiece and using a gas flow to prevent the contact between the workpiece and the vortex device.

20

European Patent Application No. EP 1 975 735 describes use of radial blowers and a duct system forming low pressure suction chambers to aerate the sides of the stack and to adhere the top sheet in the stack to a belt.

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U.S. Patent No. 6,082,728 describes use of an axial fan likewise running through a duct as a low pressure suction chamber on the opposite side of a belt from paper being conveyed thereon to lift the uppermost sheet from a stack. The upper-
30 most sheet is first separated from the stack using an air knife providing compressed air from a duct system to below the uppermost sheet.

U.S. Patent No. 5,671,920 describes use of an external low pressure generator for providing an additional force to maintain an object on a conveyor.

- 5 U.S. Patent Application Publication No. 2005/0133980 describes use of an axial fan on the opposite side of a belt from paper being conveyed thereon.

10 U.S. Patent Application No. 2010/0007082 discloses an apparatus for feeding and aligning sheets fed to a processing machine which includes at least two parallel transporting belts and a suction table. The transporting belts can be driven at different speed.

- 15 U.S. Patent No. 7,748,697 describes a sheet feeding apparatus comprising a suction table which adsorbs the sheet to two conveying belts.

20 A suction table, which is as well called a plenum chamber, is connected to a suction fan which is arranged separately due to large place requirement. The suction table includes openings on one side to be able to adsorb an object. The distance in which an object can be sucked in by a suction table is quite small, usually about 5 mm. Adjusting or controlling of the
25 suction force is possible using valves or variations of the openings which is expensive.

The goal of the invention is to provide a compact, cheap system for conveying an object.

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The goal is achieved with a suctioning and conveying system for suctioning and conveying an object comprising the features of claim 1.

Advantageous embodiments and elaborations of the invention are indicated in the secondary claims.

5 The suctioning and conveying system for suctioning and conveying an object according to an embodiment of the invention comprises first means for generating a low pressure induced by a whirlwind for sucking in the object, the whirlwind having an axis of rotation, and second means for conveying the suctioned
10 object along a transfer path transverse to the axis of rotation of the whirlwind. The first means for generating a low pressure induced by a whirlwind for sucking in the object can as well be named as a vortex suction device.

15 The transfer path and the axis of rotation of the whirlwind being transverse includes both the transfer path and the axis of rotation of the whirlwind being perpendicular relative to each other and the transfer path and the axis of rotation of the whirlwind having an angle of about $+45^\circ$ to -45° relative
20 to each other.

Vortex devices are able to suck in an object over larger distances, for example about up to 60 mm. Furthermore, vortex devices are smaller and cheaper than suction tables. The suctioning and conveying system according to the invention therefore
25 is more effective and more cost-effective.

In a preferred embodiment, the first means and the second means are disposed so that the first means suck in the object
30 against the second object to preferably achieve a compact and effective system.

In a preferred embodiment, the angle of the transfer path relative to the axis of rotation is adjustable between -45° and 45° to achieve a system that can be used flexible.

- 5 In a preferred embodiment, the first means include an impeller. An impeller is a cost-effective assembly to provide an effective whirlwind.

10 In an embodiment, the impeller includes an impeller wheel and an impeller housing, wherein the impeller wheel is arranged rotatably in the impeller housing or wherein the impeller wheel is arranged in the impeller housing in a rotatably fixed manner.

15 In a preferred embodiment, the impeller housing is cylindrical or conical with an opening angle, wherein the opening angle preferably is adjustable to control or adjust the shape or the intensity of the whirlwind.

20 In a preferred embodiment, the impeller wheel is adjustable relative to the impeller housing along the axis of rotation of the impeller wheel to preferably control or adjust the shape or the intensity of the whirlwind.

25 In an embodiment, the impeller includes an impeller wheel having blades extending radially. Therefore, the impeller is able to generate a whirlwind both if rotating clockwise and counterclockwise.

30 In an embodiment, the impeller includes an impeller wheel having blades, an outer edge of the blades being curved to preferably control or adjust the shape or the intensity of the whirlwind.

In a preferred embodiment, the impeller includes an impeller wheel and a motor which is integrated in the impeller wheel to provide a compact and space-saving impeller.

5

In a preferred embodiment, the impeller includes an impeller wheel comprising a separation plane transverse to the axis of rotation of the impeller wheel. Therefore, one part of the impeller can be used to generate the whirlwind and the other
10 part of the impeller can be used to cool the motor of the impeller.

In an embodiment, the impeller includes a brushless DC-motor, which is preferably designed as an internal rotor, to provide
15 an effective and space-saving impeller.

In an embodiment, the first means comprise a cylindrical housing in which air can be injected tangentially through a cylinder orifice to provide an alternative embodiment to generate
20 the whirlwind.

In an embodiment, the injected air is generated by an impeller, the impeller being arranged in a first cylindrical housing, wherein the axis of rotation of the impeller is arranged
25 parallel to the axis of a second cylindrical housing, wherein the second cylindrical housing and the first cylindrical housing are connected by a connecting channel, the connecting channel being arranged tangentially on the first and the second cylindrical housing. In this way, it is possible to
30 generate two basically parallel whirlwinds using only one impeller.

In a preferred embodiment, the first means are arranged within a housing having a suctioning opening and wherein the second means partially cover the suctioning opening. Surprisingly, the whirlwind still can be generated although the suctioning opening is partly covered. If the second means extend adjacent the suctioning opening, the sucked in object can be sucked against the first means, especially the impeller. With this embodiment, the suctioned in objects are prevented from being suctioned in the first means.

In a preferred embodiment, the summed width of the second means amount to about 40% to 60% of the width of the suctioning opening. Surprisingly, the whirlwind still can be generated although the suctioning opening is covered to this extent.

In a preferred embodiment, the height of the second means amount to about 2% of the width of the suctioning opening. The less high the second means the larger the suction force of the whirlwind.

In an embodiment, the second means are arranged in front of the suctioning opening so that the distance of the outer edges of the second means is smaller than the width of the suctioning opening, preferably by about 10%. Surprisingly, a whirlwind still can be generated if the middle of the suctioning opening is covered provided that the outer regions of the suctioning opening are not covered.

In a preferred embodiment, the second means comprises at least one of a conveyor belt, a transport roller or a transport ball which are cost-effective and easy to assemble.

In a preferred embodiment, the second means comprise at least one flat conveyor belt, the conveyor belt being at least partially air permeable and/or comprising a plurality of openings. If the belt is air permeable, especially if the belt
5 comprises a plurality of openings, the suctioned in object is as well sucked against the belt, resulting in less deformation of the object.

10 In an embodiment, the second means comprises two flat conveyor belts running in parallel, the belts preferably being adjustable in their distance to provide a flexible system.

In an embodiment, the second means comprises at least two transportation means, the two transportation means having different cross sectional geometries, preferably the two trans-
15 portation means being a belt and an O-ring. Especially, the O-ring extends across the middle of the suctioning opening. The O-ring is able to support the object.

20 In a preferred embodiment, the suctioning opening is designed to be closed at least partially, preferably by a sliding element or by an iris, to be able to control or adjust the suction force of the whirlwind.

25 In an embodiment, ribs are arranged transverse the suctioning opening to prevent the object from being sucked in the first means.

In an preferred embodiment, the second means comprise two ele-
30 ments, preferably two flat conveyor belts, being independently motor-driven to be able to rotate an object suctioned in by the first means, especially without moving the object along the transfer path.

In an embodiment, the second means are driven by a stepper-motor to be able to control the movement along the transfer path.

5

In an embodiment, the second means are adjustable relative to the suctioning opening of the suctioning and conveying system to provide a more flexible system.

10 In an embodiment, the suctioning and conveying system is rotatable, preferably around the axis of rotation of the whirlwind, to be able to rotate an object suctioned in by the first means, especially without moving the object along the transfer path, in an alternative manner.

15

In a preferred embodiment, a conveying system for conveying an object along a transfer path is provided, comprising at least a first and a second suctioning and conveying system according to the invention, wherein the suctioning and conveying systems are disposed in sequence in a direction of the transfer path, further comprising a main controller configured to separately control the suctioning and conveying systems so as to convey the object along the transfer path using the second means of the suctioning and conveying systems. Of course this embodiment comprises the two alternatives to use only one second means for all suctioning and conveying systems, especially for both the first and the second suctioning and conveying system, or to use second means for each suctioning and conveying system, the only one second means or the several second means being configured to support the object relative to at least one of the suctioning and conveying systems.

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In an embodiment, the second means are designed as conveyor belt being associated with the first and the second suctioning and conveying system. In an embodiment, the second means are designed as conveyor belt including at least one conveyor belt associated with the first suctioning and conveying system and at least one conveyor belt associated with the second suctioning and conveying system, the conveyor belts being configured to carry the object along the transfer path and being operable at different conveyance speeds by the main controller. In an embodiment, the at least one conveyor belt associated with the first suctioning and conveying system includes a first pair of belts arranged on the first suctioning and conveying system, and the at least one belt associated with the second suctioning and conveying system includes a second pair of belts arranged on the second suctioning and conveying system.

In a preferred embodiment, the conveying system further comprises third and fourth suctioning and conveying systems, wherein the first and third suctioning and conveying system form a first array and the second and fourth suctioning and conveying system form a second array, the main controller being configured to separately control the arrays, especially to be able to provide different possibilities to move the object.

In an embodiment, the arrays are disposed so that the suctioning opening of the first suctioning and conveying system is disposed opposite the suctioning opening of the second suctioning and conveying system, especially to be able to provide different possibilities to move the object.

30

In an embodiment, the suctioning and conveying systems include a housing disposed peripherally about the suctioning and conveying systems and having a cover thereon. In an embodiment,

the cover includes ribs extending in the direction of the transfer path.

In an embodiment, the suctioning and conveying systems are
5 movable in the direction of the transfer path, especially to be able to provide different possibilities to move the object.

In an embodiment, the main controller is configured to separately control, switch on, switch off, slow down and/or speed
10 up the first and/or the second suctioning and conveying system, preferably independently and preferably the first and second means independently, especially to be able to provide different possibilities to move the object. In an embodiment, the main controller is configured to sequentially switch on or
15 speed up or switch off or slow down the suctioning and conveying systems as the object moves along the transfer path. In this way, movement of the object and suction force of the suctioning and conveying systems can be controlled and adjusted.

20 In an embodiment, the main controller is configured to operate the first suctioning and conveying system at a different transport speed than the second suctioning and conveying system, especially to be able to provide different possibilities for the movement of the object.

25 In an embodiment, the transfer path extends into first and second secondary paths, the first suctioning and conveying system being configured to convey the object from the transfer path to the first secondary path and the second suctioning and
30 conveying system being configured to convey the object from the transfer path to the second secondary path, especially to be able to provide different possibilities for the movement of the object.

In an embodiment, a separating system for separating an object from the outer part of a stack and conveying it along a transfer path is provided, the system comprising a stack assembly
5 configured to receive a stack of objects and a mounting assembly including at least one suctioning and conveying system according to the invention, the suctioning and conveying system being disposable so as to face the stack of objects at at least one of a leading edge and a trailing edge thereof for
10 suctioning in and conveying an object from the stack. With this embodiment, an effective and space-saving system to separate an object from the outer part of a stack is provided.

In an embodiment, the stack assembly includes at least one ad-
15 hesion reduction device disposed adjacent to an outer object of the stack to be able to easily separate the object from the stack.

In an embodiment, the adhesion reduction device includes at
20 least one of an aerating device and a vibrating device configured to vary a position of the objects relative to each other, in this way an effective adhesion reduction device can be provided.

25 In an embodiment, the aerating device includes at least one side blower having a radial fan that is adjustable in height, preferably between 0 mm and 60 mm, relative to the stack so as to aerate a portion of the stack.

30 In an embodiment, the objects are flat, flexible substrates.

In an embodiment, the suctioning and conveying system is disposed above or below the stack at a distance of between 0 and

60 mm. In an embodiment, the distance between the suctioning and conveying system and the stack is adjustable, preferably between 0 mm and 60 mm. In a further embodiment, the angle of the axis of rotation of the first means to an outer object of the stack is adjustable, preferably between -45° and 45° . In this way, a flexible separating system can be provided.

In a preferred embodiment, the suctioning and conveying system is disposable at the leading edge of the stack and the angle of the axis of rotation of the first means of the suctioning and conveying system relative to the outer object of the stack is adjustable between 0° to 45° .

In an embodiment, the stack assembly includes at least one stack height sensor disposed above an outer object of the stack.

In a preferred embodiment, the second means includes at least one of a conveyor belt and a roller or ball based transportation means extending in a direction of the transfer path and configured to receive the object thereagainst under an attraction force of the at least one suctioning and conveying system.

In an embodiment, the angle of the transport path and the outer object is adjustable between -45° and 45° .

In a preferred embodiment, the system includes a plurality of suctioning and conveying systems that are individually operated.

The method of suctioning and conveying an object along a transfer path according to an embodiment of the invention com-

prises generating a low pressure induced by a whirlwind for sucking in the object, the whirlwind having an axis of rotation, and conveying the suctioned object along the transfer path transverse to the axis of rotation of the whirlwind.

- 5 The transfer path and the axis of rotation of the whirlwind being transverse includes both the transfer path and the axis of rotation of the whirlwind being perpendicular relative to each other and the transfer path and the axis of rotation of the whirlwind having an angle of about $+45^\circ$ to -45° relative
10 to each other.

The method of conveying an object along a transfer path according to an embodiment of the invention comprises disposing at least a first and a second vortex suction unit in sequence
15 in a direction of the transfer path, transferring the object relative to at least one of the vortex suction units using at least one conveyor, and controlling the vortex suction units separately using a main controller so as to convey the object using at least one of the conveyors.

20

In an embodiment, the method further comprises aligning the object relative to an alignment line, the alignment line preferably being a mechanical or electronical alignment line.

- 25 In an embodiment, the method further comprises disposing third and fourth vortex suction units in sequence in the direction of the transfer path, wherein the first and third vortex suction units are controlled together as a first array and the second and fourth vortex suction units are controlled together
30 as a second array.

In an embodiment, the controlling includes sequentially operating each vortex suction unit along the transfer path.

In an embodiment, the controlling is performed so as to control at least one of a speed of the conveying, a direction of the conveying, and an attraction force of the object to the conveyor.

In an embodiment, the method further comprises sensing a position of the object using the main controller and at least one of speed and a current of at least one of the first and second vortex suction modules.

The method of separating an object from an outer part of a stack of objects according to an embodiment of the invention comprises disposing at least one vortex suction unit, preferably a suctioning and conveying system according to the invention, at a distance opposite an edge of the stack, and attracting the object from the stack and conveying it along a transfer path using the at least one vortex suction unit, preferably using a suctioning and conveying system according to the invention.

In an embodiment, the method further comprises adjusting at least one of the distance and an angle of an impeller axis of the at least one vortex suction unit relative to the stack.

In an embodiment, the edge of the stack is a leading edge of the stack in a direction of the transfer path of the object.

In an embodiment, the at least one vortex suction unit includes a plurality of vortex suction units that are individually or commonly operated.

In an embodiment, the conveying includes transporting the object away from the stack while the object is adhered by the at least one vortex suction unit.

- 5 In an embodiment, the method further comprises reducing adhesion between the objects.

In an embodiment, the reducing adhesion includes at least one of aerating and vibrating the objects.

10

In an embodiment, the object is a flat, flexible substrate and the disposing is performed such that the distance is between 0 and 60 mm.

- 15 In an embodiment, the angle between the object surface and the suctioning opening of the suctioning and conveying system is adjusted to between -45° to 45° .

- 20 In an embodiment, the conveying is performed using a conveyor belt configured to receive the object thereagainst at a contact surface thereof under an attraction force of the at least one vortex suction unit.

- 25 In an embodiment, the method further comprises varying an angle of the contact surface relative to the stack.

- In an embodiment, the conveying is performed using a conveyor belt so as to convey the object in a direction substantially orthogonal to an impeller axis of the vortex suction unit.

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In an embodiment, the edge of the stack is at a top or a bottom of the stack.

The forgoing and other features of the present invention will be more readily apparent from the following detailed description and drawings of illustrative embodiments of the invention in which:

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Fig. 1a is a perspective view of a vortex suction unit with integrated housing in accordance with an embodiment of the present invention,

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Fig. 1b is a top view of the vortex suction unit of Fig. 1a,

Fig. 2a is a perspective view of a vortex suction unit with separated housing in accordance with an embodiment of the present invention,

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Fig. 2b is a top view of the vortex suction unit of Fig. 2a,

Fig. 3 is a perspective view of a vortex suction unit in accordance with an embodiment of the present invention,

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Fig. 4 is a perspective view of the vortex suction unit of Fig. 3,

25

Fig. 5 is a schematic view of the fluid flow generated by the vortex suction unit of Fig. 4,

Fig. 6 is a graph comparing attraction force and power consumption of vortex suction units and standard axial fans,

30

Fig. 7a is a sectional view of a vortex suction unit with separated housing in accordance with an embodiment of the present invention,

Fig. 7b is a top view of the vortex suction unit of Fig. 7a,

Fig. 8a is a sectional view of a vortex suction unit with integrated housing in accordance with an embodiment of the present invention,

Fig. 8b is a top view of the vortex suction unit of Fig. 7a,

Fig. 8c is a perspective view of a vortex suction unit in accordance with an embodiment of the present invention provided with a recess for a motor,

Fig. 9 is a sectional view of a vortex suction unit in accordance with an embodiment of the present invention,

Fig. 10a is a sectional view of a vortex suction unit including a schematic view of the air flow in accordance with an embodiment of the present invention,

Fig. 10b is a top view of the vortex suction unit of Fig. 10a,

Fig. 11a is a sectional view of a vortex suction unit including a schematic view of the air flow in accordance with an embodiment of the present invention,

Fig. 11b is a top view of the vortex suction unit of Fig. 11a,

Fig. 12 is a graph comparing the intake flow pressure of the vortex suction units of Fig. 10a and Fig. 11a,

Fig. 13 is a sectional view of a vortex suction unit including a schematic view of the air flow in accordance with an embodiment of the present invention,

Fig. 14 is a sectional view of a vortex suction unit including a schematic view of the air flow in accordance with an embodiment of the present invention,

5

Fig. 15 is a graph comparing the intake flow pressure of the vortex suction units of Fig. 13 and Fig. 14,

10

Fig. 16 is a sectional view of a vortex suction unit including a schematic view of the air flow in accordance with an embodiment of the present invention,

15

Fig. 17 is a sectional view of a vortex suction unit including a schematic view of the air flow in accordance with an embodiment of the present invention,

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Fig. 18 is a sectional view of a vortex suction unit including a schematic view of the air flow in accordance with an embodiment of the present invention,

Fig. 19 is a graph comparing the intake flow pressure of the vortex suction units of Fig. 16, Fig. 17, and Fig. 18,

25

Fig. 20 is a sectional view of a vortex suction unit including a schematic view of the air flow in accordance with an embodiment of the present invention,

30

Fig. 21 is a sectional view of a vortex suction unit including a schematic view of the air flow in accordance with an embodiment of the present invention,

Fig. 22 is a graph comparing the intake flow pressure of the vortex suction units of Fig. 20, and Fig. 21,

Fig. 23a is a sectional view of a vortex suction unit with an iris in accordance with an embodiment of the present invention,

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Fig. 23a is an exploded sectional view of the vortex suction unit of Fig. 23a,

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Fig. 24a is a top view of the vortex suction unit of Fig. 23a, the iris being closed,

Fig. 24b is a top view of the vortex suction unit of Fig. 23a, the iris being partly opened,

15

Fig. 24c is a top view of the vortex suction unit of Fig. 23a, the iris being opened,

20

Fig. 25a is a graph showing the intake flow pressure of the vortex suction units of Fig. 24a,

Fig. 25b is a graph showing the intake flow pressure of the vortex suction units of Fig. 24b,

25

Fig. 25c is a graph showing the intake flow pressure of the vortex suction units of Fig. 24c,

Fig. 26a is a top view of a vortex suction unit in accordance with an embodiment of the present invention,

30

Fig. 26b is a side view of the vortex suction of Fig. 26a including a schematic view of the air flow,

Fig. 27a is a top view of a vortex suction unit in accordance with an embodiment of the present invention,

Fig. 27b is a sectional view of the vortex suction of Fig. 27a
5 including a schematic view of the air flow,

Fig. 28 is a graph showing the intake flow pressure of the vortex suction unit of Fig. 27b,

10 Fig. 29 is a sectional top view of the vortex suction unit in a conveyance system,

Fig. 30 is a top view of a suctioning and conveying system in accordance with an embodiment of the present invention,

15

Fig. 31 is a top view of a suctioning and conveying system in accordance with an embodiment of the present invention,

Fig. 32 is a sectional side view of the suctioning and convey-
20 ing system of Fig. 31,

Fig. 33 is a top view of a suctioning and conveying system in accordance with an embodiment of the present invention having two motors,

25

Fig. 34a is a front view of a suctioning and conveying system in accordance with an embodiment of the present invention showing the force exerted on an object laying on two belts, the belts being outside of the suctioning opening of the suc-
30 tioning and conveying system,

Fig. 34b is a front view of a suctioning and conveying system in accordance with an embodiment of the present invention

showing the force exerted on an object laying on two belts, the belts partially covering the suctioning opening of the suctioning and conveying system,

5 Fig. 34c is a front view of a suctioning and conveying system in accordance with an embodiment of the present invention showing the force exerted on an object laying on two belts, the belts partially covering the suctioning opening of the suctioning and conveying system whereas the belts are partly
10 perforated,

Fig. 34d is a front view of a suctioning and conveying system in accordance with an embodiment of the present invention showing the force exerted on an object laying on two belts and
15 an O-ring, the belts partially covering the suctioning opening of the suctioning and conveying system,

Fig. 35a is a perspective view of a suctioning and conveying system with two belts partially covering the suctioning opening in accordance with an embodiment of the present invention,
20

Fig. 35b is a top view of the suctioning and conveying system of Fig. 35a,

25 Fig. 36a is a perspective view of a suctioning and conveying system with two belts partially covering the suctioning opening and an O-ring in between in accordance with an embodiment of the present invention,

30 Fig. 36b is a top view of the suctioning and conveying system of Fig. 36a,

Fig. 37a is a perspective view of a suctioning and conveying system with one belt partially covering the suctioning opening in accordance with an embodiment of the present invention,

5 Fig. 37b is a top view of the suctioning and conveying system of Fig. 37a,

Fig. 38a is a perspective view of a suctioning and conveying system with one perforated belt partially covering the suctioning opening in accordance with an embodiment of the present invention,

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Fig. 38b is a top view of the suctioning and conveying system of Fig. 38a,

15

Fig. 39a is a top view of a suctioning and conveying system in accordance with an embodiment of the present invention provided with means for rotating the system,

20 Fig. 39b is a bottom view of the suctioning and conveying system of Fig. 39a,

Fig. 39c is a bottom view of the suctioning and conveying system of Fig. 39a in a rotated position,

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Fig. 40a is a top view of a suctioning and conveying system in accordance with an embodiment of the present invention having transport balls,

30 Fig. 40b is a top view of a suctioning and conveying system of Fig. 40a with an object in different positions,

Fig. 40c is a side view of the suctioning and conveying system of Fig. 40a,

Fig. 41a is a schematic view of translating of an object,

5

Fig. 41b is a schematic view of bending of an object,

Fig. 41c is a schematic view of lifting the rim of an object,

10 Fig. 41d is a schematic view of lifting an edge of an object,

Fig. 41e is a schematic view of planing a corrugated object,

Fig. 41f is a schematic view of turning an object around a
15 cross axis,

Fig. 41g is a schematic view of turning an object around a
longitudinal axis,

20 Fig. 41h is a schematic view of rotating an object around an
axis perpendicular to a flat object,

Fig. 41i is a schematic view of conveying and sorting objects,

25 Fig. 41j is a schematic view of sorting objects in a vertical
direction,

Fig. 41k is a schematic view of transferring an object from a
horizontal position in a vertical position,

30

Fig. 41l is a schematic view of separating double-picked ob-
jects,

Fig. 41m is a schematic view of aligning an object relative to a stop bar,

Fig. 41n is a schematic view of aligning an object relative to
5 two CCD bars,

Fig. 41o is a schematic view of fixing a flat object on a cylinder,

10 Fig. 42 is a top view of a conveyor using vortex suction units in accordance with an embodiment of the present invention,

Fig. 43 is a schematic view of a system of conveying an object in accordance with an embodiment of the present invention,

15

Fig. 44 is a schematic view of a system of planing a corrugated object in accordance with an embodiment of the present invention,

20 Fig. 45a is a schematic view of a system of turning an object around a cross axis in accordance with an embodiment of the present invention in a first position,

Fig. 45b is a schematic view of the system of turning an object
25 around a cross axis of Fig. 45a in a second position,

Fig. 45c is a schematic view of the system of turning an object around a cross axis of Fig. 45a in a third position,

30 Fig. 46a is a front view of the system of turning an object around a cross axis of Fig. 45a,

Fig. 46b is a front view of the system of turning an object around a cross axis of Fig. 45c,

Fig. 47 is a schematic view of a system of conveying and sorting objects in accordance with an embodiment of the present invention,

Fig. 48 is a schematic view of a system of sorting objects in a vertical direction in accordance with an embodiment of the present invention,

Fig. 49 is a schematic view of a system of transferring objects from two different horizontal positions in a vertical position in accordance with an embodiment of the present invention,

Fig. 50 is a schematic view of a conveyance system illustrative of use of the vortex suction units for double-pick handling in accordance with an embodiment of the present invention,

Fig. 51 is a schematic view of a conveyance system having sorting containers for the handling of a double-pick in accordance with an embodiment of the present invention,

Fig. 52 is a schematic view of a conveyance system having guides for moving the vortex suction units along the transfer path in accordance with an embodiment of the present invention,

Fig. 53 is a schematic view of a flipping portion of a conveyance system in accordance with an embodiment of the present invention,

Fig. 54 is a schematic view of a system of aligning objects relative to an alignment edge or relative to a CCD bar in accordance with an embodiment of the present invention,

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Fig. 55 is a schematic view of a system of aligning objects relative to two CCD bars in accordance with an embodiment of the present invention,

10 Fig. 56 is a schematic view of a system of aligning objects relative to two CCD bars in accordance with an embodiment of the present invention,

Fig. 57 is a schematic view illustrating the individual control of vortex suction units as an object is conveyed along the transfer path in accordance with an embodiment of the present invention,

15 Fig. 58 is a schematic view illustrating the individual control of vortex suction units for conveying and sorting the object,

Fig. 59 is a sectional view of a staggered arrangement of vortex suction units in a conveyance system in accordance with an embodiment of the present invention,

25 Fig. 60a is a schematic view of a system of fixing a flat object on a cylinder in accordance with an embodiment of the present invention in a first position,

30

Fig. 60b is a schematic view of the system of fixing a flat object on a cylinder of Fig. 60a in a second position,

Fig. 61 is a schematic view of a controller for first and second vortex suction units in accordance with an embodiment of the present invention,

5 Fig. 62 is a schematic view of the controller of Fig. 61 integrated onto the first vortex suction unit in accordance with an embodiment of the present invention,

10 Fig. 63 is a schematic view of a controller for first and second vortex suction units having a shared belt and belt drive in accordance with an embodiment of the present invention,

15 Fig. 64 is a schematic view of a main controller and modular controllers in accordance with an embodiment of the present invention,

20 Fig. 65 is a schematic view of a conveyance system having two mechanical-guide conveyors and vortex suction units in accordance with an embodiment of the present invention,

25 Fig. 66a is a side view of a suctioning and conveying system positioned above a stack of objects in accordance with an embodiment of the present invention,

Fig 66b is a side view of the suctioning and conveying system of Fig. 66a lifting the uppermost object from the stack,

30 Fig. 66c is a side view of the suctioning and conveying system of Figs. 66a and 66b conveying the uppermost object away from the stack,

Fig. 67a is a front view of Fig. 66a,

Fig. 67b is a front view of Fig. 66b,

Fig. 67c is a front view of Fig. 66c,

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Fig. 68a is a schematic sectional view of a stack assembly in accordance with an embodiment of the present invention,

Fig. 68b is a detailed view of detail X of Fig. 68a,

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Fig. 69 is a top view of a stack assembly according to an embodiment of the present invention,

Fig. 70a is a sectional side view of a stack assembly with a suctioning and conveying system having means for adjusting the angle of the suctioning and conveying system relative to the stack in accordance with an embodiment of the present invention,

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Fig. 70b shows the stack assembly of Fig. 70a with the suctioning and conveying system having a different angular position,

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Fig. 70c shows the stack assembly Figs. 70a and 70b with the suctioning and conveying system having a further angular position,

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Fig. 71a is a sectional side view of a stack assembly with a suctioning and conveying system having alternate means for adjusting the angle of the suctioning and conveying system relative to the stack in accordance with an embodiment of the present invention,

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Fig. 71b shows the stack assembly of Fig. 71a with the suctioning and conveying system having been self-adjusted to a different angular position,

5 Fig. 72a is a sectional side view of a stack assembly with a suctioning and conveying system having further alternate means for adjusting the angle of the suctioning and conveying system relative to the stack in accordance with an embodiment of the present invention,

10

Fig. 72b shows the stack assembly of Figs. 72a with the suctioning and conveying system having a different angular position and height,

15 Fig. 73a is a sectional side view of a stack assembly and suctioning and conveying system with means for adjusting the height and angle of the suctioning and conveying system relative to the stack, the stack assembly being provided for handling multiple objects in accordance with an embodiment of the present invention, here opening of a flap of an envelope for
20 further processing,

Fig. 73b shows the stack assembly of Figs. 73a with a second object being provided to the first object being lifted,

25

Fig. 73c shows the stack assembly of Figs. 73a and 73b with both objects being lifted,

Fig. 73d shows the stack assembly of Figs. 73a-c with the
30 suctioning and conveying system conveying both the first and second objects away from the stack, and transferring them to an output for further processing,

Fig. 74 is a schematic wiring diagram for a stack assembly according to an embodiment of the present invention.

In the figures, same reference numbers refer to identical or analog parts. For more transparency, not all reference numbers are cited in all figures.

Referring to Figs. 1-8, a vortex suction unit 10 includes an upper vortex generator 12 driven by a motor 20. The upper vortex generator 12 includes a base 18 concentrically driven by the motor 20 and a plurality of blades 14 radially disposed on the base 18 and extending perpendicularly upwards therefrom. The blades 14 rotate around an axis of rotation. In an embodiment, a similar lower vortex generator 16 including blades 14 is provided on the opposite side of the base 18. In one embodiment, one of the vortex generators 12, 16, especially the lower vortex generator 16, is used to provide a cooling flow of air to the body of the motor 20. The base 18 might be arranged symmetrically between the upper vortex generator 12 and the lower vortex generator 16. However, in one embodiment, the lower vortex generator 16 for cooling the motor 20 is smaller in height than the upper vortex generator 12 for providing the attraction force. However, in one embodiment, only the upper vortex generator 12 is provided to generate the attraction force A based upon the principles of a tornado. The motor 20 may be an AC or DC motor. For example, the motor 20 is a brushless DC motor or a stepper motor. The blades 14 may be a number of different shapes, such as curved. In an embodiment, the blades 14 are substantially straight and flat. For example, the blades 14 of the upper vortex generator 12 may include a recessed part at an upper, inward and radially-extending portion thereof. For example, the blades 14 of the lower vortex generator 16 may include a recessed part at an

upper, inward and radially-extending portion thereof, especially to receive the motor 20. The motor might be placed in the recessed part (see for example Fig. 8c). Of course, the motor 20 can as well be arranged outside the housing 30 (see
5 for example Fig. 10a)

A housing 30 may be provided on the vortex suction unit 10 surrounding the peripheral edge of the base 18 and blades 14 (see Figs. 1, 2, 4, 5, 7 and 8). The housing 30 may be, for
10 example, a shell or a ring, which is separated from the blades 14 (see Figs. 2, 4, 5 and 7), especially providing a light impeller wheel which comprises the blades 14 and where applicable the base 18. Alternatively, the upper vortex generator 12 and/or the lower vortex generator 16 may be manufactured, for
15 example, by molding, to form a ring surrounding the blades 14, therefore the blades 14 being integrated in the housing 30 (see Figs. 1 and 8) Especially, the housing 30 can be formed integrally with the base 18 (see Fig 8a).

A vortex suction unit 10 is any device capable of generating a
20 whirlwind, particularly a vortical fluid flow FF. By way of example, a vortex attractor as described in U.S. Patent No. 6,565,321 or in U.S. Patent No. 7,204,672 may be used. The radially extending blades 14 generate the fluid flow FF helically containing a low pressure region LP within the vortex generator 12 inside the peripheral edges of the blades 14. The
25 vertical fluid flow has an axis of rotation, which is in an embodiment identical to the axis of rotation of the blades 14. An attraction force A is generated in the low pressure region
30 LP which allows the vortex suction unit 10 to both attract and move toward (when the vortex suction unit 10 is not fixed) the surface of an object. Vortex suction units 10 are effective to removably adhere to planar and non-planar surfaces or to main-

tain the same at a predetermined distance. It is also noted that the vortex suction units 10 may be modified to apply a negative attraction force A, or a repulsion force, to push an object 50 away.

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In one embodiment, the upper and lower vortex generators 12, 16 are formed from a lightweight material, such as plastic, and have a diameter of approximately 50 mm. In this manner, the rotational inertia is kept low such that the vortex suction module can be started and stopped quickly. Likewise, the speed may be adjusted quickly and easily. The motor 20 is a brushless DC motor which responds quickly to changes in power level to adjust its rotations per minute (rpm). At about 22,000 rpm, the vortex suction unit 10 generates an attraction force A of about 1.3 N throughout the low pressure region LP.

Referring to Fig. 6, a comparison is made for illustrative purposes between a vortex impeller and a vacuum suction chamber having a fan configured for low pressure generation (vacuum power). In addition to being responsive to power changes to quickly change speed and thereby increase or decrease its attraction force, the vortex impeller is also far more efficient and effective than the vacuum system when at a distance from an object to be adhered; this is a desirable positioning for proper conveyance to allow room for belts and/or prevent sticking. For example, where the object 50 is disposed at a distance of 1.0 mm from the upper vortex generator 12, an attraction of approximately 0.7 ounces is achieved while consuming only about 3.5 Watts of power. In contrast, at the same distance of 1.0 mm, the fan of the vacuum generator consumes approximately 6.5 Watts of power while providing attraction for only about 0.1 ounces.

Referring to Fig. 9, the vortex suction unit 10 includes a motor 20, which is designed as an internal rotor. The internal rotor includes a magnet 20a, which are especially arranged at or integrated in the blades 14, and one or more coils 20b, which are arranged at or integrated in the housing 30. This embodiment of a vortex suction unit 10 provides a system of small height.

Referring to Figs. 10 to 12, variations of the housing 30 of the vortex suction unit 10 are shown. The housing 30 can be designed as cylindrical ring as shown in Fig. 10a and 10b. In an alternative embodiment, the housing 30 can be designed conically, especially with a larger diameter at the suctioning opening and a smaller diameter at the opposite end, especially at a backplate 30b (see Figs. 11a and 11b). Fig. 12 discloses a graph comparing the intake flow pressure of the vortex suction units of Fig. 10a and Fig. 11a, demonstrating that a vortex suction unit 10 with a cylindrical housing 30 has a more focussed intake flow pressure K10 with a higher absolute intake flow pressure K10 at the middle of the suctioning opening whereas the vortex suction unit 10 with a conical housing 30 has a broader intake flow pressure K11 with a higher absolute intake flow pressure K11 in the outer regions of the suctioning opening.

Referring to Figs. 13 to 15, further variations of the housing 30 of the vortex suction unit 10 are shown. The angle of aperture α of a conical housing 30 can be varied. Especially, the transition between the outer ring of the housing 30 and a backplate 30b might be curved. Fig. 15 discloses a graph comparing the intake flow pressure of the vortex suction units of Fig. 13 and Fig. 14, demonstrating that a vortex suction unit 10 with a conical housing 30 with an angle of aperture close

to 90° has a more focussed intake flow pressure K13 with a higher absolute intake flow pressure K13 at the middle of the suctioning opening whereas the vortex suction unit 10 with a conical housing 30 with a smaller angle of aperture has a
5 broader intake flow pressure K14 with a higher absolute intake flow pressure K14 in the outer regions of the suctioning opening. The vortex suction units 10 according to Figs. 13 and 14 show as well variations of the blades 14. In these embodiments, the blades 14 comprise an outer edge which is curved,
10 especially corresponding the curvature of the housing 30.

Referring to Figs. 16 to 19, further variations of the housing 30 of the vortex suction unit 10 are shown, the vortex suction units 10 particularly having only a lower vortex generator 16.
15 The housing 30 of the vortex suction unit 10 of Fig. 16 is conical without a backplate, having a larger diameter at the suctioning opening and a smaller diameter at the opposite end facing the motor 20. This configuration results in a less focused intake flow pressure at high level over a broad region
20 of the suctioning opening (see graph K16 of Fig. 19). The housing 30 of the vortex suction unit 10 of Fig. 17 is conical without a backplate, having a smaller diameter at the suctioning opening and a larger diameter at the opposite end facing the motor 20. This configuration results in a focused intake
25 flow pressure at low level concentrated in the middle of the suctioning opening (see graph K7 of Fig. 19). On the other hand, because there is no backplate of the housing 30, this configuration results in a very high air flow for cooling the motor 20 (see Fig. 17). The housing 30 of the vortex suction
30 unit 10 of Fig. 18 is conical with a backplate, having a smaller diameter at the suctioning opening and a larger diameter at the opposite end facing the motor 20. This configuration results in a better intake flow pressure at the middle of

the suctioning opening compared to the embodiment of Fig. 17 (see graph K18 of Fig. 19).

Referring to Figs. 20 to 22, a further embodiment of a vortex
5 suction unit 10 is shown, the vortex suction unit 10 having a housing 30 with a backplate 30b, whereas the backplate 30b has a recessed part to receive the motor 20. The housing 30 is movable relative to the blades 14 of the impeller wheel by means of a spindle drive with shaft joint 31 driven by a fur-
10 ther motor 33 which might be a stepper motor. Fig. 20 shows the vortex suction 10 unit with the housing 30 surrounding the blades 14, Fig. 21 shows the vortex suction unit 10 with the housing being moved upwards so that the housing is axially above the blades 14. By moving the housing 30, the direction
15 and the absolute intensity of the intake flow pressure of the vortex suction unit 10 can be varied as shown in Fig. 22. The position of the housing 30 of Fig. 20 results in an intake flow pressure according to graph K20 of Fig. 22, the position of the housing 30 of Fig. 21 results in an intake flow pres-
20 sure according to graph K21 of Fig. 22.

Referring to Figs. 23 and 24, an alternative embodiment for varying the intensity of the intake flow pressure of a vortex suction unit 10 is shown. The vortex suction unit 10 comprises
25 an iris 34 arranged in front of the suctioning opening So of the vortex suction unit 10. The iris 34 can be opened and closed by means of a lever 34a, the lever being operated either manually or motor-driven. Fig. 24a is a top view of the vortex suction unit 10, the iris 34 being closed, in Fig. 24b
30 the iris 34 is partly opened and in Fig. 24c the iris 34 is opened. Fig. 25 shows graphs of the intake flow pressure corresponding to the different positions of the iris according to Figs. 24a, 24b and 24c. In a further embodiment (not shown),

the intensity of the intake flow pressure can be varied by means of a sliding element which can be moved to cover the suctioning opening partly or completely or not at all.

Referring to Figs. 26a, 26b 27a and 27b, further embodiments
5 of providing a suctioning force on basis of a whirlwind are shown. The vortex suction unit comprises a second cylindrical housing 35 in which air can be injected tangentially through at least one, particularly several openings 35a in the wall of the second cylindrical housing 35. The cylindrical housing 35
10 is closed by a backplate 35c at one end. The air can be injected using an air supplying device, particularly using compressed air. In an embodiment (see Fig. 27a), the injected air is generated by a vortex suction unit 10 on basis of an impeller with blades 14 driven by a motor 20. The axis of rotation
15 of the impeller is arranged parallel to the axis of the second cylindrical housing 35. The impeller is arranged within an impeller housing or first cylindrical housing 30. The second cylindrical housing 35 and the first cylindrical housing 30 are connected by a connecting channel 35d, the connecting channel
20 35d being arranged tangentially on the second cylindrical housing 35 and the first cylindrical housing 30. By rotating the impeller, a tangential air flow is generated which leaves the first cylindrical housing 30 tangentially in the connecting channel 35d and therefore enters the second cylindrical
25 housing 35 tangentially through the opening 35b at the end of the connecting channel 35d. Therefore, a second whirlwind is generated in the second cylindrical housing 35. As shown in Fig. 28, the absolute intake flow pressure of the second cylindrical housing 35 is smaller than the intake flow pressure
30 of the vortex suction unit in the first cylindrical housing 30. With this embodiment, two parallel vortex suction units can be provided using only a single motor 20. The second cy-

lindrical housing 35 has the benefit that no impeller wheel is needed that might damage suctioned objects.

The vortex suction units 10, particularly as described before,
5 show different embodiments of first means for generating a low pressure induced by a whirlwind for sucking in an object and can be combined with second means for conveying the suctioned object along a transfer path TP transverse to the axis of rotation of the whirlwind, particularly as described below, to
10 provide different embodiments of suctioning and conveying systems according to the present invention.

Referring to Figs. 29, 42, 43 and 59, vortex suction units 10 are disposed adjacent a transfer path TP, the direction of
15 which is indicated by arrows. An object 50 is moved by a conveyor 80 along the transfer path TP by belts 40 and/or traction rollers 46. The transfer path TP corresponds to the predetermined conveyance positions of the object 50 as it moves along the conveyor 80. The vortex suction units 10 are arranged in sequence along the transfer path TP and may also be
20 disposed into arrays 70 which may be, for example, vertical arrays 70a, 70b arranged side by side or sequentially arranged horizontal arrays 70c, 70d (see Fig. 42). It is also possible to provide the vortex suction units 10 in an offset arrangement (see Fig. 59) in order to reduce the total number of vortex suction units 10 necessary for a particular conveyor 80.
25 The vortex suction units 10 may be arranged side by side, and may be arranged with a predetermined spacing which is less than the length of a respective edge of the object 50 such
30 that it is adhered to the belts 40 at all points during conveyance.

The housings 30 of the vortex suction units 10 may be square or other shapes and surround the outside edges of the blades 14. A cover 32, which may be a screen, a grid, concentric circles, an air permeable material, a plate with openings or ribs, may be provided on the vortex suction units 10. In an embodiment shown in Fig. 31, the cover 32 includes ribs extending in the direction of the transfer path TP such that an object 50 which is flexible, such as paper, is provided a slight corrugation in the direction of the transfer path TP.

10 The housing 30 may also include idler balls or rollers which contact the object 50 during conveyance to decrease friction.

The cover 32 may be provided to minimize risk of injury, keep objects from interfering with the blades, to maintain a spacing to the object 50 and/or to aid in guiding and supporting the object 50 as it moves along the transfer path TP. In an embodiment, the cover 32 is disposed at a distance from the object 50 such that a flexible object 50 being carried by belts 40 is given a concave or corrugation shape by vortex suction units 10 positioned between pairs of belts 40, thereby imparting a degree of rigidity. Further, covers 32 may extend between vortex suction units 10 so as to provide a smooth, supported transition as the object moves from one vortex suction unit 10 to the next.

25 The belts 40 may be formed from a material having a significant coefficient of friction and may be toothed, such as in a synchronous type conveyor, textured or profiled. For example, spikes, grooves or ribs may be provided on the surface of the belts 40. Typical elastic or elastomeric belts 40 are sufficient to convert the normal force into a transport force. The surface of belts 40 may be roughened to increase friction in their entirety or only at certain areas to create a surface

having regions with different coefficients of friction. Further, the belts 40 may be at least partially air permeable. For example, the belts 40 may be perforated or formed from a nano-material. The belts 40 may be driven by a belt drive 44,
5 which may be adjustable to control the conveyance speed.

The conveyor 80 may include support rails 48 which support and assist in maintaining the position of the object 50 in the transfer path TP. In an embodiment, the vortex suction units
10 10 are arranged on the opposite side of the belts 40 from the object 50 and are positioned between adjacent pairs of belts 40. However, one air permeable belt 40 may be provided over in lieu of the covers 32. The belts 40 may also contain a plurality of perforations 42 through which the attraction force A
15 adheres the objects 50 to the belts 40 (see Fig. 34c), in which case the conveyor 80 includes just one belt 40 or multiple parallel belts 40.

Other types of conveyors 80 are also possible, such as ones
20 using sequentially arranged driven rollers with a spacing therebetween, in which case the vortex suction units 10 are arranged below the spacings and provide the attraction force A to the object 50 therethrough. Likewise, conveyors 80 include other systems of conveyance, such as supports, for example,
25 support rods or rollers, arranged such that the object is conveyed by gravity or an applied force.

The conveyors 80, may be horizontal conveyors 82, vertical conveyors 84, and may also be inclined, curved, rectangular,
30 circular, or the like. For example, as shown in Fig. 43, an object 50 enters the transfer path TP on top of a first horizontal conveyor 82a, traveling to a vertical conveyor 84 and up to the bottom of a second horizontal conveyor 82b, wherein

the attraction force A of the vortex suction units 10 is sufficient to hold the object 50 against the belts 40 even in the presence of a gravitational force downward. In this conveyance system 100, the object 50 is both flipped and translated upwards by the design of the transfer path TP. Especially when the object 50 is relatively flat and flexible, such as paper, deflectors 88 may be provided between conveyors 80 that are separated and/or at angles relative to one another, such as horizontal and vertical conveyor 82, 84, to direct the object 50 onto the respective belts 40 or other conveyance surface. Further, a main controller 60 may be provided to control belt drives 44 and vary the conveyance speed of the conveyors 82a, 82b, 84 and/or to control the attraction force provided by the vortex suction units 10 either individually (separately) or in groups. For example, since the second horizontal conveyor 82b must adhere the object 50 against gravity, the vortex suction units 10 therein can be driven at a higher speed than those of the first horizontal conveyor 82a. Similarly, the attraction force A may be increased when a heavier object 50 enters the transfer path.

Referring to Figs. 30 to 32, 39 and 54, each vortex suction unit 10 may be provided with its own means of conveyance, such as, for example, its own pair of belts 40 having perforations 42 that are driven by traction rollers 46 connected to a belt drive 44. A cover 32 having ribs is provided on the housing 30 over the upper vortex generator 12 parallel to the belts 40 to provide a slight corrugation to flexible objects 50 in conveyance direction and to minimize friction as the object 50 moves across the cover 32. In an embodiment, the housing 30 surrounds the upper and lower vortex generators 12, 16, or at least the upper vortex generator 12. Additionally, each vortex suction unit 10 may also be provided with its own modular con-

troller 62 which is functionally coupled with the motor 20 and/or the belt drive 44 to control the speed of the vortex suction unit 10 and belts 40 by varying power levels provided thereto. Further, each individual modular controller 62 may
5 also be functionally coupled to a main controller 60 which, for example, is able to provide various signals to first and second vortex suction units 10a and 10b so as to move their respective motors 20 or belts 40 at different speeds depending on, for example, the desired attraction force, conveyance
10 speed, positioning of the object 50 and predetermined transfer path TP.

The dimensions of a suctioning and conveying system with a vortex suction unit 10 and belts 40 for lifting a standard paper of A4 format or 11" format with a grammage of up to 80g/m²
15 from a distance of up to 60 mm against gravitation force are less than 100mm x 80 mm x 40 mm. The attraction force, which is the force needed to remove an object from the suctioning and conveying system against the attraction force, is about
20 1,6 N. An even smaller system which is able to lift a standard paper from a distance of up to 30 mm has dimensions of 80 mm x 60 mm x 25 mm. The attraction force is about 0,7 N.

Each suctioning and conveying system might be provided with
25 two belts 40 that might be controlled independently (see Figs. 33a and 33b). Each belt 40 might be provided with one motor 20a, 20b. In an embodiment, both motors 20a, 20b are arranged side to side on one side of the impeller between the belts 40, for example if the distance between the belts 40 is large
30 enough (see Fig. 33a). In an alternative embodiment, the motors 20a, 20b are arranged on different sides of the impeller between the belts 40, for example if the distance between the belts 40 is smaller (see Fig. 33b). If the belts are con-

trolled independently, it is possible to rotate an object, in particularly on the spot, if both belts 40 are driven in opposite directions at same speed and center of area of the object is located over the center of the impeller.

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Referring to Figs. 34a to 34d, different arrangements of conveyors relative to the vortex suction device or the impeller are described. In the embodiment shown in Fig. 34a, the belts 40 are located next to the impeller wheel with blades 14, not covering the suctioning opening defined by the outer dimensions of the impeller wheel or the housing 30 of the impeller wheel. The suctioned object 50 is drawn against the blades 14 of the impeller due to the intake flow or intake flow pressure.

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In the embodiment shown in Fig. 34b, the belts 40 partially cover the suctioning opening. Surprisingly, this arrangement has nearly no impact on the intake flow pressure. In this embodiment, the object 50 is prevented from contacting the blades 14 of the impeller. But the object still might be deformed due to the intake flow pressure. The deformation might increase the stability of the object 50 while moving. If this deformation should be avoided, the belts might be provided with perforations 42, resulting in an attraction force through the belts 40 and a resting of the object 50 on the belts 40 (see Fig. 34c). If a convex deformation of the object 50 between the belts 40 should be provided, a O-ring 41 can be arranged between the belts 40 to provide a higher stability of flat, flexible objects 50 while moving (see Fig. 34d).

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Figs. 35a and 35b shows a suctioning and conveying system with a vortex suction unit 10 and two parallel belts 40, the belts being arranged partly over the suctioning opening 50. The

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summed width of the belts 40 amount to about 40% to 60% of the width of the suctioning opening SO. The height of the belts 40 amount to about 2% of the width of the suctioning opening SO. The belts 40 are arranged in front of the suctioning opening
5 SO so that the distance d of the outer edges of the belts 40 is smaller than the width w of the suctioning opening SO, preferably by about 10%. For example, the width of each of the belts 40 might be about 14 mm. The width w of the suctioning opening SO might be about 52 mm. The distance d of the outer
10 edges of the belts 40 might be about 46 mm. The distance of the inner edges of the belts 40 might be about 18 mm. The height of the belts 40 might be around 1 mm.

Figs. 36a and 36b shows a suctioning and conveying system with
15 a vortex suction unit 10 and two parallel belts 40, the belts being arranged partly over the suctioning opening SO. Between the two belts 40, an O-ring 41 is provided, analog the embodiment of Fig. 34d. For example, the width of the belts 40 is about 15 mm. The distance of the inner edges of the belts is
20 about 30 to 40 mm. The O-ring has a diameter of about 2 mm. Instead of the O-ring, a small belt with a width of about 2 mm can be used.

Figs. 37a and 37b shows a suctioning and conveying system with
25 a vortex suction unit 10 and one belt 40, the belt 40 being arranged partly over the suctioning opening SO. The distance d of the outer edges of the belt 40 can be about 21 to 31 mm if the diameter w of the suctioning opening is about 52 mm.

30 Figs. 38a and 38b shows a suctioning and conveying system with a vortex suction unit 10 and one belt 40, the belt 40 being arranged partly over the suctioning opening SO. The belts 40 are preferably air permeable to support the objects over the

complete width of the belt 40. For example, a perforated elastomeric belt with perforations 42 might be used or a textile belt. If the covered area of the suctioning opening is less than 60%, still a reasonable intake flow pressure can be
5 achieved.

Each vortex suction unit 10 may also be provided with its own means for rotation (see Fig. 39), such as a rotation motor 52 connected to a crown gear 54 disposed on a rear surface of the
10 vortex suction unit 10. The rotation motor 52 is attached to a support 56 which is fixed at one end and at the other end is rotatably connected to the vortex suction unit 10 at the axis of rotation of the motor 20. The main controller 60, directly through control lines 64 or through a modular controller 62,
15 provides power to the rotation motor 52 in order to rotate the crown gear 54 and position a vortex suction unit 10 at a particular alignment angle α (see Fig. 54). Further, the angular rotation of individual vortex suction units 10, which may be provided for both vertically and horizontally, can provide for
20 numerous different, complex transfer paths TP in three-dimensions, and also allows for quick adjustments in transfer paths TP and for changes in alignment of objects 50 therein. For example, such rotatable vortex suction units 10 could be rotated before and or while holding an object 50 to distribute
25 it to various conveyors 80 or belts 40 of other vortex suction units 10 disposed horizontally at angles to its own belts 40 and/or positioned vertically above or below.

Additionally, vortex suction units 10 provided with individual
30 belts and/or rotation means may be used to align an object 50, for example, to an alignment edge 58 of a conveyor 80 (see Fig. 54). The vortex suction units 10 are rotated to or disposed at an alignment angle α directed toward the alignment

edge 58 to translate an object 50 from its position at an input traction rollers 46a and align it to the alignment edge 58 before exiting through the output traction rollers 46b. Alternatively or additionally, one row of vortex suction units 10 could be part of a first array 70a and a parallel row of vortex suction units 10 could be part of a second array 70b. In such a case, the controller 60 would be able to rotate the vortex suction units 10 of the first array 70a to the alignment angle α and/or drive their belts 40 at higher speeds than those of the vortex suction units 10 of the second array 70b to align the objects 50.

Referring to Figs. 40a to 40c, a vortex suction device 10 with a transport ball 210 as conveying means is shown. The transport ball 210 is connected to an axis 212 which is rotatably fixed in a cylindrical housing 214. The cylindrical housing 214 is rotatably mounted by means of a crown gear 216 in a housing 218 horizontally to a suctioning area 220. The cylindrical housing 214 can be rotated by means of a motor 222, which can be designed as a stepper motor or as a DC motor and which preferably includes an encoder for rotating the transport ball 210 by 360° or by $\pm 180^\circ$. The transport ball 210 is driven by a motor 224, which can be designed as a stepper motor or as a DC motor. The suctioning force which attracts the object 50 to a contact area 226 of the transport ball 210 is generated by an impeller with blades 14 which is driven by the motor 20, the impeller having an axis 228 of rotation. The motor 20 is connected to the housing 218. In an embodiment, further transport balls 230 are provided which are arranged free-wheeling.

Referring to Fig. 41a to o, different possibilities of varying the position and/or orientation of an object, preferably a

flat, flexible object, in particular a sheet of paper, are described. Fig. 41a is a schematic view of translating of an object. Fig. 41b is a schematic view of bending of an object.

Fig. 41c is a schematic view of lifting the rim of an object.

5 Fig. 41d is a schematic view of lifting an edge of an object.

Fig. 41e is a schematic view of planing a corrugated object.

Fig. 41f is a schematic view of turning an object around a cross axis. Fig. 41g is a schematic view of turning an object around a longitudinal axis. Fig. 41h is a schematic view of

10 rotating an object around an axis perpendicular to a flat object. Fig. 41i is a schematic view of conveying and sorting objects. Fig. 41j is a schematic view of sorting objects in a vertical direction. Fig. 41k is a schematic view of transferring an object from a horizontal position in a vertical position.

15 Fig. 41l is a schematic view of separating double-picked objects. Fig. 41m is a schematic view of aligning an object relative to a stop bar. Fig. 41n is a schematic view of aligning an object relative to two CCD bars. Fig. 41o is a schematic view of fixing a flat object on a cylinder. Systems for

20 providing the possibility of varying the position and/or the orientation of the object schematically shown in Fig. 41a to o are described with respect to different figures.

25 Fig. 42 is a schematic view of a conveyor using vortex suction units 10 for providing a translational movement of the object 50 as already described above.

Fig. 43 is a schematic view of a system of conveying an object 30 50 for turning the object 50 with a vertical displacement as already described above.

Fig. 44 is a schematic view of a system of planing a corrugated object 50. Such a system can be used for example in connection with scanning devices, cameras or ink-jet printers, where it is necessary to provide a flat sheet of paper without deformations. The object 50 is moved over a suctioning and conveying system with a vortex suction device 10 and at least one belt 40. The conveyance speed and direction is controlled using a controller 60. The flattened object 50 is moved to a scanning device, a printing head, or any kind of read- or write system 56.

Referring to Figs. 45 and 46, a system of turning an object around a cross axis AD is described. A vortex suction unit 10 with at least one conveyor belt 40 is arranged on a wheel 25 which is pivotably mounted around an axis AD. The rotation of the wheel can be driven by a motor 24. The object 50 can be moved in direction of a transfer path TP by means of the belts 40. The object can be located on the suctioning and conveying system by means of the vortex suction device 10. The wheel including the suctioning and conveying system can be rotated around the axis AD while fixing the object 50, therefore flipping the object 50 upside down. The side 50A of the object that was facing upwards before reaching the suctioning and conveying system (see Fig. 45a and 46a) is facing downwards after rotating the wheel by 180° (see Fig. 45c and 46b).

Fig. 47 provides a schematic view of a system of conveying and sorting objects 50. Flat, flexible objects 50 deriving from different sources 311, 312, 313, 314 are transferred along different transfer paths TP1, TP2, TP3, TP4 to a sorting device 330 by means of several suctioning and conveying systems arranged along the transfer paths TP1, TP2, TP3, TP4. The objects 50 include an optic or magnetic code that can be read by

readers 331, 332, 333, 334 arranged for example above the transfer paths TP1, TP2, TP3, TP4. The sorting device comprises a further suctioning and conveying system with a vortex suction unit 10 and conveyor belts 40 which is preferably rotatable analog to the embodiment of Fig. 39. Depending on the code on the object 50, the object 50 is rotated in the desired direction, the point of time for the rotation can be calculated by the controller 60 taking into account the position of the code on the object 50, the conveyance speed of the suctioning and conveying systems, the rotation angle can be calculated by the controller 60 taking into account the position of the sources 311, 312, 313, 314 and the position to which the object 50 should be transferred. The objects 50 can be transferred to deposit units 341, 342 or further transferred in opposite direction along the transfer paths TP1, TP2, TP3, TP4. The controller 60 controls motors of the vortex suction units 10 and motors of the conveying systems of the vortex suction units 10.

Fig. 48 is a schematic view of a system of sorting objects 50 in a vertical direction. In direction of a transfer path TP a single suctioning and conveying system is followed by two suctioning and conveying systems facing each other. The vortex suction units 10 of the two suctioning and conveying systems facing each other are provided with means for controlling the intake flow and the intake flow pressure, for example using an iris 34 in accordance with embodiments of Fig. 23 and 24. Depending on which of the suctioning and conveying systems facing each other provides the suction force, the object 50 moved along the upper transfer path TPU or the lower transfer path TPL. The distance between the two suctioning and conveying systems facing each other can be up to 50 mm provided that the

objects 50 are of format A4 or format 11" and feature a gram-
mage of up to 80g/m².

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Fig. 49 is a schematic view of a system of transferring ob-
5 jects from two different horizontal positions in a vertical
position or vice versa using several vortex suction units 10
arranged in arrays 70a, 70b, 70c. The arrays 70a, 70b are ar-
ranged horizontally facing upwards and having a displacement.
The array 70c is arranged vertically. Objects 50 moving along
10 the arrays 70a, 70b meet the array 70c, will be turned around
about 90° and further move along array 70c.

Referring to Figs. 50 and 51, examples of conveyance systems
100 using vortex suction units 10 to handle double-picks, or
15 multiple overlapping objects 50 in the transfer path TP, are
shown. First and second arrays 70a, 70b are arranged in paral-
lel and facing one another. Referring to FIG. 50, as overlap-
ping first and second objects 50a, 50b travel upwards along
the transfer path TP on the vertical conveyor 84, the second
20 object 50b will start to peel away from the first object 50a.
An air knife 90 may provide a tangential air stream to facili-
tate the separation of the first and second objects 50a, 50b.
The vortex suction units 10 of the first and second arrays
70a, 70b may be provided an increasing or decreasing attrac-
25 tion force A in the direction of the transfer path P. For ex-
ample, the vortex suction units 10 at the lower end of the
first array 70a may have a smaller attraction force A to en-
sure that an overlapping second object 50b will start to sepa-
rate from the first object 50a. Additionally, as the second
30 object 50b nears the vortex suction units 10 of the second ar-
ray 70b, the air flow will become hindered, causing current to
decrease and rpm to increase, at which point additional power
may be provided to one or more of the vortex suction units of

the second array. The conveyance system 100 of Fig. 51 is similar to that of Fig. 50, except that gravitational force aids in the separation of the second object 50b and that a stacking container 94 and a double-pick container 92 are provided for sorting first and second objects 50a, 50b, respectively. Further, the vortex suction units 10 above the stacking container may be sequentially slowed and/or disengaged so as to provide a gradual release of the object 50.

Referring to Fig. 52, a conveyor 80 includes vortex suction units 10 which adhere to the objects 50 and move them along the transfer path TP. The vortex suction units 10 are mechanically and/or electrically connected to a guide 38 which travels in the direction of the transfer path TP. The guide 38 may be belts 40 or other conveyance means for moving the vortex suction units 10 in the direction of the transfer path TP. For example, a belt drive 44 can be used to drive one or more traction rollers 46 moving one or more belts 40 to which the vortex suction units 10 are attached. Additionally, the traction rollers 46 and the inside surfaces of the belts 40 may each be formed from a conductive material and electrically connected to the vortex suction units 10 to route power thereto from a controller 60 or power source. The controller 60 may also be used to drive the belt drive 44 at various speeds and/or to adjust the power level at individual vortex suction units 10. While the conveyor 80 shown in Fig. 52 is an elevator conveyor which flips an object 50 from input I to output O, movable vortex suction units 10 traveling with or along a guide 38 in the direction of the transfer path TP may be provided in any type of conveyance system 100 alone or in combination with stationary vortex suction units 10.

Referring to Fig. 53, a conveyance system 100 which is also effective for flipping an object 50 provides the object 50 through a deflector 88 and input/output roller 46a/46b to a horizontal conveyor 82 having vortex suction units 10. The object is then directed to an inclined conveyor 83 after being flipped by a deflector 88 having a radius of curvature r . The inclined conveyor 83 then carries the flipped object out through input/output roller 46a/46b. A controller 60 may be provided to control the respective belt speeds of conveyors 82, 83 and the speed of each of their respective vortex suction units 10.

Fig. 54 is a schematic view of a system of aligning objects 50 relative to an alignment edge 58 or relative to a CCD bar as already described above.

Fig. 55 is a schematic view of a system of aligning objects 50 relative to two CCD bars 58a, 58b. Vortex suction units 10 provided with individual belts 40 and/or rotation means, for example analog the embodiment of Fig. 39, may be used to align the object 50 to two CCD bars 58a, 58b being arranged parallel to each other, the vortex suction units 10 arranged between the two CCD bars 58a, 58b. The distance B between the CCD bars 58a, 58b is smaller than the width of the objects 50 by about 10-20%. After passing the system of aligning objects 50, the objects 50 should be arranged with its longitudinal edges parallel to the CCD bars 58a, 58b, preferably symmetrical to a symmetrical axis between the CCD bars 58a, 58b. The movement of the object 50 is controlled by the controller 60 which detects the coverage of the elements of the CCD bars 58a, 58b and controls the angle of the vortex suction units 10 and the conveyance speed and/or direction of the belts 40 so that the desired alignment of the object after passing the system is

achieved. One suctioning and conveying system comprising a vortex suction unit 10 and conveyor belts 40 might be sufficient to achieve the desired alignment of the object 50. Use of several suctioning and conveying systems provide usually a better result of alignment. If the desired result is not achieved, the object 50 can be moved backwards along the system and be aligned once more.

The controller has to be able to handle data of both CCD bars 58a, 58b and to control several, for example three, motors for each of the several, for example three, suctioning and conveying systems, namely a motor for rotating the suctioning and conveying system and two motors for the two belts 40 of each suctioning and conveying system. It might as well be necessary to further control the intake flow and intake flow pressure. While the object 50 is passing from one suctioning and conveying system to the next, the controller 60 has to control up to 6 motors independently and simultaneously and further to detect and process the positions of the objects 50 on the CCD bars 58a, 58b.

Fig. 56 is a schematic view of a system of aligning objects relative to one CCD bar in accordance with an alternative embodiment of the present invention. For aligning the objects 50, two independently controlled conveyor belts 40 are used. The belts 40 are driven by two motors 20a, 20b and might be controlled in conveyance speed and direction independently. The objects are hold to the belts 40 by several vortex suction units arranged between the CCD bar 58a and a mechanical limiter bar 58c under the belts 40, the vortex suction units being operated simultaneously.

Figs. 57 and 58 are schematic representations of different control schemes which may be provided to individual vortex suction units 10 of a conveyance system 100 through a main controller 60. The controller 60 may control individual vortex suction units 10 separately or in groups. When an object 50 is positioned in the low pressure region LP of a vortex suction unit 10, the air flow is hindered causing the current (i) to decrease and the speed (rpm) to increase compared to idle conditions. Thus, the current level and/or speed may be used as an indicator that a substrate is present adjacent a vortex suction unit 10, in other words, that a low pressure condition exists. Since the vortex suction unit 10-A is not covered by an object 50 as indicated to the controller 60 by a relatively high current and low speed, it may be switched off. Vortex suction units 10-B and 10-C are actively maintained in operation by the controller 60 since the object 50 is hindering air flow and causing the controller 60 to recognize a relatively low current and high speed. Further, the controller 60 recognizes that the subsequently arranged vortex suction unit 10-D will need to be switched on as it is next in the sequence. Once the object 50 is covering the vortex suction unit 10-D, vortex suction unit 10-B can be switched off and so on. The timing of such provident triggering of sequentially arranged vortex suction units 10-A through E by the controller 60 may be determined in accordance with a predetermined conveyance speed, the speed at which the controller 60 drives belts 40 and/or by relative changes in current or speed as the object 50 moves past individual vortex suction units 10. Because vortex suction units 10 are relatively small and lightweight, they may be shut off and activated relatively quickly. Thus, a consistent adherence may be applied efficiently since only vortex suction units 10 carrying an object 50 are active.

Alternatively or additionally, the controller 60 may provide different power levels to the motors 20 of the sequentially arranged vortex suction units 10-A through E so as to drive them at different speeds and thereby provide various magnitudes of an attraction force A. For example, the controller 60 could provide decreasing speeds to the sequentially arranged vortex suction units 10-A through E carrying an object 50 along a transfer path TP against the force of gravity. Heavier objects 50 will fall away sooner than lighter objects 50 because of the decreasing attraction force A. Thus, a sorting function may be obtained using deflectors 88 or sorting bins arranged in sequence to capture different objects 50a, 50b, 50c of various type, weight and/or size.

Fig. 60a and 60b are schematic views of a system of fixing a flat object 50 on a cylinder 400 as used for example in ink jets or laser printers. A feeder 410 provides single objects 50 tangentially to the cylinder 400. The cylinder 400 comprises several vortex suction units 10, the cylinder 400 acting as conveyance means. The object 50 provided by the feeder 410 is suctioned by a vortex suction unit 10a. By rotating the cylinder 400, the object 50 is fixed on the cylinder 400 by the vortex suction 10a and rotated as well, further fixed by the next vortex suction unit 10b. The higher the number of vortex suction units 10 in the cylinder 400, the more precise the fixation of the object 50. If one of the vortex suction units 10 can as well push the object 50, a deposition of the object 50 in a desired angle is possible.

Referring to Figs. 61-64, the controller 60 for at least first and second vortex suction units 10a, 10b may be provided externally (Figs. 61 and 63) or with one of the vortex suction units 10 (Fig. 62). The controller 60 provides power to the

vortex suction units 10 either directly or through a modular controller 62 and senses current and speed. Additionally, the controller 60 may also power the belts 40, which may be common (Fig. 63) or provided for each vortex suction unit 10 (Figs. 61 and 62), and control the direction thereof by switching the rotation of the belt drive 44.

A control system 110 includes a main controller 60, and optionally includes modular controllers 62 for individual vortex suction units 10. The main controller 60 and the modular controllers 62 may include one or more sub-controllers 66, which may be, for example microcontroller Model No. ATMEGA88P manufactured by ATMEL Corp. Further, the main controller 60 and the modular controllers 62 may include communication interfaces 67 connected through control lines 64 for data exchange. The communication interfaces 67 may be, for example, Control Area Network (CAN) controllers Model No. MCP2515 manufactured by Microchip Technology Inc. which communicate with the controllers 60, 62 through a standard Serial Peripheral Interface (SPI) and the control lines 64 may be a CAN bus system or a communication system using the RS-485 communication standard.

The main controller 60, which may be, for example, controller Model No. AT90CAN128 manufactured by ATMEL Corp., is provided to control the speed of belt drives 44, rotation motors 52 and/or the motors 20 of individual suction units 10 either directly or through modular controllers 62. The modular controllers 62 may include motor controllers 68 which may be, for example, control chip Model No. NJM 2673 manufactured by New Japan Radio Co., Ltd. for stepper motors or control chip Model No. EBL-H-50-03-05 manufactured by Portescap for brushless DC motors. In an embodiment, the belt drives 44 and the rotation motors 52 are stepper motors and the motors 20 are brushless.

DC motors. Further, sensors 65 may be provided for measuring the speed (rpm) of the belt drive 44, rotation motor 52 and/or motor 20, and for transmitting such data as an encoded signal to the main controller 60 either directly or through the modular controllers 62. Other configurations of the control system 110, however, are also possible. For example, where the modular controllers 62 are not provided the motor controllers 68 may be provided with the main controller 60 or on individual suction units 10.

Referring to Fig. 65, a conveyance system 100 having first and second conveying devices 80a, 80b with first and second vortex suction units 10a, 10b, is shown. As an object 50 moves along the transfer path TP between the first and second vortex suction units 10a, 10b, the main controller 60 selectively engages a respective one of the first and second suction units 10a, 10b to adhere the object 50 thereto. In the embodiment shown, the first conveying device 80a is a mechanical-guide conveyor which moves the first vortex suction unit 10a along a first secondary path TP1 extending from Position A1 in the transfer path TP to Position A2 at a first stacking container 94a. The second conveying device 80b is likewise a mechanical-guide conveyor which moves the second vortex suction unit 10b along a second secondary path TP2 extending from Position B1 in the transfer path TP to Position B2 at a second stacking container 94b. Mechanical-guide conveyors may use rollers 112 movable along rails 114 and/or drive gears 116 meshing with teeth 118. Further, the rollers 112 or the drive gears 116 connected with the vortex suction units 10 may also be coupled with the belt drives 44 thereof, or could be directly connected to the controller 60, to control speed and direction. Likewise, the first and second conveying devices 80a, 80b may utilize belts

40 respectively attached to the first and second vortex suction units 10a, 10b as in FIG. 52, which are bidirectional.

For example, where the object 50 is printed paper, it is adhered to either the first vortex suction unit 10a or the
5 second vortex suction unit 10b depending on which side of the paper contains ink. When a first object 50a has printing on a first side, the controller 60 switches on or speeds up the first vortex suction unit 10a which then travels along the
10 first secondary path TP1 to the first stacking container 94a, into which the first object 50a is dropped once the ink has dried. Similarly, when a second object 50b is printed on the opposite side, the controller 60 switches on or speeds up the second vortex suction unit 10b which then travels along the
15 second secondary path TP2 to the second stacking container 94b, into which the second object 50b is dropped once the ink has dried.

The objects 50 may be flat, flexible objects, such as paper or
20 plastic sheets. However, other types of objects, such as boxes or containers of various shape may be carried by conveyance systems 100 using vortex suction units 10 according to the present invention.

25 Referring to Figs. 66a-c and 67a-c, a vortex suction unit 10 including at least one belt 40 is shown lifting and transferring the uppermost object 50 on the top of a stack 800 (in the embodiment shown, an aerated portion 820) along a transfer path TP and through a pair of exit rollers 460. The vortex
30 suction unit 10 is positioned over the leading edge 780 of the stack 800 at a distance b such that the attraction force A over the low pressure area LP is sufficient to lift the uppermost object 50. The distance b from which the uppermost object

50 is positioned from the vortex suction unit 10 depends on the size of the diameter D of the circular area, or orifice, and the speed of the vortex suction unit 10, as well as the mass, size and material of the object 50. For example, with a diameter D of about 50 mm and a speed of 18,000 rpm, a vortex suction unit 10 can lift an object 50 of about 70 grams from a distance b of 6 to 8 mm, when a surface of the object offers at least a flat area having a size similar to the circular area of the impeller. Lifting can occur, however, even at a distance a of up to about 60 mm from an object 50 that is a 11" sheet material, such as paper, with a specific weight of up to about 75 g/m² using the vortex suction unit 10. Additionally or alternatively, a vortex suction unit 10 may be disposed at the trailing edge 790 of the stack 80.

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Due to the high suction force, the suction module also is able to separate substrates in bottom feeding mode where the outmost sheet is the lowermost sheet of the stack. Separation of sheets of stacks of flat substrates is possible with the substrate stack positioned in virtually all angles with respect to the horizontal. In a preferred bottom feed mode wherein a reload of the substrate stack is possible while separating sheets, the substrate stack and the suction unit's belt surface is positioned in a 60° angle to the horizontal which advantageously reduces the gravity related pressure between the sheets which facilitates the separation of the outmost sheet accordingly. An angle of the contact surface and/or an angle of the impeller axis relative to the stack may be varied. In some embodiments, the angle of the contact surface and the angle of the impeller axis may be varied independently of each other.

The adhesion force A in the low pressure region LP that must be provided in order to lift the uppermost object 50 depends upon the type of objects 50 in the stack 800. For example, when handling heavy, glossy media, adjacent sheets have a greater tendency to adhere to one another due to higher mass, a smooth surface, a static adhesion force and/or a higher coefficient of friction of the glossy media. Different types of objects 50 also accumulate static charges which can cause adjacent objects to attract and adhere to one another, especially in central regions. In order to ensure a smooth separation of only the uppermost object 50, it has been found that positioning the vortex suction unit 10 over a leading edge 780 and/or a trailing edge 790 of the stack 800 achieves a gradual separation wherein the uppermost object 50 is first more easily adhered by lifting at an edge and gradually separated while conveying along a transfer path TP.

In some embodiments, the vortex suction unit may be operated so as to be at times turned off or operated at times in a partial blowing mode.

Referring to Figs. 68a, 68b and 69, a stack assembly 1000 according to an embodiment of the present invention includes a frame 1020 and possibly adjustable side blowers 900 mounted within first and second side sections 1030, 1040 thereof. The side blowers 900 may be provided on one or several or even all sides of the stack 800. Further, the speed and height of side blowers 900 can be asynchronously controlled. For example, operating side blowers 900 at the leading edge 780 at an increased height and speed relative to side blowers 900 at the trailing edge 790 can result in increased separation in the aerated portion 820, especially at the leading edge 780. In the embodiment shown in Fig. 69, side blowers 900 are provided

at each side between the leading and trailing edges 780, 790, as well as at the trailing edge 790. The height of the stack 800 can be measured and/or controlled using one or more stack height sensors 860, which may be, for example, optical fork
5 sensors. A lift table 840 disposed beneath the stack 800 can be used to lift the stack 800 upwards, for example, such that the uppermost object 50 is always disposed at a predetermined height relative to a vortex suction unit 10 mounted above the stack 800. The stack height sensors 860 can be regulated by
10 one or more sensor controller 880 and the height of the side blowers 900 may be adjusted by the sensor controller 880 and/or by one or more lift controllers 640 so that the adjustable side blowers 900 are positioned adjacent the uppermost objects 50 of the stack 800 and provides an aerated portion
15 820 at the top portion thereof. In other embodiments, other types of aerating devices may be used in place of side blowers 900.

In the embodiment shown in Fig. 68b, each side blower 900 includes a radial impeller 920 and a radial impeller motor 1200
20 to aerate the top portion of the stack 800. Alternatively or additionally, one or several air knives directing compressed air between the objects 50 in the aerated portion 820 can be used. The height of the side blowers 900 in the first and
25 second side sections 1030, 1040 is adjustable relative to side apertures 960 in the frame 1020 of the stack assembly 1000 using a height adjustment device 980. One such height adjustment device 980 includes a lift motor 1220 which moves a respective side blower 900 up and down along a vertical spindle 1260. The
30 side apertures 960 are disposed adjacent a predetermined portion of the top of the stack 800 such that air provided radially from the side blowers 900 extends between the objects 50 and separates them from one another in an aerated portion

820. Accordingly, the frictional and static adhesion forces between adjacently stacked objects 50 can be substantially eliminated in the aerated portion 820 as an uppermost object 50 will float above the stack 800, thereby allowing a vortex suction unit 10 to adhere the uppermost object 50 from a distance without disturbing the rest of the stack 800 or unintentionally adhering more than one object, i.e. a double-pick. Alternatively, however, other means may be employed to reduce or break adhesion and/or electrostatic forces between the objects. For example, electromagnetic, electromechanical or motor-driven vibrating devices, able to slightly vary the position of the individual substrates relative to each other, thereby reducing friction and static forces, may be used.

Referring to Fig. 69, a plurality of vortex suction units 10 are disposed over the stack 800 and distributed evenly along the leading edge 780, for example, along mounting bar 1060, so that first, second, third and fourth objects 50a-d of various sizes can be lifted from the stack 800 by separately controlling each of the vortex suction units 10. For example, when a first object 50a of a smaller size is lifted, only the center vortex suction unit 10 can be operated while when a larger fourth object 50d is lifted, all of the vortex suction units are operated.

Referring to Figs. 70a-c, a first embodiment of a mounting assembly 1300 for positioning the vortex suction unit 10 over the leading edge 780 of an aerated portion 820 of the stack 800 includes a lever 1340 pivotally connected to a mounting bar 1060 at pivot 1320. A motor or other known means can be used to rotate the lever 1340 at pivot 1320. Accordingly, the vortex suction unit 10 can be disposed at an angle α relative to the uppermost object 50 of the stack 800. It has been found

that the uppermost object 50 can be more easily separated from the stack 800 by disposing the vortex suction unit 10 at an angle relative to the surface of the uppermost object 50 rather than parallel to the surface. With this angled arrangement, a portion of the uppermost object 50, for example, the peripheral side of the leading edge 78 (see Fig. 70c), can be lifted to a different height than the portion of the uppermost object 50 that is adhered on the opposite side of the circular area of the vortex suction unit 10. A more gradual separation of the uppermost object 50 from the subsequent one in the stack 80 is achieved than when picking from a parallel arrangement where there is a larger common surface area that will receive the same adhesion force at the same time; thus, undesired double-picks can be avoided. A positive (Fig. 70c) or negative (Fig. 70a) inclination angle is possible and can be chosen based on whether the vortex suction unit 10 is placed at the leading or trailing edge 780, 790 of the stack 80. The angle α is preferably in the range of -45° to 45° . In one embodiment shown in Fig. 70c, the vortex suction unit 10 is positioned with a center-point distance b of between 0 mm and 60 mm preferably 5 and 20mm from the uppermost object 50 and at a positive angle α between 0° and 30° , preferably between 8° and 15° and more preferably 12° . Where a fixed distance b and angle α are desired, for example where the stack 800 always contains identical objects 50, the vortex suction units 10 may instead be fixedly arranged on the mounting bar 1060. In a further embodiment, the vortex suction unit can move as the uppermost object is adhered and moved along the transfer path TP. For example, the uppermost object 50 can be gradually separated by a vortex suction unit 10 disposed at a negative angle α (see Fig. 70a) and, once fully adhered to the orifice, the vortex suction unit 10 can be rotated through to parallel (see Fig. 70b) or to a positive angle α (see Fig.

70c) by the lever 1340. This angular rotation not only attains a gradual separation and decreases the likelihood of a double-pick, but also moves the uppermost object 50 laterally along the transfer path TP and toward an exit of the stack assembly 1000. In an embodiment, the at least one vortex suction unit is disposed above or below the stack at a distance of between 0 and 60 mm.

Referring to Figs. 71a and 71b, an alternative embodiment of the mounting assembly 1300 includes an extension 1330 from the mounting bar 1060. Vortex suction units 10 are pivotally connected to the extension 1330 at pivot 1320. The vortex suction units 10 may be rotated manually, but preferably a motor is attached to rotate the vortex suction unit about the pivot 1320. In order to provide a mounting assembly 1330 that has a self-adjusting angle α , the rotation of the vortex suction units 10 about the pivot 1320 can be controlled by a main controller 60 (see Fig. 74) or modular controllers. For example, the vortex suction unit 10 can rotate toward the uppermost object 50 to a first angle α_1 (until a desired angle α or a distance b for the particular object 50 is obtained) in order to gradually adhere the uppermost object 50. After the uppermost object 50 has peeled away and gradually adhered to cover the entire orifice of the vortex suction unit 10, as indicated by a significant increase in speed and decrease in current consumption of the suction motor 20, the vortex suction unit is rotated away from the stack 800 to a second angle α_2 (a desired angle α or a distance b for transferring the object 50 along the transfer path is obtained). The extension 1330 can also include a slot for moving the pivot 1330 and the vortex suction unit 10 in the vertical direction to provide for further adjustment of distance b . Further, because the desired angle α and the desired distance b will differ with the type

of objects 50, the vortex suction unit 10 can automatically adjust when the type of object 50 and its position is known.

Referring to Figs. 72a and 72b, a further embodiment of the mounting assembly 1300 includes a pair of linkages 1350 connected at one end to the mounting bar 1060 and at a second end to opposite sides of the vortex suction unit 10 in order to adjust both the angle α and the distance b. The linkages 1350 can be a scissor-type jack or other types of linkages which may or may not cross one another. Such shortening or lengthening arrangement can change the angle α and can change the distance b. Where the linkages cross, as shown in Figs. 72a and 72b, the ends of the linkages 1350 are slidably or rotatably retained in the mounting bar 1060 and/or on the vortex suction unit 10 in order to adjust both the angle α (for example, by sliding or pivoting one linkage 1350) and the distance b (for example, by sliding or rotating both linkages 1350).

As is illustratively shown in Figs. 73a-d, a mounting assembly 1300 which is adjustable to different angles α and distances b can be advantageously used to handle a wide array of objects 50. For example, the vortex suction unit 10 is first disposed at a distance b sufficient to lift the leading edge of the uppermost object 50, here an envelope 50m, and is rotated to an angle α that ensures a gradual separation (see Fig. 73a). As shown in Fig. 73b, the angle α also controls the degree of openness of the envelope 50m for a subsequent stuffing operation with a letter 50n (see Fig. 73b). Once the envelope 50m is stuffed, the vortex suction unit 10 can be moved away from the stack 800, for example, by moving the pivot 1320 up the extension 1330 (see Fig. 73c) so that the envelope 50m and letter 50n can be transferred along the transfer path TP for further processing (see Fig. 73d).

Referring to Fig. 74, a control system 1100 includes a main controller 60 for individually controlling the lift table motor 850, the height adjustment devices 980 of the side blowers 900 and one or more vortex suction units 10 either directly or through sub-controllers. The main controller 60, which can be, for example, controller Model No. AT90CAN128 manufactured by ATMEL Corp., receives feedback from the stack height sensors 860 to determine a relative location of the top of the stack 800, as well as a distance of the uppermost object 50 from the vortex suction unit 10. Based on the feedback from the stack height sensors 860, the vortex suction unit 10 is moved downward toward the stack 800 and/or the lift table 850 moves the stack upward toward the vortex suction unit 10 so that the vortex suction unit 10 is positioned at a predetermined distance b from the uppermost object 50 (see Fig. 67b). Alternatively, the vortex suction unit 10 could include a proximity sensor. The height of the side blowers 900 can also be adjusted from its position based on the feedback from the stack height sensors 860 and/or further height sensors can be provided to determine the height of the side blowers 900 individually.

The vortex suction units 10 can be continuously operated such that when the trailing edge 790 of an uppermost object 50 begins to pass by and uncover the orifice of the vortex suction unit 10, the subsequent object 50 begins to adhere and an uninterrupted separation and feeding along the transfer path TP is obtained. Alternatively, the speed or current consumption of the vortex suction unit 10 can be used to indicate that an object 50 is no longer covering the orifice and the vortex suction unit can be turned off, for example, in between objects 50 or stacks 800. Other means for determining whether an

object is covering the orifice of the vortex suction unit 10 such as optical, mechanical or electrical sensors can also be used.

- 5 The objects 50 may be flat, flexible objects, such as paper or plastic sheets. However, other types of flat objects, such as boxes or containers of various shapes may be carried by conveyance systems 100 using vortex suction units 10 according to the present invention.

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While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from
15 the spirit and scope of the invention. Accordingly, the invention is to be limited only by the scope of the claims and their equivalents.

20

Patent Claims

1. A suctioning and conveying system for suctioning and conveying an object comprising first means for generating a low pressure induced by a whirlwind for sucking in the object, the whirlwind having an axis of rotation, wherein the system comprises second means for conveying the suctioned object along a transfer path transverse to the axis of rotation of the whirlwind.
2. The suctioning and conveying system according to claim 1, wherein the first means and the second means are disposed so that the first means suck in the object against the second object.
3. The suctioning and conveying system according to claim 1 or 2, wherein the angle of the transfer path relative to the axis of rotation is adjustable between -45° and 45° .
4. The suctioning and conveying system according to one of the preceding claims, wherein the first means include an impeller.
5. The suctioning and conveying system according to claim 4, wherein the impeller includes an impeller wheel and an impeller housing, wherein the impeller wheel is arranged rotatably in the impeller housing or wherein the impeller wheel is arranged in the impeller housing in a rotatably fixed manner.

6. The suctioning and conveying system according to claim 4 or 5,
wherein the impeller housing is cylindrical or conical with an opening angle, wherein the opening angle preferably is adjustable.
7. The suctioning and conveying system according to one of the claims 4 to 6,
wherein the impeller wheel is adjustable relative to the impeller housing along the axis of rotation of the impeller wheel.
8. The suctioning and conveying system according to one of the claims 4 to 7,
wherein the impeller includes an impeller wheel having blades extending radially.
9. The suctioning and conveying system according to one of the claims 4 to 8,
wherein the impeller includes in impeller wheel having blades, an outer edge of the blades being curved.
10. The suctioning and conveying system according to one of the claims 4 to 9,
wherein the impeller includes an impeller wheel and a motor which is integrated in the impeller wheel.
11. The suctioning and conveying system according to one of the claims 4 to 10,
wherein the impeller includes in impeller wheel comprising a separation plane transverse to the axis of rotation of the impeller wheel.

12.The suctioning and conveying system according to one of
the preceding claims,
wherein the first means comprise a cylindrical housing in
which air can be injected tangentially through openings
5 in the cylinder wall.

13.The suctioning and conveying system according to one of
the preceding claims,
wherein the injected air is generated by an impeller, the
10 impeller being arranged in a first cylindrical housing,
wherein the axis of rotation of the impeller is arranged
parallel to the axis of a second cylindrical housing,
wherein the second cylindrical housing and the first cy-
lindrical housing are connected by a connecting channel,
15 the connecting channel being arranged tangentially on the
first and the second cylindrical housing.

14.The suctioning and conveying system according to one of
the preceding claims,
20 wherein the first means are arranged within a housing
having a suctioning opening and wherein the second means
partially cover the suctioning opening.

15.The suctioning and conveying system according to one of
the preceding claims,
25 wherein the summed width of the second means amount to
about 40% to 60% of the width of the suctioning opening.

16.The suctioning and conveying system according to one of
the preceding claims,
30 wherein the height of the second means amount to about 2%
of the width of the suctioning opening.

17. The suctioning and conveying system according to one of the preceding claims,

wherein the second means are arranged in front of the suctioning opening so that the distance of the outer edges of the second means is smaller than the width of the suctioning opening, preferably by about 10%.

18. The suctioning and conveying system according to one of the preceding claims,

wherein the second means comprises at least one of a conveyor belt, a transport roller or a transport ball.

19. The suctioning and conveying system according to one of the preceding claims,

wherein the second means comprise at least one flat conveyor belt, the conveyor belt being at least partially air permeable and/or comprising a plurality of openings.

20. The suctioning and conveying system according to one of the preceding claims,

wherein the second means comprises two flat conveyor belts, the belts preferably being adjustable in their distance.

21. The suctioning and conveying system according to one of the preceding claims,

wherein the second means comprises at least two transportation means, the two transportation means having different cross sectional geometries, preferably the two transportation means being a belt and an O-ring.

22. The suctioning and conveying system according to one of the preceding claims,

wherein the suctioning opening is designed to be closed at least partially, preferably by a sliding element or by an iris.

5 23.The suctioning and conveying system according to one of the preceding claims,
wherein ribs are arranged transverse the suctioning opening.

10 24.The suctioning and conveying system according to one of the preceding claims,
wherein the second means comprise two elements, preferably two flat conveyor belts, being independently motor-driven.

15 25.The suctioning and conveying system according to one of the preceding claims,
wherein the second means are adjustable relative to the suctioning opening of the suctioning and conveying system.
20

26.The suctioning and conveying system according to one of the preceding claims,
wherein the suctioning and conveying system is rotatable,
25 preferably around the axis of rotation of the whirlwind.

27.A conveying system for conveying an object along a transfer path, comprising at least a first and a second suctioning and conveying system according to one of the preceding claims, wherein the suctioning and conveying systems are disposed in sequence in a direction of the transfer path, further comprising a main controller configured to separately control the suctioning and conveying
30

systems so as to convey the object along the transfer path using the second means of the suctioning and conveying systems.

5 28.The conveying system according to claim 27,
further comprising third and fourth suctioning and conveying systems, wherein the first and third suctioning and conveying system form a first array and the second and fourth suctioning and conveying system form a second
10 array, the main controller being configured to separately control the arrays.

29.The conveying system according to claim 28,
wherein the arrays are disposed so that the suctioning
15 opening of the first suctioning and conveying system is disposed opposite the suctioning opening of the second suctioning and conveying system.

30.The conveying system according to one of the claims 27 to
20 29,
wherein the suctioning and conveying system are movable in the direction of the transfer path.

31.The conveying system according to one of the claims 27 to
25 30,
wherein the second means are designed as conveyor belt being associated with the first and the second suctioning and conveying system.

30 32.The conveying system according to one of the claims 27 to 31,
wherein the main controller is configured to separately control, switch on, switch off, slow down and/or speed up

the first and/or the second suctioning and conveying system, preferably independently and preferably the first and second means independently.

5 33.The conveying system according to one of the claims 27 to 32,

wherein the main controller is configured to operate the first suctioning and conveying system at a different transport speed than the second suctioning and conveying system.

10

34.The conveying system according to one of the claims 27 to 33,

wherein the transfer path extends into first and second secondary paths, the first suctioning and conveying system being configured to convey the object from the transfer path to the first secondary path and the second suctioning and conveying system being configured to convey the object from the transfer path to the second secondary path.

15

20

35.A separating system for separating an object from the outer part of a stack and conveying it along a transfer path, the system comprising a stack assembly configured to receive a stack of objects and a mounting assembly including at least one suctioning and conveying system according to one of claims 1 to 26, the suctioning and conveying system being disposable so as to face the stack of objects at at least one of a leading edge and a trailing edge thereof for suctioning in and conveying an object from the stack.

25

30

36.The separating system according to claim 35,
wherein the stack assembly includes at least one adhesion
reduction device disposed adjacent to an outer object of
the stack.

5

37.The separating system according to claim 36,
wherein the adhesion reduction device includes at least
one of an aerating device and a vibrating device confi-
gured to vary a position of the objects relative to each
other.

10

38.The separating system according to claim 37,
wherein the aerating device includes at least one side
blower having a radial fan that is adjustable in height,
preferably between 0 mm and 60 mm, relative to the stack
so as to aerate a portion of the stack.

15

39.The separating system according to one of claims 35 to
38,
wherein the distance between the suctioning and conveying
system and the stack, preferably between 0 mm and 60 mm,
and/or the angle of the axis of rotation of the first
means to an outer object of the stack, preferably between
-45° and 45°, is adjustable.

25

40.The separating system according to one of claims 35 to
39,
wherein the suctioning and conveying system is disposable
at the leading edge of the stack and the angle of the
axis of rotation of the first means of the suctioning and
conveying system relative to the outer object of the
stack is adjustable between 0° to 45°.

30

41. The separating system according to one of claims 35 to 40,

wherein the stack assembly includes at least one stack height sensor disposed above an outer object of the stack.

42. The separating system according to one of claims 35 to 41,

wherein the second means includes at least one of a conveyor belt and a roller or ball based transportation means extending in a direction of the transfer path and configured to receive the object thereagainst under an attraction force of the at least one suctioning and conveying system.

43. The separating system according to one of claims 35 to 42,

wherein the angle of the transport path and the outer object is adjustable between -45° and 45° .

44. The separating system according to one of claims 35 to 43,

wherein the system includes a plurality of suctioning and conveying systems that are individually operated.

45. Method of suctioning and conveying an object along a transfer path comprising:

generating a low pressure induced by a whirlwind for sucking in the object, the whirlwind having an axis of rotation,

conveying the suctioned object along the transfer path transverse to the axis of rotation of the whirlwind.

46. Method of conveying an object along a transfer path comprising:

disposing at least a first and a second vortex suction unit in sequence in a direction of the transfer path;
5 transferring the object relative to at least one of the vortex suction units using at least one conveyor; and controlling the vortex suction units separately using a main controller so as to convey the object using at least one of the conveyors.

10

47. The method of claim 46, further comprising:

aligning the object relative to an alignment line, the alignment line preferably being a mechanical or electronic alignment line.

15

48. Method of separating an object from an outer part of a stack of objects comprising:

disposing at least one vortex suction unit, preferably a suctioning and conveying system according to one of
20 claims 1 to 26, at a distance opposite an edge of the stack; and

attracting the object from the stack and conveying it along a transfer path using the at least one vortex suction unit, preferably using a suctioning and conveying
25 system according to one of claims 1 to 26.

Fig. 1a

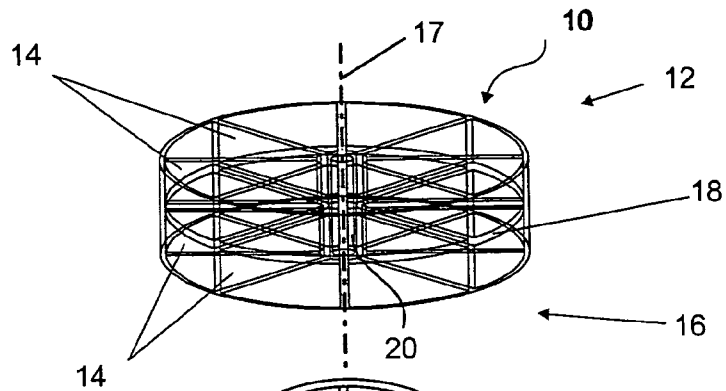


Fig. 1b

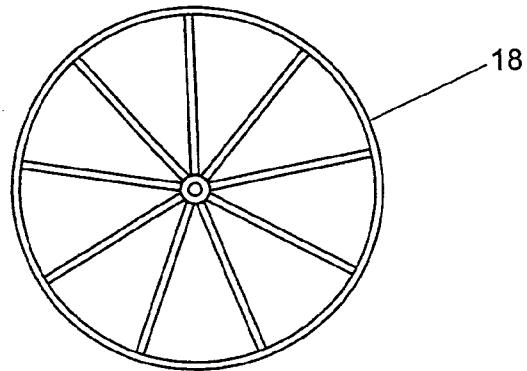


Fig. 2a

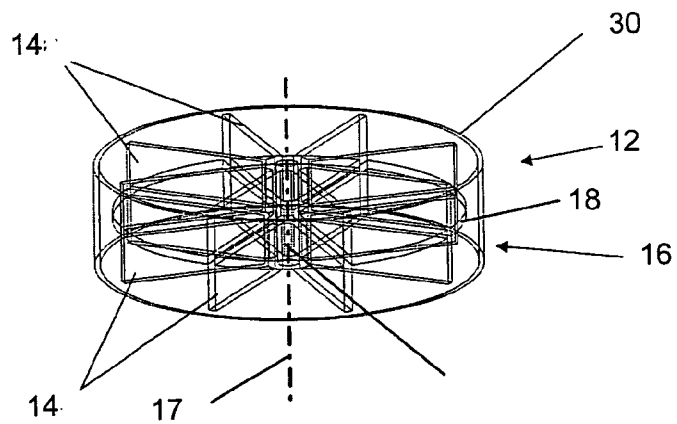
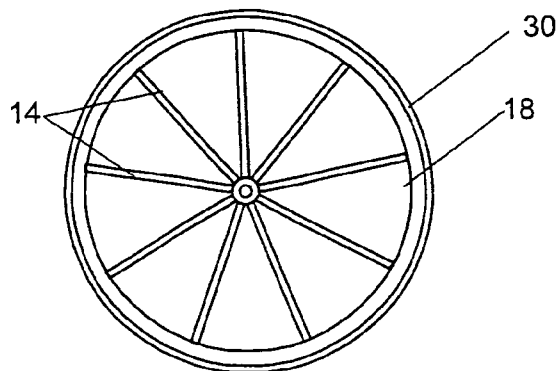


Fig. 2b



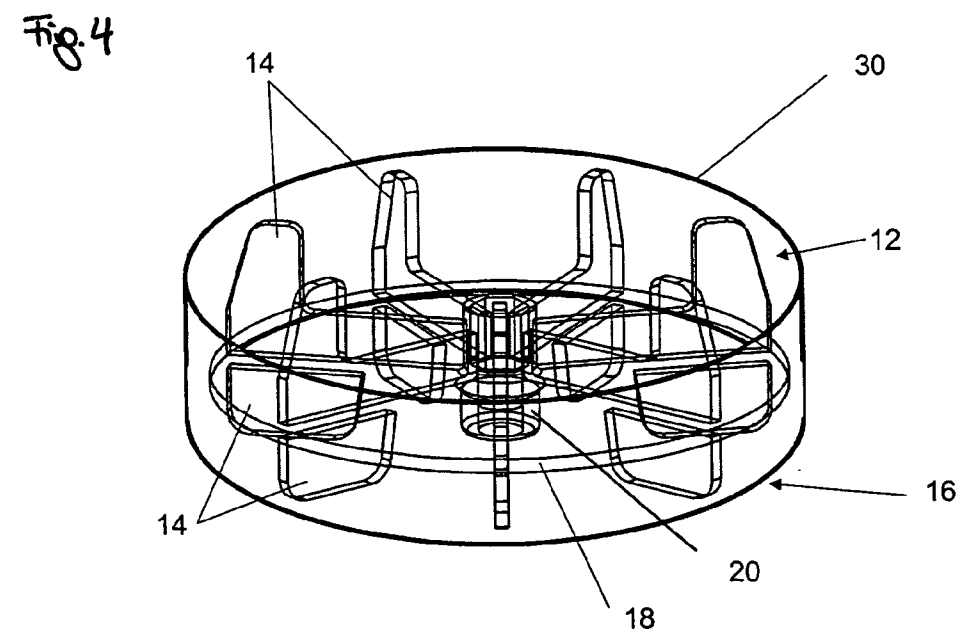
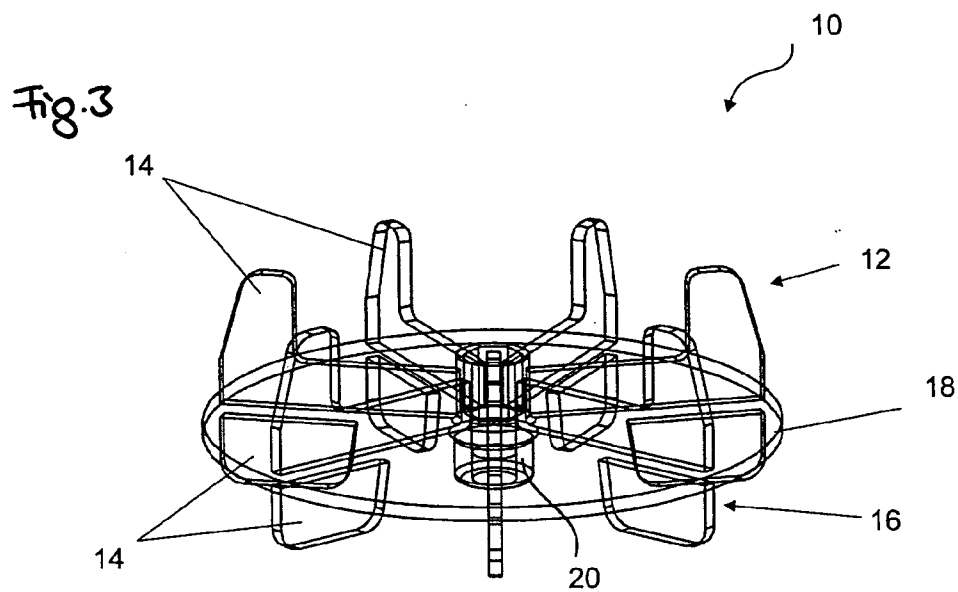


Fig. 5

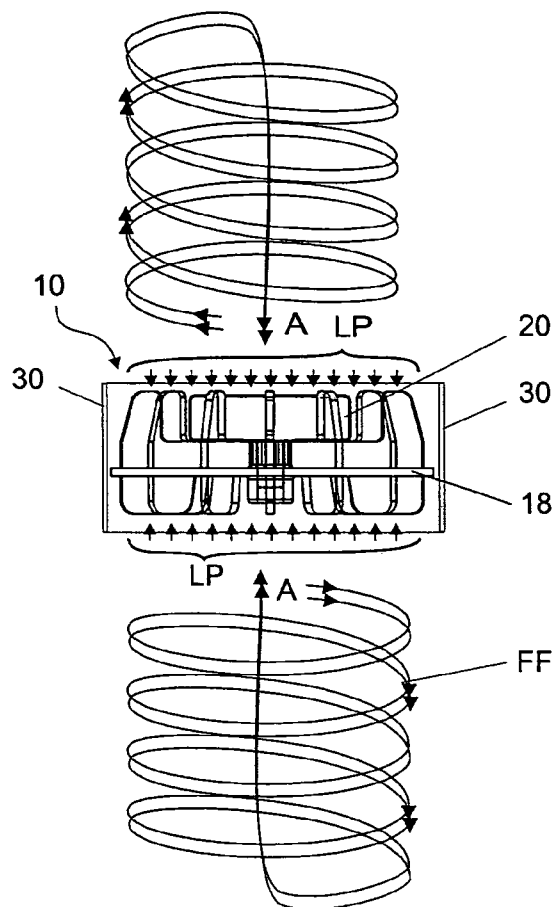
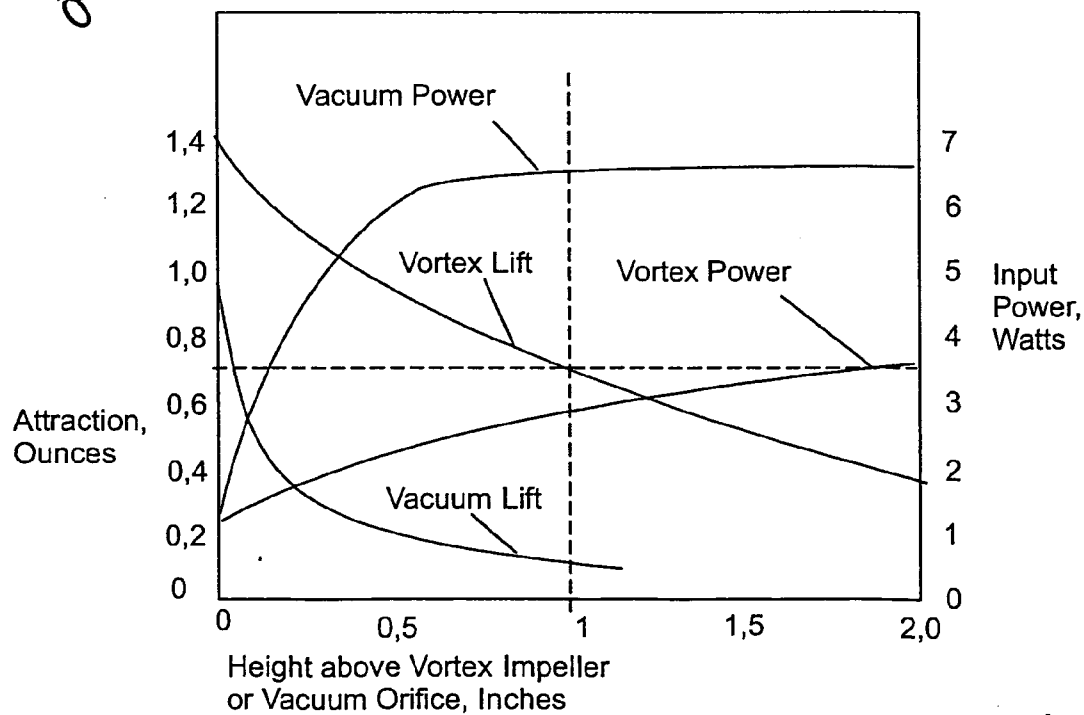
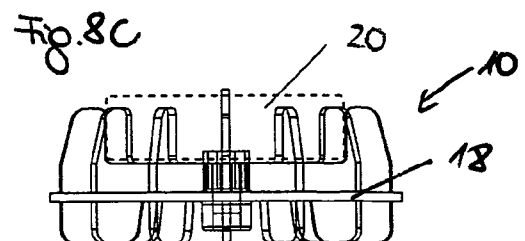
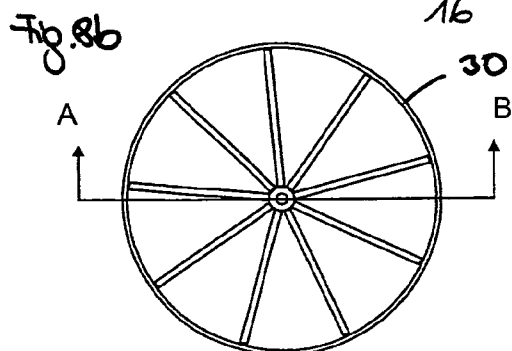
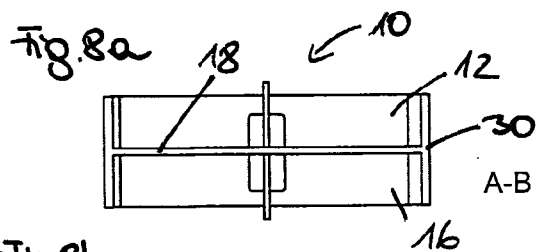
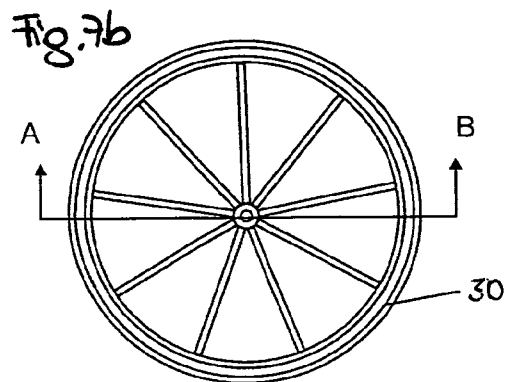
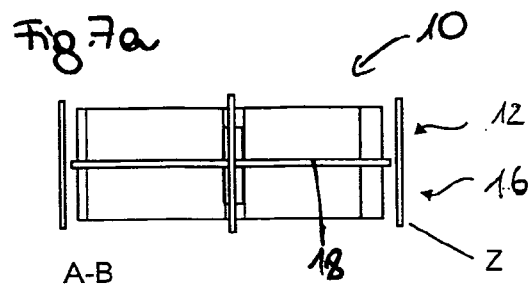
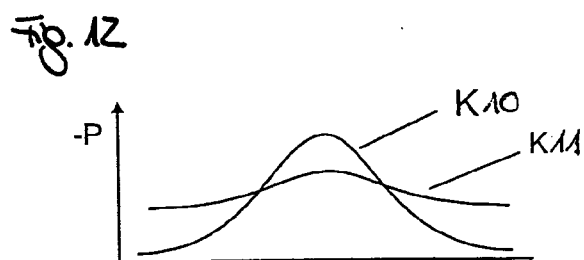
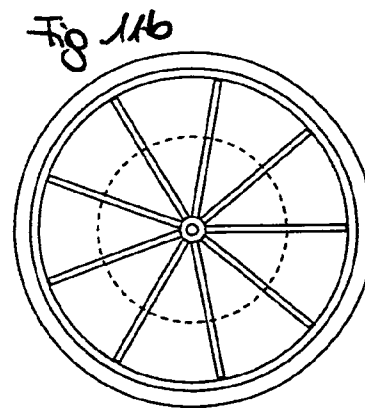
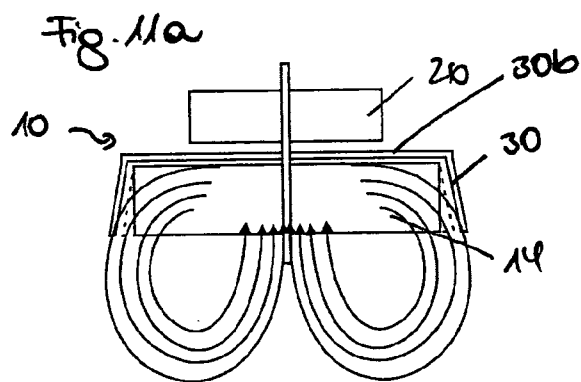
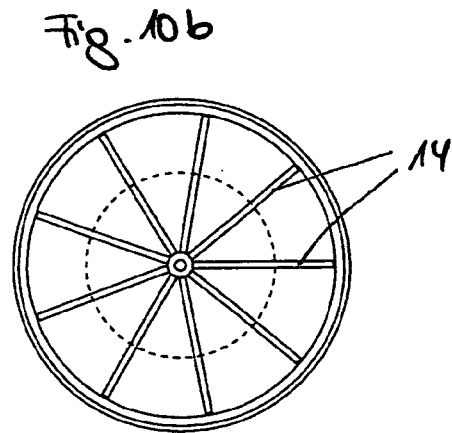
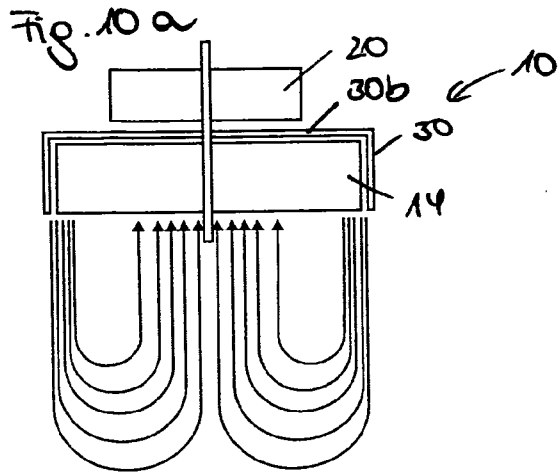
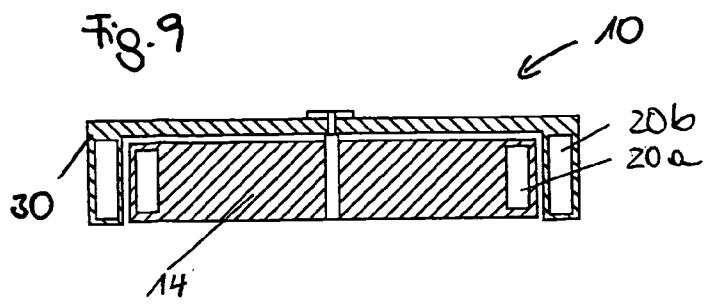
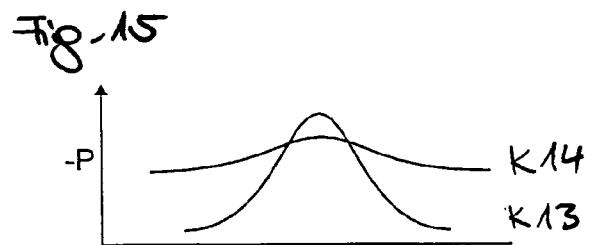
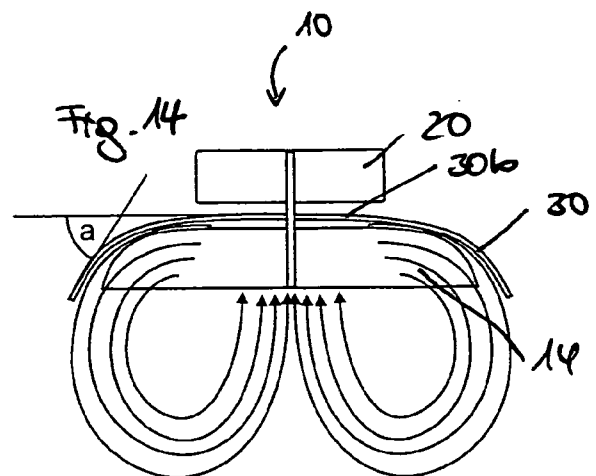
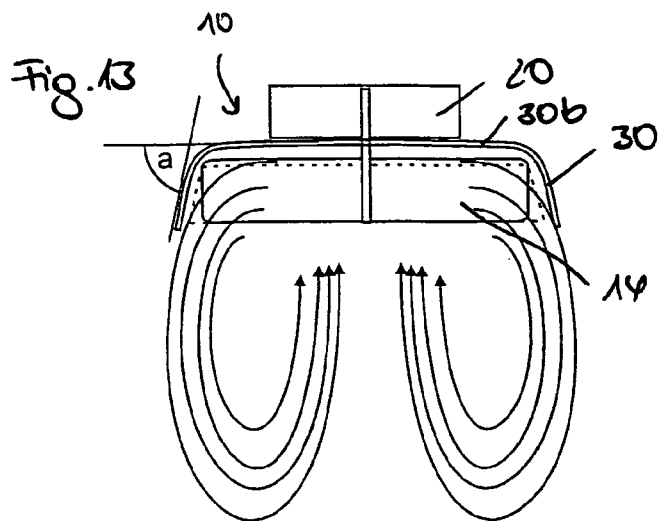


Fig. 6









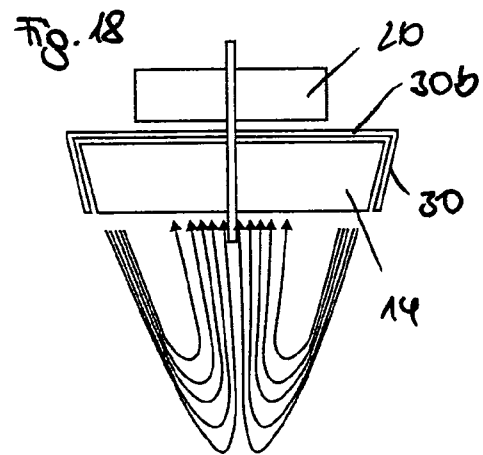
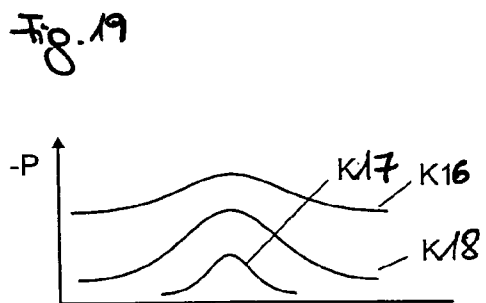
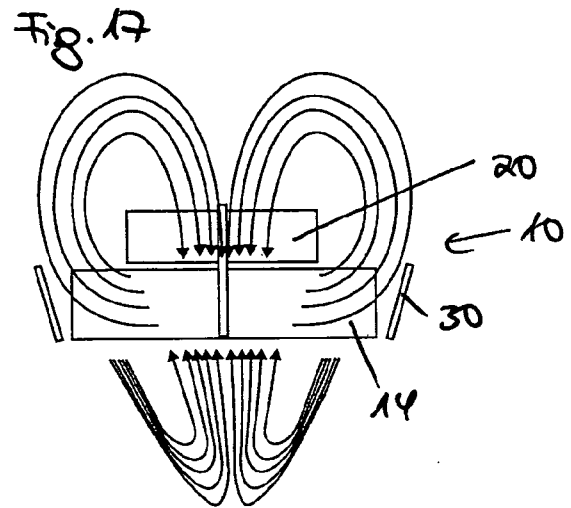
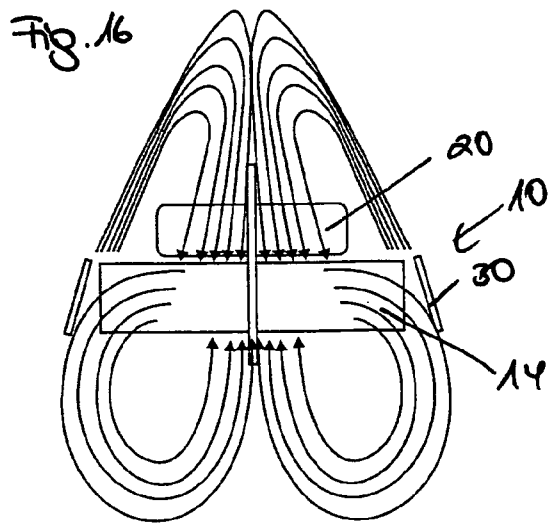


Fig. 20

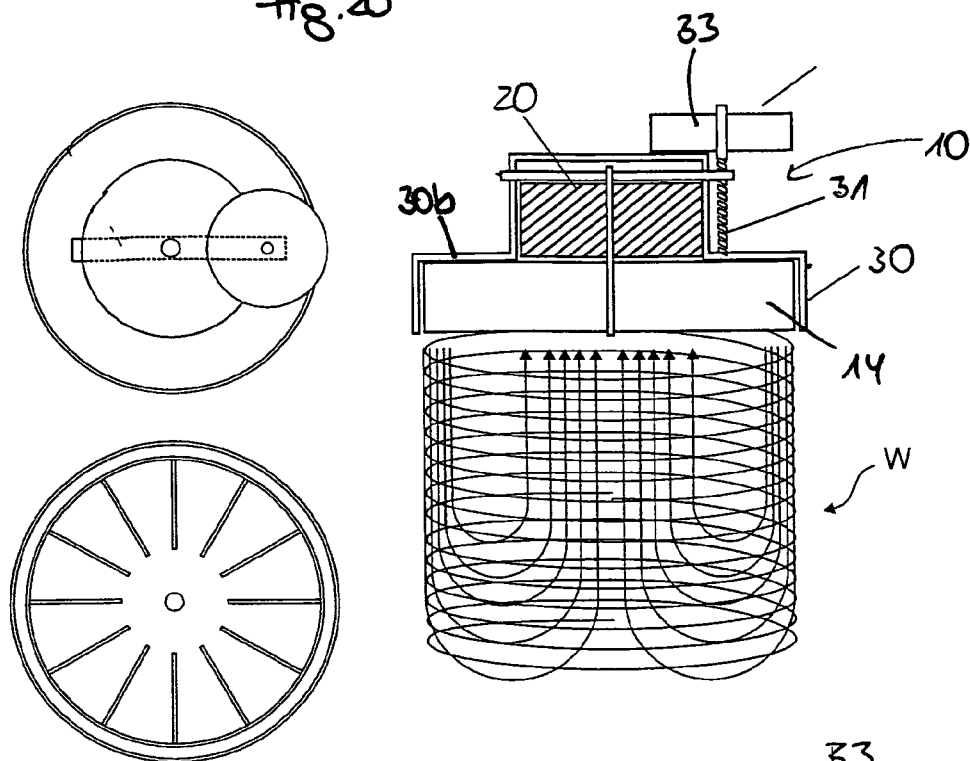


Fig. 21

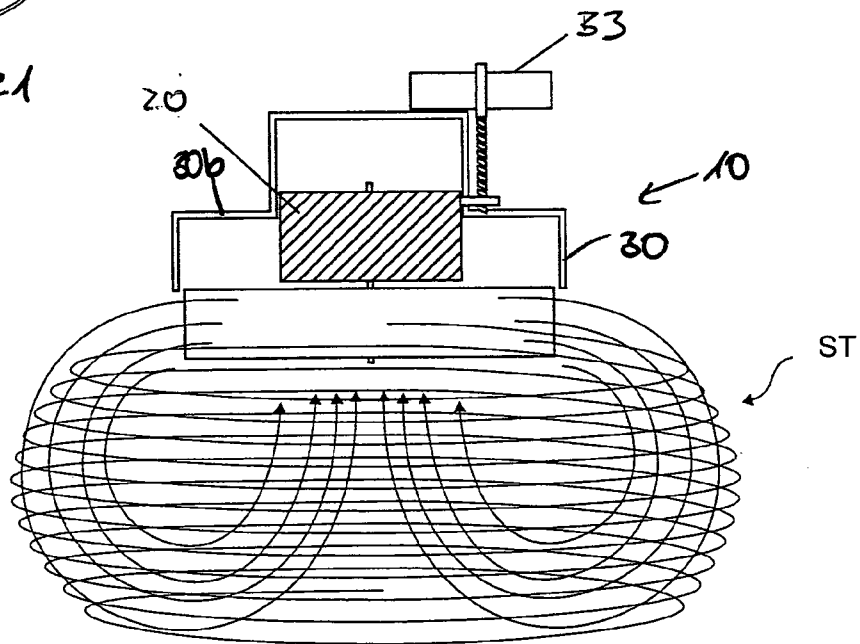
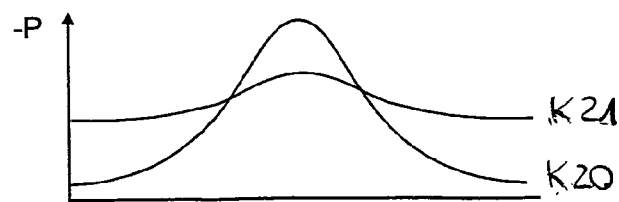
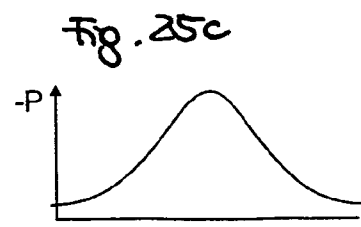
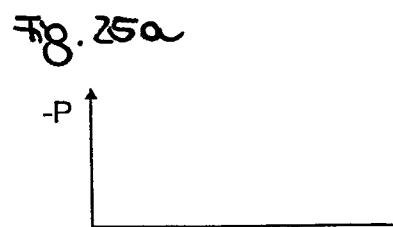
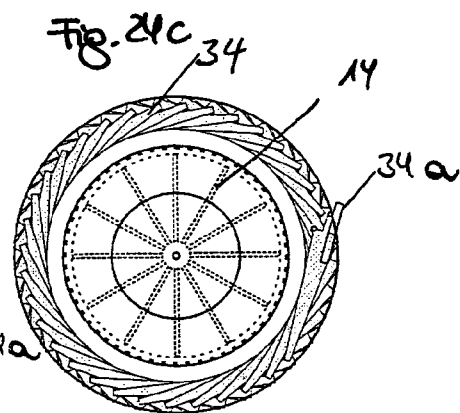
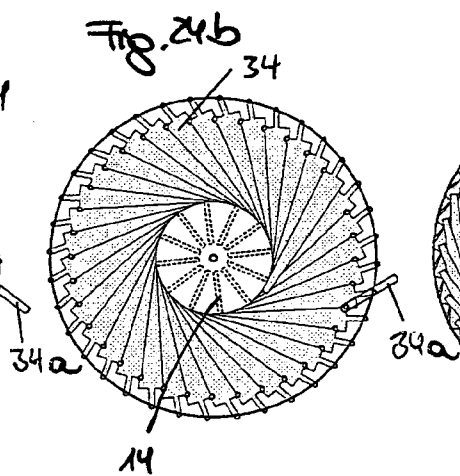
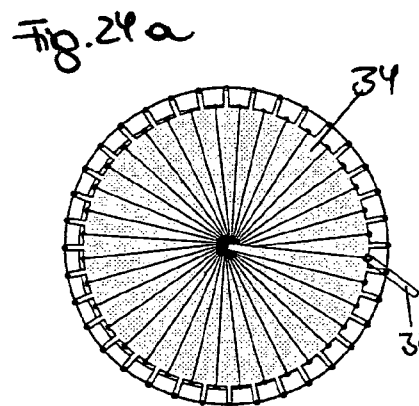
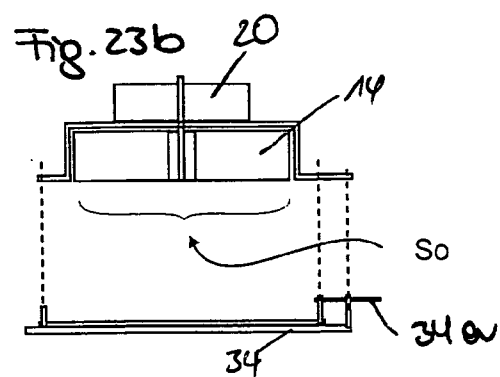
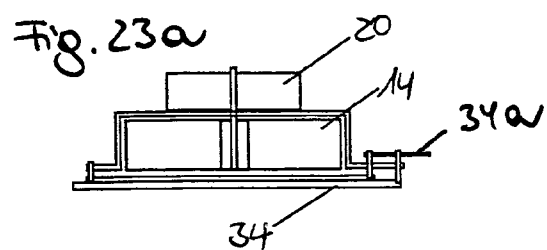


Fig. 22





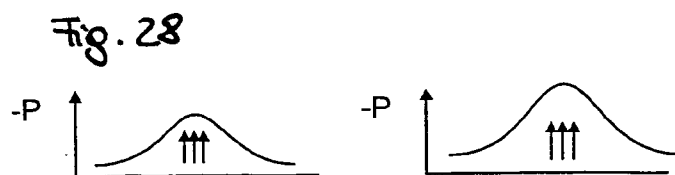
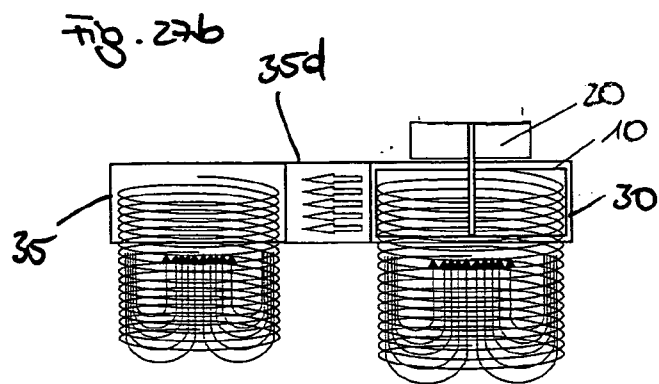
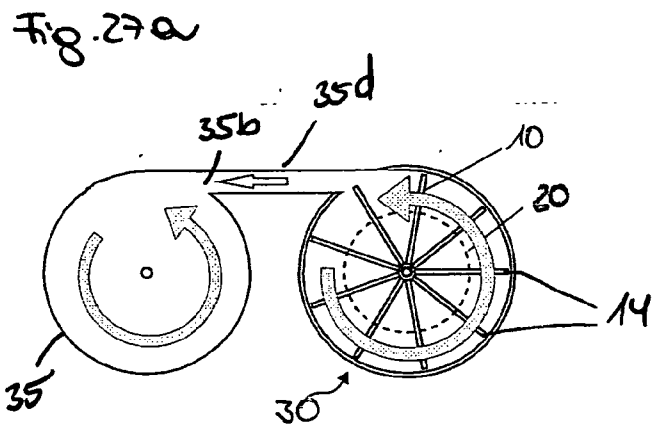
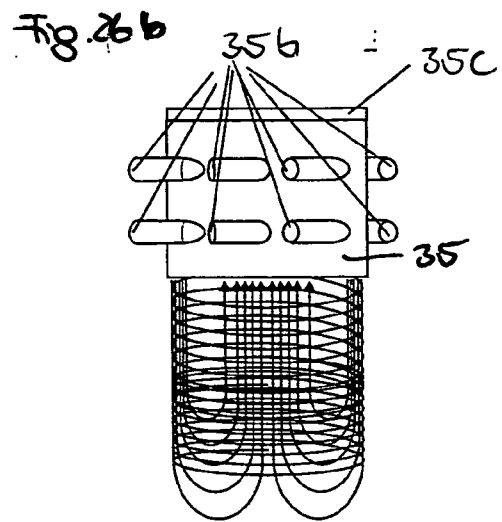
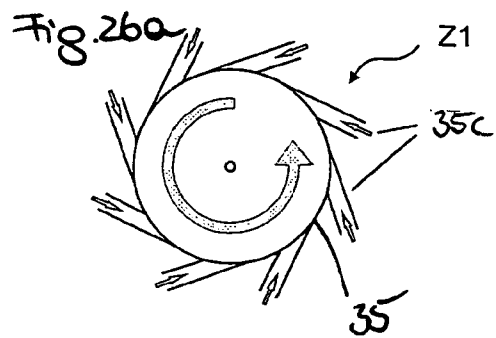


Fig. 29

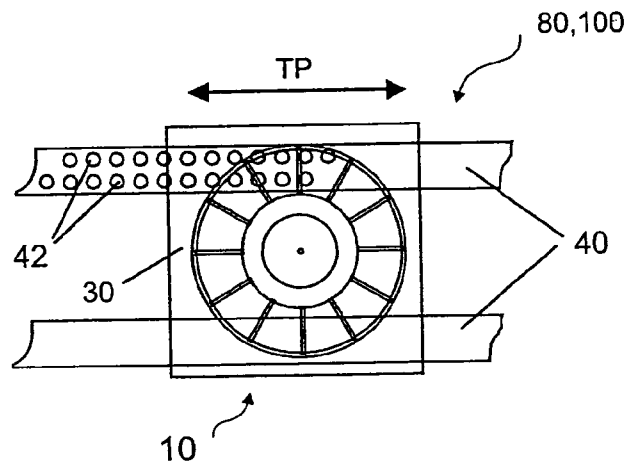
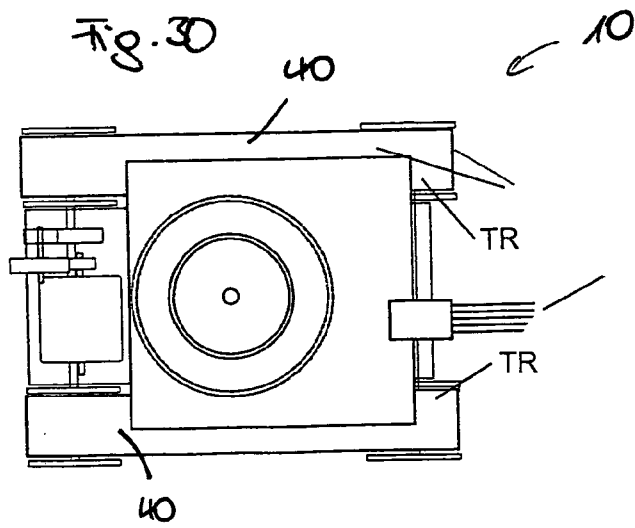


Fig. 30



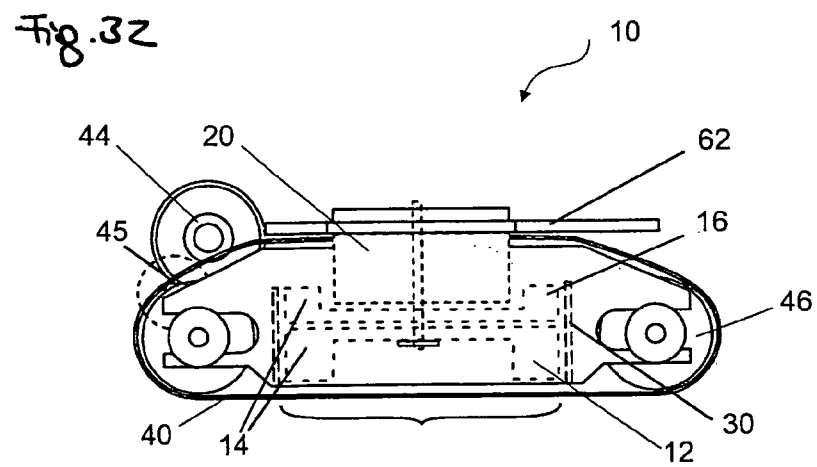
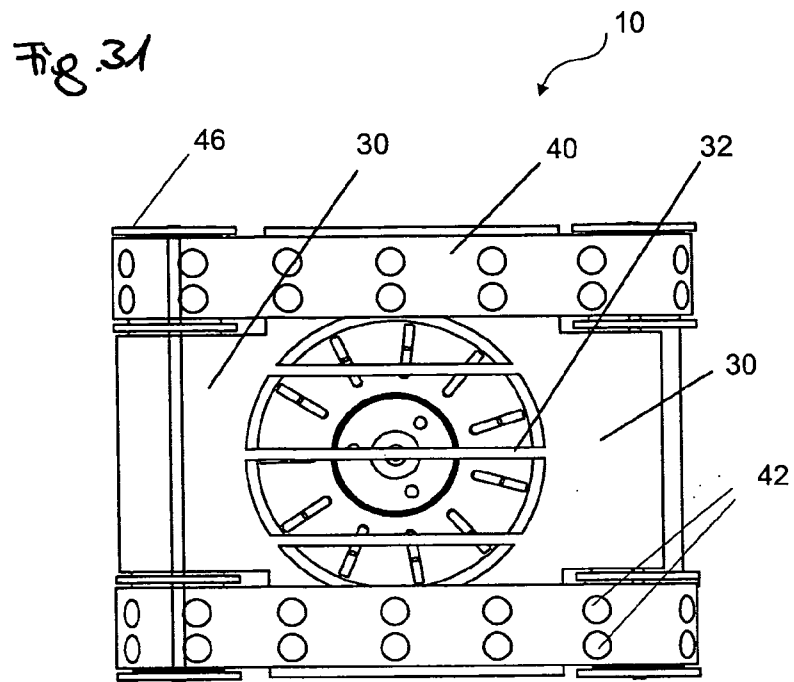


Fig. 33a

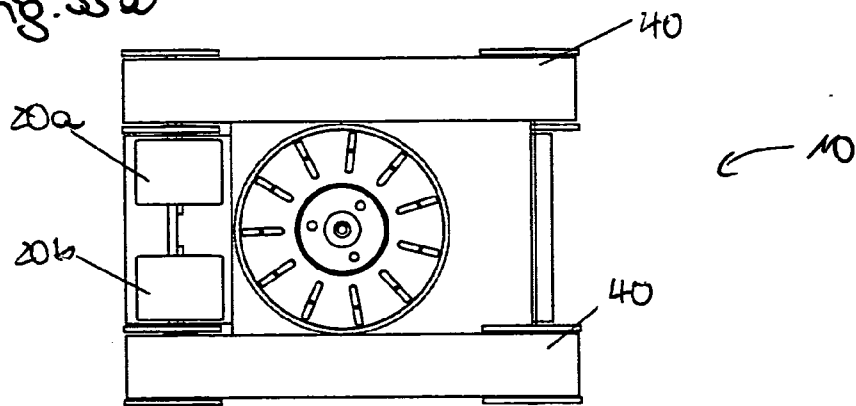


Fig. 33b

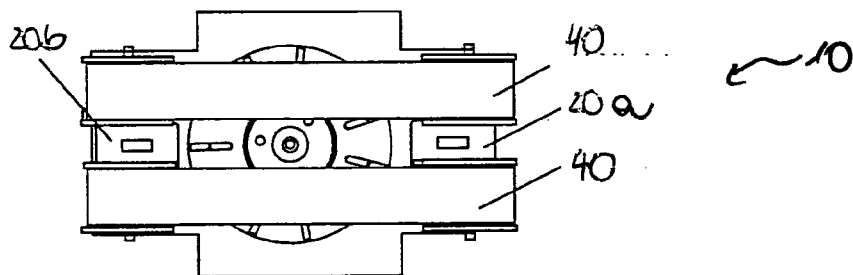


Fig. 34a

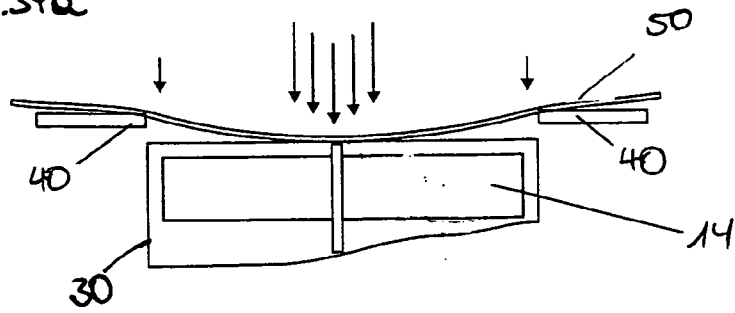


Fig. 34b

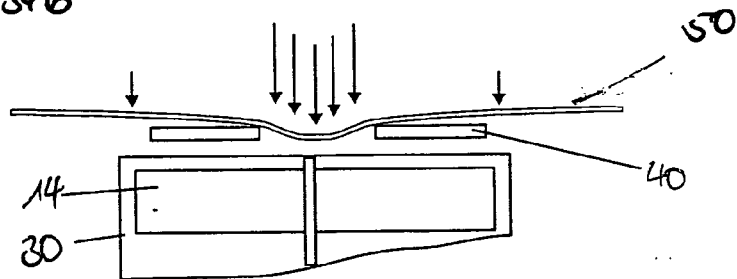


Fig. 34c

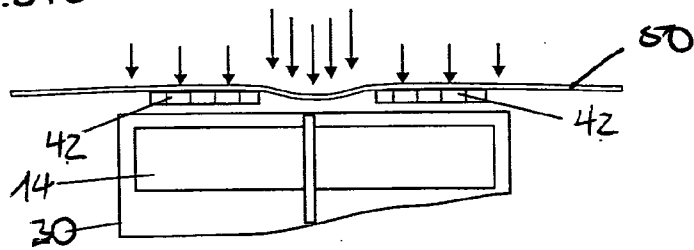
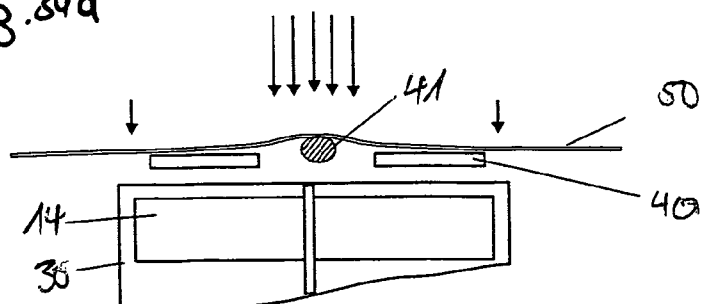
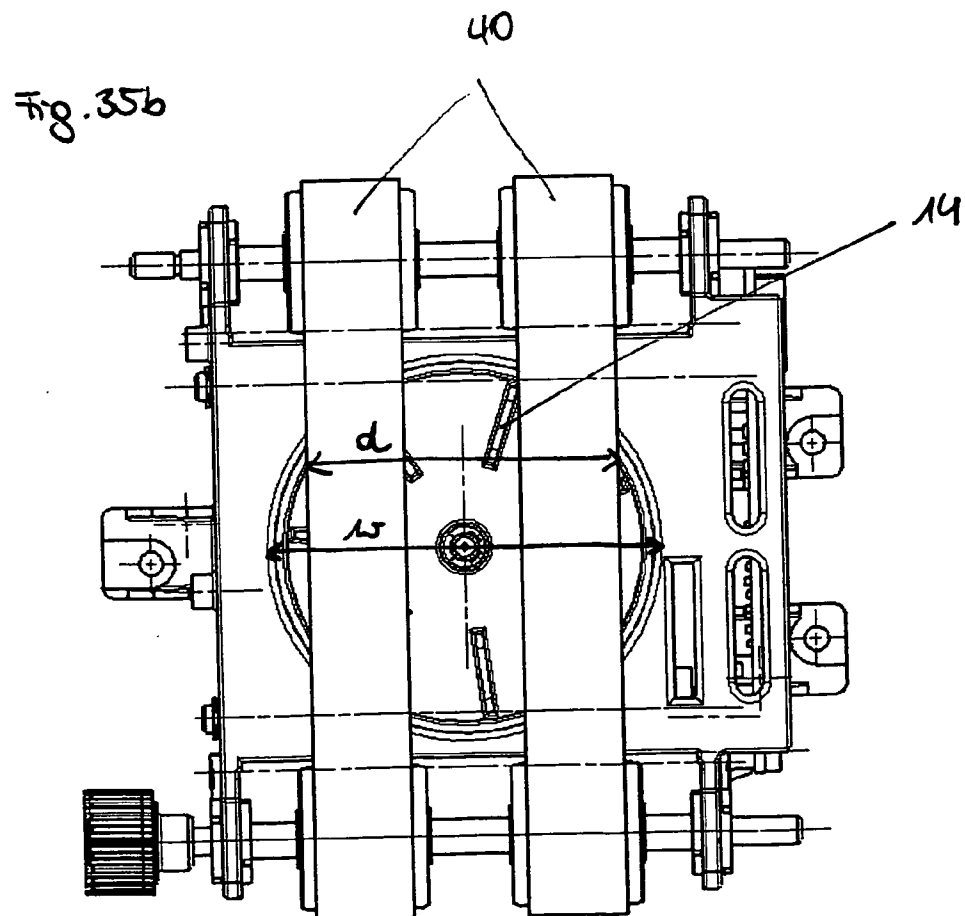
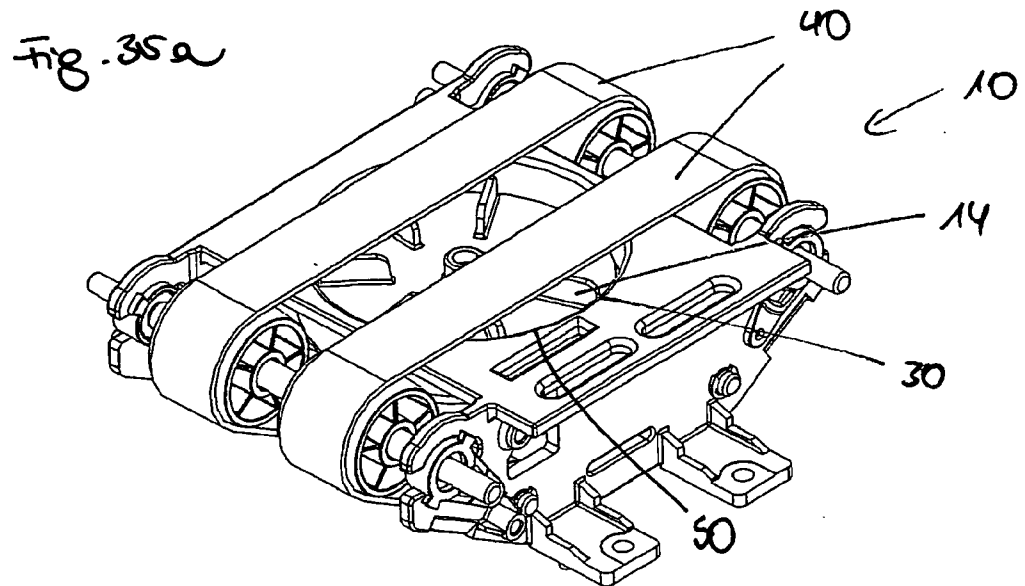
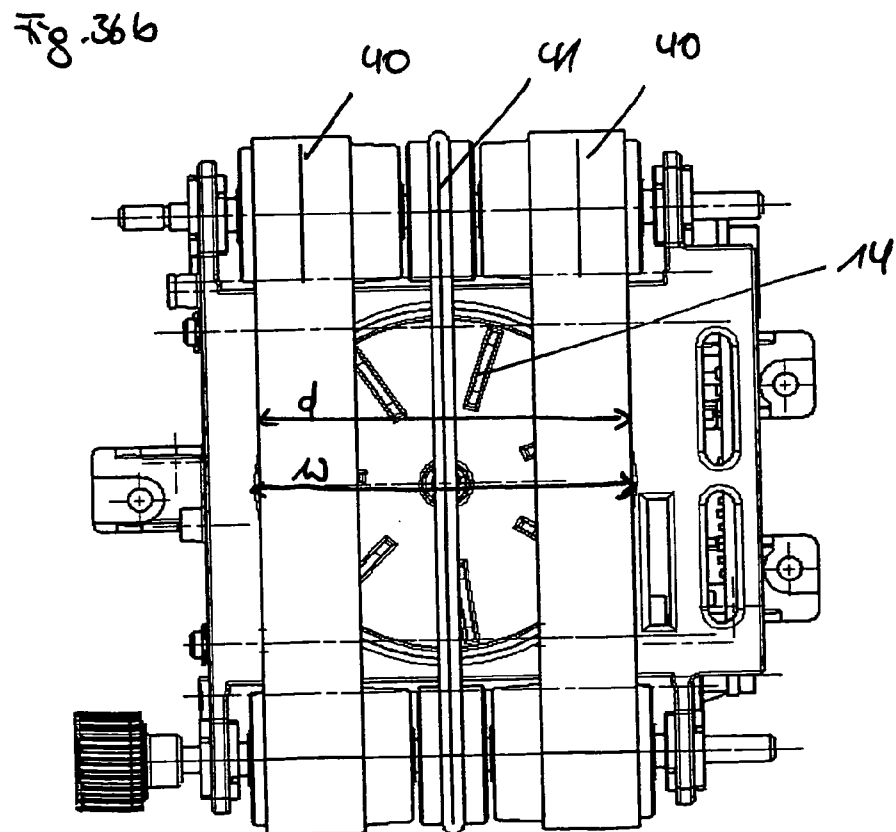
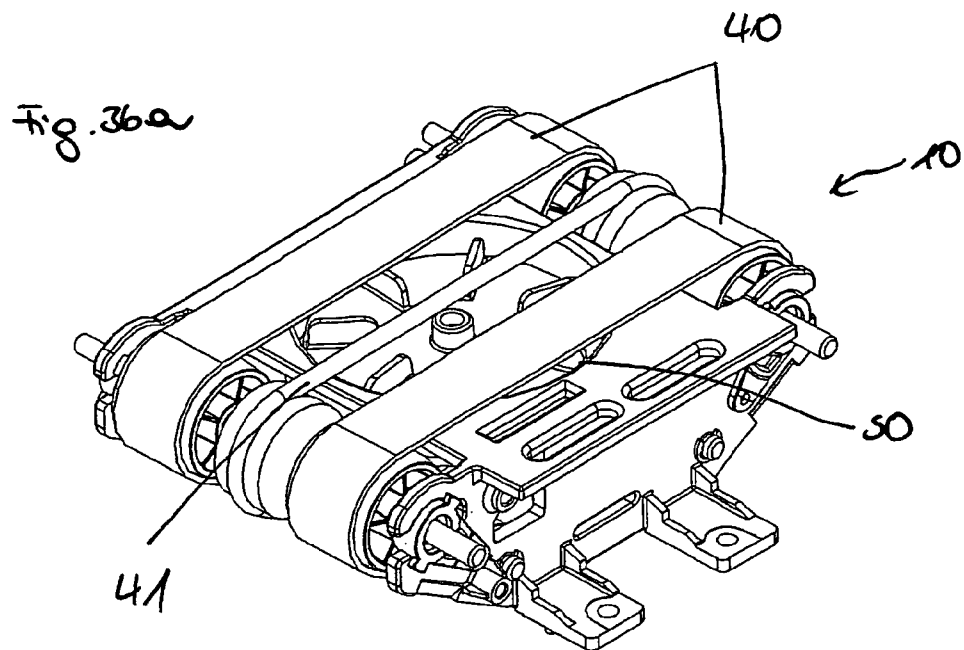


Fig. 34d







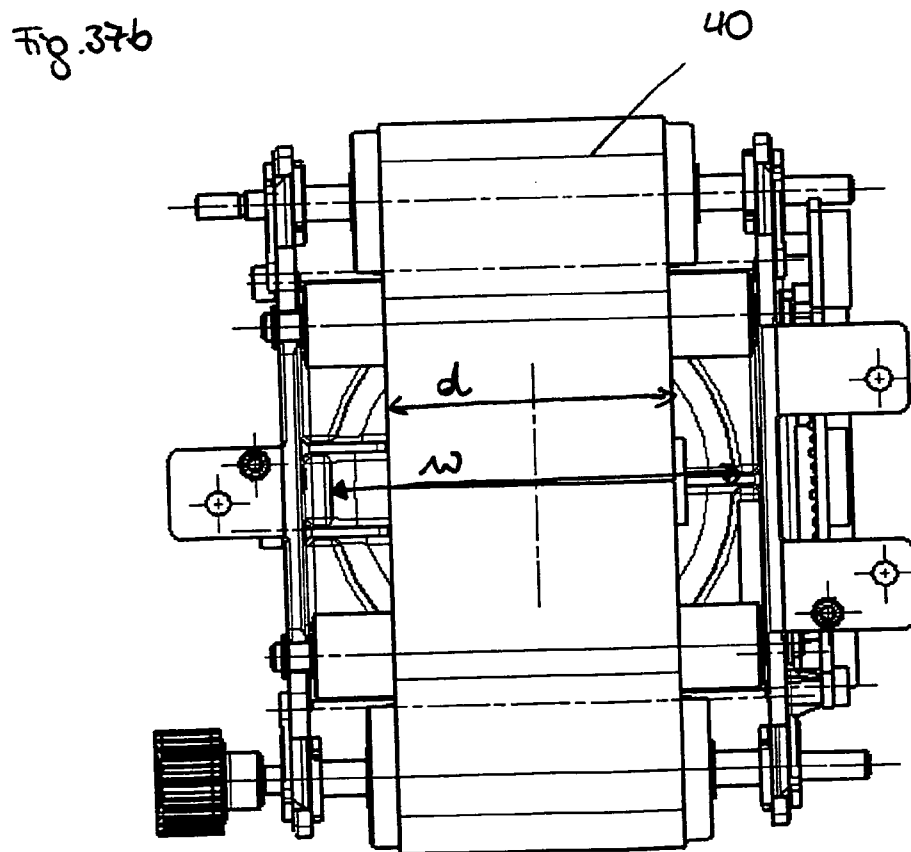
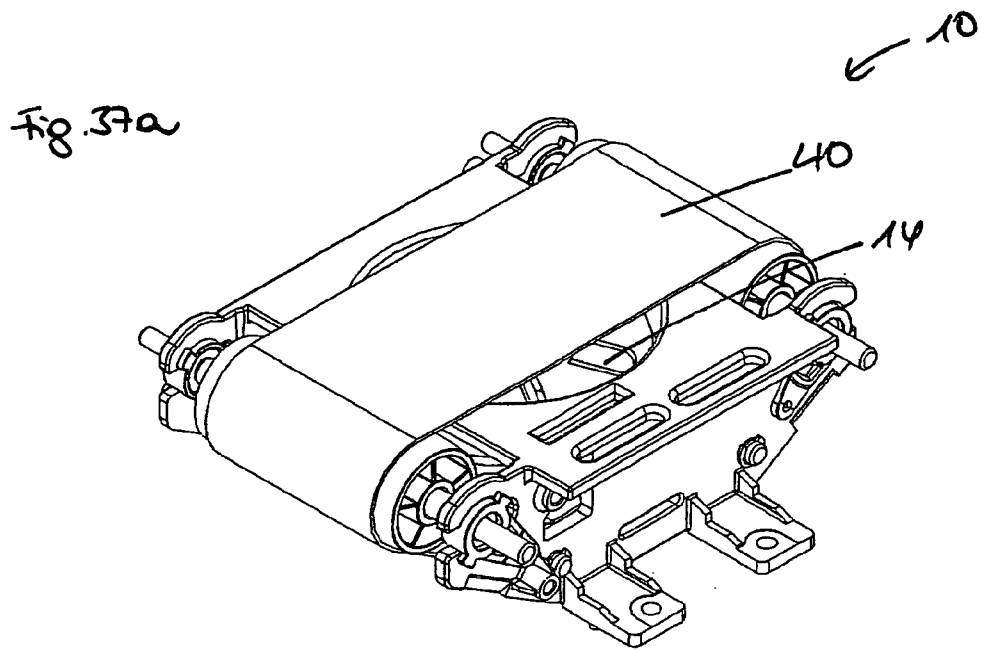


Fig. 38a

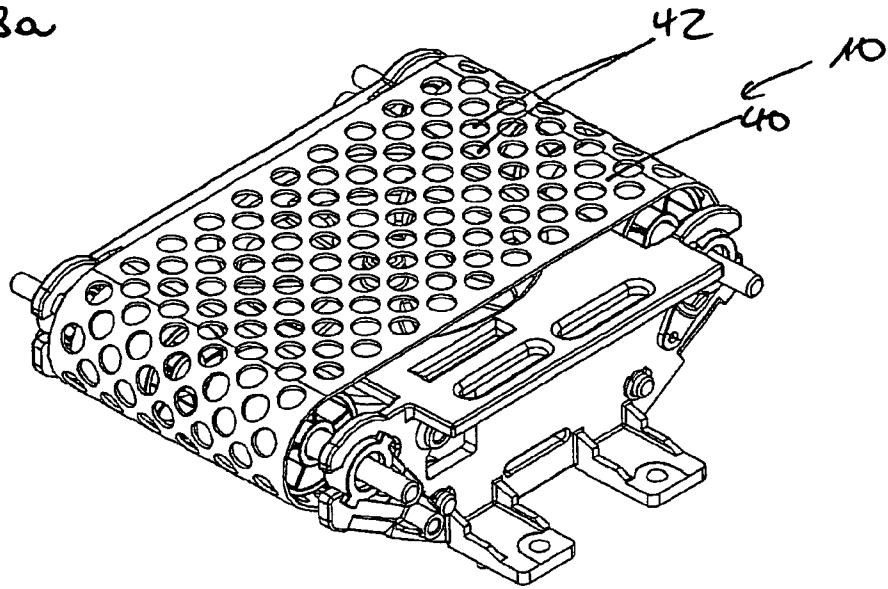
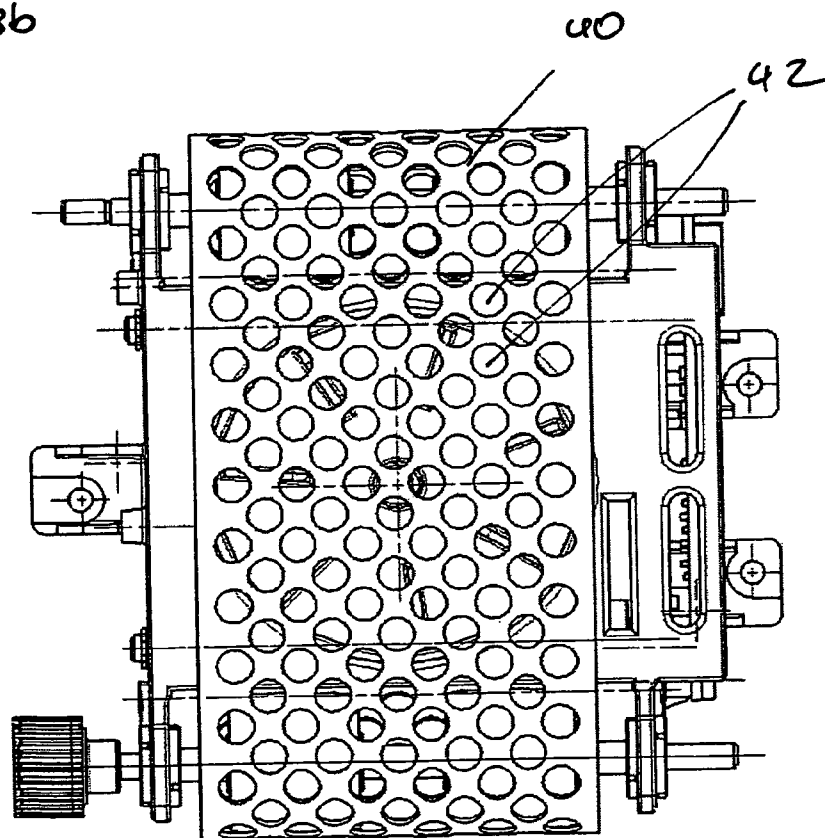


Fig. 38b



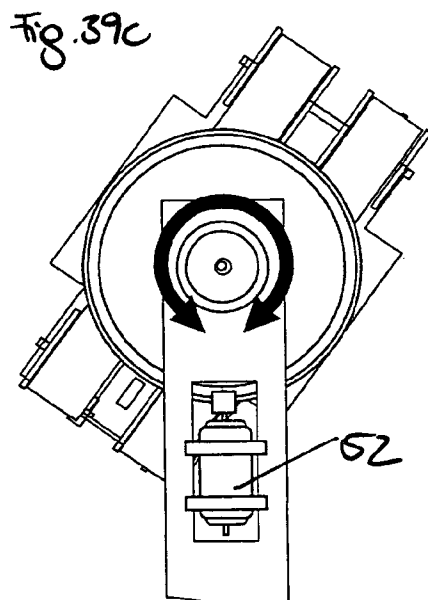
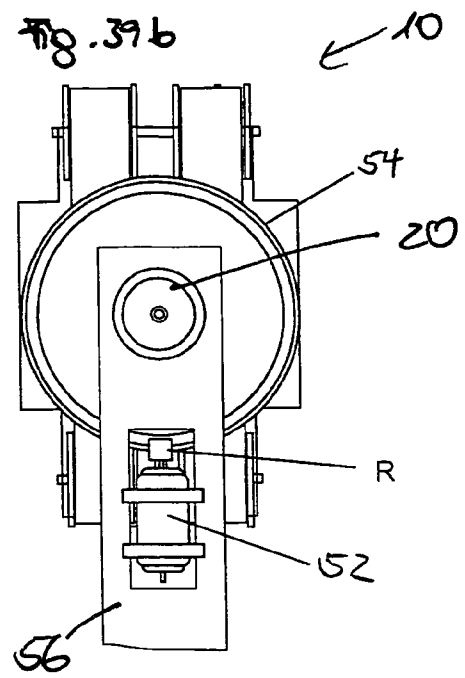
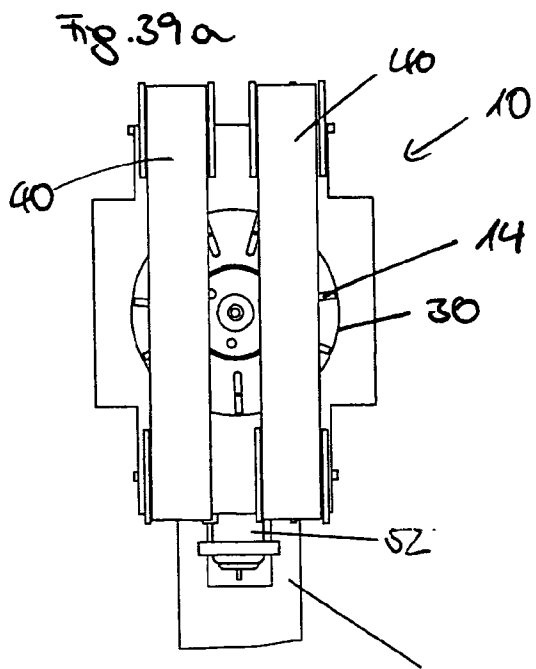


Fig. 40a

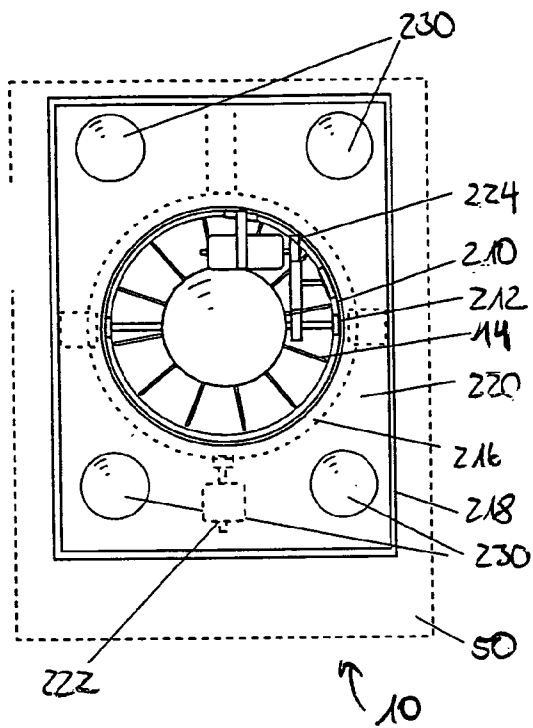


Fig. 40b

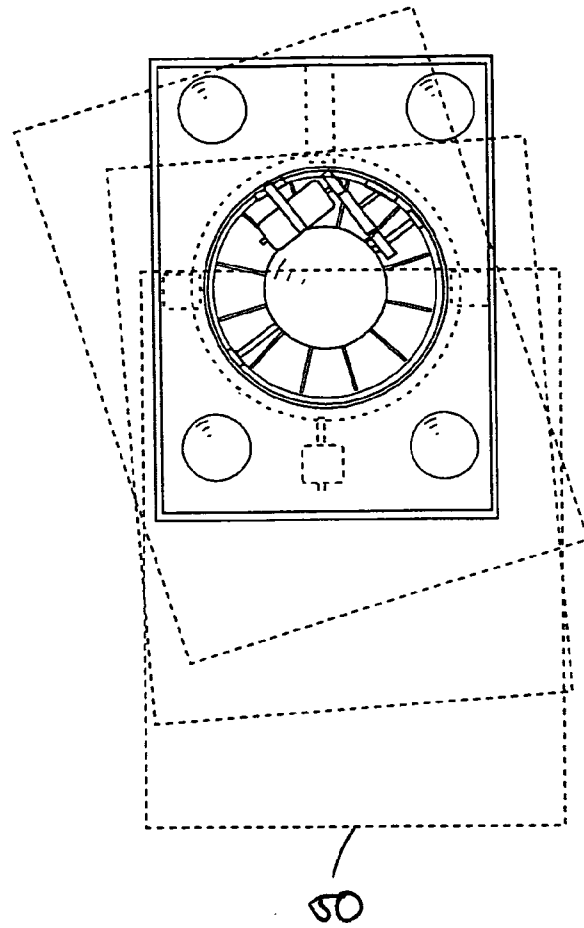
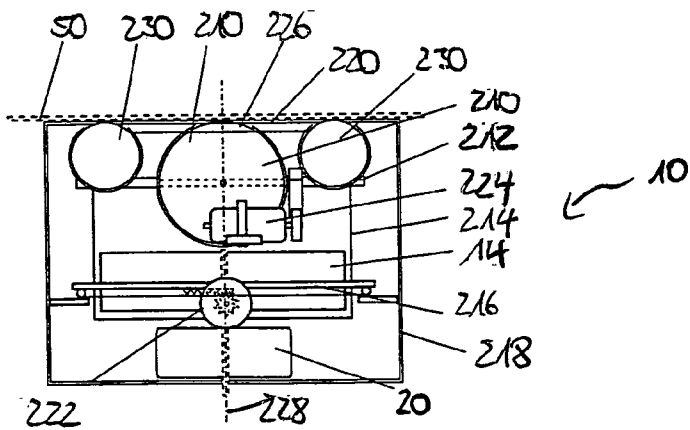


Fig. 40c



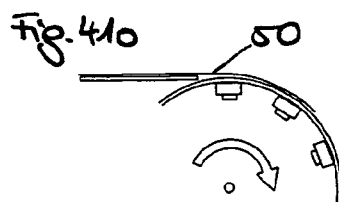
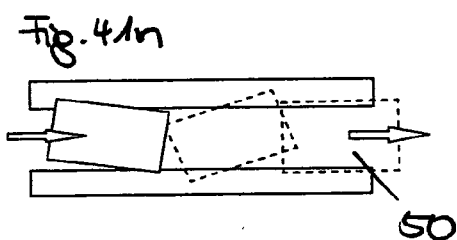
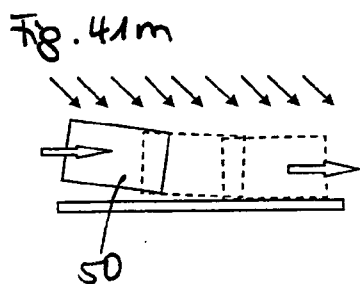
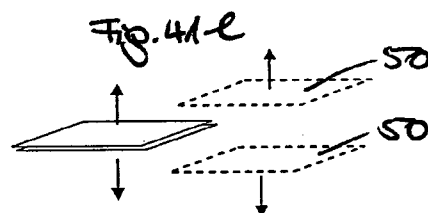
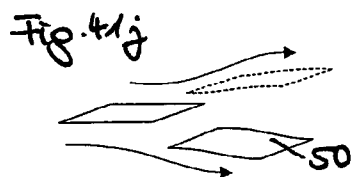
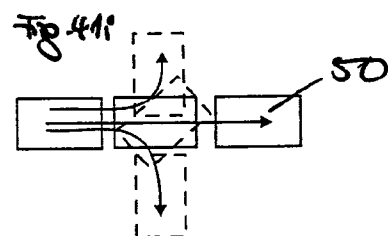
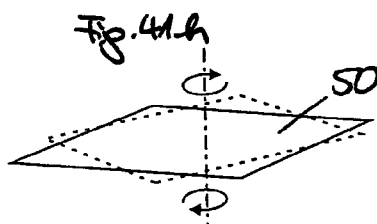
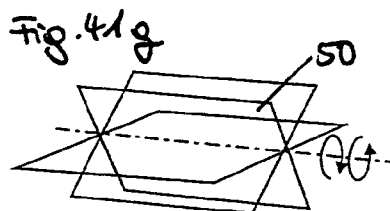
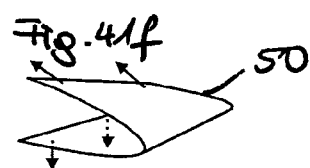
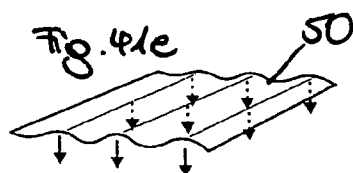
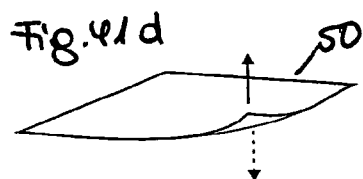
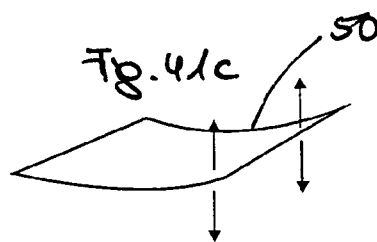
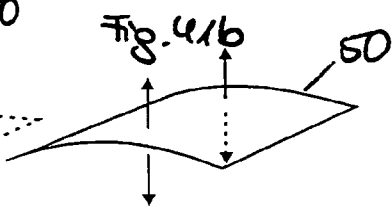
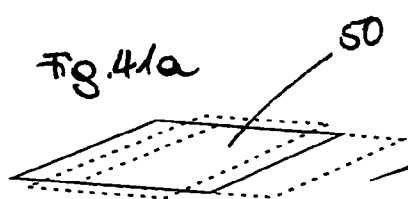


Fig. 42

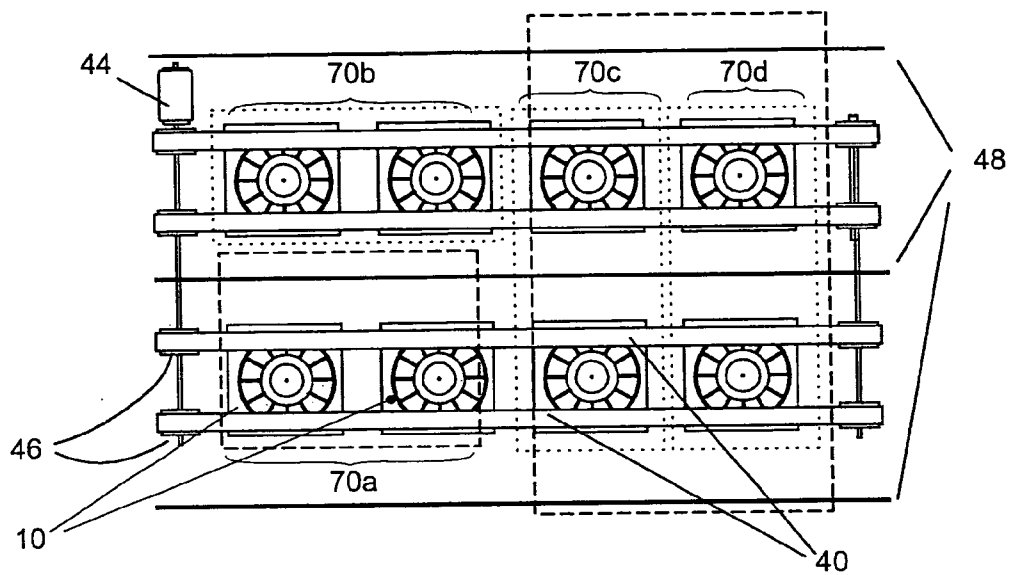


Fig. 43

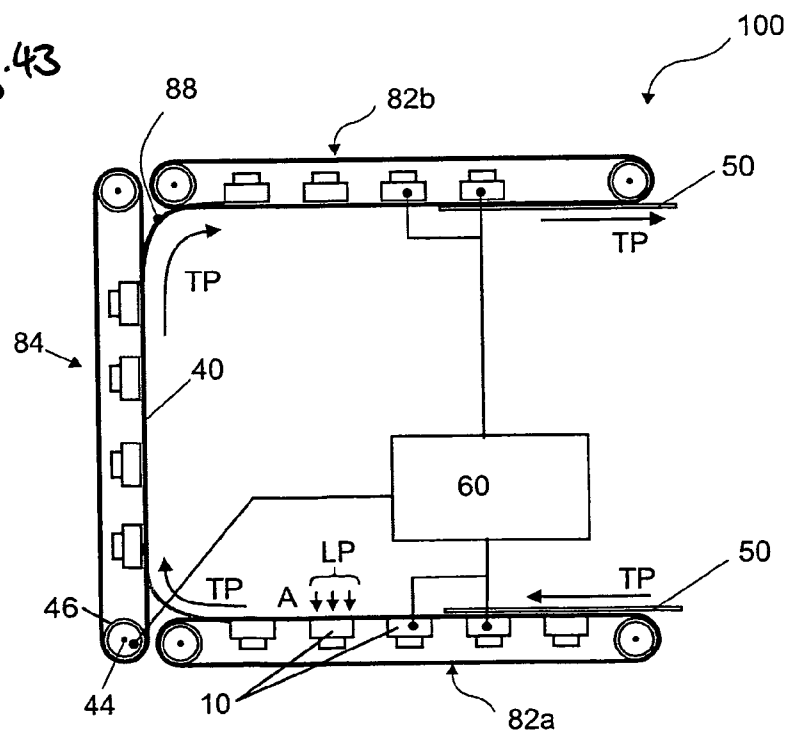


Fig. 45a

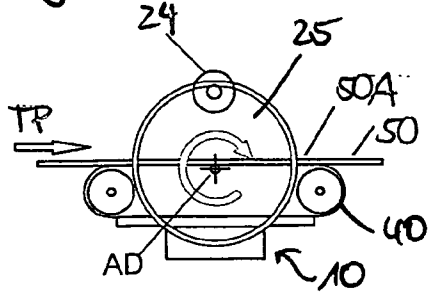


Fig. 45b

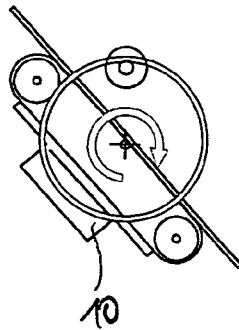


Fig. 45c

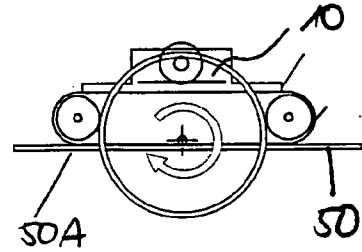


Fig. 46a

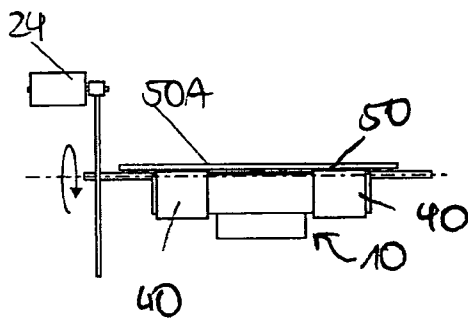


Fig. 46b

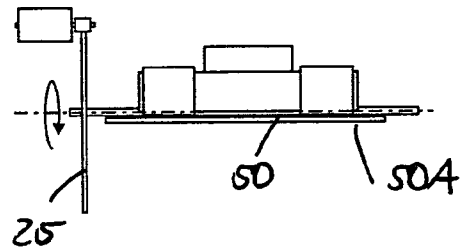


Fig. 44

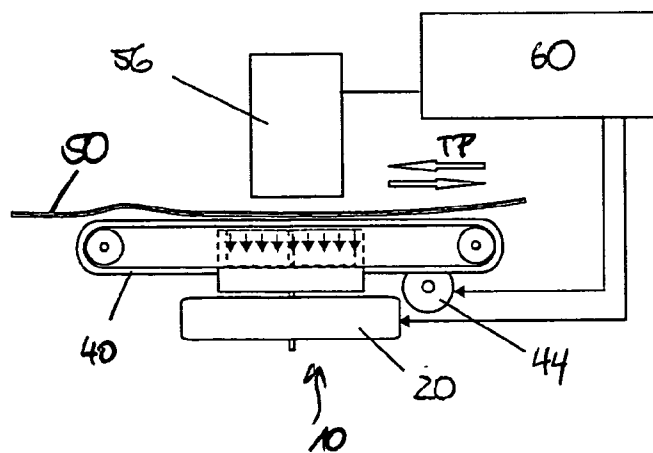
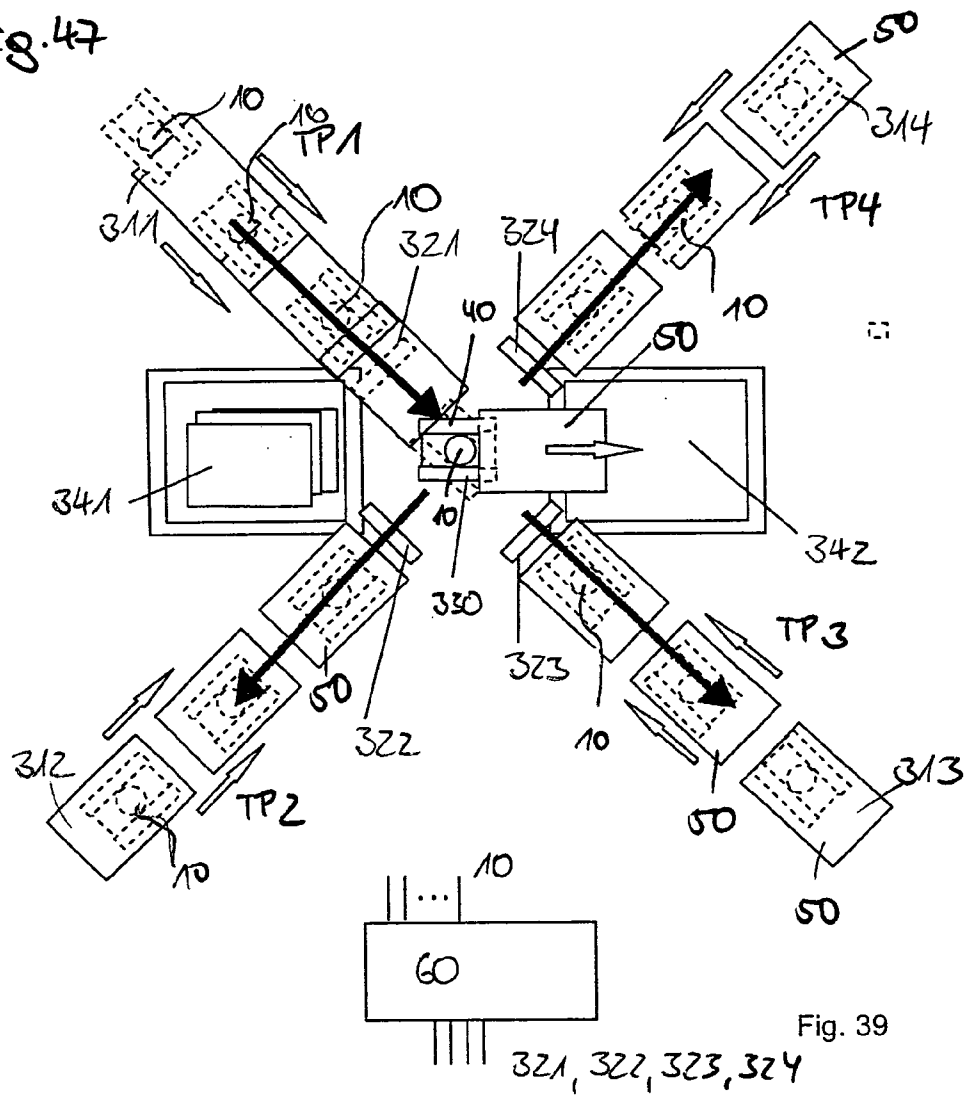


Fig. 47



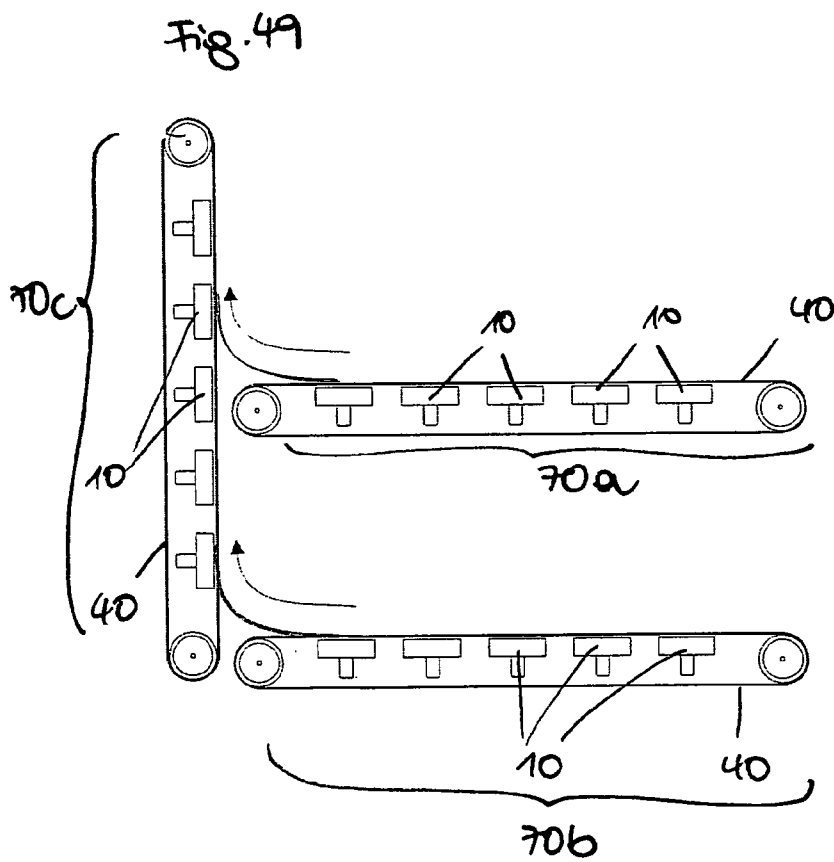
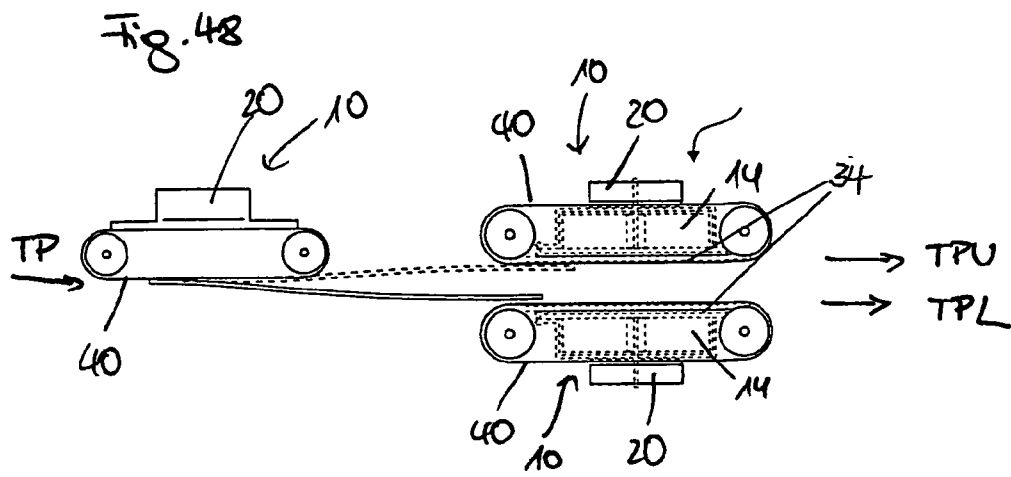


Fig. 30

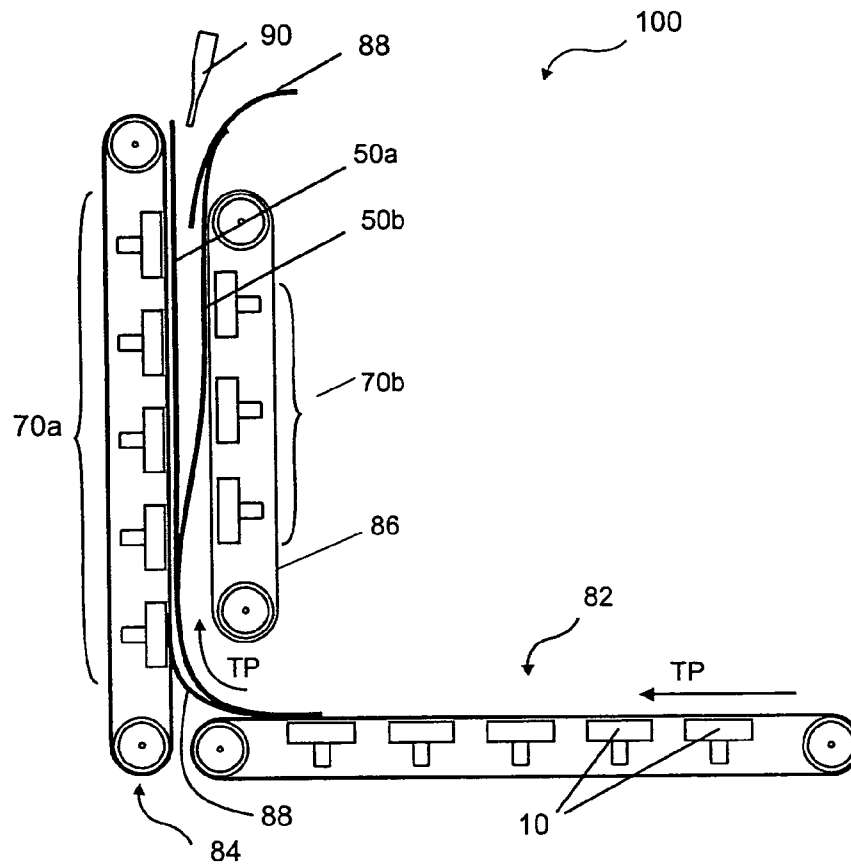


Fig. 51

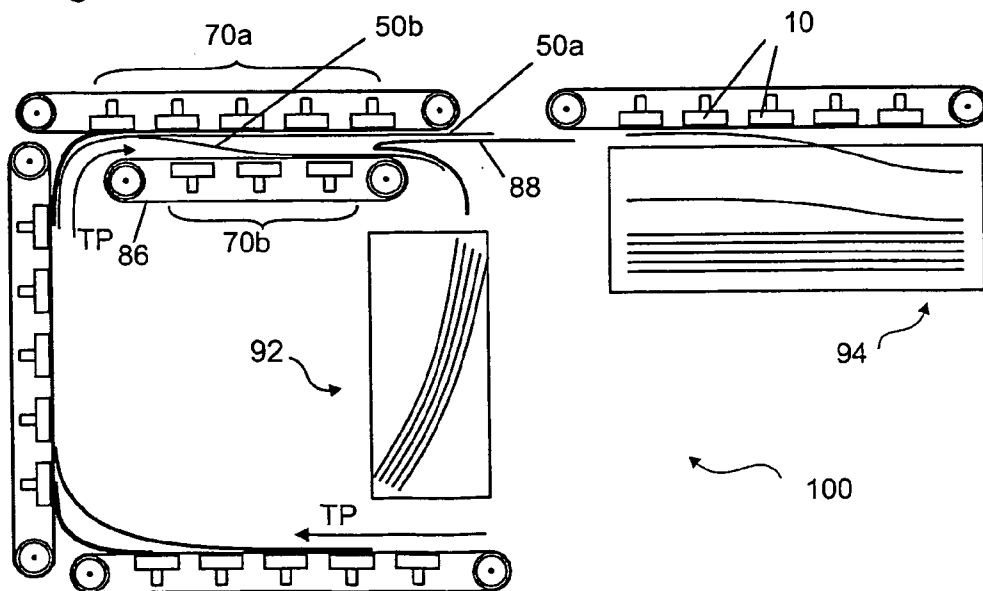


Fig. 52

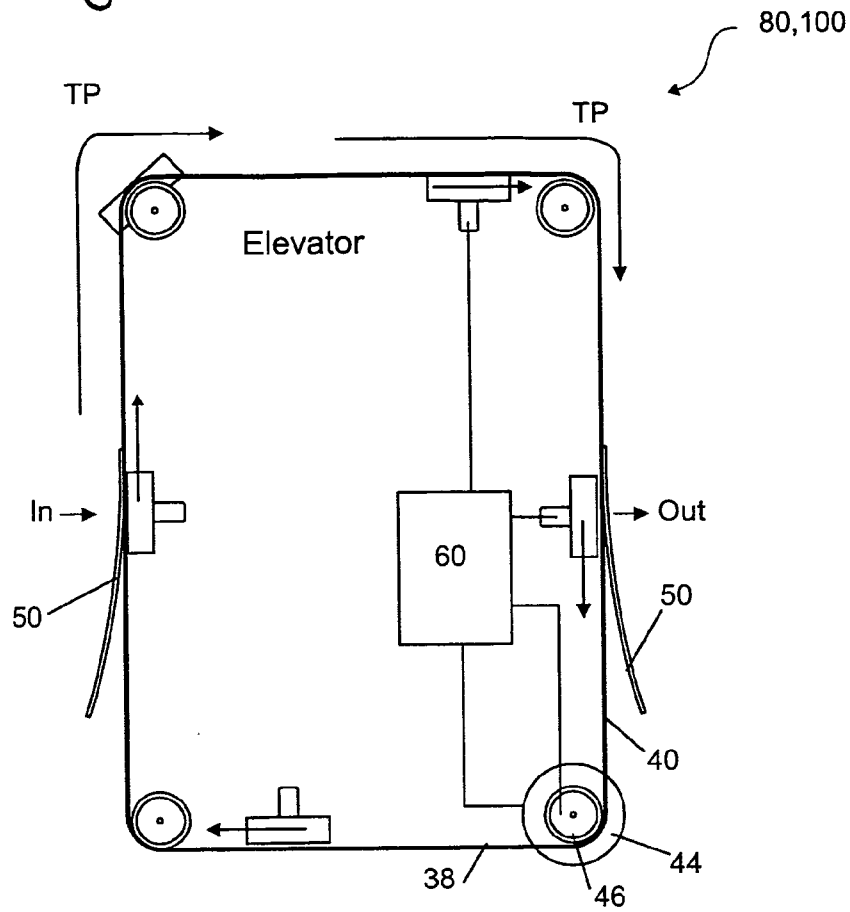


Fig. 53

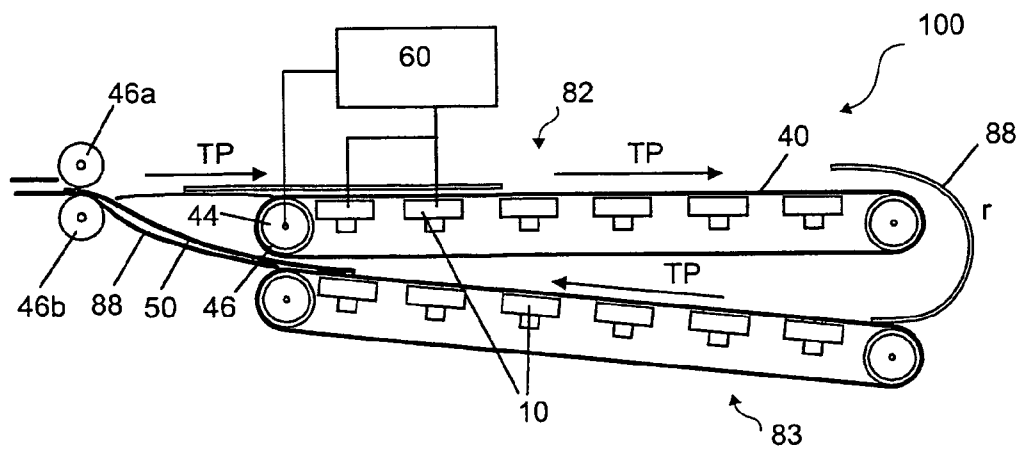


Fig. 54

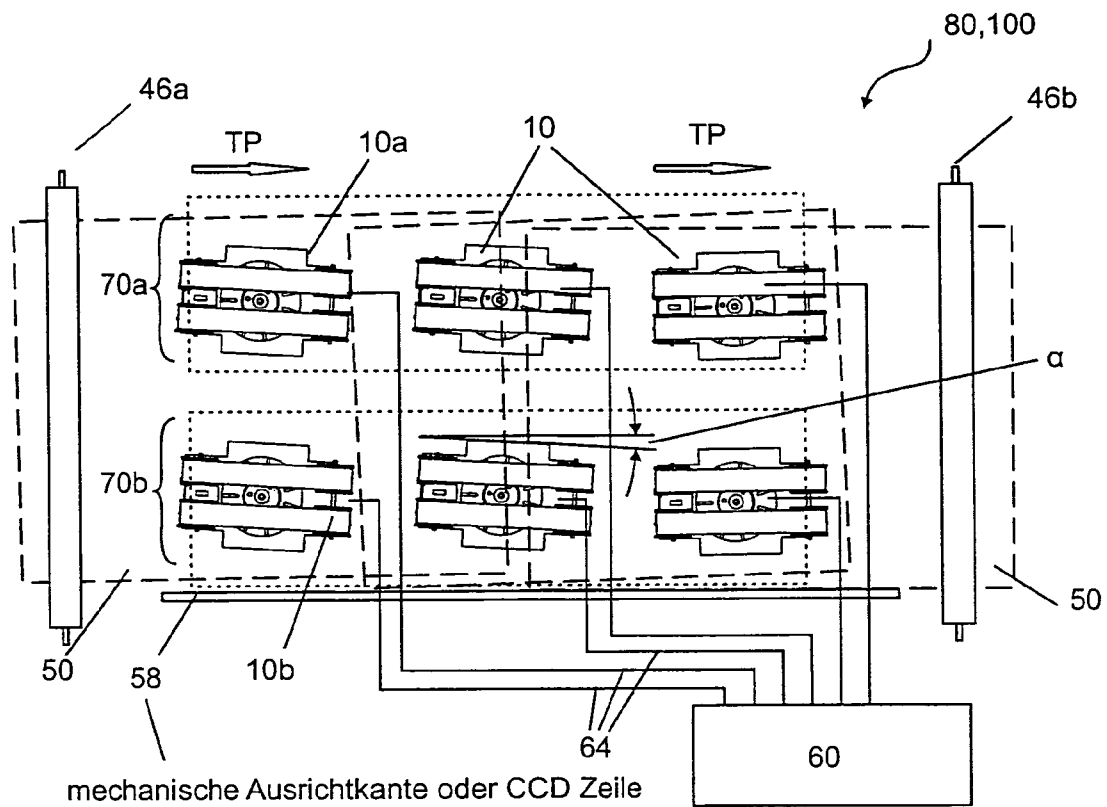


Fig. 55

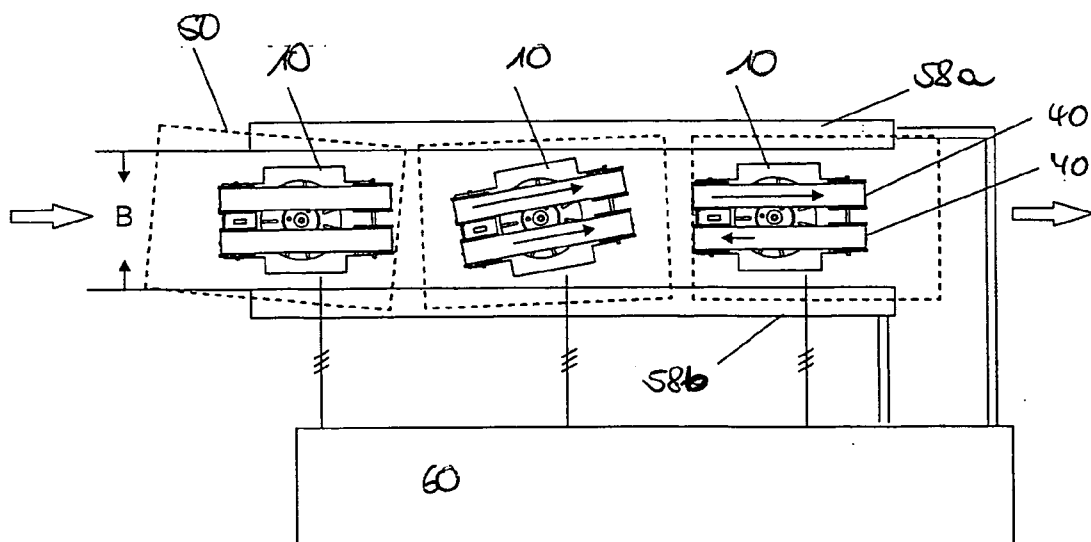


Fig. 57

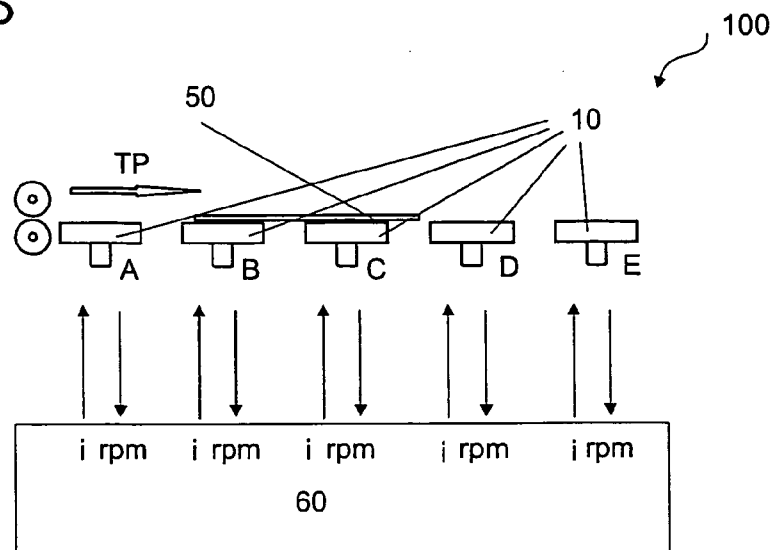


Fig. 58

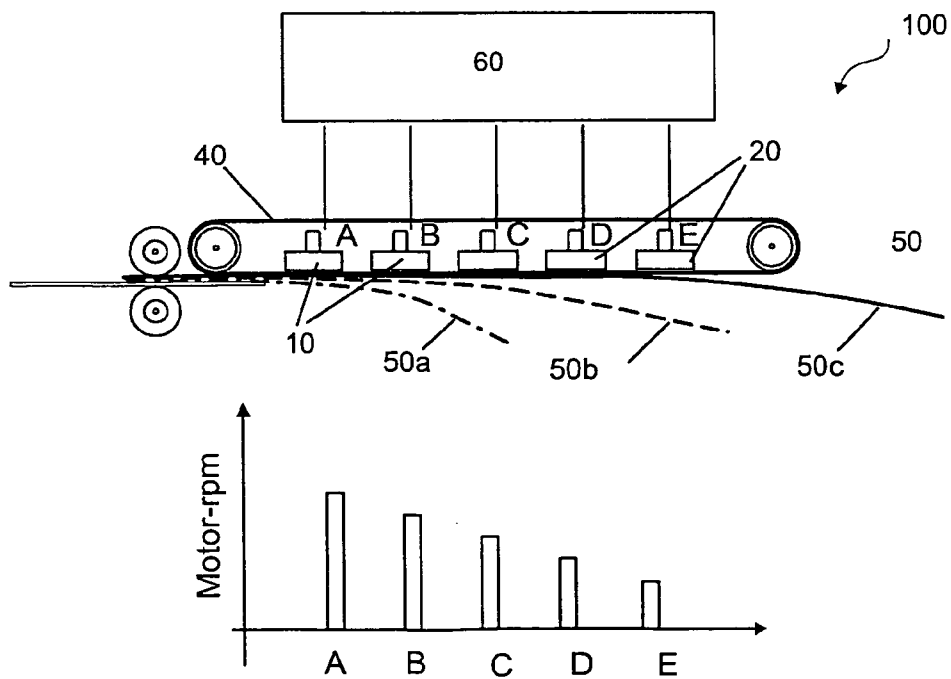


Fig. 59

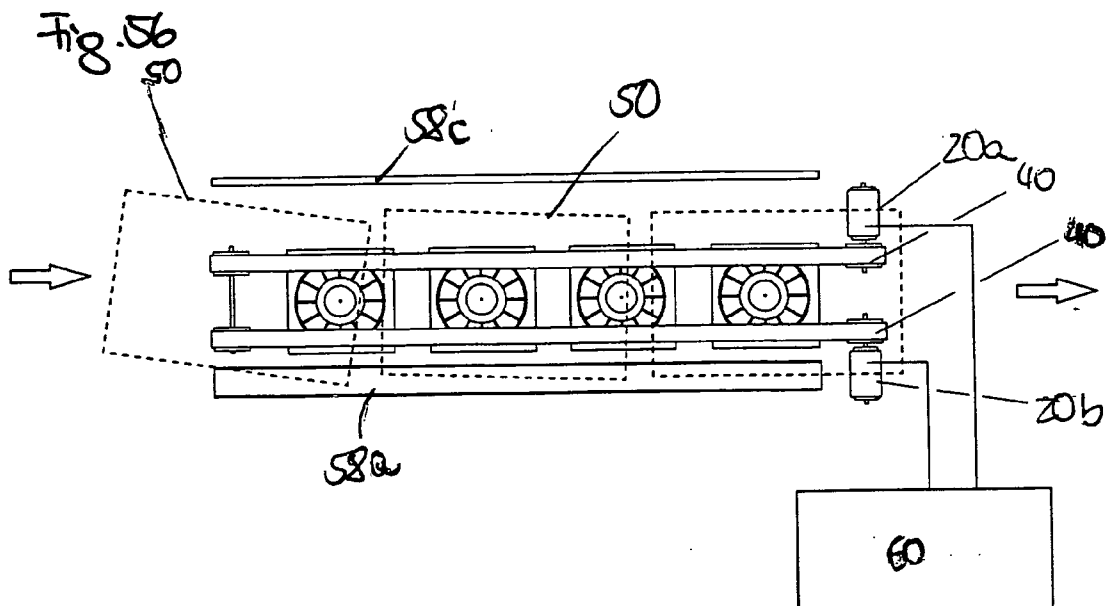
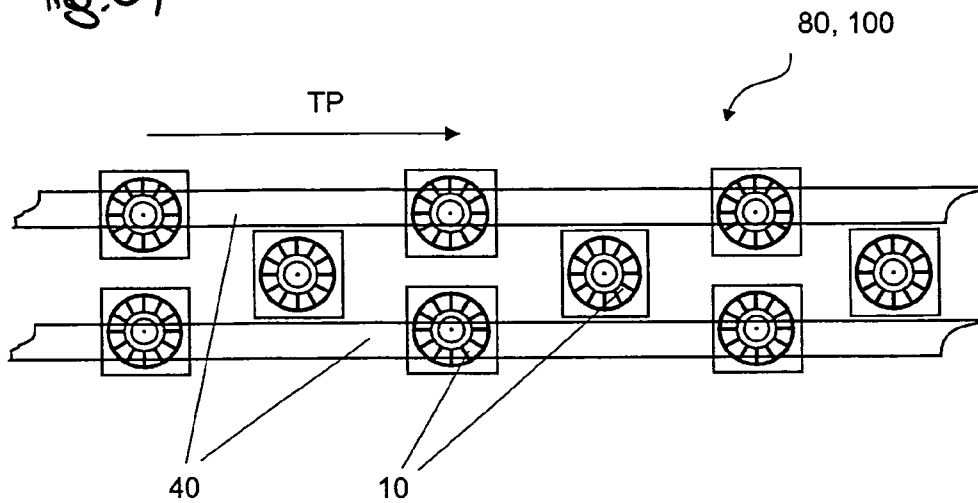


Fig. 60a

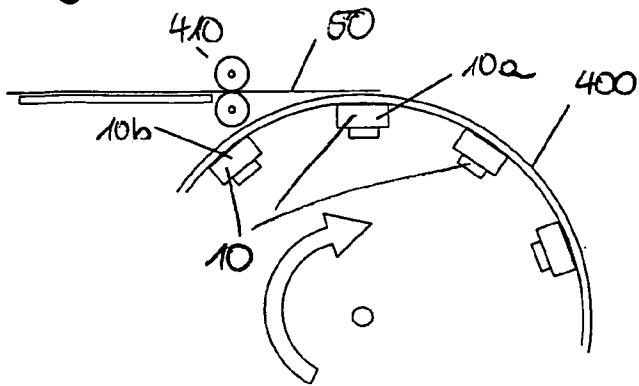


Fig. 60b

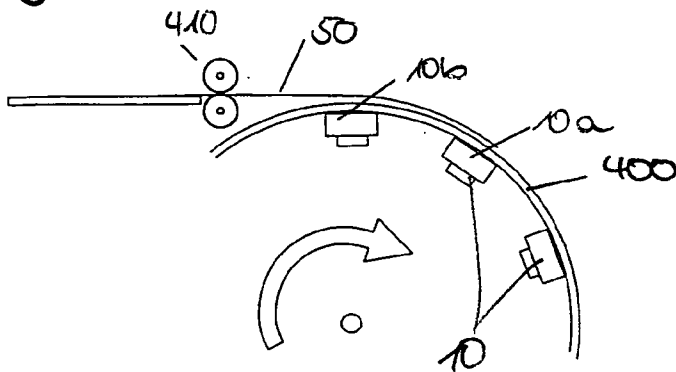


Fig. 61

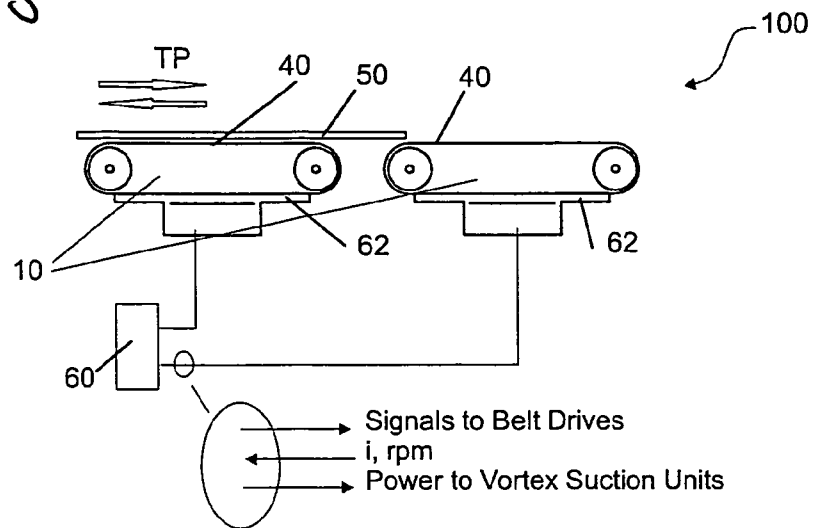


Fig. 62

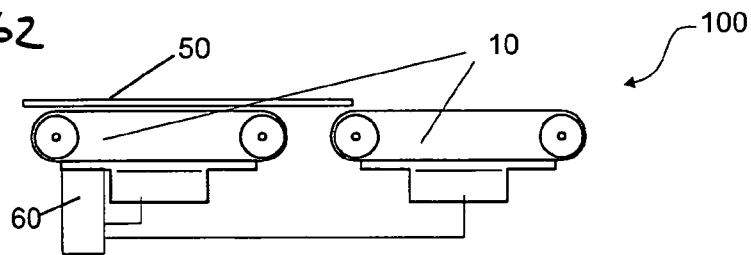


Fig. 63

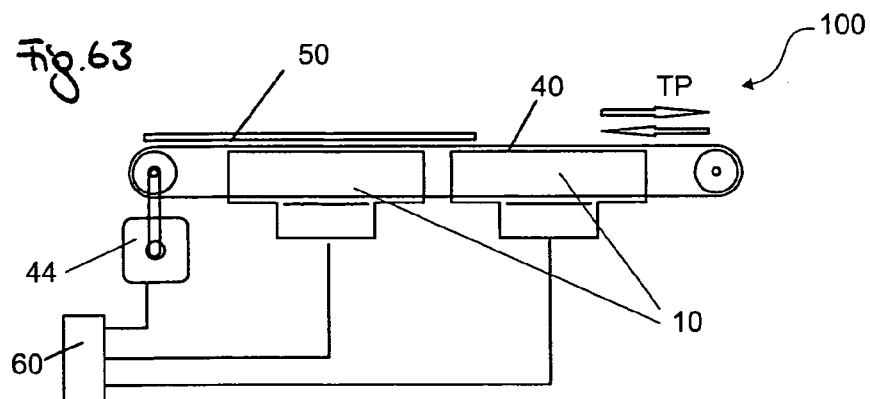


Fig. 64

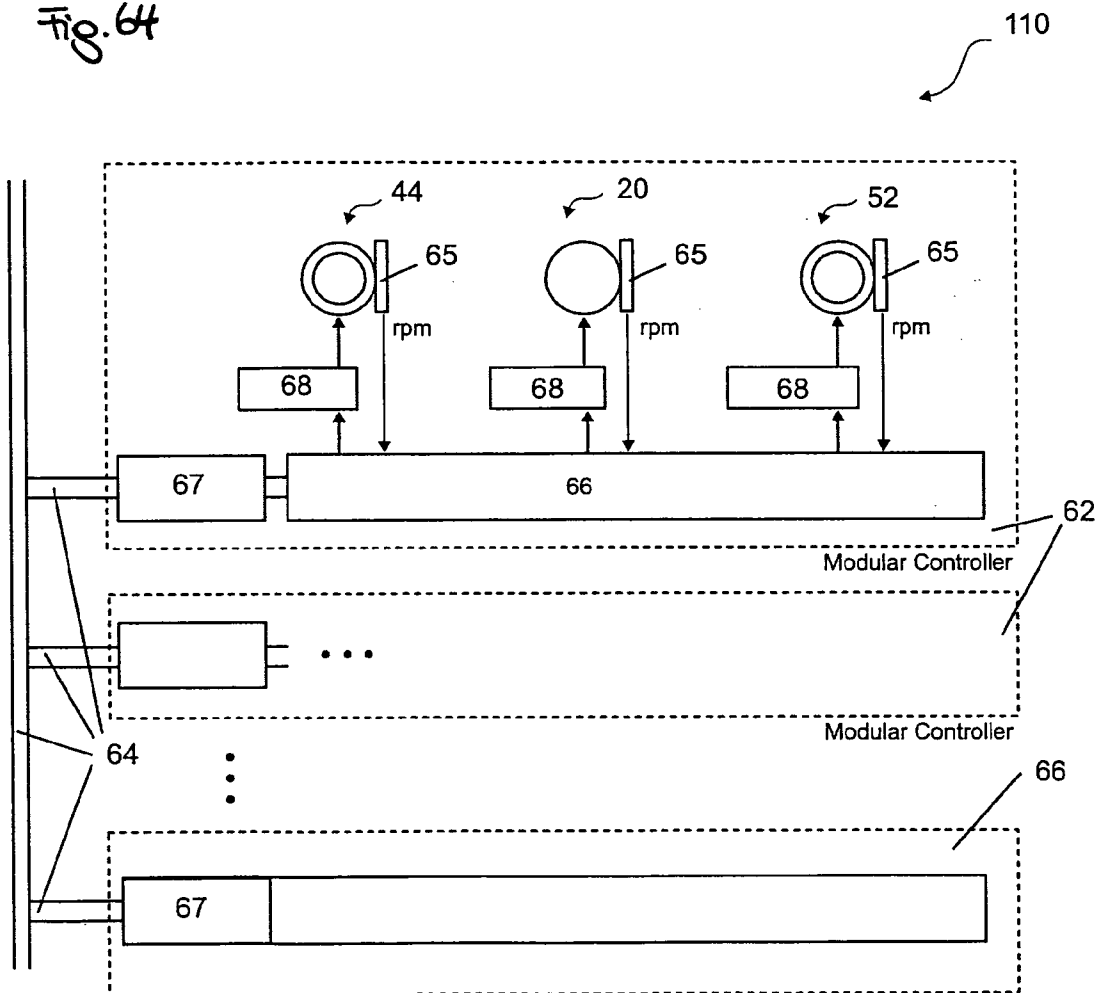
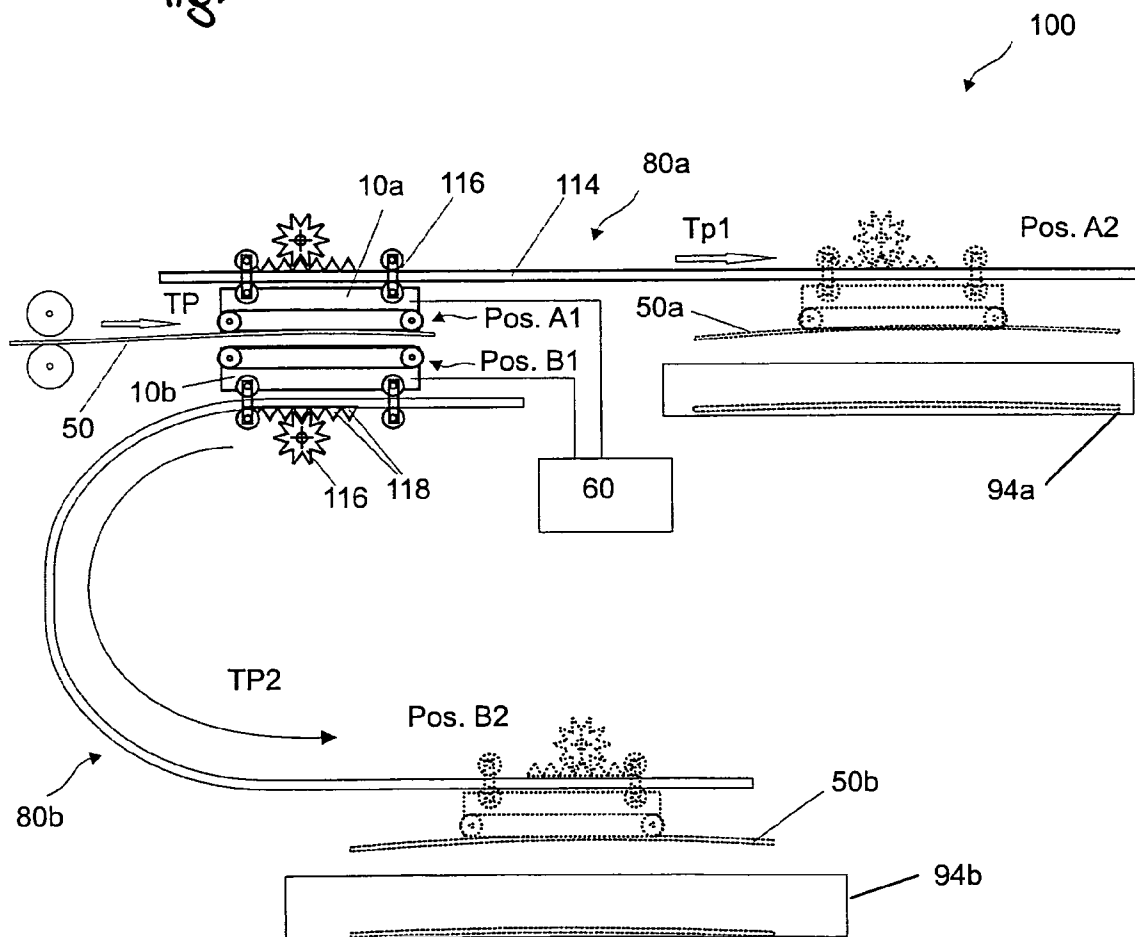
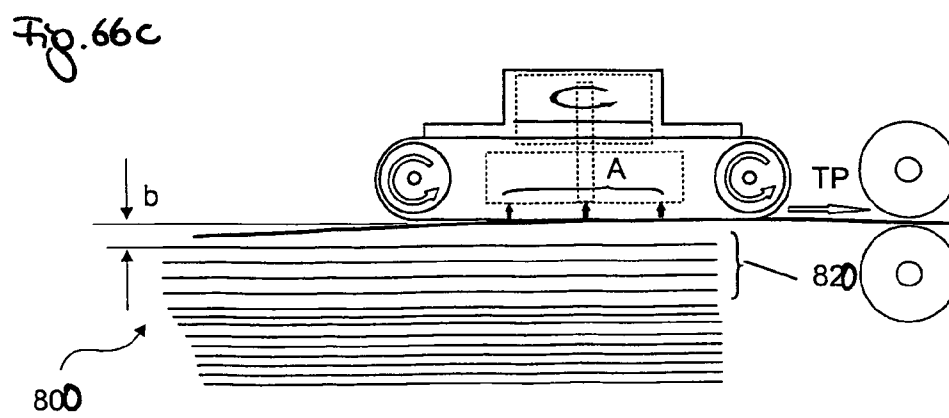
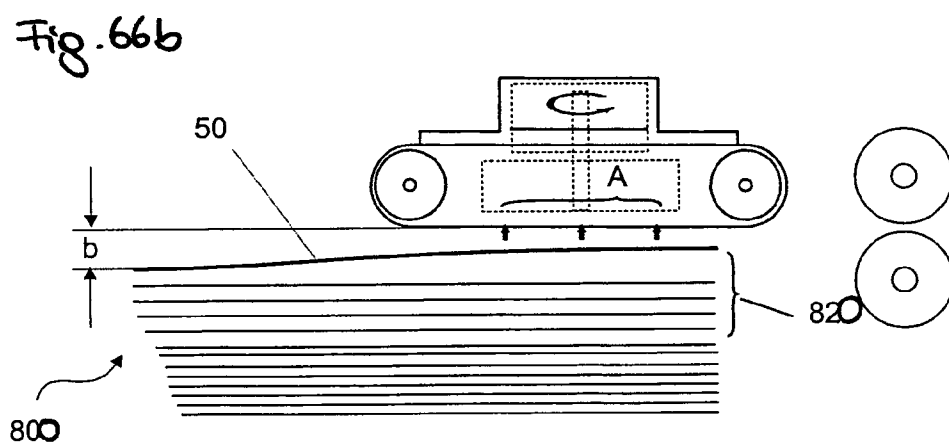
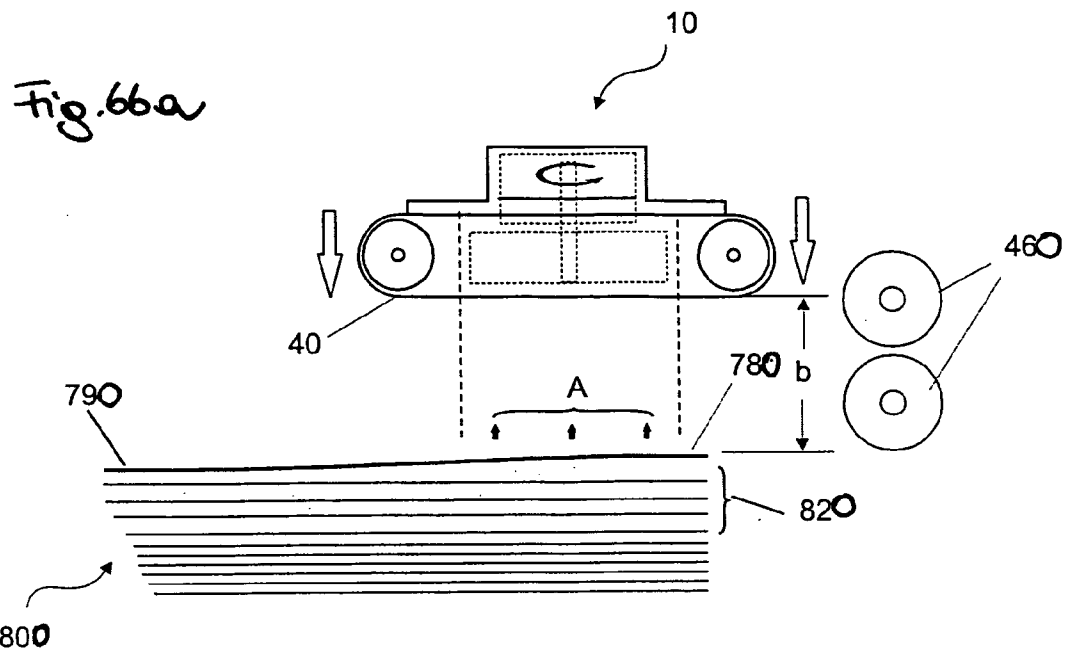


Fig. 65





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Fig. 67a

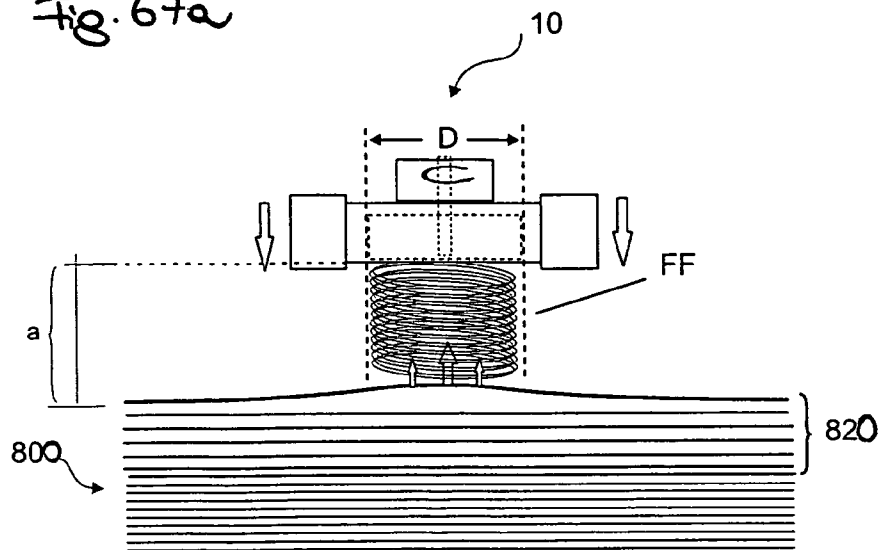


Fig. 67b

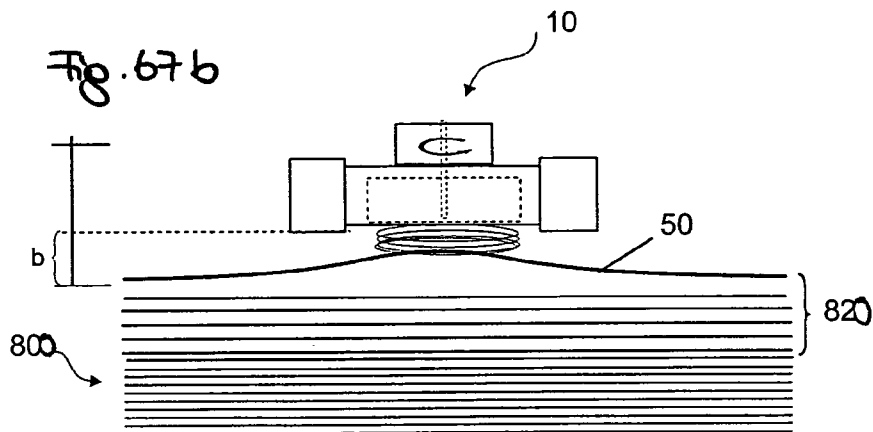
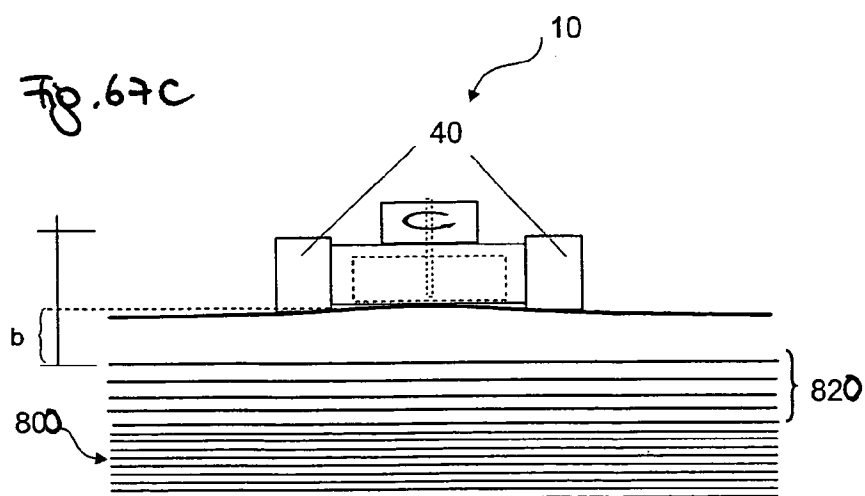


Fig. 67c



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Fig. 68a

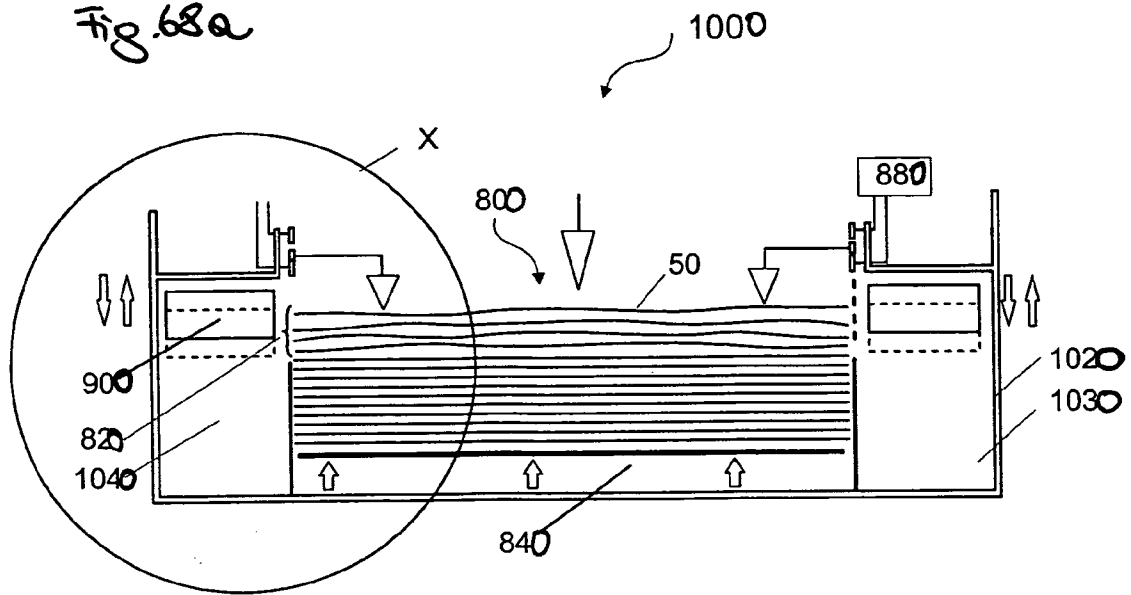
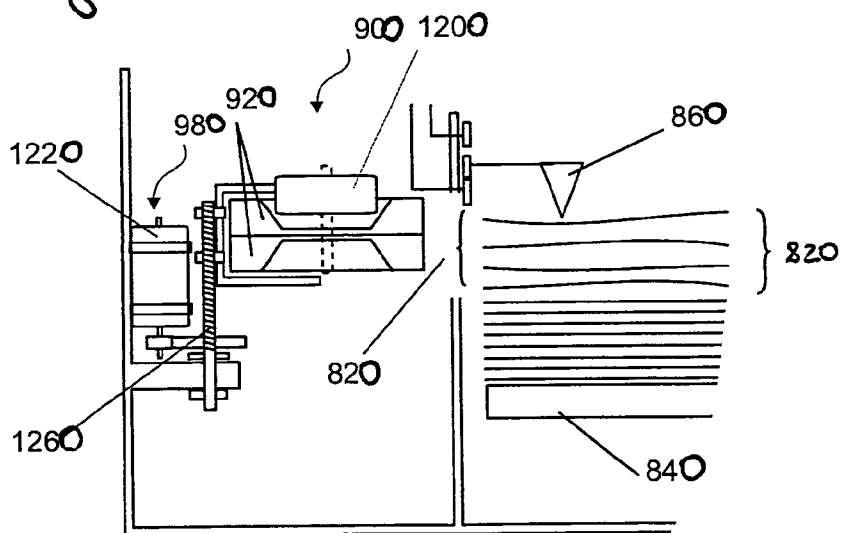


Fig. 68b



Detail X

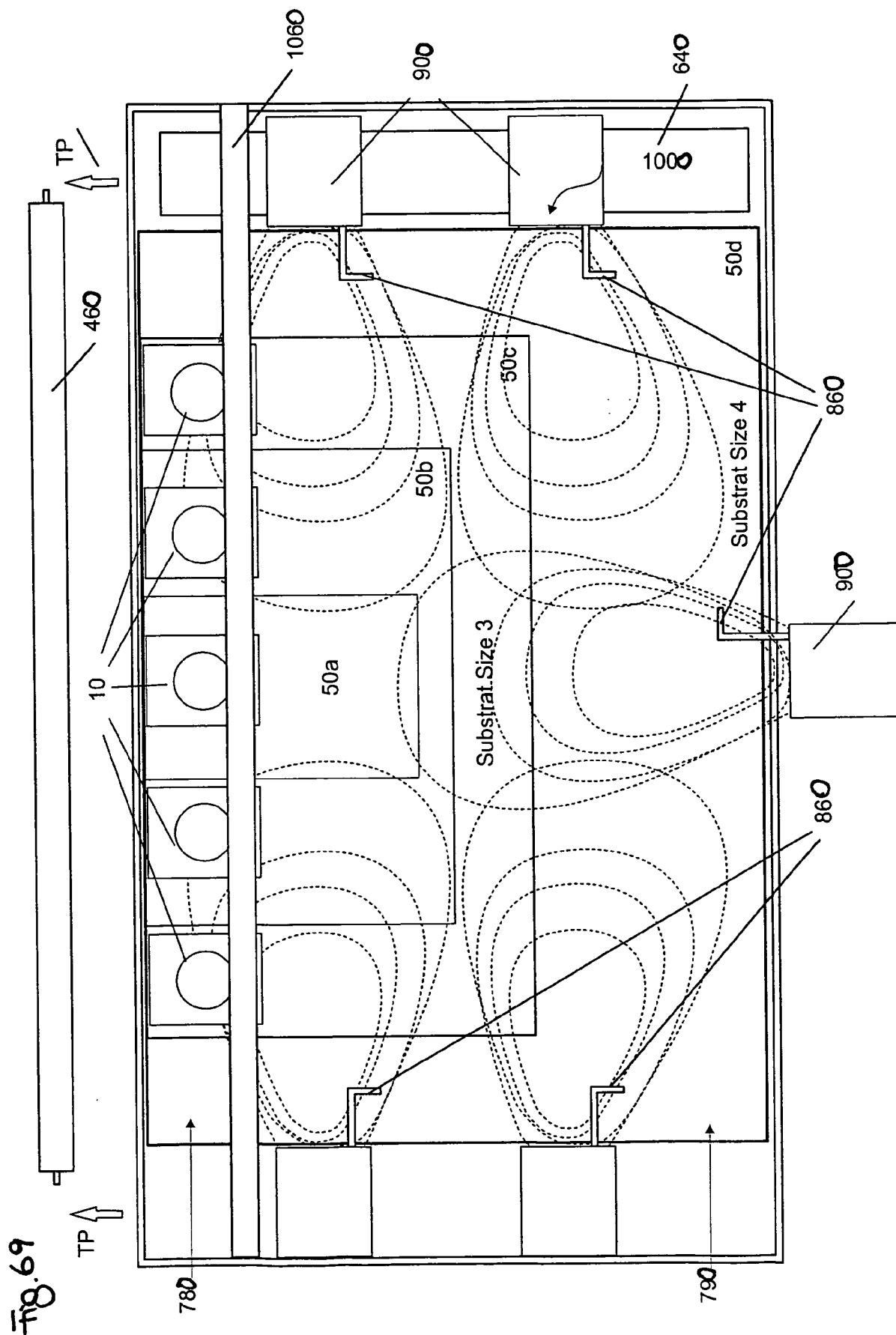


Fig. 70a

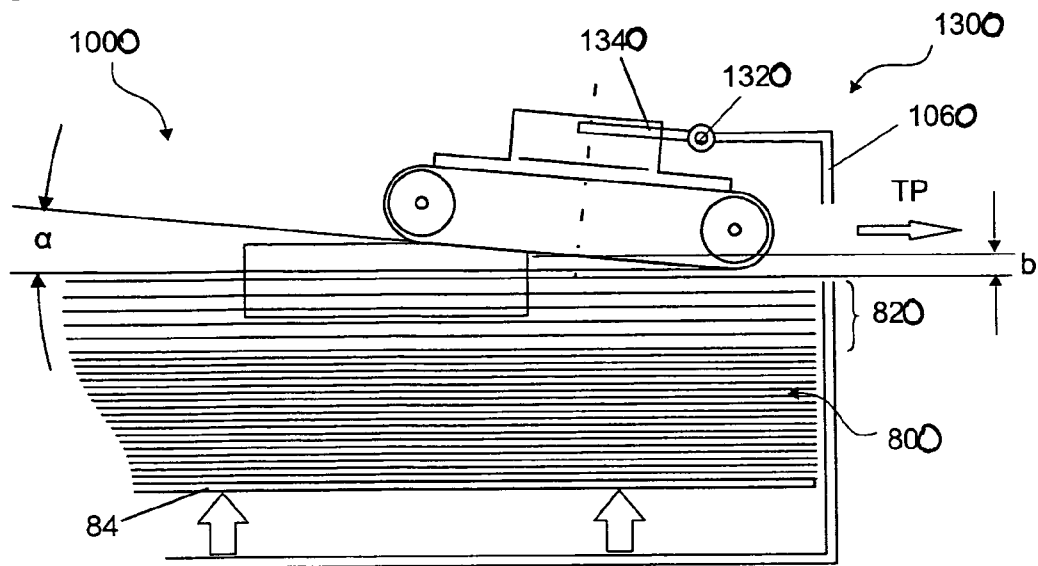


Fig. 70b

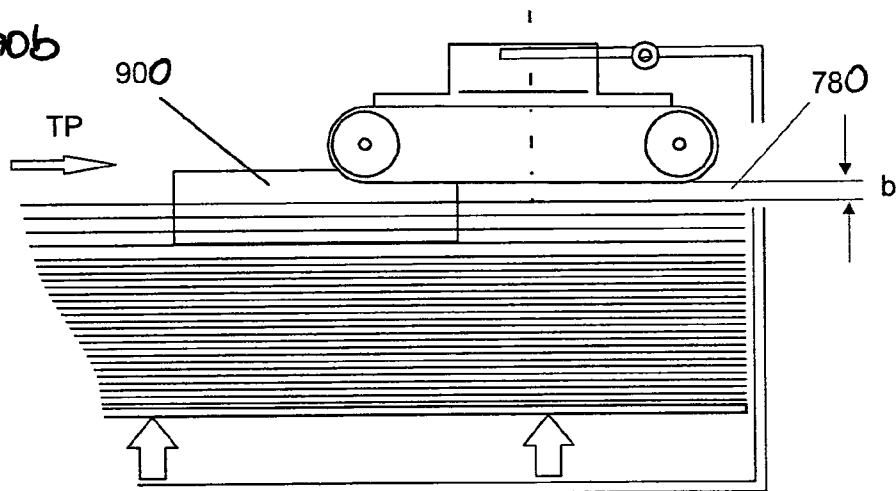
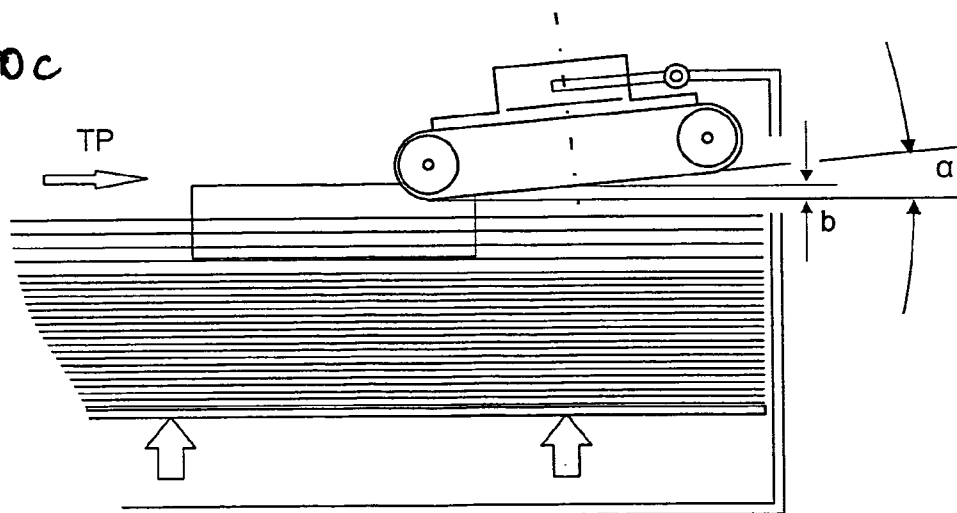
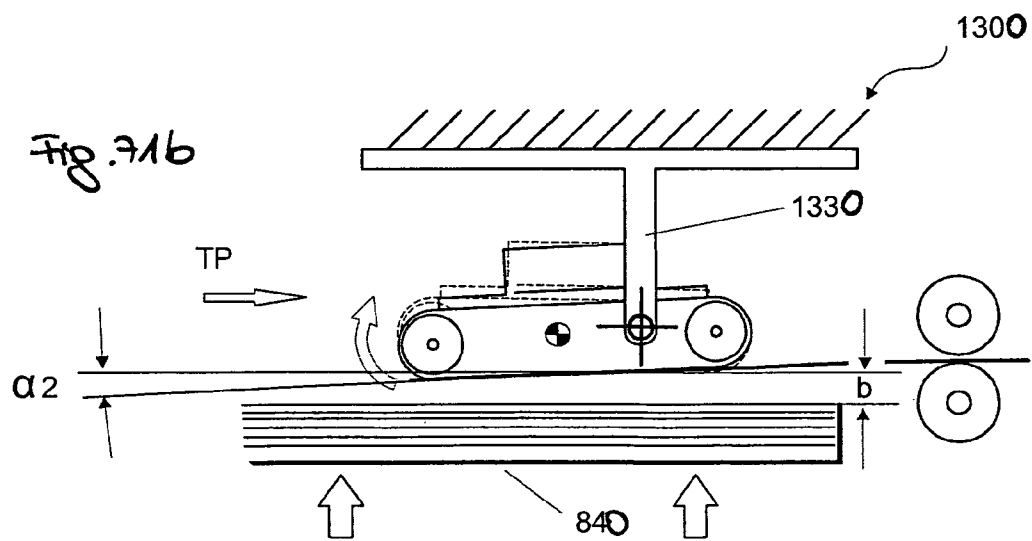
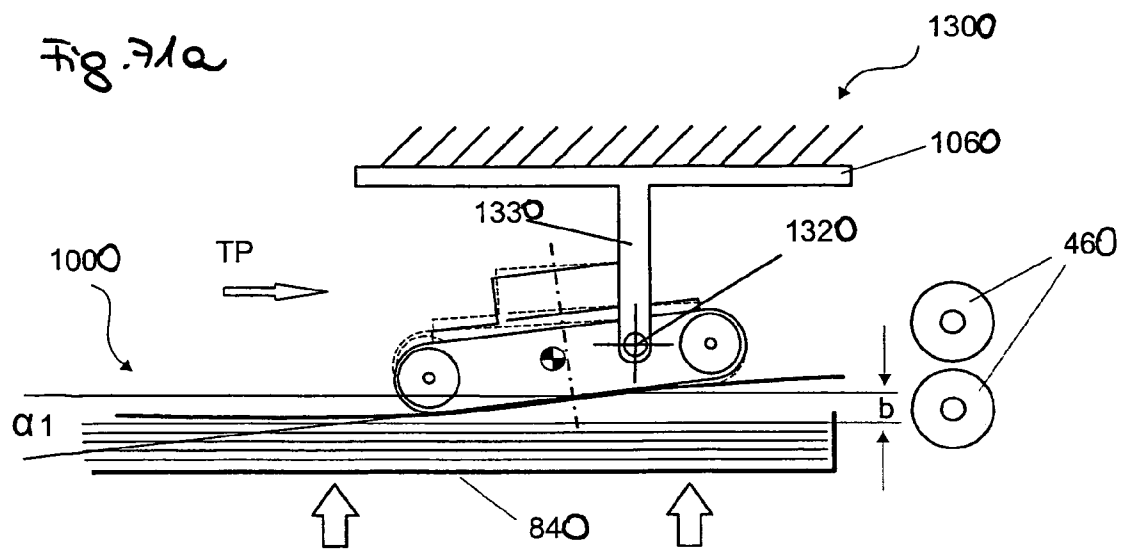


Fig. 70c





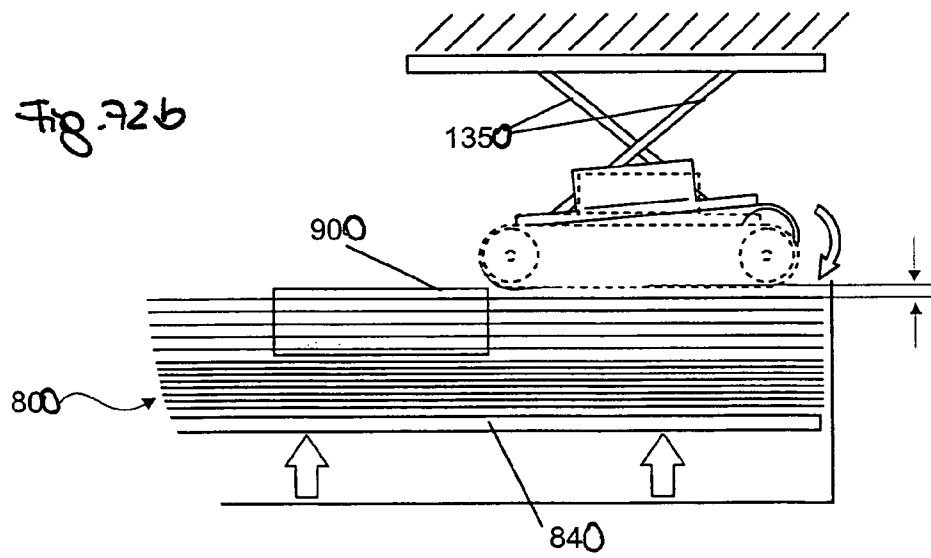
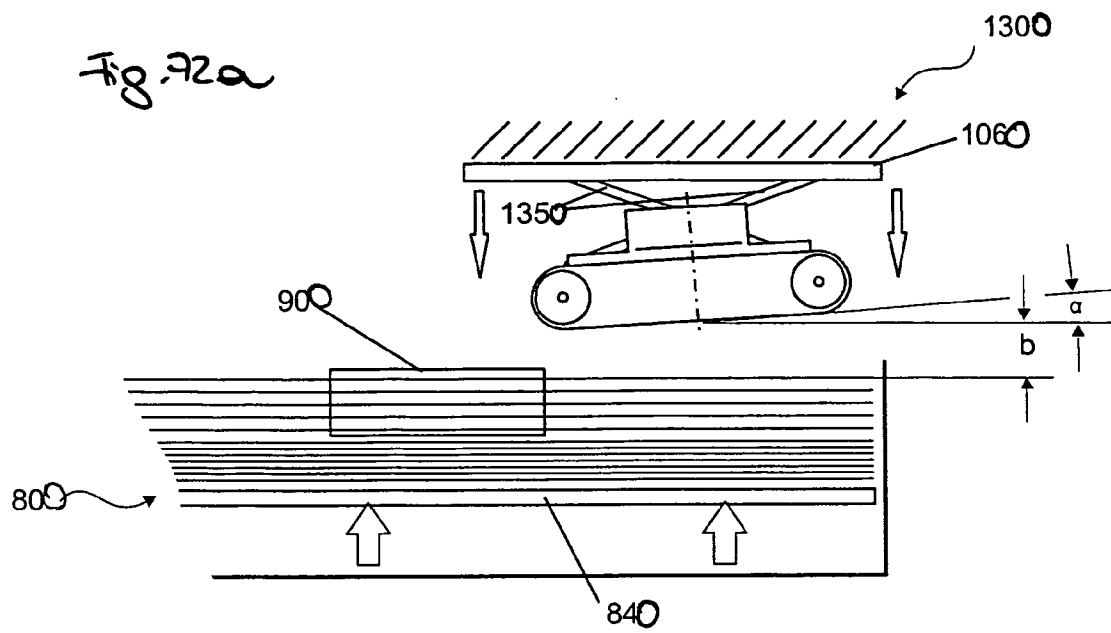


Fig. 73a

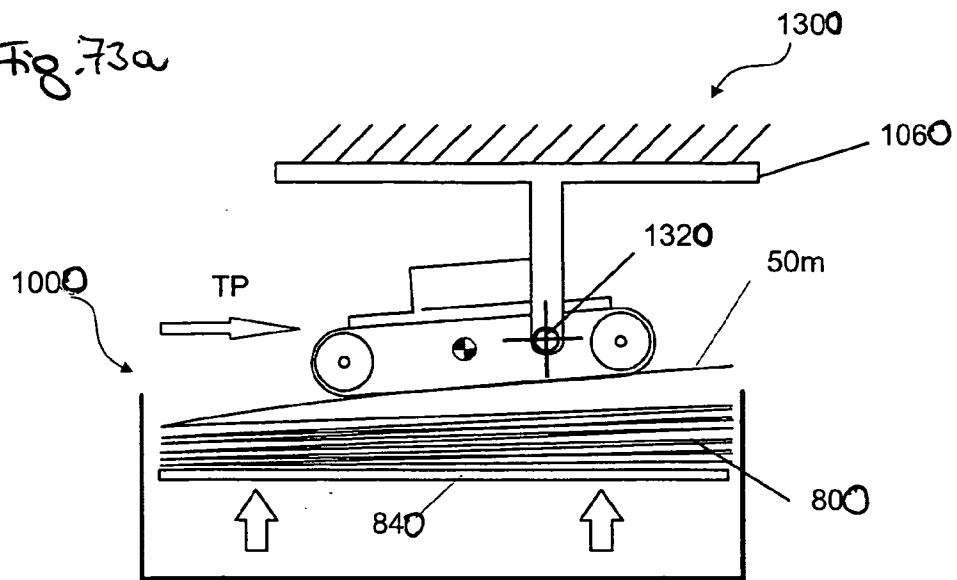


Fig. 73b

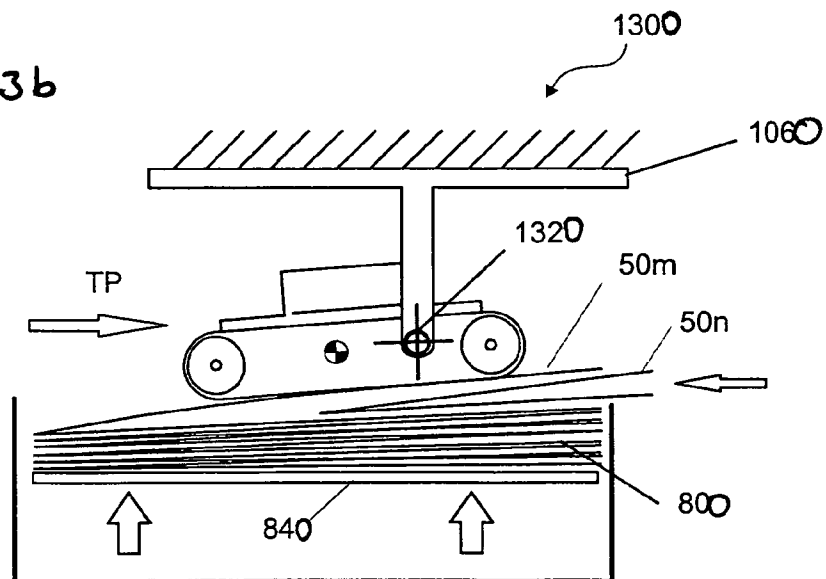


Fig. 73c

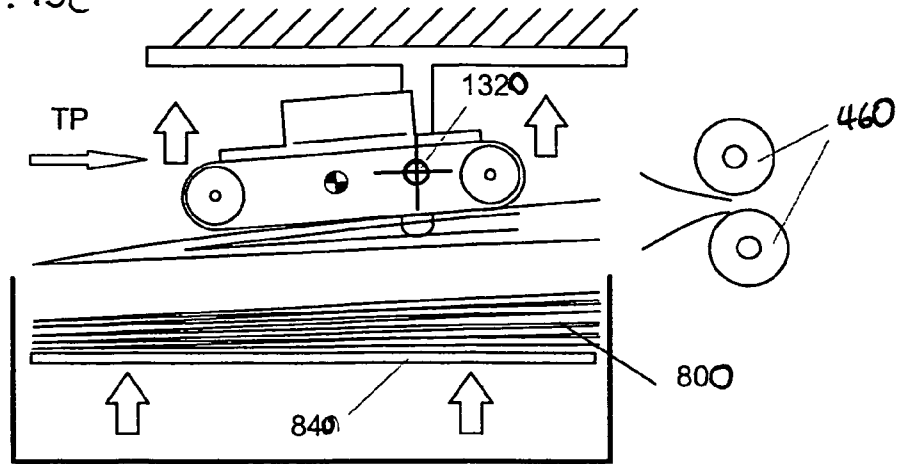


Fig. 73d

