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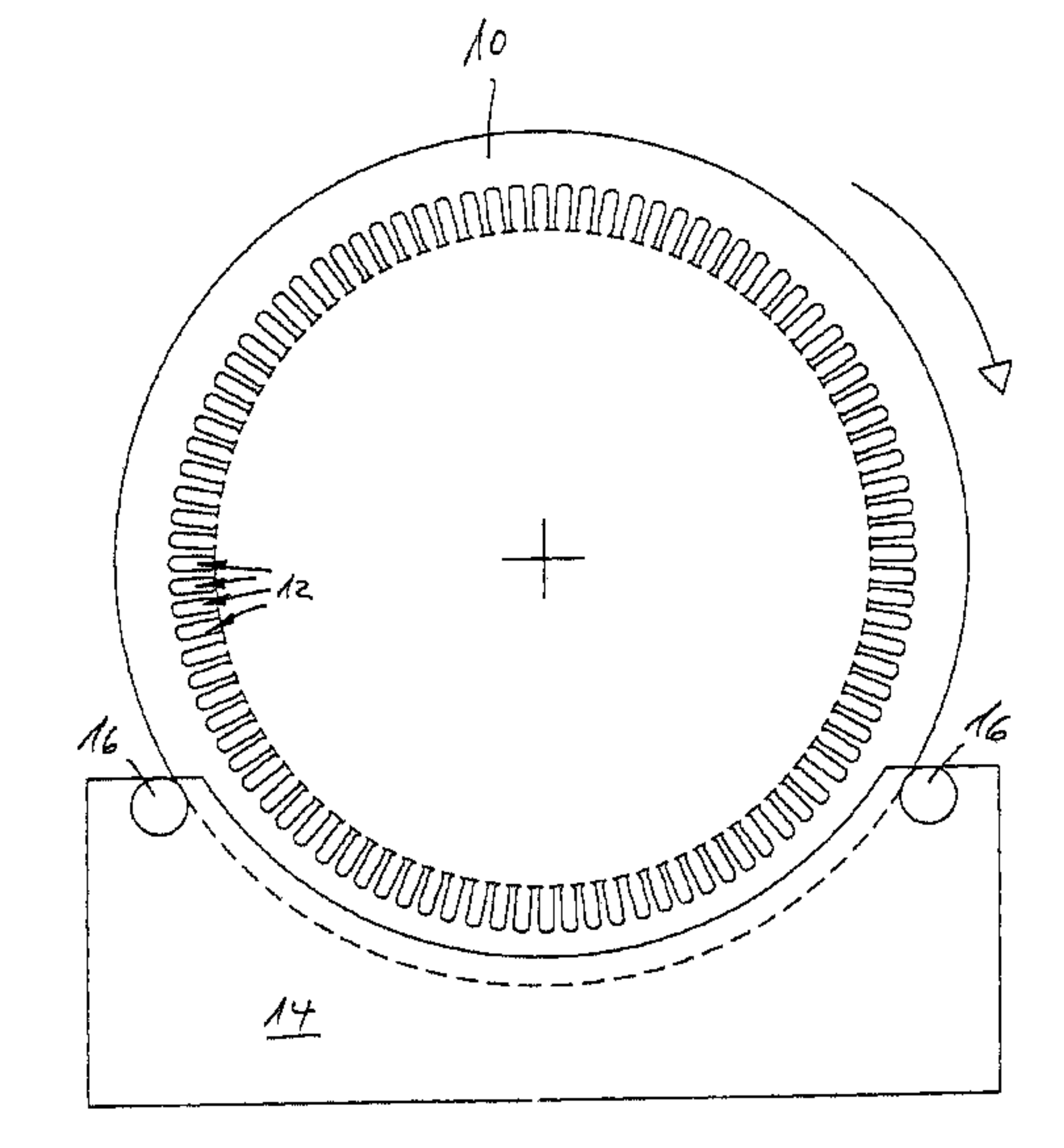
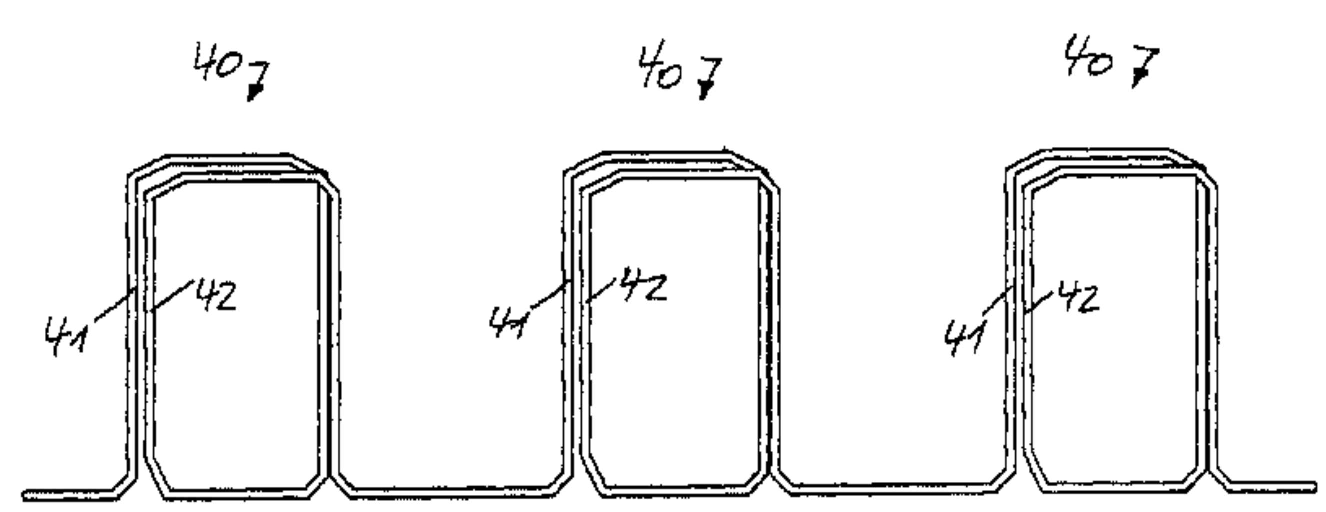
(54) Titre : INSTALLATION D'ENERGIE EOLIENNE A GENERATRICE ANNULAIRE
(54) Title: WIND-ENERGY INSTALLATION COMPRISING A RING GENERATOR





(57) Abrégé/Abstract:
The invention relates to a wind-energy installation comprising a (ring) generator with a stator. Said stator is provided with grooves, spaced at intervals on the internal or external periphery, for receiving a stator winding. The aim of the invention is to produce a stator with a winding, whose susceptibility to interference caused by the high load on the generator is at least reduced. To achieve this, the stator winding is wound in a continuous manner without interruption.

Abstract

The present invention concerns a wind power installation having a (ring) generator which has a stator in which grooves are provided at the inner or outer periphery in mutually spaced relationship to receive a stator winding. In order to provide a stator having a winding, in which the susceptibility to trouble as a consequence of the high loading on the generator is substantially reduced, the stator winding is wound without interruption continuously throughout.

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Wind power installation with ring generator

The present invention concerns a wind power installation having a generator which has a stator in which grooves are provided at the inner or outer periphery in mutually spaced relationship to receive a stator winding. Such wind power installations are known and are produced and marketed for example by ENERCON.

A known process for the production of stator windings in generators includes the use of what are referred to as former-wound coils. Those former-wound coils are individual windings of the stator winding, which are already adapted in respect of their form to the grooves and groove spacings of the stator and which are firstly individually inserted into the grooves and then connected together.

It will be appreciated however that wind power installations are always exposed to high levels of loading during operation thereof. With an increasing wind speed the power output of the wind power installation increases but at the same time the mechanical loading also rises. That means that the stress on the wind power installation increases substantially simultaneously, from the mechanical and the electrical point of view. At high wind speeds the mechanical stress on the installation is high and at the same time a great deal of electrical power is generated so that the stress on the electrical components is also high.

In that situation, the generator of the wind power installation, which is subjected to mechanical and electrical stresses, is particularly stressed. That combination gives rise to problems if for example, as a consequence of high electric currents generated, the temperature in the region of the generator is also high and, as a consequence of mechanical stress, connections between individual components are subjected to the effect of vibration. If thermal expansion also gives rise to a small amount of play or a loosening effect, the mechanical loadings can here result in a defect or even damage.

If that trouble involves the stator winding or a phase thereof, at least that phase is out of commission in terms of energy production. Furthermore this involves an additional asymmetrical loading in the generator as, as a consequence of the interruption, that phase acts as in the no-load mode of operation. In that respect mechanical damage due to released and freely movable components such as connecting sleeves is not even taken into consideration.

In the case of a stator, wound in six-phase configuration, of a generator with 72 poles, there are 432 former-wound coils which are connected together by 864 connecting locations. Those connecting locations are usually in the form of screw, clamping or solder connections.

Having regard to statistical probabilities (of no matter how small magnitude), the high number of connecting locations and the permanent changes in load mean that, even if the connection between the former-wound coils is carefully made, this involves a serious source of trouble. In that respect only one stator is taken into account in the foregoing considerations. The aspect of mass production clearly reveals the actual probability of such a problem occurring.

Therefore the object of the present invention is to provide a stator having a winding, in which the above-discussed problems are substantially reduced.

In a wind power installation of the kind set forth in the opening part of this specification, that object is attained by a stator winding which is of a continuous nature throughout. That arrangement avoids in particular connecting means between individual portions of a stator winding.

In a preferred embodiment of the invention all phases are respectively wound continuously throughout on the stator.

In order to be able to compensate for current-displacement effects in the individual turns, the turns are produced from at least two conductor bundles, wherein a plurality of mutually insulated conductors is present in each conductor bundle. Those conductor bundles are introduced into grooves in the stator in a predetermined sequence and the sequence is altered at also predetermined spacings so that each of the conductor bundles is alternately affected as uniformly as possible by those effects. It is possible to forego compensation measures by virtue of that uniform influence in respect of all conductor bundles of a phase.

In order to facilitate handling of the stator during production of the winding and to provide a situation which is favourable in work-physiological terms, the stator is kept in a mounting apparatus in which the grooves are at a favourable working height for production of the winding and which permits rotation of the stator in the peripheral direction by a desired amount. This can preferably be effected using a motor drive.

In a particularly preferred development of the invention there is further provided at least one carrier apparatus for carrying at least one coil with winding wire. That carrier apparatus makes it possible to handle the winding wire, for example in the form of conductor bundles, the length of which, in accordance with the invention, is such that the phase can be wound continuously throughout on the stator. The conductor bundle length required for that purpose results in a considerable weight which can no longer be handled manually.

In a particularly preferred embodiment two respective drums with winding wire are handled in pairs in order in that way to be able to handle both conductor bundles at the same time and a carrier apparatus carries three pairs of the drums with winding wire so that, using such a carrier apparatus, a three-phase system with two respective conductor bundles per phase can be wound on the stator.

In a particularly preferred development of the invention the drums with the winding wire are arranged pivotably about a central axis of rotation of the carrier apparatus. That arrangement makes it possible to compensate for twisting of the conductor bundles, which arises out of the rotation of the stator in the holding apparatus, by virtue of the drums being correspondingly rotationally entrained on the carrier apparatuses.

Further advantageous embodiments of the invention are set forth in the appendant claims.

The invention is described in greater detail hereinafter with reference to the drawings in which:

Figure 1 is a simplified view of a stator of a ring generator in a holding apparatus,

Figure 2 is a view in cross-section through a conductor bundle,

Figure 3a shows a part of the stator grooves according to the invention with inserted conductor bundles,

Figure 3b shows a part of the stator grooves according to the invention (alternative) with inserted conductor bundles,

Figure 3c shows a known structure of a stator winding,

Figure 3d shows a structure according to the invention of a stator winding,

Figure 4 is a simplified side view of the carrier apparatus according to the invention,

Figure 5 is a front view of a carrier apparatus, and

Figure 6 shows the arrangement of carrier apparatuses and stator for the production of a stator winding according to the invention.

In Figure 1 reference numeral 10 denotes the stator which has grooves 12 extending in the axial direction at the inner periphery. That is the most frequent structural configuration of a generator. The rotor (not shown) is within the stator 10. That structural configuration is referred to as an internal rotor. Alternatively, in the case of a so-called external rotor in which the rotor encloses the stator 10, the grooves 12 can be provided at the outer periphery of the stator. The grooves 12 are shown on an enlarged scale in the Figure. The stator 10 is held in a holding apparatus 14 which stands on the ground and thus holds the stator 10 and in particular the grooves 12 at a height which forms a working position which is favourable in terms of working physiology.

As such a stator 10 of a ring generator is of a diameter of several metres and accordingly is high in weight, the stator 10 is supported rotatably on rotary mountings 16 and can be rotated for example in the direction of the arrow by a desired amount in order to move the grooves 12 to be worked upon, into a desired position. It will be appreciated that this rotary movement of the stator 10 can also be produced by using a drive motor (not shown).

Figure 2 shows a conductor bundle 20 comprising a plurality of individual conductors 22 which are fitted in the form of a bundle into the grooves (reference 12 in Figure 1). In this case the individual conductors 22 are insulated in relation to each other by a coating.

Forming conductor bundles 20 from individual conductors 22 has the advantage that those conductor bundles are not fixed in respect of their cross-sectional shape but are variable so that on the one hand they can be passed through a relatively narrow groove opening but on the other hand, by virtue of suitable deformation, they can fill the wider groove cross-section to the greatest possible extent in order to achieve a good filling factor for the groove (reference 12 in Figure 1).

Figure 3a shows an unwound section of the inner periphery of the stator 10. Here, the grooves 12 are arranged horizontally one beside the other. Fitted into the grooves 12 are the conductor bundles which are shown here in simplified form as circular conductor bundles 20. Each two of those conductor bundles 20 are combined to form a turn of a phase. This is shown in the Figure by arms 24 which connect a respective pair of the conductor bundles 20. Accordingly as shown in this Figure, two turns of a phase are inserted into each groove. For greater ease of viewing the drawing, the individual conductor bundles are numbered by figures 1 - 4 in an upward direction. In order to distinguish the individual phases of the six-phase system illustrated here, they are identified by the identifications P1 - P6 beneath the groove.

It will be clearly seen from the Figure that the conductor bundles 1 and 2 always form the first turn while the conductor bundles 3 and 4 always form the second turn which is inserted into the corresponding groove 12.

Beginning by looking at the left in Figure 3a, the phases P1 - P6 are shown in mutually juxtaposed relationship in a rising sequence and the succession of the conductor bundles is specified by references 4, 3, 2, 1. After the groove 12 with the phase P6, that phase sequence is repeated again beginning with P1. In the second groove 12 with the phase P5 illustrated in this Figure the sequence of the conductor bundles 20 is now altered. The first turn arranged in the groove 12 at the bottom thereof admittedly still consists of the conductor bundles 1 and 2, but they are now interchanged in their sequence. Equally, the second turn still consists of the conductor bundles 20 identified at 3 and 4 but the sequence thereof is also interchanged. The phase P6 arranged therebeside again involves the succession of conductor bundles, which is already known.

The phases P1 - P6 are shown once again in the right-hand part of this Figure. In addition to the interchange of the conductor bundles 20 of the phase P5, which are identified by 1 and 2, and 3 and 4 respectively, in this case the conductor bundles of the phase P3 are also shown as being interchanged. It will be appreciated that, in this case also, the conductor bundles 20 identified by 1 and 2 form the first turn and the conductor bundles identified by 3 and 4 form the second turn of that phase, but it will be appreciated that within the turn, the position of the conductor bundles is again interchanged.

The reason for this interchange will be apparent if it is realised that the magnetic field lines extend not only in the longitudinal direction of the limbs 26 laterally delimiting the grooves 12, but also through the grooves between two limbs 26 of differing polarities. That results in a skin or current-displacement effect in the individual conductor bundles 20 in dependence on the position thereof in the groove 12.

If now the position of the conductor bundles is interchanged at given spacings, both conductor bundles 20 of a turn are correspondingly alternately subjected to that effect so that, with a suitable choice in respect of the interchange position and the frequency thereof, both conductor bundles 20 of a phase are subjected approximately uniformly to that effect so that no serious compensating currents resulting from non-uniform action flow and thus the maximum possible current can be delivered by the generator.

Figure 3b therefore shows an illustration of the stator grooves with stator windings or stator conductors inserted therein, in which it can be seen that the stator grooves are very substantially filled with the windings and in which it is also possible to see the direction of current flow in the conductors (the arrow head and the arrow cross). In addition, the arrangement of the phases is altered in comparison with Figure 3a in order also better to show the change in the direction of winding. The view in Figure 3b however also makes it clear that more than 80% and preferably more than 95% of the total space of the stator groove is filled with windings and thus the proportion of air in the stator groove is extremely slight.

Figure 3c shows a part of a conventionally produced winding, although without illustrating the stator and the grooves in which the winding is inserted. In this case the winding is formed from former-wound coils 40 having two turns 41, 42. For the sake of improved clarity of the drawing those turns 41, 42 are shown in mutually displaced relationship. It will be appreciated that in the groove (not shown in this Figure), they are arranged exactly one over the other.

The Figure shows three former-wound coils 40 of a phase. The spacing arises out of the fact that arranged alternately between former-wound coils of this phase are former-wound coils of the other phases of the stator, but they are not shown in the Figure. The former-wound coils 40 of a phase can be connected to each other by solder connections or screw-clamp connections or similar devices.

Those connections which are shown in Figure 3c are potential sources of trouble.

Figure 3d shows the configuration according to the invention of a phase which is wound continuously throughout. In this case also, corresponding to the view in Figure 3b, the Figure again shows a part of the winding of a phase. In this case the individual turns 41, 42 are also shown in mutually displaced relationship in order clearly to show the nature of the design.

It can be seen immediately in this embodiment that the transitions illustrated as potential sources of trouble in Figure 3b are eliminated with this invention. Therefore, an interruption can no longer occur at the transitions between the individual winding portions.

Figure 4 shows a side view of a carrier apparatus 30 for the conductor bundles used as the winding wires. An L-shaped base frame 31 provides that the entire carrier apparatus 30 stands securely. A carrier plate 32 is connected to the base frame 31 by way of a rotary mounting 33. Fixed on the carrier plate 32 are carrier arms 34 which extend from the centre of the carrier plate 32 a predetermined distance towards the periphery of the carrier plate 32 and which extend substantially horizontally away from the carrier plate 32 by a predetermined length.

Drums 36 with the conductor bundles used as the winding wire are rotatably fixed to those horizontally extending portions of the carrier arms 34.

A rotary mounting (not shown) is provided between the vertical portion of the carrier arm 34, which portion extends parallel to the carrier plate 32, and the horizontally extending portion of the carrier arm. That rotary mounting co-operates with a drive 35 and permits a rotary movement of the horizontal portion of the carrier arm 34 about its longitudinal axis together with the drum 36 arranged thereon. That makes it possible to counteract a twist effect which occurs upon winding of the stator winding between the conductor bundles of that winding.

Figure 5 shows a front view of that carrier apparatus 30. Figure 5 shows a base frame 31 which tapers from the base towards the tip. Two transverse portions 38 and 39 are provided to enhance the stability of the structure.

The carrier plate 32 is arranged rotatably on the base frame 31. Arranged on the carrier plate 32 are three carrier arms 34 which are respectively displaced by the same angle (120°) and to the substantially horizontally extending cantilever portions of which are fixed two respective drums 36 for the conductor bundles. By virtue of the rotatable mounting of the carrier plate 32, with the drums 36 fixedly connected thereto by way of the carrier arms 34, the unit can be rotated by a second motor 37.

In the operation of producing the winding on the stator 10 each conductor bundle 20 is inserted into a groove 12, it is bent over at the end of the groove 12 in the winding head and it is passed to a new, parallel-extending groove 12 in the winding head. The conductor bundle 20 is then bent over again in such a way that it can be inserted into that groove 12. At the exit of that groove 12 the conductor bundle 20 is again bent over in the winding head in such a way that it can be passed to the next groove 12. It will be appreciated that a corresponding twist is also produced in the conductor bundle 20 which is passing to the drum 36.

The drums 36 are arranged in pairs on the horizontal portions of the carrier arms 34. As those horizontal portions are rotatable by the drives 35 about the longitudinal axis thereof, the drums 36 are also rotated. It is possible in that way to counteract a twist in the conductor bundles, by rotation of the corresponding carrier arm 34.

A second drive 37 is arranged between the base frame 31 and the carrier plate 32 and permits rotation of the carrier plate 32 with all carrier arms 34 disposed thereon and the drums 36 in order also to implement rotation of the stator 10 in the stator holder 14 and in that way to avoid twisting of the conductor bundles.

Figure 6 shows in simplified form and without a conductor bundle between the carrier apparatuses 30 and the stator 10 the arrangement of two carrier apparatuses 30 and a stator 10 to be wound. The stator 10 is stored in a holding apparatus 14 and is rotatable in the peripheral direction (the direction of the arrow). As each of the carrier apparatuses 30 also has rotatably supported drums 36, they can also perform or implement the rotary movement of the stator by virtue of a corresponding rotary movement. Therefore, the provision of two carrier apparatuses 30 each with three pairs of drums means that it is possible for six phases to be wound simultaneously on a stator.

It will be apparent that the present invention can be applied not only to ring generators for wind power installations but basically to any synchronous machine, in which respect it must be made clear that this does not involve very small-scale machines but machines which involve a considerable spatial extent and which usually have connected loads of under some circumstances several 100 kW and more. For a ring generator of a wind power installation for example a rated output of more than 500 kW is typical, even generators with a rated output of more than 4 MW have already been tested and will be used in the future. Just the stator alone of the described synchronous machine weighs several tonnes, while in the case of ring generators of over 4 MW, under some circumstances it weighs even more than 50 tonnes.

CLAIMS

1. A wind power installation having a (ring) generator which has a stator in which grooves are provided at the inner or outer periphery in mutually spaced relationship to receive a stator winding, wherein the winding is wound without interruption continuously throughout.

2. A wind power installation according to claim 1 characterised by a stator (10) having at least two phase windings which are wound continuously throughout, preferably 6-phase windings.

3. A wind power installation according to one of the preceding claims wherein only respective windings of a phase are arranged within a groove.

4. A wind power installation according to one of the preceding claims characterised in that groove windings of different phases are arranged in adjacent relationship.

5. A wind power installation according to one of the preceding claims characterised in that the winding of a phase comprises at least one conductor bundle, preferably at least two conductor bundles, wherein a conductor bundle comprises a plurality of mutually insulated conductors.

6. A wind power installation according to claim 5 characterised in that at least two conductor bundles are arranged in mutually superposed relationship in a groove.

7. A wind power installation according to claim 6 characterised in that, in grooves in which a plurality of conductor bundles are arranged, the positions of the upper and lower conductor bundles are interchanged in a predetermined order.

8. A wind power installation according to one of the preceding claims characterised in that inserted into each groove are two turns which preferably correspond to the same phase.

9. Apparatus for the production of a stator of a synchronous machine according to one of the preceding claims characterised by a mounting apparatus for the stator, in which the stator is held in a standing position.

10. Apparatus according to claim 9 characterised by at least one drive for rotating the stator in the mounting apparatus in its peripheral direction.

11. Apparatus according to one of claims 9 and 10 characterised by a carrier apparatus for holding at least one drum with winding wire, the carrier apparatus being separate from the mounting apparatus (14).

12. Apparatus according to claim 11 characterised by a pair-wise arrangement of a plurality of drums, wherein the pairs of drums are arranged in uniformly spaced relationship on a notional circle.

13. Apparatus according to one of the preceding claims characterised by a carrier apparatus arranged at each side of the stator.

14. Apparatus according to one of the preceding claims characterised by a number of the pairs of drums, equal to the number of phases to be wound on the stator.

15. Apparatus according to claim 14 characterised in that each of the carrier apparatuses carries the respective half of the drum.

16. Apparatus according to one of the preceding claims characterised by a substantially vertically arranged carrier plate and carrier arms

extending outwardly from the centre of the carrier plate for receiving the drums.

17. Apparatus according to claim 16 characterised by a rotatable mounting for the carrier plate.

18. Apparatus according to claim 17 characterised by a drive for rotating the carrier plate in the peripheral direction.

19. Apparatus according to one of claims 16 to 18 characterised in that the drums are mounted to a substantially horizontally extending portion of the carrier arms (34) and that the horizontally extending portion is adapted to be rotatable about its longitudinal axis.

20. A synchronous machine comprising a rotor and a stator, wherein the stator has grooves provided in mutually spaced relationship at the inner or outer periphery for receiving a stator winding and wherein the stator winding is of a continuous nature throughout in the grooves.

21. A synchronous machine according to claim 20 characterised in that the stator winding is of an at least 2-phase, preferably 6-phase nature and wherein windings of different phases are disposed in adjacent grooves, wherein each winding comprises at least one conductor having a plurality of conductors, and each winding preferably comprises two conductor bundles which are possibly interchangeable in their arrangement relative to each other within a groove over the stator periphery.

22. Use of a synchronous machine according to one of the preceding claims.

23. A ring generator for a wind power installation wherein the stator is secured fixedly to the machine carrier of the wind power installation

whereas the rotor of the synchronous machine is coupled to the rotor of the wind power installation.

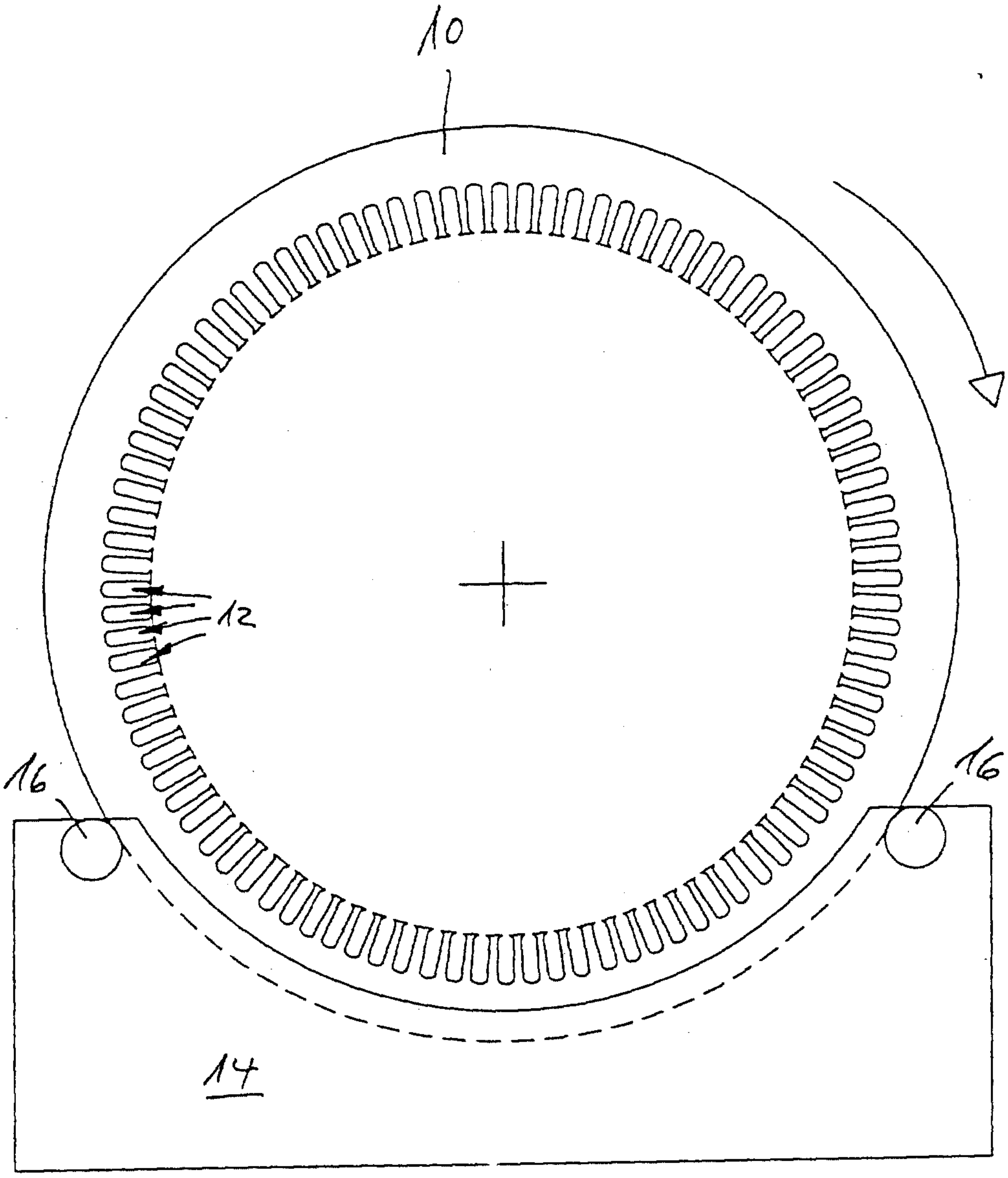


Fig. 1

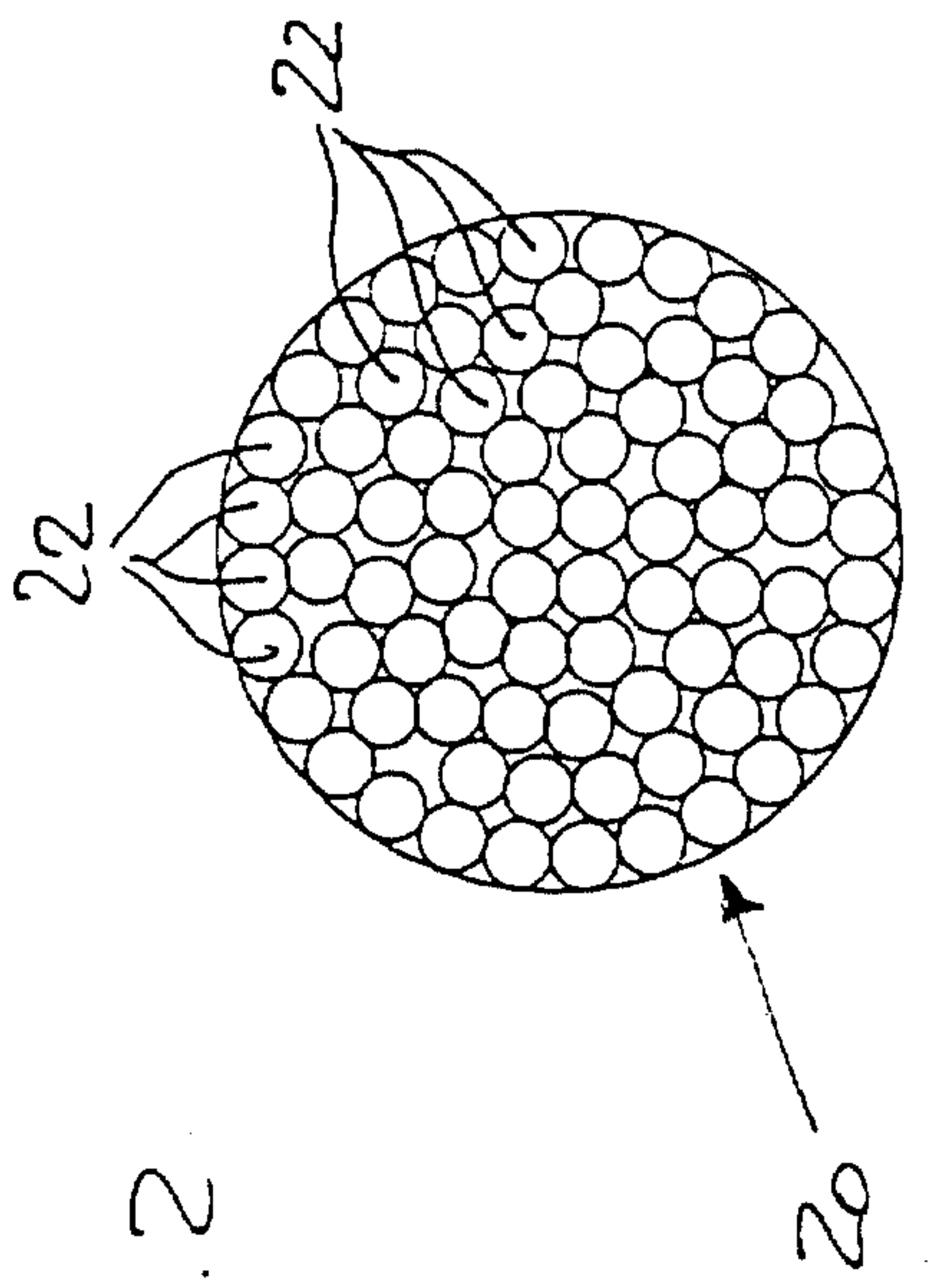


Fig. 2

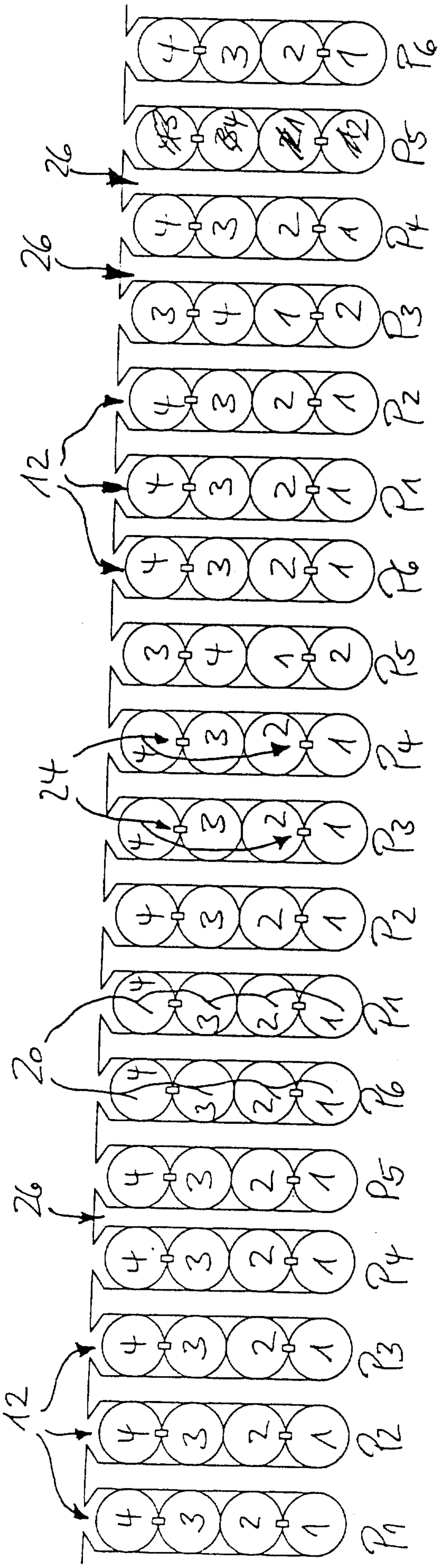


Fig. 3a

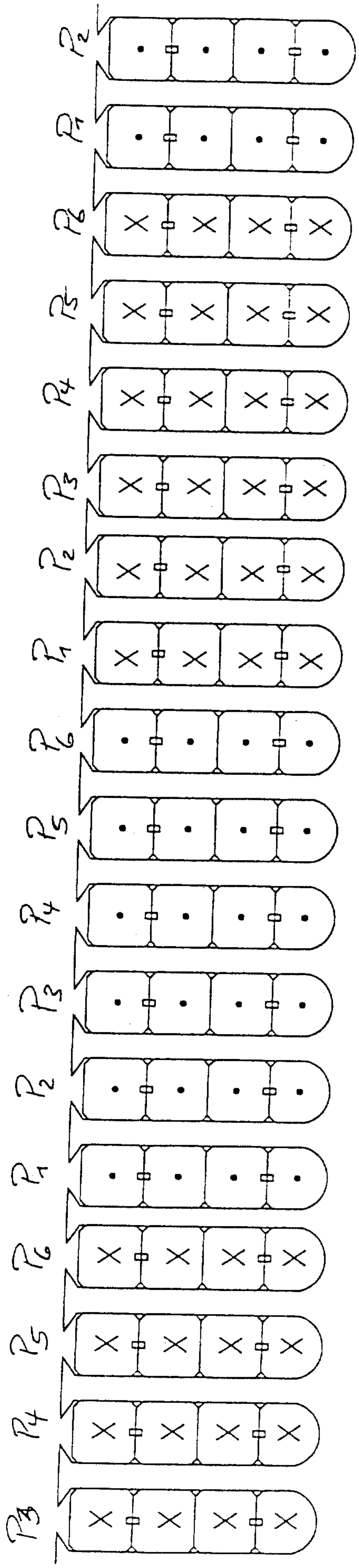


Fig. 36

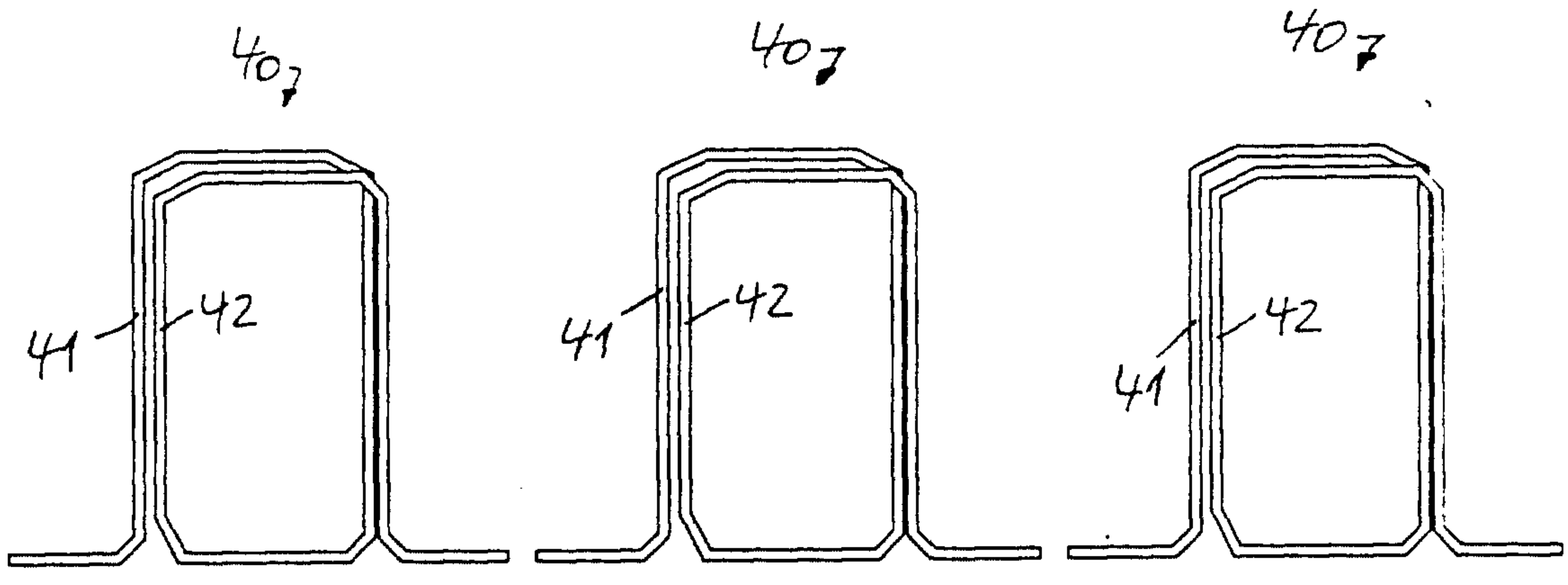


Fig. 3c

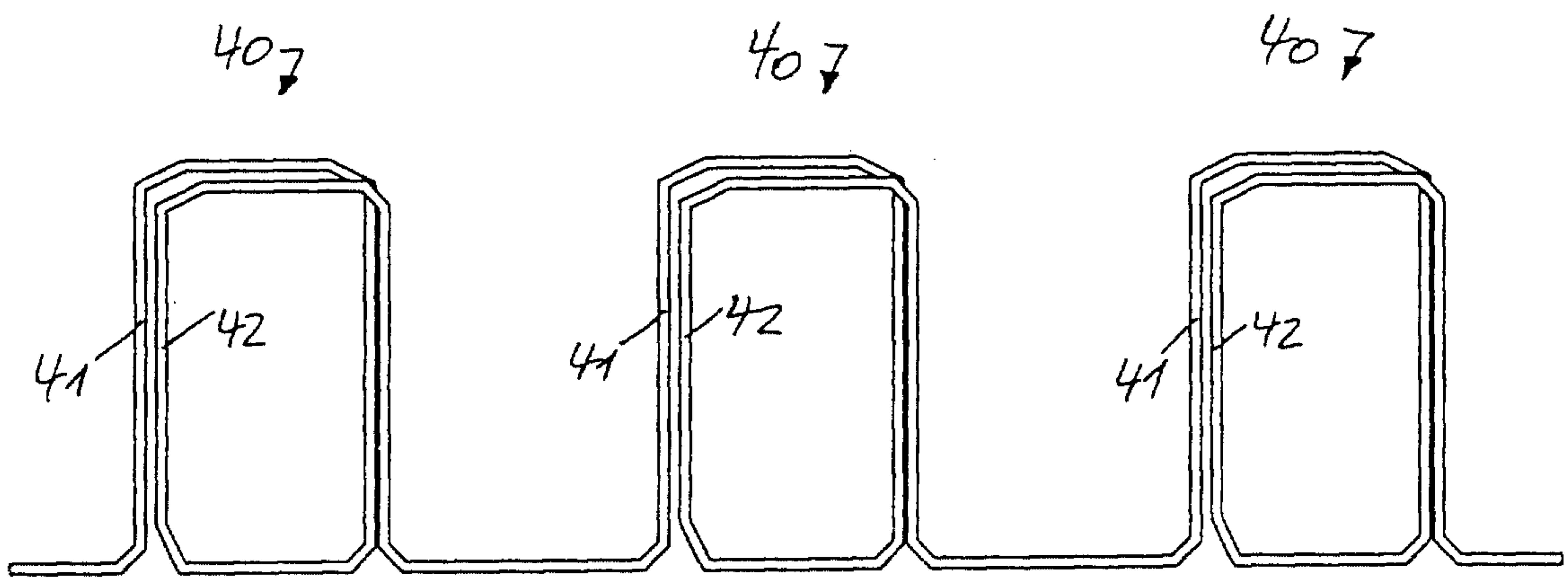


Fig. 3d

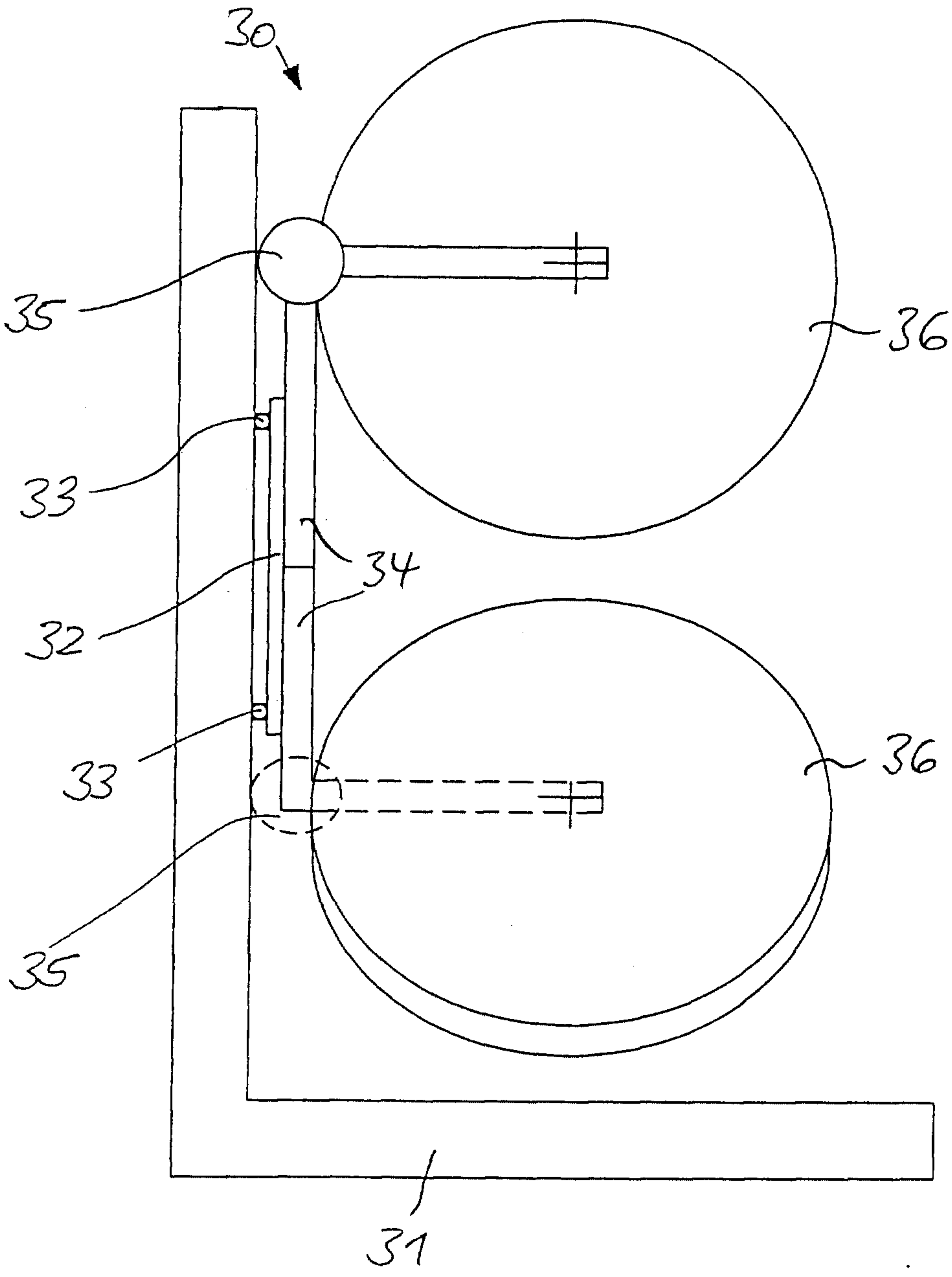


Fig. 4

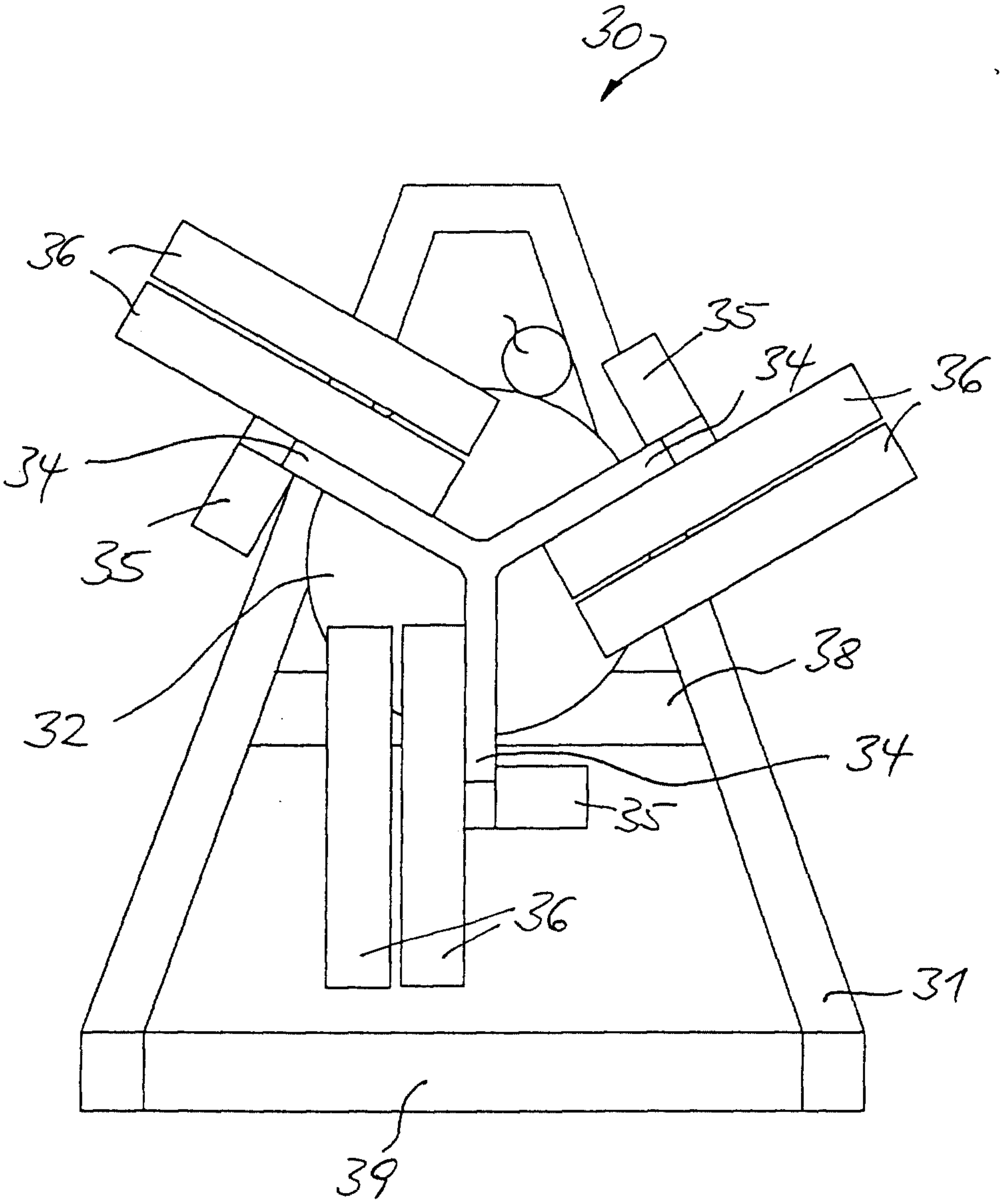


Fig:5

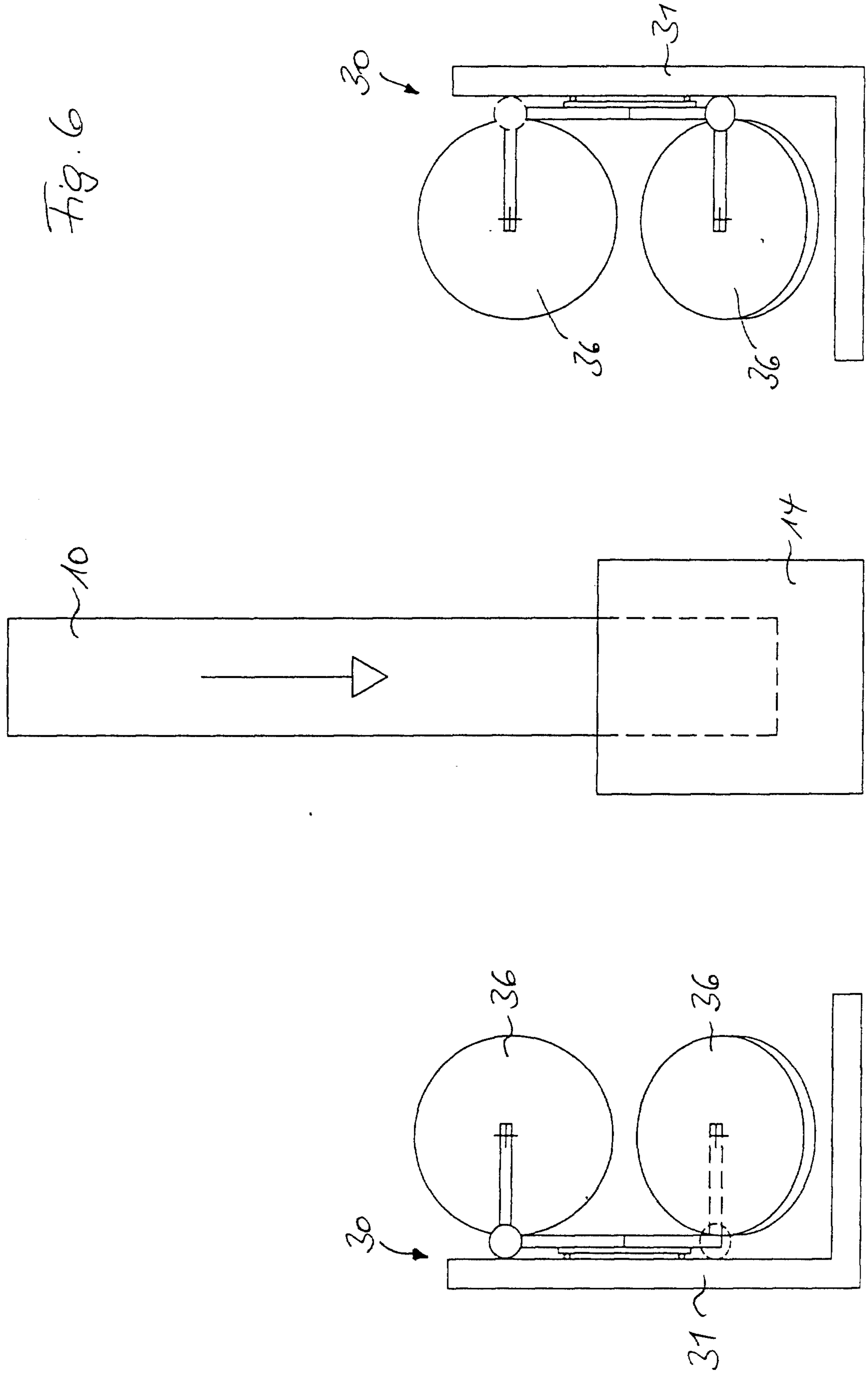
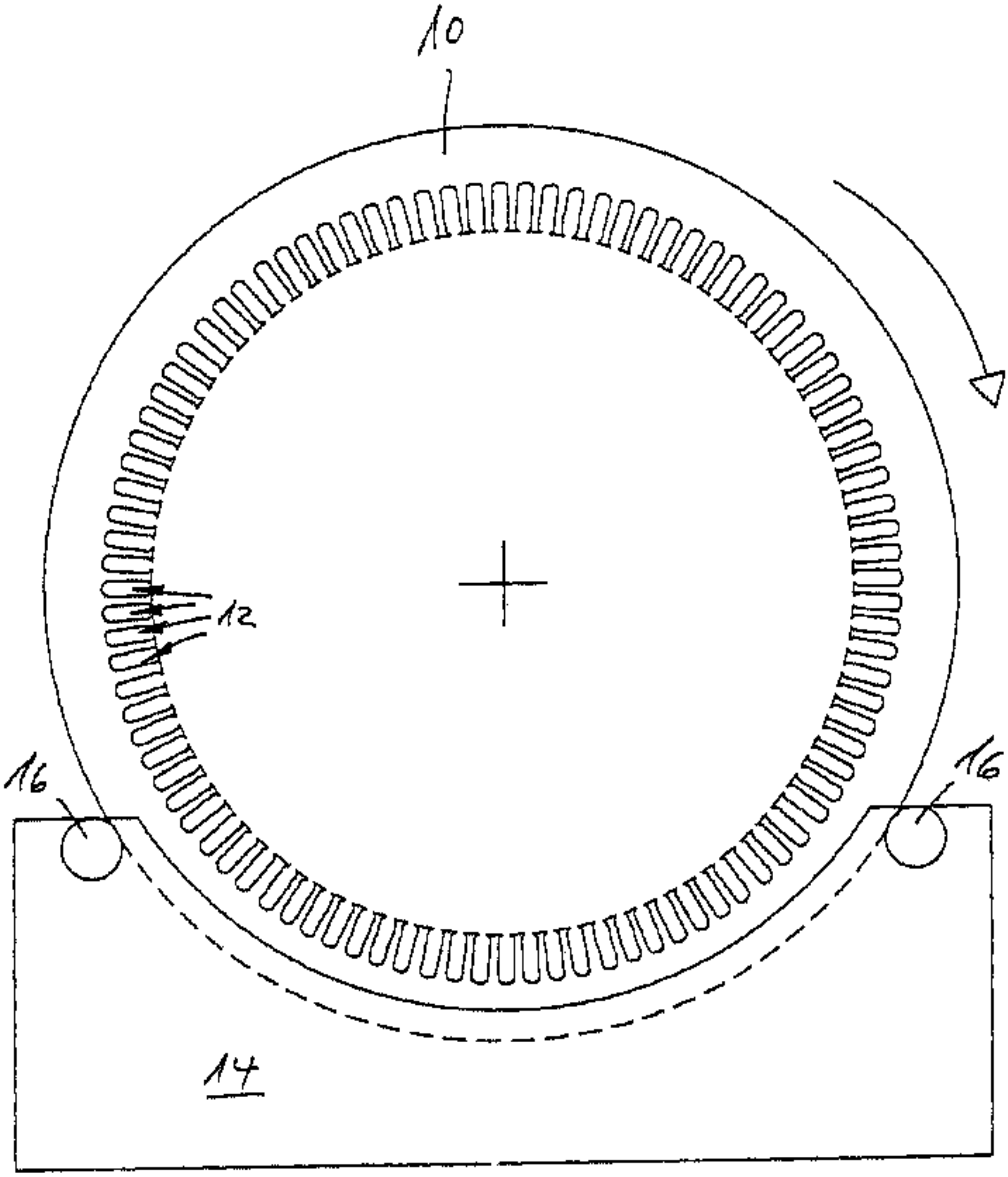


Fig. 6



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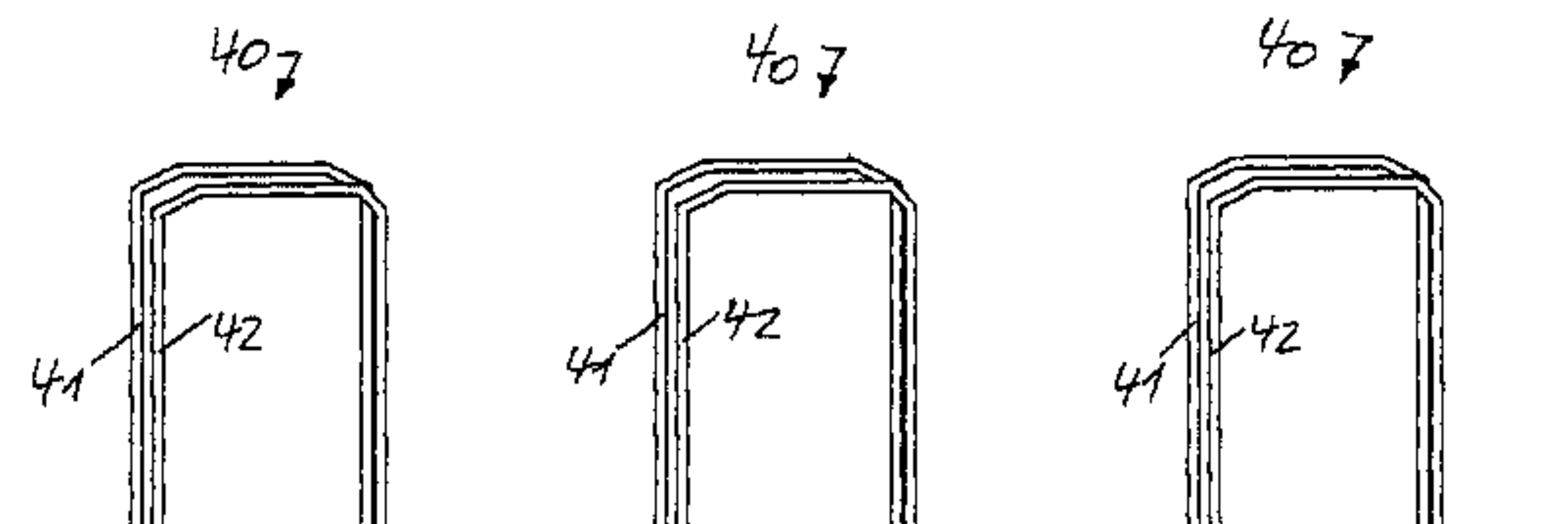

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