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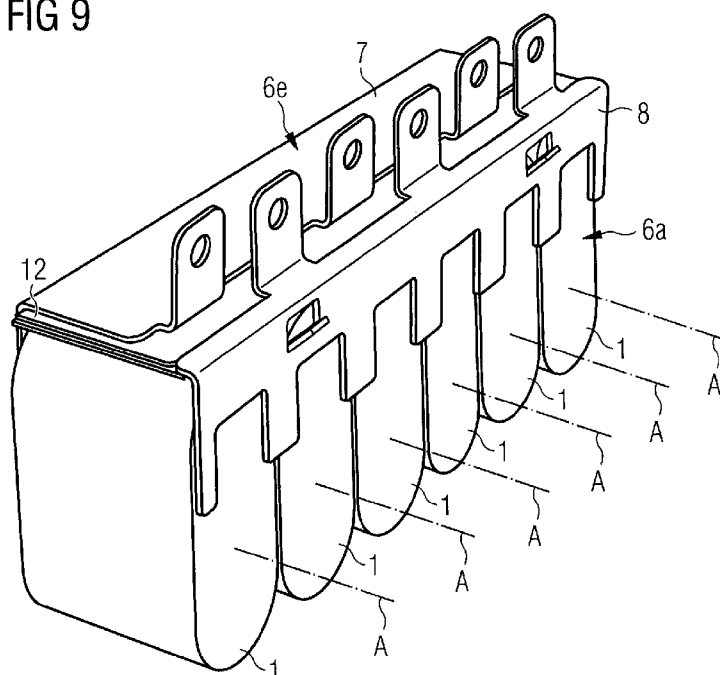
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(54) Title: VERY LOW INDUCTANCE BUSBAR FOR CAPACITOR ASSEMBLY

FIG 9



(57) Abstract: The present invention concerns a capacitor comprising at least two winding elements (1), a first busbar (7) and a second busbar (8), wherein the first busbar (7) and the second busbar (8) connect the winding elements (1) in parallel to each other and wherein the first busbar (7) and the second busbar (8) are arranged such that they overlap each other. Due to the overlap of the busbars (7, 8), the magnetic fields have opposite orientations and, therefore, weaken or even cancel each other. Thus, overall, only a very weak magnetic field may be generated, when a voltage is applied to the first busbar (7) and the second busbar (8). This results in a small inductance of the connection of the busbars and between the winding elements. Thus, the inductance of the capacitor may also be very small.

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Description

VERY LOW INDUCTANCE BUSBAR FOR CAPACITOR ASSEMBLY

5 The present invention concerns a capacitor. In particular, the capacitor may be a metallized DC-link film capacitor.

Metallized film DC-Link capacitors are critical components for many power electronics applications: renewable energies,
10 electric vehicles, traction, motor drives, uninterruptible power supply, energy transmission, etc.

DC-Link capacitor requirements strongly depend on the parameters of a semiconductor implemented in a converter
15 connected to the capacitor and a modulation strategy of the converter.

The development of Wide-bandgap semiconductors (WBGs), to higher on-state voltage, has changed the characteristics of
20 high power converters: higher switching frequencies, higher harmonic frequencies, lighter cooling systems, higher power density, more compact designs, etc.

As a consequence, in order to work correctly in such
25 applications, the capacitor should be able to be operated at high frequencies, e.g. frequencies above 10 kHz, without too many losses due to parasitic inductances and resistances.

In power conversion, when AC is converted to low voltage DC, or AC from one frequency to another, the AC is usually
30 rectified and smoothed. Once this is accomplished, the power is then routed to an inverter to obtain the final output. The DC that is fed into the inverter is called the DC link. As

the name implies, the two sources are linked together with a filter capacitor which is called DC link capacitor.

5 In electric vehicle applications, the DC link capacitor is used as a load-balancing energy storage device. The DC link capacitor is placed between the DC, i.e. the battery, and the AC, i.e. a load side, of a voltage inverter.

10 It is the object of the present invention to provide an improved capacitor, for example a capacitor that does not suffer many losses due to parasitic inductances and resistances at high switching frequencies.

15 This object is solved by a capacitor according to claim 1.

A capacitor is provided that comprises at least two winding elements, a first busbar and a second busbar, wherein the first busbar and the second busbar connect the winding elements in parallel to each other and wherein the first
20 busbar and the second busbar are arranged such that they overlap each other.

A winding element may be a capacitance unit. Each winding element of the capacitor may have the same capacitance. Each
25 winding element may have a first pole of a first polarity, e.g. a positive polarity, and a second pole of a second polarity, e.g. a negative polarity. By applying a voltage between the first and the second pole, energy may be stored in the winding element.

30

A busbar may be a metallic strip or a metallic bar configured for local high current power distribution.

Due to the overlap of the first busbar and the second busbar, a capacitor is provided which has a characteristic that is well suited for power applications with voltages above 600 V and switching frequencies of more than 10 kHz. When a current
5 flows through the first busbar, a magnetic field is generated by the current. Further, when a current flows through the second busbar, another magnetic field is generated by this current. Due to the overlap of the busbars, the magnetic fields have opposite orientations and, therefore, weaken or
10 even cancel each other. Thus, overall, only a very weak magnetic field may be generated, when a voltage is applied to the first busbar and the second busbar. This results in a small inductance of the connection of the busbars and between the winding elements. Thus, the inductance of the capacitor
15 may also be very small.

A small inductance between the winding elements is important for a power capacitor as a high inductance would result in resonance effects and high losses due to parasitic
20 inductances and resistances.

Overall, an homogeneous impedance can be provided by each winding element having the same capacitance and by each connection from a terminal to a winding element having the
25 same inductance. Due to design requirements, it may not always be possible to provide the same inductance for each winding element. Thus, instead of trying to adapt the inductances to each other, it is proposed to reduce the inductances to minimal values by cancelling or weakening the
30 magnetic fields.

A capacitor with a first and a second busbar overlapping each other may have a low equivalent series resistance (ESR), a

frequency-stable ESR, a homogeneous ESR for each winding element, a low equivalent series inductance (ESL), a homogeneous ESL for each winding element and a homogeneous internal current distribution. Internal resonances may be avoided.

The first busbar and the second busbar may be arranged such that at least 50% of the area of the first busbar is overlapped by the second busbar. The larger the overlap between the busbars, the better is the weakening or cancelling of the magnetic fields. Preferably, the first busbar and the second busbar are arranged such that at least 70% of the area of the first busbar is overlapped by the second busbar. Even more preferably, the first busbar and the second busbar are arranged such that at least 90% of the area of the first busbar is overlapped by the second busbar.

In the area of the overlap of the busbars, a thin isolator may be arranged between the busbars which prevents a short circuit between the busbars. The thin isolator may not significantly influence the magnetic fields.

The first busbar and the second busbar may be arranged such that a current flowing through the first busbar generates a first magnetic field and a current flowing through the second busbar generates a second magnetic field, wherein the first magnetic field and the second magnetic field compensate each other. The compensation of the magnetic fields may result in a low inductance and homogeneous impedance for all the winding elements. Thus, the capacitor may not show any resonance effects even when operated at switching frequencies above 10 kHz.

Each winding element may have a positive pole and a negative pole, wherein the first busbar is connected either to the positive pole of each winding element or to the negative pole of each winding element. The second busbar may be connected
5 to the respective other of the positive pole of each winding element or the negative pole of each winding element. The busbars may be configured such that currents of opposite polarity flow in the busbars.

10 In one embodiment, the capacitor comprises a fifth busbar and a sixth busbar. The first busbar and the second busbar are arranged on a side of the stack and the fifth and the sixth busbar are arranged on a side of the stack opposite to the side at which the first busbar and the second busbar are
15 arranged. The fifth busbar is connected to the same poles as the first busbar and the sixth busbar is connected to the same poles as the second busbar.

The first and the second busbar may be arranged on a lateral
20 side of the stack which has a surface normal perpendicular to a stacking direction of the stack. The fifth busbar and the sixth busbar may be arranged on a lateral side opposite to the lateral side on which the first and the second busbar are arranged and which also has a surface normal perpendicular to
25 the stacking direction.

The arrangement of the fifth and sixth busbar opposite to the first and second busbar may result in a symmetric coupling of currents into the winding elements. In particular, for each
30 winding element, the first and the fifth busbar may be connected to one pole of the winding element at two positions being symmetric with respect to each other and the second and sixth busbar may be connected to the other pole of the

winding element at two positions being symmetric with respect to each other.

Moreover, as current may be coupled to each pole of the winding element by two busbars, i.e. the first and the fifth busbar and, respectively, the second and the sixth busbar, the capacitor may be particularly suited for high current applications.

10 The at least two winding elements may be arranged in a stack, wherein the first busbar and the second busbar are arranged at a lateral face of the stack. The lateral face of the stack may be a face that is perpendicular to a top face and a bottom face of the stack, wherein metallizations and
15 connection elements for contacting the winding element are arranged on the top face and the bottom face of the winding elements. The top face of the stack may be formed by the top faces of the winding elements. The bottom face of the stack may be formed by the bottom faces of the winding elements.

20 The at least two winding elements may be arranged in a stack, wherein the first busbar and the second busbar are arranged on at least two faces of the stack. In particular, the first and the second busbar may completely or partly cover one or
25 more lateral faces, and/or the top face and/or the bottom face of the stack.

All winding elements may be arranged in a single stack. The stack may comprise more than two winding elements.

30 In a stacking direction, the first busbar may be alternately connected to a top face of one winding element and to a bottom face of the next winding element. In the

stacking direction, the second busbar may be alternately connected to a bottom face of one winding element and to a top face of the next winding element. Accordingly, the top face of each winding element is connected either to the first busbar or to the second busbar and the bottom face of each winding element is also connected either to the first busbar or the second busbar.

In the stack, the top faces of each winding element may face in the same direction. The bottom face of each winding element may be opposite to the top face of the winding element. The top faces of the winding elements may form the top face of the stack. The bottom faces of the winding elements may form the bottom face of the stack that is opposite to the top face of the stack.

In this embodiment, the windings are connected to both busbars in an alternate way. Thereby, the polarities of the winding elements alternate along the stacking direction. In other words, in the stacking direction, each winding element has an opposite polarity compared to the adjacent winding element.

As a result, the magnetic flux may be compensated in all connections, including the connection between winding elements. This may result in only very small parasitic inductances and resistances between winding elements and between winding elements and terminals. By reducing the parasitic inductances and resistances, the impedance from the terminals to each winding is more homogeneous between the winding elements for each frequency in the bandwidth in which the capacitor may be operated. Thus, the performance of the capacitor in the complete bandwidth is better due to a low

and frequency stable ESR, an homogeneous ESR from each pair of terminals, a low and homogeneous ESL from each pair of terminals, an homogeneous internal current distribution and the avoidance of internal resonances.

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In an alternative embodiment, the first busbar may be connected to a top face of each of the winding elements, and the second busbar may be connected to a bottom face of each of the winding elements.

10

The capacitor may comprise at least four winding elements, wherein at least two winding elements are arranged in a first stack and at least two winding elements are arranged in a second stack. The winding elements may be arranged in the first stack and, respectively, in the second stack such that the top face of the first stack has a polarity opposite to the polarity of the top face of the second stack. This arrangement of the winding elements in the stack may ensure that a current flows in an opposite direction in the overlapping busbars.

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The first busbar and the second busbar may be arranged between the first stack and the second stack. This may facilitate contacting the first busbar and the second busbar to both of the first stack and the second stack.

30

The first busbar may have a larger thickness in a section between the stacks than in a section overlapping a top face or a bottom face of the winding elements. The second busbar may have a larger thickness in a section between the stacks than in a section overlapping a top face or a bottom face of the winding elements. The larger thickness between the stacks

results in a high current capability of the capacitor. The low thickness in the sections overlapping the top or bottom faces ensures that the busbars can easily be fixed to the winding elements by welding.

5

The first busbar may be folded in the section between the stacks and/or the second busbar may be folded in the section between the stacks. The fold may be formed by a 180° turn of the respective busbar.

10

The winding elements may be arranged in the first stack and, respectively, in the second stack such that a top face of the first stack has a polarity opposite to the polarity of a top face of the second stack.

15

The first busbar may be connected to the top faces of the winding elements in the first stack and to the bottom faces of the winding elements in the second stack. The second busbar may be connected to the bottom faces of the winding

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elements in the first stack and to the top faces of the winding elements in the second stack. Thereby, it can be ensured that each winding element of the first stack is arranged adjacent to a winding elements of the second stack which is inverted in its polarity with respect to the winding

25

element of the first stack.

The first busbar may be arranged on the top face of the first stack and on the top face of the second stack and connected to the top faces of the winding elements in the first stack.

30

The second busbar may be arranged on the top face of the first stack and on the top face of the second stack and connected to the top faces of the winding elements in the second stack. Accordingly, both of the first busbar and the

second busbar may be arranged on the top faces of both stacks, resulting in a large overlap of the busbars.

Further, the capacitor may comprise a third busbar and a
5 fourth busbar. The third busbar may be arranged on the bottom
face of the first stack and on the bottom face of the second
stack and connected to the bottom faces of the winding
elements in the first stack. The fourth busbar may be
arranged on the bottom face of the first stack and on the
10 bottom face of the second stack and connected to the bottom
faces of the winding elements in the second stack, wherein
the third busbar and the fourth busbar overlap each other.
Accordingly, both of the third busbar and the fourth busbar
may be arranged on the bottom faces of both stacks, resulting
15 in a large overlap of the busbars.

In one embodiment, the capacitor may comprise four busbars,
wherein the busbars are arranged between the first stack and
the second stack and wherein the busbars are connected to the
20 winding elements such that a current flows in adjacent
busbars in opposite directions. This arrangement of the
busbars may result in a particularly well cancellation of the
magnetic fields. The four busbars may be arranged such that
each busbar connected to a pole of a first polarity is
25 adjacent only to busbars connected to poles of the second
polarity and, vice versa, each busbar connected to a pole of
a second polarity is adjacent only to busbars connected to
poles of the first polarity.

30 In particular, the first busbar may be connected to the top
faces of the winding elements in the first stack having a
first polarity. The second busbar may be connected to the top
faces of the winding elements in the second stack having a

second polarity opposite to the first polarity. The third busbar may be connected to the bottom faces of the winding elements in the second stack having the first polarity. The fourth busbar may be connected to the bottom faces of the winding elements in the first stack having the second polarity. The first busbar may be directly adjacent to the second busbar. The second busbar may be directly adjacent to the third busbar. The third busbar may be directly adjacent to the fourth busbar.

The first busbar may comprise two parts and/or the second busbar may comprise two parts. Each of the parts may have a Z-shaped cross-section. This design of the busbars may provide a particularly large overlapping area and, thus, a very effective cancellation of the electromagnetic flux. Thereby, low parasitic inductances and low parasitic resistances may be provided and negative electromagnetic interactions may be avoided.

The first busbar may be connected to the winding elements directly, e.g. by welding or soldering, and the second busbar may be connected to the winding elements directly, e.g. by welding or soldering. The direct connection reduces parasitic inductances and parasitic resistances and avoids negative electromagnetic interactions compared to a connection by connecting elements. However, in alternate embodiments, the busbars may be connected to the winding elements by connecting elements.

The first busbar may be formed such that it contacts two connection elements on a top face of each winding element, wherein the second busbar is formed such that it contacts two connection elements on a bottom face of each winding element,

wherein the first and the second busbar each cover three lateral faces of the stack and the first busbar partly covers the top face of the stack and the second busbar partly covers the bottom face of the stack.

5

The capacitor may comprise at least four winding elements, wherein at least two winding elements are arranged in a first stack and at least two winding elements are arranged in a second stack, wherein the winding elements are arranged in the first stack and, respectively, in the second stack such that a top face of the first stack has a polarity opposite to the polarity of a top face of the second stack, wherein each of the first and the second busbar has a z-shaped cross-section, wherein the first busbar and the second busbar are arranged between the first stack and the second stack, wherein each of the first busbar and the second busbar partly covers the top face of the first stack and partly covers the bottom face of the second stack.

20 The winding elements have a non-circular diameter. In particular, the winding element may be flat. Flat winding elements may be arranged in a stack such that no space is wasted between the winding elements.

25 The capacitor may be a DC link capacitor. The capacitor can be any kind of capacitor. For example, the capacitor may be a film capacitor or an electrolyte capacitor. The capacitor may be a power capacitor.

30 An electrolytic capacitor is polarized - with a positive and negative terminal- and is filled either with a chemical or solid polymer electrolyte, which gives the characteristic

of achieving extremely large capacitance values. The film capacitor may comprise metallized films.

5 In the following, the present invention is described with respect to the drawings.

Figures 1 to 42 shows capacitors according to a first to thirteenth embodiment.

10 Figure 43 shows a comparison of the ESR of a capacitor of the seventh embodiment and a reference capacitor.

Figure 44 shows the reference capacitor.

15 Figures 45 to 98 show capacitor according to a fourteenth to twenty-third embodiment.

Figures 1 and 2 show a capacitor according to a first embodiment. Figure 1 shows the capacitor in a bottom view and
20 figure 2 shows the capacitor in a side view.

The capacitor is a DC link capacitor which is designed for voltages above 600 V and switching frequencies of more than 10 kHz.

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The capacitor comprises a plurality of winding elements 1. In the embodiment shown in figures 1 and 2, the capacitor comprises five winding elements 1. However, the capacitor may also comprise any other number of winding elements 1.

30

Each winding element 1 is wound around an axis A. The axis A extends from a bottom face 2 of the winding element 1 to a top face 3 of the winding element 1. The top face 3 of each

winding element 1 is covered with a metallization 4, the so-called Schoop-layer. The metallization 4 of the top face 3 is connected to a first electrode or a first set of electrodes of the winding element. The bottom face 2 of each winding
5 element 1 is also covered with a metallization 4, i.e. a Schoop-layer. The metallization 4 of the bottom face 3 is connected to a second electrode or a second set of electrodes of the winding element 1. The first electrode and the metallization 4 on the top face 3 or the first set of
10 electrodes and the metallization 4 on the top face 3 form a first pole of the winding element 1. The second electrode and the metallization 4 on the bottom face 2 or the second set of electrodes and the metallization 4 on the bottom face 2 form a second pole of the winding element 1. During the operation
15 of the capacitor 1, a voltage is applied between the first pole and the second pole.

For the sake of visualization, the first pole is marked with a "plus" in the drawings and the second pole is marked with a
20 "minus". As alternating currents are applied, the polarizations can be altered continuously.

On the top face 3 and on the bottom face 2 of each winding element 1 a connection element 5, e.g. a connection stripe or
25 a bonding wire, is arranged.

The winding elements 1 have a non-circular cross section. In particular, the winding elements 1 are flat.

30 The winding elements 1 are arranged in a stack 6. The winding elements 1 are arranged in the stack 6 such that the top face 3 of each winding element 1 faces in the same direction. The winding elements 1 are arranged in the stack 6 such that

their axes A are parallel. A top face 6a of the stack 6 is formed by the top faces 3 of the winding elements 1. Further, a bottom face 6b of the stack 6 is formed by the bottom faces 2 of the winding elements 1. The bottom face 6b of the stack 6 is opposite to the top face 6a of the stack 6. Moreover, the stack 6 has four lateral faces 6c, 6d, 6e, 6f. Each of the lateral faces 6c, 6d, 6e, 6f is perpendicular to the top face 6a and to the bottom face 6b.

10 The capacitor comprises a first busbar 7 and a second busbar 8, which enable contacting the stack 6 of winding elements 1. In particular, the first busbar 7 is configured to apply a voltage to the first electrode or the first set of electrodes of each winding element 1. The second busbar 8 is configured
15 to apply a voltage to the second electrode or the second set of electrodes of each winding elements 1.

The first busbar 7 is connected to the top face 3 of each winding element 1. In particular, the first busbar 7 is
20 connected to the connection element 5 on the top face 3 of each winding element 1. The second busbar 8 is connected to the bottom face 2 of each winding element 1. In particular, the second busbar 8 is connected to the connection element 5 on the bottom face 2 of each winding element 1.

25 The first busbar 7 comprises at least one terminal 9. The first busbar 7 is configured to be connected to a pole of an external power supply, for example an insulated-gate bipolar transistor (IGBT), via the at least one terminal 9. The
30 second busbar 8 also comprises at least one terminal 9. The second busbar 8 is configured to be connected to another pole of the external power supply, for example the insulated-gate bipolar transistor (IGBT), via the at least one terminal 9.

Each of the first busbar 7 and the second busbar 8 can comprise more than one terminal 9.

In the first embodiment, the terminal 9 of the first busbar 7 is arranged at the top face 6a of the stack 6 and the terminal 9 of the second busbar 8 is arranged at the bottom face 6b of the stack 6. The first busbar 7 and the second busbar 8 are arranged at a lateral face 6e of the stack 6. Additionally, the first busbar 7 partly overlaps the top face 6a of the stack. The second busbar 8 partly overlaps the bottom face 6b of the stack 6.

The first busbar 7 and the second busbar 8 are arranged such that they overlap each other. A thin isolator plate is arranged between the first busbar 7 and the second busbar 8 in the area of the overlap of the busbars 7, 8. The thin isolator plate prevents a short circuit between the busbars. The thin isolator plate is not shown in Figures 1 and 2.

The first busbar 7 is configured to apply a voltage to the first electrode or the first set of electrodes of each winding element 1. The second busbar 8 is configured to apply a voltage to the second electrode or the second set of electrodes of each winding elements 1. As the first electrode and the second electrode or, respectively, the first set of electrodes and the second set of electrodes have an opposite polarity, a current flowing through the first busbar 7 and a current flowing through the second busbar 8 have an opposite direction.

30

The current flowing through the first busbar 7 generates a first magnetic field. The current flowing through the second busbar 8 generates a second magnetic field. As the first

busbar 7 and the second busbar 8 overlap each other and as the currents in the first busbar 7 and the second busbar 8 have opposite directions, the magnetic fields generated in the first busbar 7 and in the second busbar 8 cancel each other or at least weaken each other.

Thus, the arrangement of the busbars 7, 8 overlapping each other results in reduced magnetic fields of the busbars 7, 8. Thereby, the inductance of the busbars 7, 8 is reduced. As the inductance from the busbar 7, 8 to each of the winding element 1 is very low and homogeneous and as each winding element 1 has the same capacitance, each winding element 1 has almost the same impedance. If the winding elements 1 had different impedances, resonance effects in the capacitor, in particular when applying high switching frequencies above 10 kHz, would be unavoidable. Due to the overlapping busbars 7, 8, the impedance for each winding element 1 is almost the same such that no significant resonance effects occur. Accordingly, the losses in the capacitor can be reduced. In particular, parasitic inductances and resistances are strongly reduced. The impedance from the terminal 9 to each winding element 1 is homogeneous in all the frequency bandwidths. This results in a low equivalent series resistance (ESR), a frequency stable ESR, a homogeneous ESR between each terminal and each connection element, a low equivalent series inductance (ESL), a homogeneous ESL between each terminal and each connection element and the avoidance of an internal resonance. This enables the operation of the capacitor at voltages above 600 V and at switching frequencies of more than 10 kHz.

The use of the busbars 7, 8, which are connected to the connection elements 5 of each winding element 1 as shown in

figures 1 and 2 results in a homogeneous internal current distribution. In particular, the length along which the current has to travel through the busbars 7, 8 from the terminal 9 of the busbar 7, 8 to the connection element 5 is
5 roughly the same. Due to the design of the capacitor it is not possible to design the busbar 7, 8 such that the length along which the current has to travel is identical for each winding element 1. However, as the inductance of the busbars 7, 8 is very low due to the cancelation of the magnetic
10 fields, the differences in the length along which the current has to travel do not significantly impair the performance of the winding elements 1.

Figures 3 and 4 show a capacitor according to a second
15 embodiment. Figure 3 shows a bottom view of the capacitor and figure 4 shows a side view.

The capacitor according to the second embodiment comprises a fifth busbar 10 and a sixth busbar 11. The fifth 10 and the sixth busbars 11 are arranged at an opposite lateral side of the stack 6 with respect to the first busbar 7 and the second busbar 8.

In the capacitor of the second embodiment, each winding
25 element 1 comprises two connection elements 5 arranged at its top face 3 and two connection elements 5 arranged at its bottom face 2. The connection elements 5 arranged at the top face 3 are both connected to the metallization 4 covering the top face 3 and, thereby, to the first electrode or,
30 respectively, to the first set of electrodes. The connection elements 5 arranged at the bottom face 2 are both connected to the metallization 4 covering the bottom face 2 and,

thereby, to the second electrode or, respectively, to the second set of electrodes.

The fifth busbar 10 is connected to the top face 3 of each winding element 1. In particular, the first busbar 7 is connected to one of the connection elements 5 on the top face 3 of each winding element 1 and the fifth busbar 10 is connected to the respective other connection element 5 on the top face 3 of each winding element 1.

The sixth busbar 11 is connected to the bottom face 2 of each winding element 1. In particular, the second busbar 8 is connected to one of the connection elements 5 on the bottom face 2 of each winding element 1 and the sixth busbar 11 is connected to the respective other connection element 5 on the bottom face 2 of each winding element 1.

Accordingly, according to the second embodiment, a current can be coupled into each winding element 1 to the first electrode or the first set of electrodes by the first busbar 7 and by the fifth busbar 10 and to the second electrode or the second set of electrodes by the second busbar 8 and by the sixth busbar 11. As the current is coupled into each pole of winding element 1 by two busbars at two points, the capacitor according to the second embodiment is configured to be operated by stronger currents than the capacitor according to the first embodiment.

The fifth and the sixth busbars 10, 11 overlap each other. Thus, their magnetic fields cancel or at least weaken each other. Therefore, the fifth and the sixth busbars 10, 11 also have a low inductance.

Moreover, the capacitor of the second embodiment is symmetric as the current can be induced into each pole of each winding element 1 from two positions which are symmetric to each other. This symmetric design of the capacitor can further
5 reduce resonance effects, thereby reducing losses due to parasitic impedances and resistances.

Figures 5 to 10 show a capacitor according to a third embodiment. Figure 5 shows the capacitor in a perspective
10 view. Figure 6 shows the capacitor in a side view. Figure 7 shows the capacitor in a top view. Figure 8 shows the capacitor in another side view which is rotated by 90 degrees relative to figure 6. Figure 9 shows the busbars 7, 8 and the winding elements 1 of the capacitor in a perspective view.
15 Figure 10 shows only the busbars 7, 8 in a perspective view.

The capacitor according to the third embodiment also comprises a first busbar 7 connected to the first electrode or the first set of electrodes of each winding element 1 and
20 a second busbar 8 connected to the second electrode or the second set of electrodes of each winding element 1. The first busbar 7 and the second busbar 8 are both arranged on a first lateral face 6e of the stack 6. The first busbar 7 and the second busbar 8 overlap completely on the first lateral face
25 6e. Further, the first busbar 7 partly overlaps the top face 6a of the stack 6 and the second busbar 8 partly overlaps the bottom face 6b of the stack 6. The first busbar 7 is electrically connected to the metallization 4 on the top face 3 of each winding element 1. The second busbar 8 is
30 electrically connected to the metallization 4 on the bottom face 2 of each winding element 1. As shown in figure 9, an isolator plate 12 is arranged between the first busbar 7 and the second busbar 8 in order to avoid a short circuit between

the busbars. The isolator plate 12 is thin such that it does not influence the magnetic field significantly.

As already discussed with respect to the previous

5 embodiments, due to the overlap of the busbars 7, 8, a magnetic field generated by a current flowing through the first busbar 7 is weakened or cancelled by a magnetic field generated by a current flowing through the second busbar 8, wherein the current through the second busbar 7 flows in a
10 direction opposite to the current flowing through the first busbar 7. This results in a very low inductance.

Figures 11 to 14 show a capacitor according to a fourth embodiment. Figure 11 shows a top view of the capacitor.

15 Figure 12 shows a perspective view of the capacitor. Figure 13 shows a side view and figure 14 shows another side view from a different angle. The capacitor according to the fourth embodiment differs from the third embodiment in the arrangement of the terminals 9 of the busbars 7, 8. According
20 to the third embodiment, the terminals 9 are arranged on the first lateral face 6e of the stack 6. According to the fourth embodiment, the terminals 9 are arranged on the top face 6a of the stack 6.

25 Further, the first busbar 7 and the second busbar 8 are designed differently in the fourth embodiment. In particular, each of the first and second busbar 7, 8 is arranged such that it completely covers the first lateral face 6e of the stack 6 and that it partly covers the top face 6a and the
30 bottom face 6b of the stack 6.

Moreover, the capacitor of the fourth embodiment differs from the previous embodiments in the number of winding elements 1.

The capacitor of the fourth embodiment comprises nine winding elements 1. The capacitor can also be constructed with any other number of winding elements 1.

- 5 In the fourth embodiment, the first and the second busbar 7, 8 also overlap each other, resulting in a cancelation of weakening in the magnetic fields generated by currents flowing through the busbars 7, 8.
- 10 Figure 15 to 18 show a capacitor according to a fifth embodiment. The fifth embodiment differs in the design of the first busbar 7 and the second busbar 8 from the previous embodiments.
- 15 The busbars 7, 8 are connected to each winding element 1 at two points similar to the second embodiment. However, instead of providing two separate busbars 7, 8 which are connected to the same pole of each winding element 1 as shown in the second embodiment, the first busbar 7 is formed such that it
- 20 contacts both of the connection elements 5 on the top face 3 of each winding element 1. The second busbar 8 is formed such that it contacts both of the connection elements 5 on the bottom face 2 of each winding element 1. The first and the second busbar 7, 8 completely cover three lateral faces 6c, 6d, 6e of the stack 6 and partly cover the top face 6a and
- 25 the bottom face 6b of the stack 6.

The first and the second busbar 7, 8 overlap each other. In particular, the first busbar 7 and the second busbar 8 are

30 arranged at almost identical positions. The second busbar 8 overlaps more than 90% of the area of the first busbar 7. The overlap of the busbars 7, 8 results in a very low inductance, as discussed above.

As discussed with respect to the second embodiment, the capacitor of the fifth embodiment is suitable for strong currents as the current is coupled via two connection
5 elements 5 to each pole of each winding element 1.

Figures 19 and 20 show a capacitor according to a sixth embodiment. Figure 19 shows a top view of the capacitor and Figure 20 shows a side view of the capacitor.

10

The capacitor comprises two stacks 6, 13, each stack 6, 13 consisting of a plurality of winding elements 1. The winding elements 1 in the first stack 6 are arranged such that they are inverted in their polarity compared to the adjacent
15 winding elements 1 in the second stack 13. In particular, the top face 3 of the winding elements 1 of the first stack 6 corresponds to the first pole and the top face 3 of the winding elements 1 of the second stack 13 corresponds to the second pole.

20

The capacitor according to the sixth embodiment comprises a first busbar 7 and a second busbar 8. Each of the first and the second busbar 7, 8 has a z-shaped cross-section. Each of the first busbar 7 and the second busbar 8 is arranged
25 between the two stacks 6, 13. Moreover, the first busbar 7 partly covers the top face 6a of the first stack 6 and partly covers the bottom face 13b of the second stack 13. The first busbar 7 is connected to the connection element 5 of each winding element 1 on the top face 6a of the first stack 6 and
30 to each connection element 5 on the bottom face 13b of each winding element 1 in the second stack 13. Vice versa, the second busbar 8 is connected to each connection element 5 on the bottom face 2 of each winding element 1 of the first

stack 6 and to the connection element 5 on the top face 3 of each winding element 1 of the second stack 13. The current flowing through the first busbar 7 is applied to the first pole of the first stack 6 and the first pole of the second stack 13 and the current flowing through the second busbar 8 is applied to the second pole of the first stack 6 and the second pole of the second stack 13. In the first stack 6, the first pole is arranged at the top face 6a of the stack 6 and in the second stack 13 the second pole is arranged at the top face of the second stack 13a. Accordingly, the currents flowing through the busbars 7, 8 flow in opposite directions, resulting in magnetic fields that cancel or weaken each other. Thereby, a capacitor having a very low inductance and homogeneous impedance between the winding elements is provided.

Figures 21 to 23 show a capacitor according to a seventh embodiment. Figure 21 shows the capacitor in a perspective view. Figure 22 shows the capacitor in a top view and Figure 23 shows the capacitor in a side view.

The capacitor also comprises two stacks of winding elements 1 as already discussed with respect to the sixth embodiment. The design of the busbars is different in the seventh embodiment.

In the seventh embodiment, the first busbar 7 is arranged at the top faces 6a, 13a of both of the first stack 6 and the second stack 13. The first busbar 7 is connected only to the connection elements 5 on the top faces 3 of the winding elements 1 in the first stack 6. The first busbar 7 is not electrically connected to the top face 13a of the second stack 13. The second busbar 8 is connected only to the

connection elements 5 on the top faces 3 of the winding elements 1 in the second stack 13. The second busbar 8 is not electrically connected to the top face 6a of the first stack 6. Moreover, both busbars 7, 8 overlap each other.

5

Additionally, the capacitor comprises a third busbar 14 which is connected to the connection elements 5 on the bottom face 13b of the second stack 13 and a fourth busbar 15 which is connected to the connection elements 5 on the bottom face 6b of the first stack 6. The third busbar 14 and the fourth busbar 15 are both arranged on the bottom faces 6b, 13b of both stacks 6, 13 and overlap each other.

10

The first busbar 7 and the third busbar 14 are configured to apply a current to the electrodes of the first pole. The second busbar 8 and the fourth busbar 15 are configured to apply a current to the electrodes of the second pole. The magnetic fields of the third busbar 14 and the fourth busbar 15 cancel or weaken each other as the busbars 14, 15 overlap each other and as the currents flow in opposite directions in the busbars 14, 15.

15

20

Figures 24 and 25 show a capacitor according to an eighth embodiment. The busbars 7, 8, 14, 15 of the eighth embodiment also overlap each other. The capacitor of the eighth embodiment also comprises two stacks 6, 13 of winding elements 1. In contrast to the sixth and seventh embodiment, the winding elements 1 are rotated in the stacks by 90°.

25

Figures 26 to 28 show a capacitor according to a ninth embodiment. Figure 26 shows a top view of the capacitor, Figure 27 shows a side view of the capacitor and Figure 28 shows a perspective view of the capacitor.

30

The capacitor comprises four busbars 7, 8, 14, 15. Moreover, the capacitor comprises two stacks 6, 13 of winding elements 1. The first busbar 7 and the second busbar 8 are arranged at a lateral side 6e of the first stack 6 of winding elements 1. Moreover, the first busbar 7 and the second busbar 8 partly cover the top face 6a and the bottom face 6b of the first stack 6. The first busbar 7 is connected to the connection elements 5 on the top face 3 of the winding elements 1 of the first stack 6. The second busbar 8 is connected to the connection elements 5 on the bottom face 6b of the first stack 6.

Further, a third busbar 14 and a fourth busbar 15 are arranged on a lateral face 13e of the second stack 13. In particular, the third busbar 14 and the fourth busbar 15 are arranged on the lateral face 13e which is directly adjacent to the lateral face 6e of the first stack 6 on which the first and the second busbar 7, 8 are arranged. The third busbar 14 is connected to the connection elements 5 on the bottom face 13b of the second stack 13. The fourth busbar 15 is connected to the connection elements 5 on the top face 13a of the second stack 13.

Figure 29 shows a schematic view explaining the connections of the busbars 7, 8, 14, 15 and the winding elements 1. For the sake of simplicity, the first pole is marked again with a "plus" and the second pole is again marked with a "minus" in Figure 29. It can be seen in Figure 29 that busbars having opposite polarities are arranged adjacent to each other. In particular, each busbar has an opposite polarity with respect to its adjacent busbars. Thus, as the four busbars 7, 8, 14, 15 overlap in the gap between the two stacks 6, 13, it is

ensured that their magnetic fields cancel each other very efficiently. This design results in an even lower inductance and an even more homogeneous impedance between the winding elements.

5

Figures 30 and 31 show a capacitor according to a tenth embodiment. The capacitor of the tenth embodiment also comprises two parallel stacks 6, 13 of winding elements 1 and four busbars 7, 8, 14, 15 arranged between the winding
10 elements 1. The capacitor according to the tenth embodiment differs from the capacitor according to the ninth embodiment only in the arrangement of the terminals 9 of the busbar.

Figures 32 and 33 show a capacitor according to an eleventh
15 embodiment. The capacitor according to the eleventh embodiment is based on the capacitor according to the tenth embodiment and additionally comprises a fifth and sixth busbar 10, 11 arranged at a lateral face 6f of the first stack 6 and a seventh and eighth busbar 16, 17 arranged at a
20 lateral face 13f of the second stack 13. The capacitor according to the eleventh embodiment is designed to apply a current to each pole of each stack 6, 13 at two positions, thereby enabling the application of stronger currents similar to the second embodiment. This capacitor further provides a
25 high degree of symmetry, resulting in even fewer resonance effects. Thereby, losses due to parasitic inductances and resistances are further reduced.

Figures 34 to 37 show a capacitor according to a twelfth
30 embodiment. Figure 38 shows the busbars 7, 8, 14, 15 of the capacitor of the twelfth embodiment. Figure 39 also shows a perspective view of the busbars 7, 8, 14, 15 of the twelfth embodiment from a different perspective. The busbars 7, 8,

14, 15 are bent and folded such that a stack is formed wherein alternatively busbars of the first polarity and busbars of the second polarity are arranged overlapping each other and can be seen best in Figure 39. Thin isolation
5 plates 12 are arranged between the busbars 7, 8, 14, 15 in order to prevent a short circuit. As discussed with respect to the previous embodiments, this design of the busbars 7, 8, 14, 15 also ensures that the magnetic fields cancel each other resulting in a low inductance. For the sake of
10 simplicity, the isolator plates are not shown in Figure 38.

In the gap between the first stack 6 and the second stack 13, four layers of overlapping busbars are arranged. The magnetic fields of the four layers of busbars cancel each other. Thus,
15 parasitic inductances are avoided, parasitic resonances are avoided and negative electromagnetic interactions are also avoided.

The first busbar 7 and the second busbar 8 are connected to
20 the winding elements 1 directly, e.g. by soldering or welding. No extra or separate connection elements are required for connecting the busbars 7, 8 to the winding elements 1. Such extra or separate connection elements would result in increased parasitic inductances, increased
25 parasitic resonances and the generation of negative electromagnetic interactions. As the capacitor is free from extra or separate connection elements between the first and second busbar 7, 8 and the winding elements 1, parasitic inductances are avoided, parasitic resonances are avoided and
30 negative electromagnetic interactions are also avoided.

The busbars 7, 8 can be designed and dimensioned such that the busbars 7, 8 are connected to a middle point of the top

face 3 of the winding elements 1 and to a middle point of the bottom face 2 of the winding elements 1. This design of the busbars 7, 8 results in a high current capability and allows to use winding elements 1 with a large maximum size.

5

Figures 40 to 42 show a capacitor according to a thirteenth embodiment. The capacitor according to the thirteenth embodiment results in two capacitors according to the fifth embodiment being arranged side by side and forming two stacks 6, 13 of winding elements 1 wherein in the second stack 13 the winding elements 1 are arranged oppositely with respect to their polarity. Again, the busbars 7, 8, 14, 15 having opposite polarities overlap each other, resulting in a cancellation or weakening of the respective magnetic fields.

15

Figure 43 shows a plot of the ESR over the frequency of a capacitor according to the seventh embodiment of the present invention represented by curve C1 compared to a reference capacitor as shown in Figure 44 wherein busbars of opposite polarities do not overlap each other represented by curve C2. It can be seen in Figure 43 that the ESR of the reference capacitor is higher than the ESR of the capacitor according to the seventh embodiment and that it is less frequency-stable due to a non-homogeneous internal current distribution and internal resonances. In particular, at frequencies higher than 10 KHz, a significant reduction in the ESR can be observed in the capacitor according to the seventh embodiment.

25

Figures 45 to 48 show a capacitor according to a fourteenth embodiment. Figures 45, 47 and 48 show perspective views of the capacitor according to a fourteenth embodiment. Figure 46 shows the first and the second busbar 7, 8 of the capacitor.

30

Moreover, Figure 46 shows an isolator plate 12 being arranged between the busbars 7, 8.

Figure 49 shows the first busbar 7 and the second busbar 8.

5 Each of the first busbar 7 and the second busbar 8 comprises two parts. A first part 7a of the first busbar 7 is shown in Figure 50. A second part 7b of the first busbar 7 is shown in Figure 51. A first part 8a of the second busbar 8 is shown in Figure 52. A second part 8b of the second busbar 8 is shown
10 in Figure 53.

The winding elements 1 of the capacitor are arranged in a single stack 6. In a stacking directions S, the winding elements 1 alternate regarding their polarity.

15 The first busbar 7 and the second busbar 8 are both arranged on a lateral face 6c of the stack 6. The first busbar 7 and the second busbar 8 overlap each other on the lateral face 6a of the stack. Further, each of the first busbar 7 and the second busbar 8 overlaps with the top face 6a of the stack 6
20 and with the bottom face 6b of the stack 6.

When an alternating current is applied to the capacitor, the currents in the overlap of the first busbar 7 and the second busbar 8 have opposite directions. Thus, parasitic
25 inductances, parasitic resistances and negative electromagnetic interactions are low.

In the stacking direction S, the first busbar 7 is alternatingly connected to the top face 3 of one winding
30 element 1 and to the bottom face 2 of the adjacent winding element 1. The second busbar 8 is connected to the respective other face, i.e. the bottom face 3 of the one winding element 1 and the top face 2 of the adjacent winding element 1. This

connection of the two busbars 7, 8 to the winding elements 1 in an alternating manner results in the winding elements 1 having alternating polarities along the stacking direction S. Thereby, the magnetic flux of adjacent winding elements 1 can
5 compensate each other. The compensation of the magnetic flux results in a low parasitic inductance, a low parasitic resistance and low negative electromagnetic interactions.

Due to the compensation of the magnetic flux, the parasitic
10 inductances and resistances between the winding elements 1 and between the winding elements 1 and the terminals are reduced. Thereby, the impedance from the terminals 9 to each winding element 1 is more homogeneous between winding
elements 1 in all the bandwidth, so the performance of the
15 capacitor in all the bandwidth is better. In particular, the capacitor has a low and frequency stable ESR, an homogeneous ESR from each pair of terminals, a low and homogeneous ESL from each pair of terminals, a homogeneous internal current distribution and internal resonances are avoided.

20 As mentioned above, each of the first busbar 7 and the second busbar 8 consists of two parts. The two parts 7a,m 7b of the first busbar 7 each have a Z-shaped cross-section.

25 The first part 7a comprises a first section 18, a second section 19 and a third section 20. The second section 19 is arranged between the first section 18 and the third section 20. The second section 19 is perpendicular to each of the first section 18 and the third section 20. The first section
30 18 and the third section 20 are parallel to each other. This design of the first section 18, the second section 19 and the third 20 section results in the Z-shaped cross section of the first part 7a of the first busbar 7.

The first section 18 of the first part 7a is part of the terminal 9 of the first busbar 7. The second section 19 of the first part 7a is arranged on the lateral face 6c of the stack 6. The third section 20 of the first part 7a is arranged on the bottom face 6b of the stack 6. The third section 20 comprises a pair of two protrusions 21 that are electrically and mechanically connected to the bottom face 2 of a winding element 1. In particular, the third section 20 comprises multiple pairs of two protrusions 21 that are electrically and mechanically connected to the bottom face 2 of every second winding element 1 in the stacking direction S.

The second part 7b of the first busbar 7 is designed analog to the first part 7a of the first busbar 7. In particular, the second part 7b also comprises a first section 18, a second section 19 and a third section 20. The second part 7b also has a Z-shaped cross-section.

The first section 18 of the second part 7b of the first busbar 7 is part of the terminal 9 of the first busbar 7. In particular, the terminal 9 is formed by the two first sections 18 of the first part 7a and of the second part 7b. The second section 19 of the second part 7b is perpendicular to the first section 18 and is arranged on the lateral face 6c of the stack 6. The third section 20 of the second part 7b is perpendicular to the second section 19 and is arranged on the top face 6a of the stack 6. The third section 20 comprises a pair of two protrusions 21 that are electrically and mechanically connected to the top face 3 of a winding element 1. In particular, the third section 20 comprises multiple pairs of two protrusions 21 that are electrically

and mechanically connected to the top faces 2 of those winding element 1 which have a bottom face 2 that is not connected to the first part 7a.

- 5 The first and the second part 8a, 8b of the second busbar 8 are formed analog to the first and second part 7a, 7b of the first busbar 7 and are, therefore, not described in detail.

The first busbar 7 and the second busbar 8 completely overlap
10 each other apart from the protrusions 21 that are connected to the top face 3 or the bottom face 2 of the winding elements 1. Thus, the protrusions 21 are the only parts of the busbars 7, 8 wherein the electromagnetic flux of the two busbars 7, 8 is not compensated by the respective other
15 busbar. Overall, this results in a very large compensation of the electromagnetic flux in the busbars 7, 8.

Each of the first busbar 7 and the second busbar 8 comprises multiple terminals 9. The terminals 9 are distributed
20 symmetric with respect to the winding elements 1 along the first busbar 7 and the second busbar 8. The symmetric arrangement of the terminals 9 optimizes a current balance between the winding elements 1. A non-symmetric arrangement of the terminals 9 would result in an unbalanced current
25 between the winding elements 1 and, thus, a reduced performance of the capacitor.

When an alternating current is applied to the terminals 9 of the first busbar 7 and the second busbar 8, the alternating
30 current flows through each of the first part 7a and the second part 7b of the first busbar 7 and the first part 8a and the second part 8b of the second busbar 8.

The Z-shaped cross-section of each of the parts 7a, 7b, 8a, 8b of the busbars 7, 8 results in a large overlapping area of the busbars 7, 8. Thus, due to the large overlap, the parasitic inductances are very low, the parasitic resistances are very low and negative electromagnetic interactions can be avoided.

The first busbar 7 and the second busbar 8 are electrically connected to the middle points of the top face 3 or the bottom face 2 of the winding elements 1. The busbars 7, 8 can be adapted to the dimensions of the winding elements 1 and can, in particular, be dimensioned such that they are connected to the middle points of the top face 3 or, respectively, the bottom face 2 of the winding elements 1 independently of the dimensions of the winding elements 1. This increases the current capability and the allowed maximum winding size.

Figures 54 and 55 show a capacitor according to a fifteenth embodiment. Figure 56 shows the busbars 7, 8 of the capacitor according to the fifteenth embodiment in a perspective view. Figure 57 shows a first part 7a of the first busbar 7. A second part 7b of the first busbar 7 is shown in Figure 58. A first part 8a of the second busbar 8 is shown in Figure 59. A second part 8b of the second busbar 8 is shown in Figure 60. Figure 61 shows the first busbar 7 and the second busbar 8 in a cross-sectional view.

The capacitor of the fifteenth embodiment is substantially identical to the capacitor of the fourteenth embodiment and differs from the capacitor of the fourteenth embodiment only in the shape and the number of the terminals 9. According to the fifteenth embodiment, each of the first busbar 7 and the

second busbar 8 has only one terminal 9. The terminal 9 is formed by a first section 18 of the first part 7a, 8a and a first section 18 of the second part 7b, 8b of the respective busbar 7, 8. The first sections 18 each comprise to sub-
5 sections that are perpendicular to each other. Thereby, a bend terminal 9 is formed. The bend terminal 9 has a subsection that is perpendicular to the lateral face 6c of the stack 6 and a sub-section that is parallel to the lateral face 6c.

10

The capacitor of the fifteenth embodiment has the same advantages as the capacitor of the fourteenth embodiment resulting from a large overlap of the busbars 7, 8 and from the arrangement of the winding elements 1 with alternating
15 polarity.

Figures 62 and 63 show a capacitor according to a sixteenth embodiment. Figure 64 shows the busbars 7, 8 of the capacitor according to the sixteenth embodiment in a perspective view.
20 Figure 65 shows the busbars 7, 8 in a cross-sectional view. Figure 66 shows an enlarged view of a part of Figure 65. 67 shows a first part 7a of the first busbar 7. A second part 7b of the first busbar 7 is shown in Figure 68. A first part 8a of the second busbar 8 is shown in Figure 69. A second part
25 8b of the second busbar 8 is shown in Figure 70.

The capacitor according to the sixteenth embodiment differs from the capacitor of the fifteenth embodiment in that the terminals 9 are arranged on the lateral face 6d. The surface
30 normal of the lateral face 6d is parallel to the stacking direction S. In contrast to this, the terminals 9 of the capacitor of the fifteenth embodiment are arranged on the lateral face 6c wherein the surface normal of the lateral

face 6c is perpendicular to the stacking direction S. The other features of the capacitor of the sixteenth embodiment are identical to the capacitor of the fifteenth embodiment. The capacitor of the sixteenth embodiment has the same
5 advantages as the capacitor of the fourteenth embodiment and the capacitor of the fifteenth embodiment resulting from a large overlap of the busbars 7, 8 and from the arrangement of the winding elements 1 with alternating polarity.

10 Figures 71 and 72 show a capacitor according to a seventeenth embodiment. Figure 73 shows the busbars 7, 8 of the capacitor according to the seventeenth embodiment in a perspective view. Figure 74 shows a first part 7a of the first busbar 7. A first part 8a of the second busbar 8 is shown in Figure 75.
15 A second part 8b of the second busbar 8 is shown in Figure 76. A second part 7b of the first busbar 7 is shown in Figure 77. Figure 78 shows the busbars 7, 8 in a cross-sectional view.

20 The capacitor according to the seventeenth embodiment is similar to the capacitor of the twelfth embodiment and differs only in the design of the terminals 9. According to the seventeenth embodiment, the terminals 9 comprise a separate, hook-shaped element that is fixed to the busbars,
25 e.g. by screwing. The hook-shaped element is electrically connected to the busbars 7, 8 and allows to connect the capacitor to further circuit elements.

The capacitor according to the seventeenth embodiment has
30 four layers of overlapping busbars 7, 8 between the stacks 6, 13 of winding elements 1 such that the parasitic inductances are very low, the parasitic resistances are very low and negative electromagnetic interferences can be avoided. The

busbars 7, 8 are connected to the middle points of the top face 3 or, respectively, the bottom face 2 of the winding elements 1, thus enabling a high current capability of the capacitor and the use of large winding elements.

5

Figure 79 shows a capacitor according to an eighteenth embodiment. Figure 80 shows the busbars 7, 8 of the capacitor according to the eighteenth embodiment in a perspective view. Figure 81 shows the busbars 7, 8 in a cross-sectional view.

10 Figure 82 shows the first busbar 7. Figure 83 shows the second busbar 8.

The winding elements 1 are arranged in a single stack 6. Along the stacking direction S, the winding elements 1 are arranged such that their polarity alternates. Thus, each winding element 1 has an opposite polarity compared to its adjacent winding element 1. Due to the alternating winding polarities along the stacking directions S, parasitic inductances, the parasitic resistance and negative electromagnetic interactions are reduced compared to a capacitor wherein all winding elements 1 have the same polarities.

The capacitor comprises the first busbar 7 and the second busbar 8. Each busbar 7, 8 consists of one single piece or part. Thus, in contrast to the seventeenth embodiment, the busbars 7, 8 do not comprise multiple parts. Thus, the first busbar 7 is connected to each face of the winding elements 1 which has the first polarity and the second busbar 8 is connected to each face of the winding elements 1 which has the second polarity. As the busbars 7, 8 consist of a single piece, their design is simpler compared to busbars 7, 8 comprising multiple pieces.

When an AC current is applied to the terminals 9, the AC current flows through the entire busbars 7, 8.

5 The first busbar 7 and the second busbar 8 each have a U-shaped cross-section. In particular, they are arranged on the same faces of the stack 6 of winding elements 1 and overlap each other almost completely. Thus, the overlapping area of the two busbars 7, 8 is very large. Thus, the parasitic
10 inductance and the parasitic resistance are low and negative electromagnetic interactions are avoided.

The busbars 7, 8 are connected to the middle point of the top face 3 of the winding elements 1 or, respectively, to the
15 middle point of the bottom face 2 of the winding elements 1. This design of the busbars 7, 8 results in a capacitor having a large current capability. Moreover, the busbars 7, 8 can be adapted to a wide range of winding elements 1, thereby allowing for a large maximum size of the winding elements 1.

20 The first and the second busbar 7, 8 overlap with each other and the AC current flows in the busbars 7, 8 in opposite directions. Thus, the electromagnetic flux generated by the busbars 7, 8 cancels each other. This reduces parasitic
25 inductances, parasitic resistances and negative electromagnetic interferences. Electromagnetic flux cancellation can be assured till the connection to the winding elements 1.

30 Figures 84 and 85 show a capacitor according to a nineteenth embodiment in a perspective view, wherein in Figure 87 the isolator plates are not shown for visualization purposes. Compared to the eighteenth embodiment, the capacitor of the

nineteenth embodiment comprises two additional terminals. Each of the first busbar 7 and the second busbar 8 has two terminals 9. In the stacking direction S, a first pair of terminals 9 is arranged at one end of the capacitor and a second pair of terminals 9 is arranged at the opposite end of the capacitor. This arrangement of the terminals 9 is optimized for the use of the capacitor in a back-to-back converter. The same capacitor can be connected to an inverter side and to a rectifier side.

The capacitor of the nineteenth embodiment has the same advantages as previously discussed with respect to the capacitor of the eighteenth embodiment.

Figure 86 shows a capacitor of a twentieth embodiment and Figure 87 shows the busbars 7, 8 of the capacitor of the twentieth embodiment. The capacitor of the twentieth embodiment differs from the capacitor of the eighteenth embodiment in the arrangement of the terminals 9. According to the twentieth embodiment, each of the first busbar 7 and the second busbar 8 comprises one terminal 9 wherein the terminal 9 is arranged centrally on the busbar 7, 8. The capacitor of the twentieth embodiment has the same advantages as previously discussed with respect to the capacitor of the eighteenth embodiment.

Figure 88 shows a capacitor according to a twenty-first embodiment in a perspective view. Figures 89 to 92 show the busbars 7, 8 of the capacitor of the twenty-first embodiment.

The capacitor comprises a first stack 6 of winding elements 1 and a second stack 13 of winding elements 1. The winding elements 1 in the first stack 6 all have the same polarity

and the winding elements 1 in the second stack 13 also all have the same polarity.

The busbars 7, 8 are arranged between the stacks 6, 13.

5 Between the stacks 6, 13, the busbars 7, 8 overlap each other. Each of the first busbar 7 and the second busbar 8 has a double-L shape and is folded by 180° in its middle. The position of the folding 22 is marked in Figure 92. Each of the first busbar 7 and the second busbar 8 comprises sections
10 that are arranged between the stacks 6, 13 and sections that overlap with the top faces 3 or the bottom faces 2 of the winding elements 1. Due to the folding 22 of the busbars 7, 8, the busbars 7, 8 have a larger thickness in the sections between the stacks 6, 13 than in the sections overlapping
15 with the top or bottom faces 2, 3. The increased thickness between the stacks 6, 13 results in a large current capability between the stacks 6, 13. As the busbars 7, 8 are thinner at the top or bottom faces 2, 3 of the winding elements 1, it is easy to fix the busbars 7, 8 to the winding
20 elements 1 by welding.

No extra or separate connection elements between the winding elements 1 and the busbars 7, 8 are required. The busbars 7, 8 are fixed to the winding elements 1 directly, e.g by
25 welding or soldering. This reduces parasitic inductances, parasitic resistances and avoids negative electromagnetic interactions compared to a capacitor comprising separate connection elements.

30 As discussed above with respect to previous embodiments, the busbars 7, 8 are connected to the middle points of the top face 3 or, respectively, the bottom face 2 of the winding elements 1.

As the polarity of both stacks 6, 13 is not opposite, it is not required to interlace the connections between the busbars 7, 8 and the winding elements 1. Thus, a simple solution can
5 be obtained.

Figure 93 shows a capacitor according to a twenty-second embodiment in a perspective view. Figures 94 to 96 show the busbars 7, 8 of the capacitor according to the twenty-second
10 embodiment.

The capacitor of the twenty-second embodiment is similar to the capacitor of the sixth embodiment shown in Figures 19 and 20. The capacitor comprises two stacks 6, 13, each stack 6,
15 13 consisting of a plurality of winding elements 1. The winding elements 1 in the first stack 6 are arranged such that they are inverted in their polarity compared to the adjacent winding elements 1 in the second stack 13. In particular, the top face 3 of the winding elements 1 of the
20 first stack 6 corresponds to the first pole and the top face 3 of the winding elements 1 of the second stack 13 corresponds to the second pole.

The design of the busbars 7, 8 of the capacitor of the
25 twenty-second embodiment is different the capacitor of the sixth embodiment. The busbars 7, 8 are arranged between the stacks 6, 13 and comprise protrusions 21 overlapping the top face 3 or the bottom face 2 of the winding elements 1. The busbars 7, 8 are connected directly to the winding elements
30 1, e.g. by soldering or welding. The capacitor has a low parasitic inductance, a low parasitic resistance and negative electromagnetic interactions are avoided.

Figure 97 shows a capacitor according to a twenty-third embodiment in a perspective view. Figure 98 shows an enlarged view of a part of the first busbar and the second busbar.

5 The capacitor according to the twenty-third embodiment is similar to the capacitor of the twenty-second embodiment. In contrast to the twenty-second embodiment, the first busbar 7 and the second busbar 8 have a larger thickness in sections that are arranged between the two stacks 6, 13 than in
10 sections that overlap the top face 3 or the bottom face 2 of a winding element 1. This larger thickness is achieved by folding each of the busbars 7, 8 in the sections between the stacks 6, 13.

15 The current capability is high due to the large thickness of the busbars 7, 8 between the stacks 6, 13. A welding process is easy as the sections of the busbars 7, 8 that overlap the top face 3 or the bottom face 2 of the winding elements 1 have a low thickness.

20 The busbars 7, 8 can be connected to the winding elements 1 directly, i.e. without extra connection elements, e.g. by welding or soldering. Thereby, it is ensured that parasitic inductances are low, parasitic resistance is low and negative
25 electromagnetic interaction is avoided.

For all the embodiments describes above, the quantity of the winding elements 1 per capacitor can be varied. The shape and the dimensions of the winding elements 1 can also be varied
30 in all of the above described embodiments. The terminal 9 layout can also be varied in each of the embodiments.

Reference numerals

	1	winding element
	2	bottom face of a winding element
5	3	top face of a winding element
	4	metallization
	5	connection element
	6	(first) stack
	6a	top face of the stack
10	6b	bottom face of the stack
	6c	lateral face of the stack
	6d	lateral face of the stack
	6e	lateral face of the stack
	6f	lateral face of the stack
15	7	first busbar
	7a	first part of first busbar
	7b	second part of first busbar
	8	second busbar
	8a	first part of second busbar
20	8b	second part of second busbar
	9	terminal
	10	fifth busbar
	11	sixth busbar
	12	isolator plate
25	13	second stack
	13a	top face of the second stack
	13b	bottom face of the second stack
	14	third busbar
	15	fourth busbar
30	16	seventh busbar
	17	eighth busbar
	18	first section
	19	second section

20 third section

21 protrusion

22 folding

5 A axis

S stacking direction

Claims (We claim)

1. Capacitor

comprising at least two winding elements (1), a first
5 busbar (7) and a second busbar (8), wherein the first
busbar (7) and the second busbar (8) connect the winding
elements (1) in parallel to each other and wherein the
first busbar (7) and the second busbar (8) are arranged
such that they overlap each other.

2. Capacitor according to the preceding claim,

wherein the first busbar (7) and the second busbar (8)
are arranged such that at least 50% of the area of the
first busbar (7) is overlapped by the second busbar (8).

3. Capacitor according to one of the preceding claims,

wherein the first busbar (7) and the second busbar (8)
are arranged such that a current flowing through the
first busbar (7) generates a first magnetic field and a
20 current flowing through the second busbar (8) generates
a second magnetic field, wherein the first magnetic
field and the second magnetic field compensate each
other.

4. Capacitor according to one of the preceding claims,

wherein each winding element (1) has a positive pole and
a negative pole,
wherein the first busbar (7) is connected either to the
positive pole of each winding element (1) or to the
30 negative pole of each winding element (1), and
wherein the second busbar (8) is connected to the
respective other of the positive pole of each winding

element (1) or the negative pole of each winding element (1).

5. Capacitor according to one of the preceding claims,
5 wherein the at least two winding elements (1) are arranged in a stack (6).

6. Capacitor according to the preceding claims,
wherein, in a stacking direction (S), the first busbar
10 (7) is alternately connected to a top face (3) of one winding element (1) and to a bottom face (2) of the next winding element (1), and
wherein, in the stacking direction (S), the second
busbar (8) is alternately connected to a bottom face
15 (2) of one winding element (1) and to a top face (3) of the next winding element (1).

7. Capacitor according to the claim 5,
wherein the first busbar (7) is connected to a top face
20 (3) of each of the winding elements (1), and
wherein the second busbar (8) is connected to a bottom face (2) of each of the winding elements (1).

8. Capacitor according to one of claims 5 to 7,
25 wherein the first busbar (7) and the second busbar (8) are arranged at a lateral face (6e) of the stack (6).

9. Capacitor according to one of claims 5 to 8,
comprising a fifth busbar (10) and a sixth busbar (11),
30 wherein the first busbar (7) and the second busbar (8) are arranged on a side (6e) of the stack (6) and the fifth and the sixth busbar (10, 11) are arranged on a side (6f) of the stack (6) opposite to the side (6e) at

which the first busbar (7) and the second busbar (8) are arranged,

wherein the fifth busbar (10) is connected to the same poles as the first busbar (7) and the sixth busbar (11) is connected to the same poles as the second busbar (8).

10. Capacitor according to the previous claim,
wherein the first and the second busbar (7, 8) are arranged on a lateral side of the stack (6) which has a surface normal perpendicular to a stacking direction (S) of the stack (6) and wherein the fifth busbar (10) and the sixth busbar (11) are arranged on a lateral side opposite to the lateral side on which the first and the second busbar (7, 8) are arranged and which also has a surface normal perpendicular to the stacking direction (S).

11. Capacitor according to one of claims 5 to 10,
wherein the first busbar (7) and the second busbar (8) are arranged on at least two faces (6e, 6f; 6a, 6b) of the stack (6).

12. Capacitor according to one of the preceding claims,
wherein the capacitor comprises at least four winding elements (1),
wherein at least two winding elements (1) are arranged in a first stack (6) and at least two winding elements (1) are arranged in a second stack (13).

13. Capacitor according to the preceding claim,
wherein the first busbar (7) and the second busbar (8) are arranged between the first stack (6) and the second stack (13).

14. Capacitor according to the preceding claim,
wherein the first busbar (7) has a larger thickness in a
section between the stacks (6, 13) than in a section
5 overlapping a top face (3) or a bottom face (2) of the
winding elements (1),
and/or
wherein the second busbar (8) has a larger thickness in
a section between the stacks (6, 13) than in a section
10 overlapping a top face (3) or a bottom face (2) of the
winding elements (1).
15. Capacitor according to the preceding claim,
wherein the first busbar (7) is folded in the section
15 between the stacks (6, 13),
and/or
wherein the second busbar (8) is folded in the section
between the stacks (6, 13).
- 20 16. Capacitor according to one of claims 12 to 15,
wherein the winding elements (1) are arranged in the
first stack (6) and, respectively, in the second stack
(13) such that a top face (6a) of the first stack (6)
has a polarity opposite to the polarity of a top face
25 (13a) of the second stack (13).
17. Capacitor according to the preceding claim,
wherein the first busbar (7) is connected to the top
faces (3) of the winding elements (1) in the first stack
30 (6) and to the bottom faces (2) of the winding elements
(1) in the second stack (13), and
wherein the second busbar (8) is connected to the bottom
faces (2) of the winding elements (1) in the first stack

(6) and to the top faces (3) of the winding elements (1) in the second stack (13).

18. Capacitor according to claim 15,

5 wherein the first busbar (7) is arranged on the top face (6a) of the first stack (6) and on the top face (13a) of the second stack (13) and is electrically connected to the top face (6a) of the first stack (6),

10 wherein the second busbar (8) is arranged on the top face (6a) of the first stack (6) and on the top face (13a) of the second stack (13) and is electrically connected to the top faces (13a) of the second stack (13),

15 wherein the capacitor further comprises a third busbar (14) and a fourth busbar (15),

20 wherein the third busbar (13) is arranged on the bottom face (6b) of the first stack (6) and on the bottom face (13b) of the second stack (13) and is electrically connected to the bottom face (6b) of the first stack (6),

25 wherein the fourth busbar (15) is arranged on the bottom face (6b) of the first stack (6) and on the bottom face (13b) of the second stack (13) and is electrically connected to the bottom face (13b) of the second stack (13), and

wherein the third busbar (14) and the fourth busbar (15) overlap each other.

19. Capacitor according to claim 15,

30 further comprising a third busbar (14) and a fourth busbar (15), wherein each of the first, the second, the third and the fourth busbar (7, 8, 14, 15) is arranged between the first stack (6) and the second stack (13)

and wherein the busbars (7, 8, 14, 15) are connected to the winding elements (1) such that a current flows in adjacent busbars (7, 8, 14, 15) in opposite directions.

- 5 20. Capacitor according to the preceding claim,
wherein the first busbar (7) is connected to the top
faces (3) of the winding elements (1) in the first stack
(6) having a first polarity,
wherein the second busbar (8) is connected to the top
10 faces (3) of the winding elements (1) in the second
stack (13) having a second polarity opposite to the
first polarity,
wherein the third busbar (14) is connected to the bottom
faces (2) of the winding elements (1) in the second
15 stack (13) having the first polarity, and
wherein the fourth busbar (15) is connected to the
bottom faces (2) of the winding elements (1) in the
first stack (6) having the second polarity.
- 20 21. Capacitor according to one of the preceding claims,
wherein the first busbar (7) comprises two parts (7a,
7b) and/or wherein the second busbar (8) comprises two
parts (8a, 8b).
- 25 22. Capacitor according to the preceding claim,
wherein each of the parts (7a, 7b, 8a, 8b) has a Z-
shaped cross-section.
- 30 23. Capacitor according to one of the preceding claims,
wherein the first busbar (7) is connected to the winding
elements (1) directly, e.g. by welding or soldering, and

wherein the second busbar (8) is connected to the winding elements (1) directly, e.g. by welding or soldering.

5 24. Capacitor according to claim 1,
wherein the first busbar (7) is formed such that it
contacts two connection elements (5) on a top face (3)
of each winding element (1), wherein the second busbar
10 (8) is formed such that it contacts two connection
elements (5) on a bottom face (2) of each winding
element (1), wherein the first and the second busbar (7,
8) each cover three lateral faces (6c, 6d, 6e) of the
stack (6) and the first busbar (7) partly covers the top
face (6a) of the stack (6) and the second busbar (8)
15 partly covers the bottom face (6b) of the stack.

25. Capacitor according to claim 1,
wherein the capacitor comprises at least four winding
elements (1), wherein at least two winding elements (1)
20 are arranged in a first stack (6) and at least two
winding elements (1) are arranged in a second stack
(13), wherein the winding elements (1) are arranged in
the first stack (6) and, respectively, in the second
stack (13) such that a top face (6a) of the first stack
25 (6) has a polarity opposite to the polarity of a top
face (13a) of the second stack (13), wherein each of the
first and the second busbar (7, 8) has a z-shaped cross-
section, wherein the first busbar (7) and the second
busbar (8) are arranged between the first stack (6) and
30 the second stack (13), wherein each of the first busbar
(7) and the second busbar (8) partly covers the top face
(6a) of the first stack (6) and partly covers the bottom
face (13b) of the second stack (13).

26. Capacitor according to one of the preceding claims,
wherein the winding elements (1) have a non-circular
diameter.

5

27. Capacitor according to one of the preceding claims,
wherein the capacitor is a DC link capacitor.

10

FIG 1

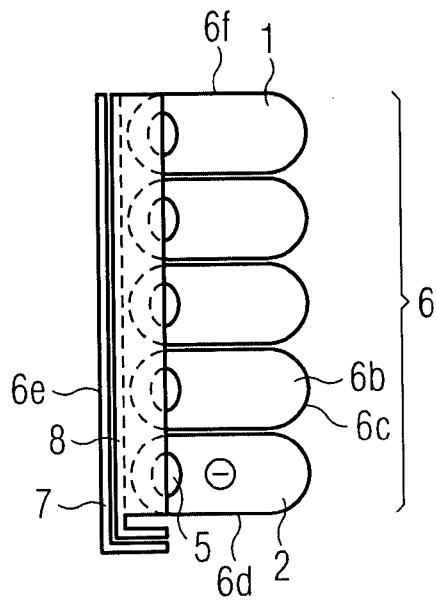


FIG 2

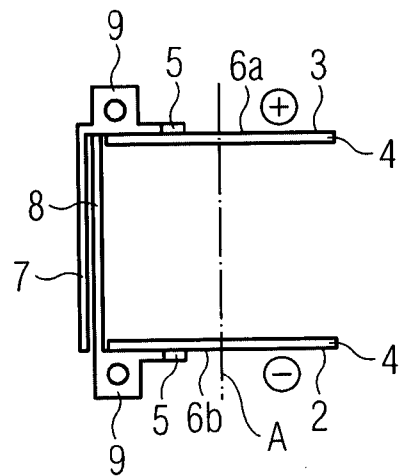


FIG 3

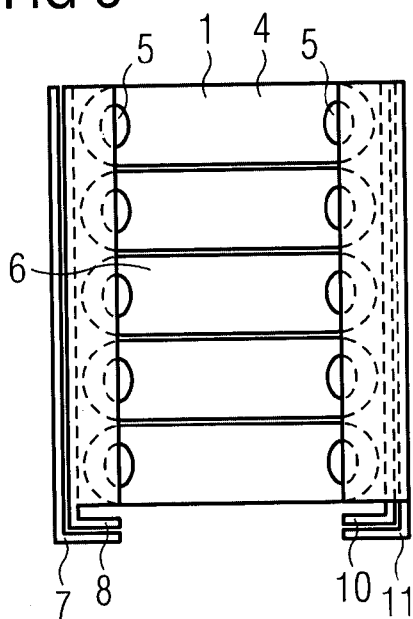


FIG 4

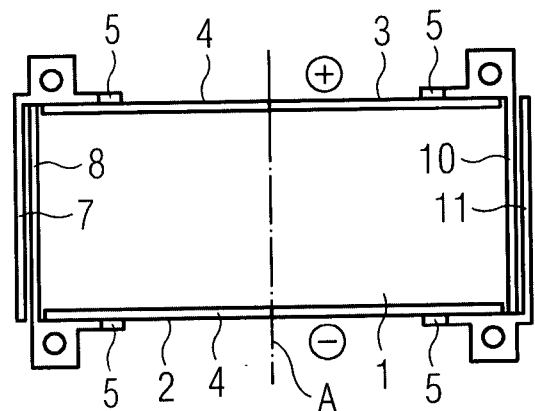


FIG 5

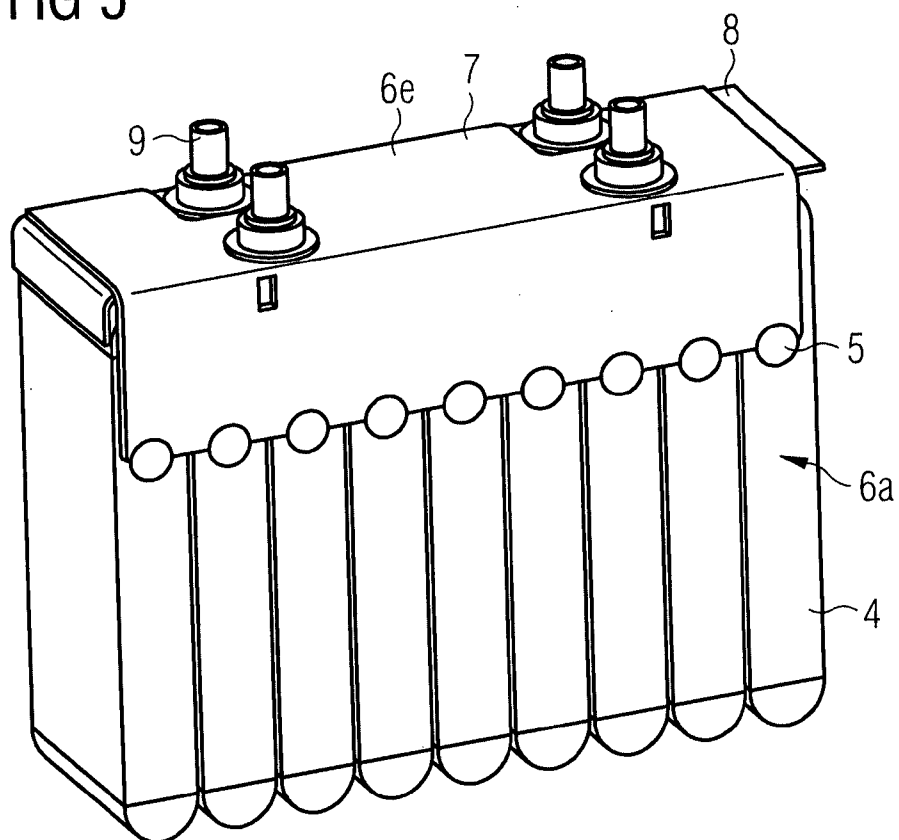


FIG 6

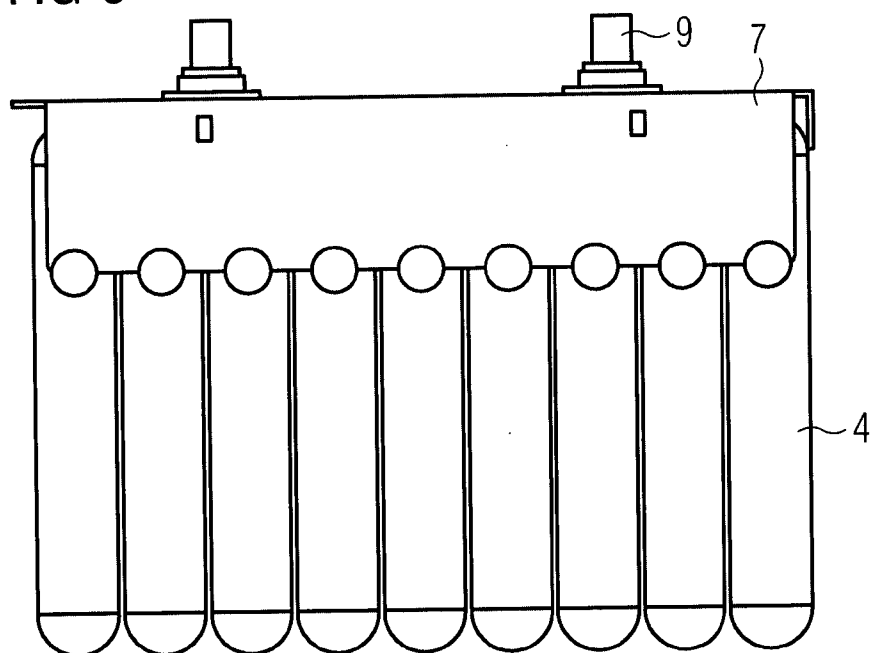


FIG 7

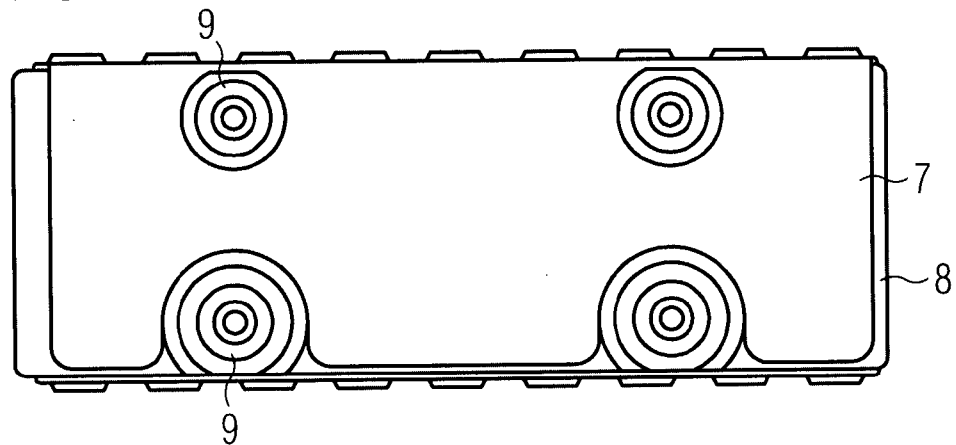


FIG 8

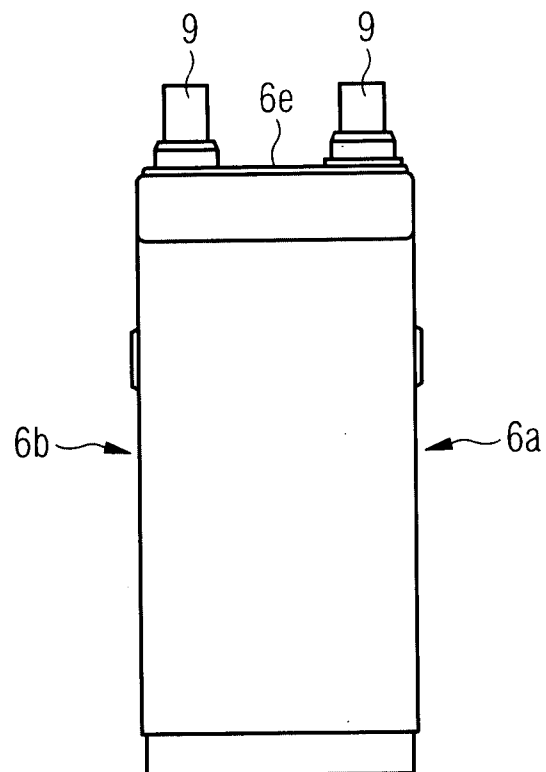


FIG 9

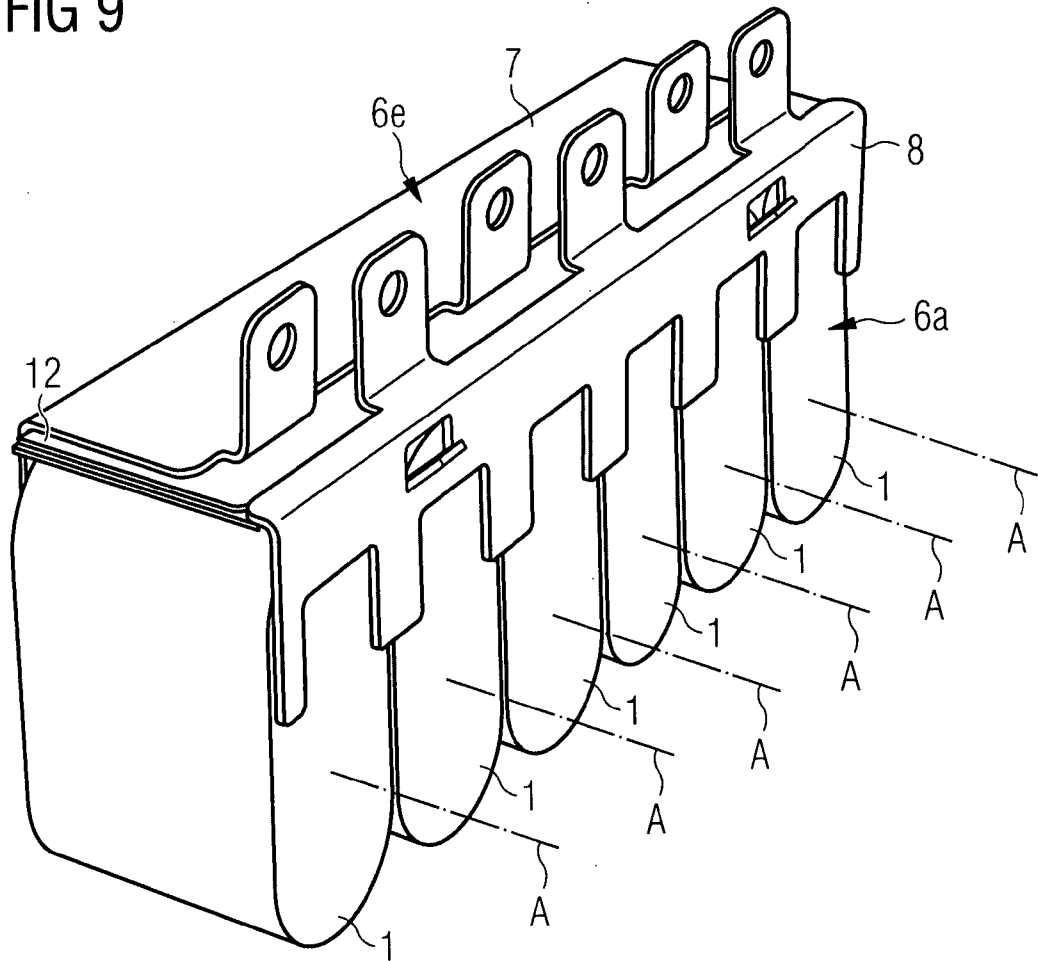


FIG 10

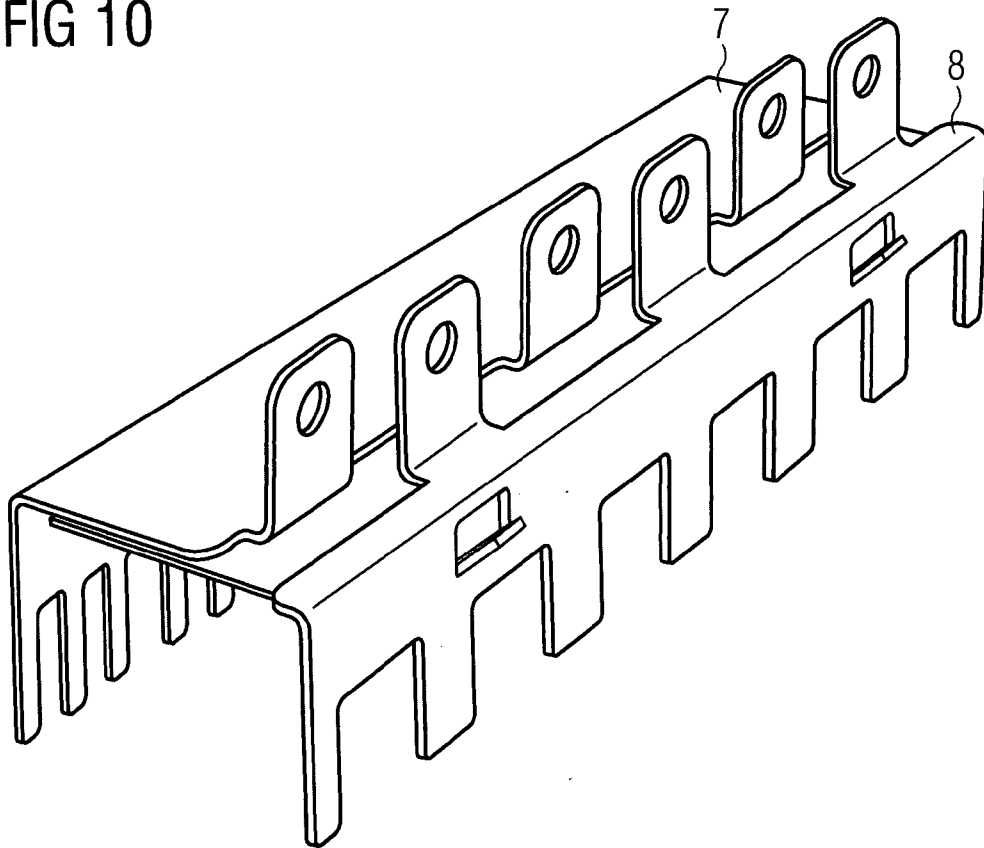


FIG 11

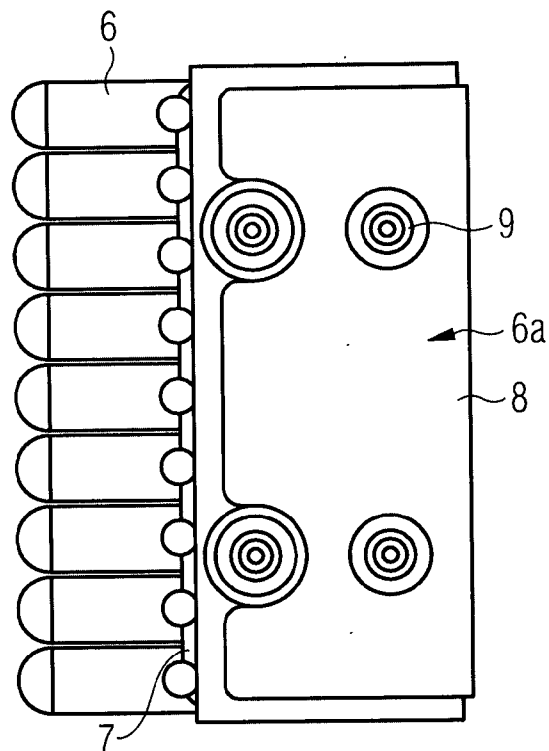


FIG 12

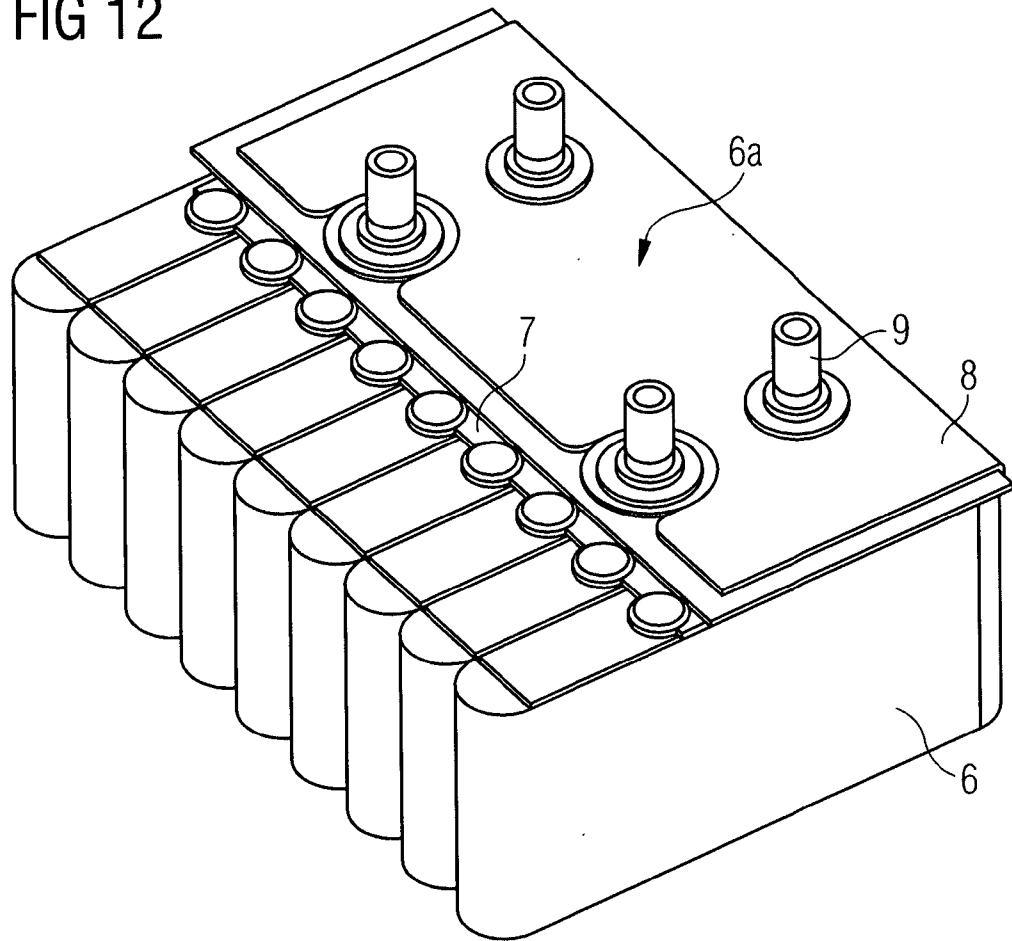


FIG 13

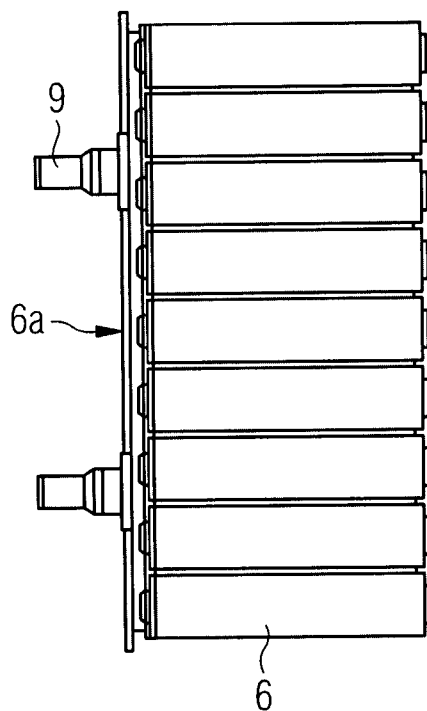


FIG 14

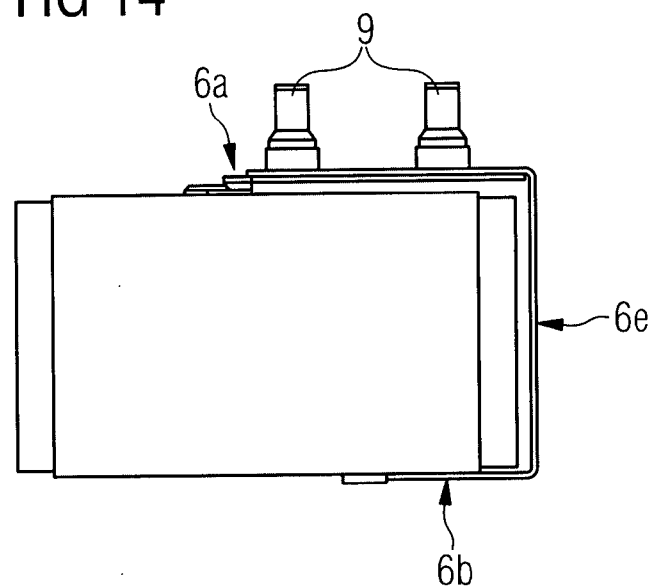


FIG 15

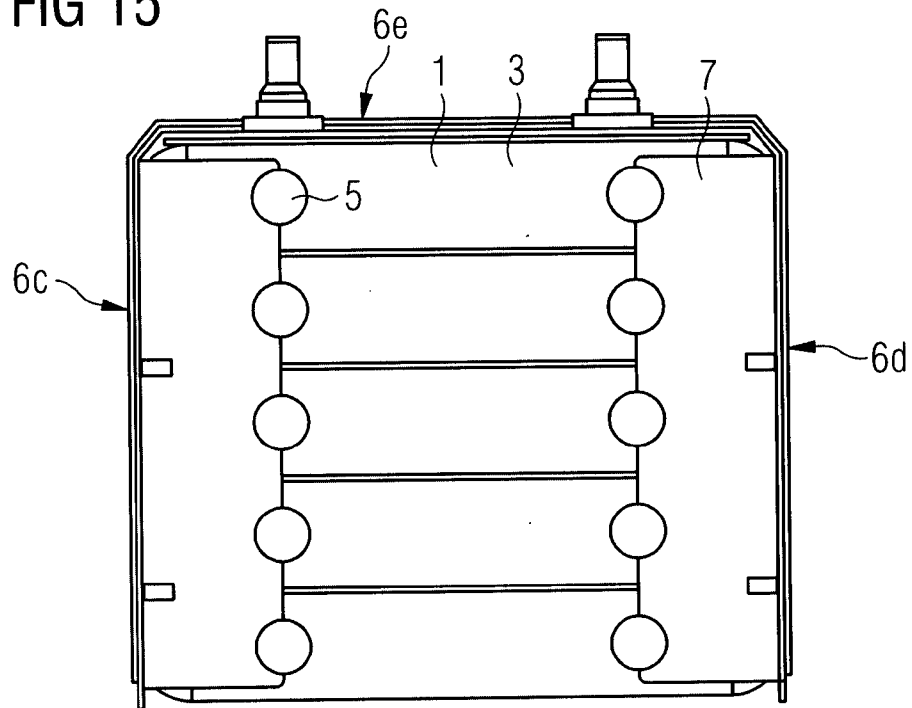


FIG 16

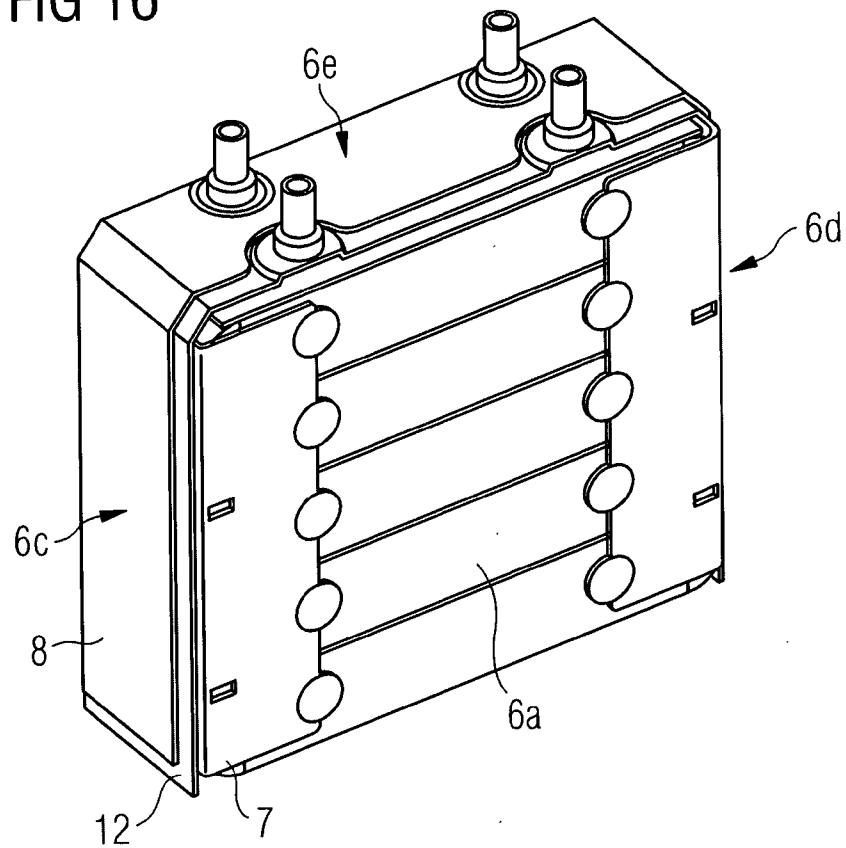


FIG 17

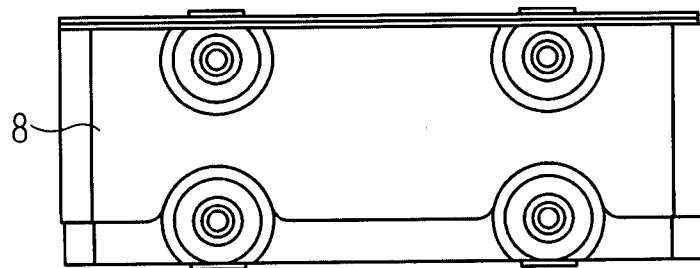


FIG 18

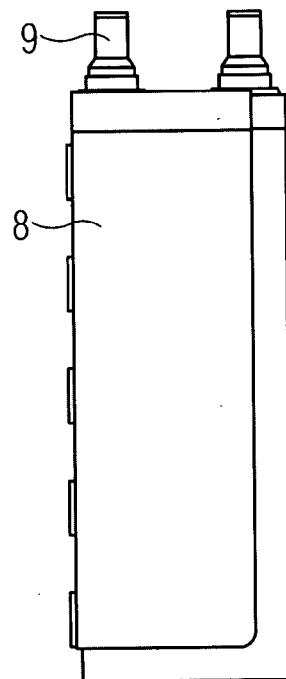


FIG 19

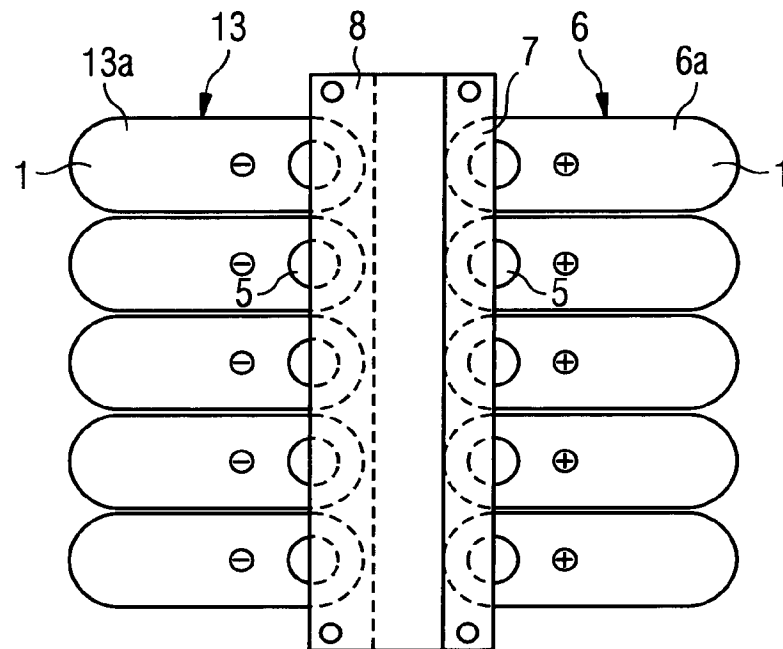


FIG 20

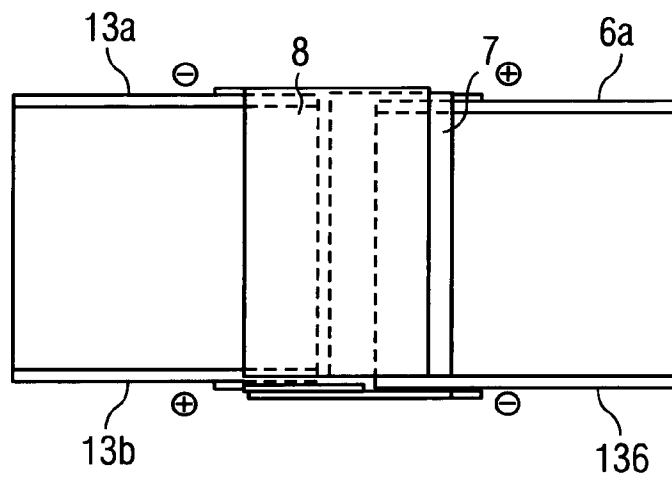


FIG 21

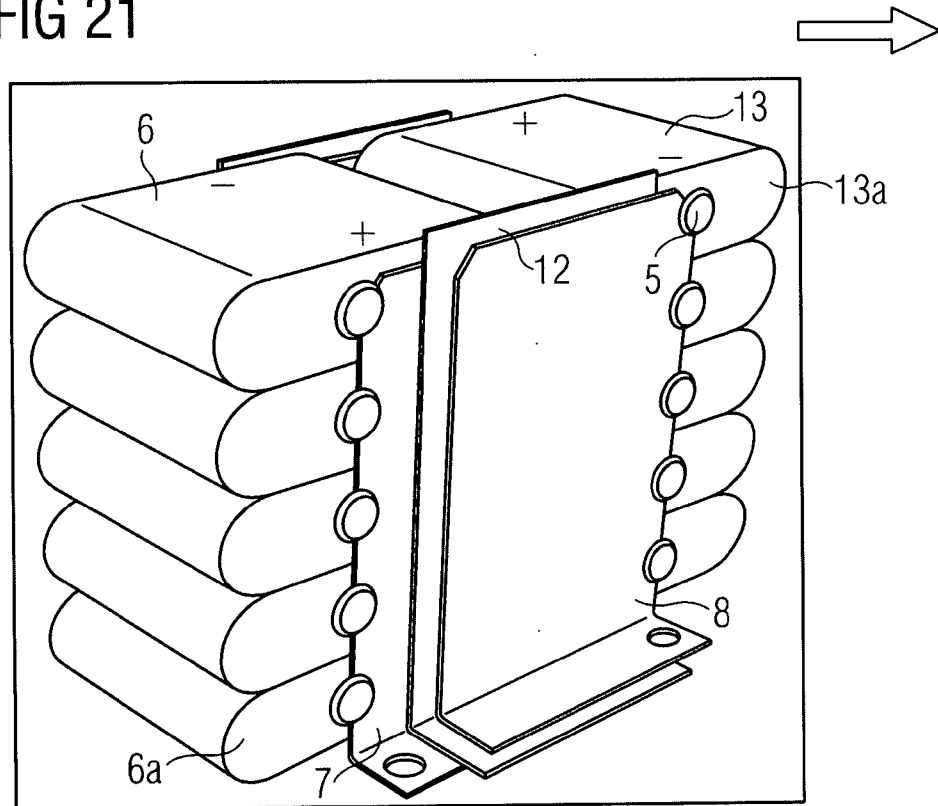


FIG 22

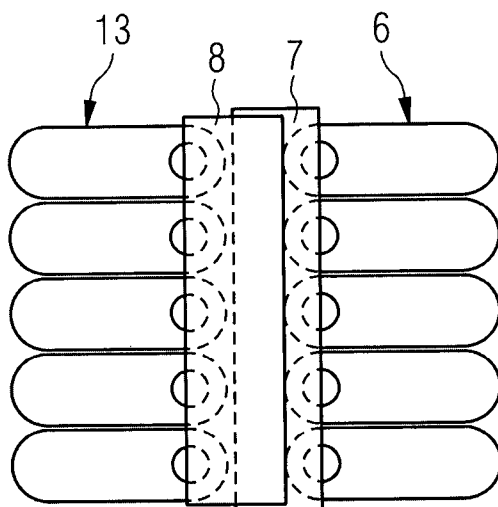


FIG 23

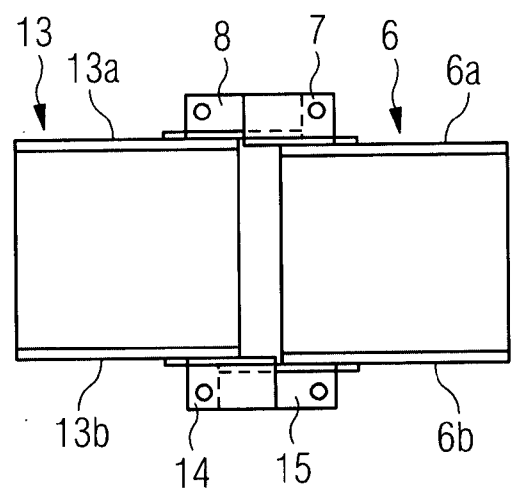


FIG 24

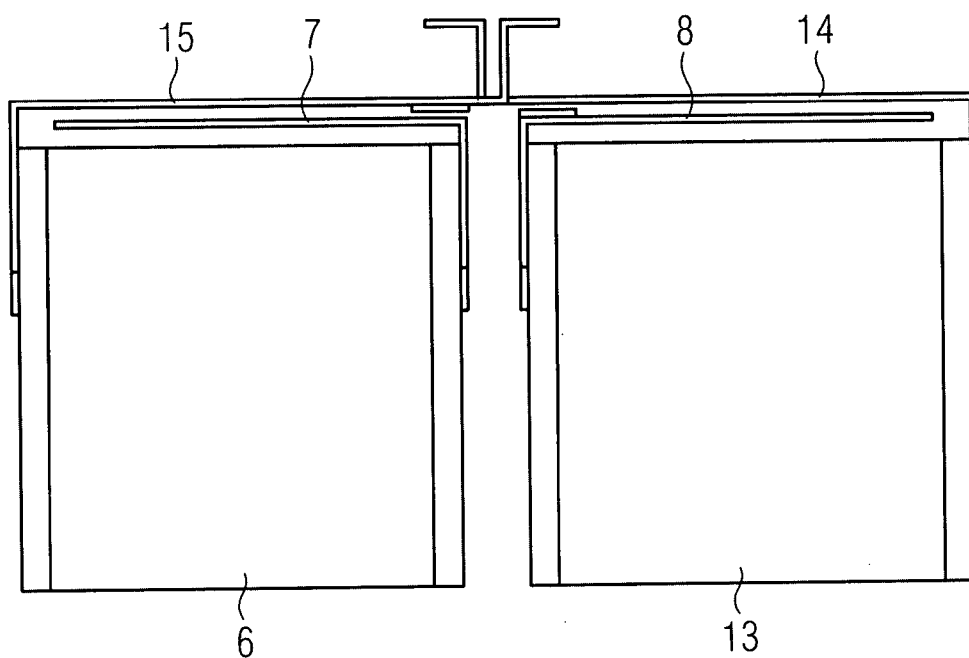


FIG 25

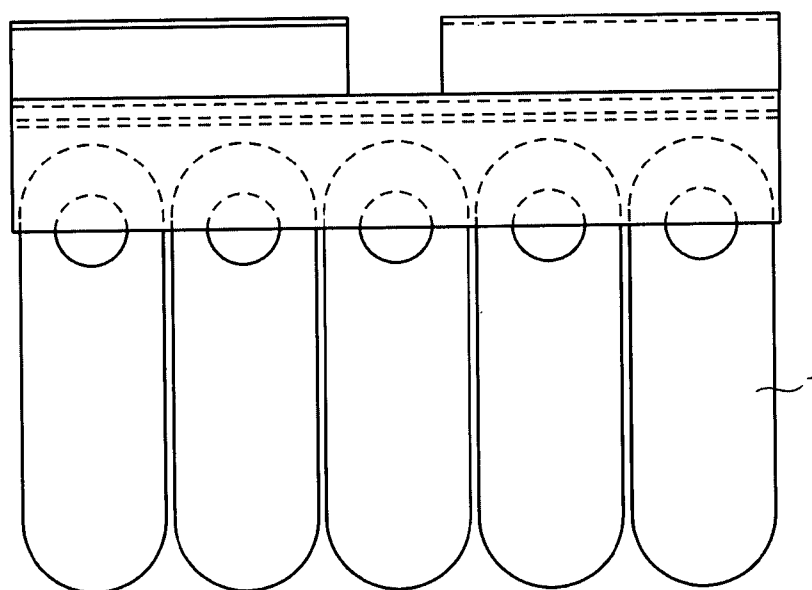


FIG 26

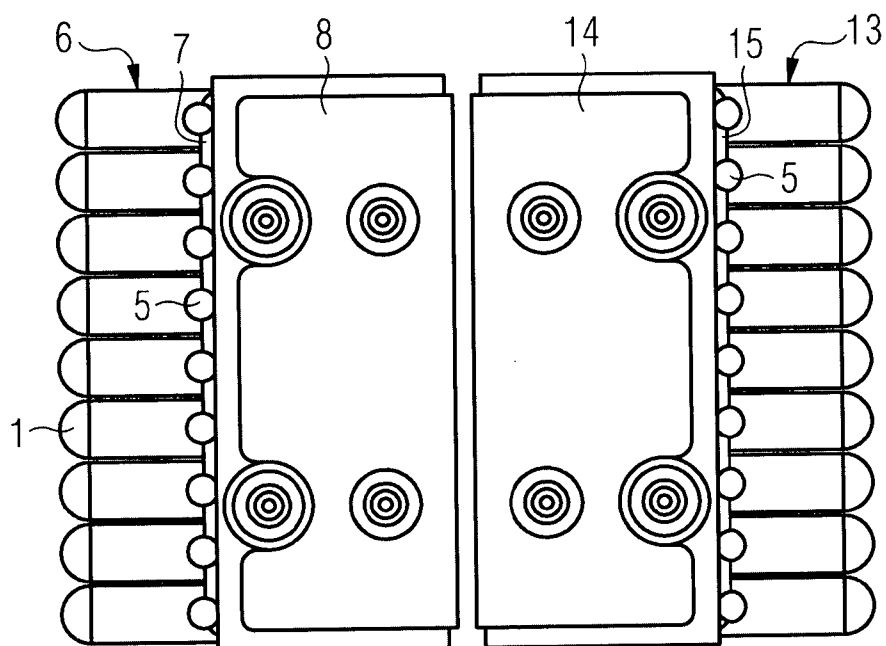


FIG 27

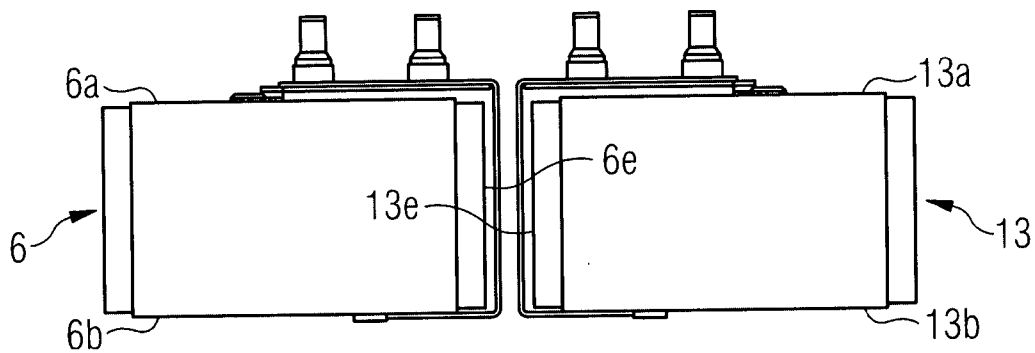


FIG 28

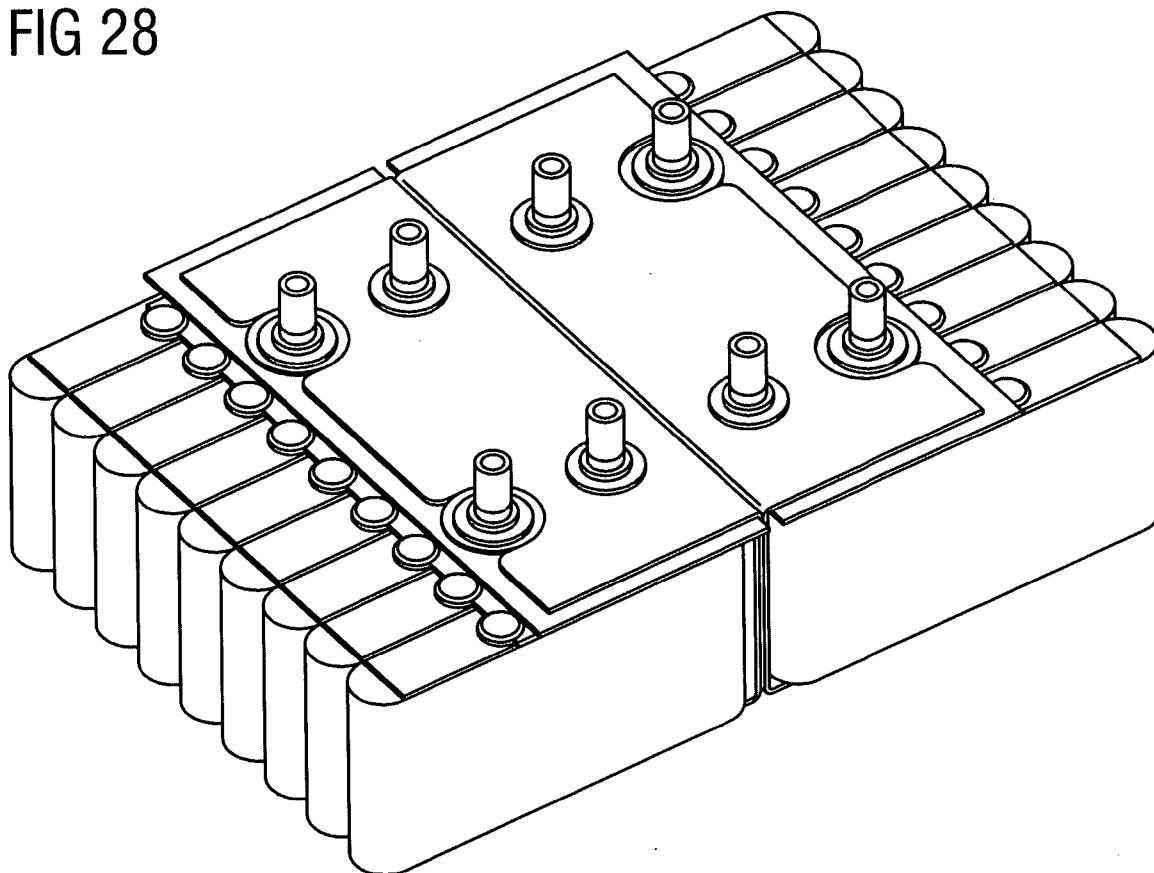


FIG 29

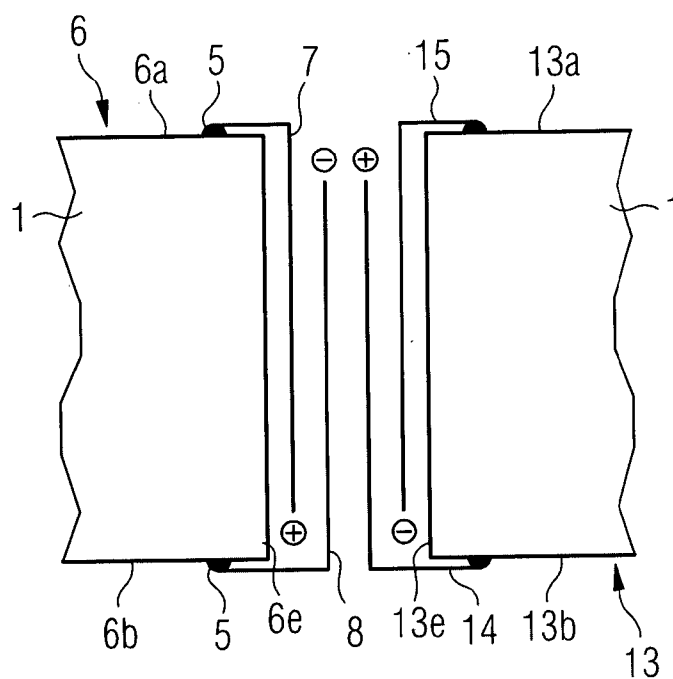


FIG 30

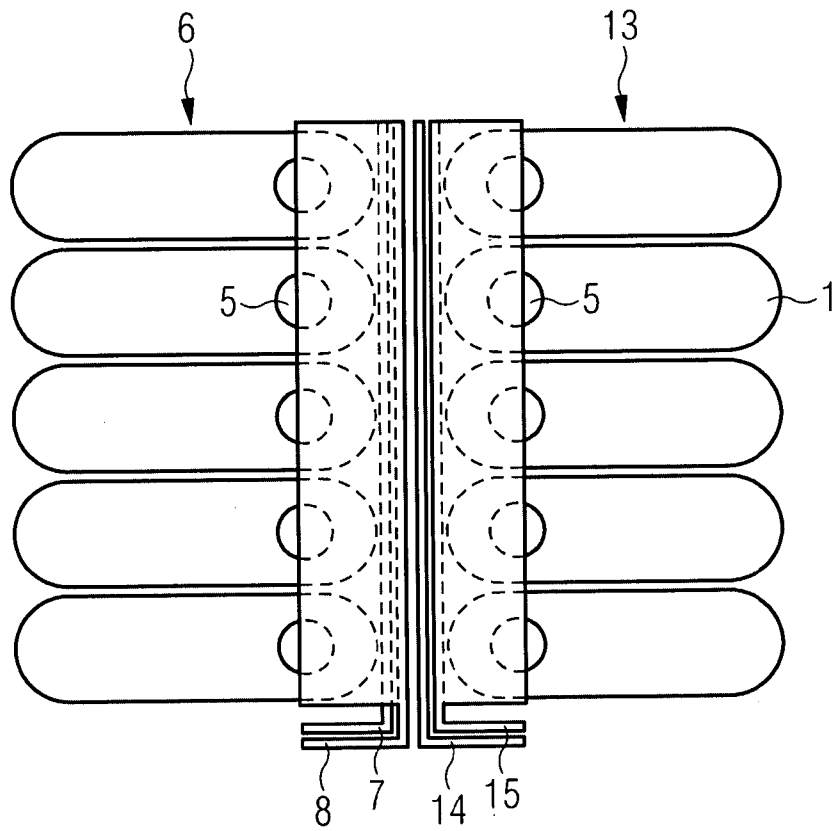


FIG 31

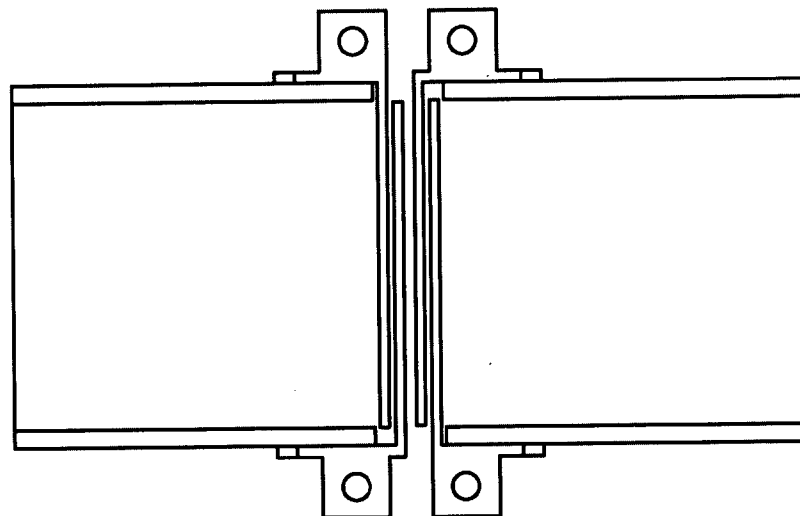


FIG 32

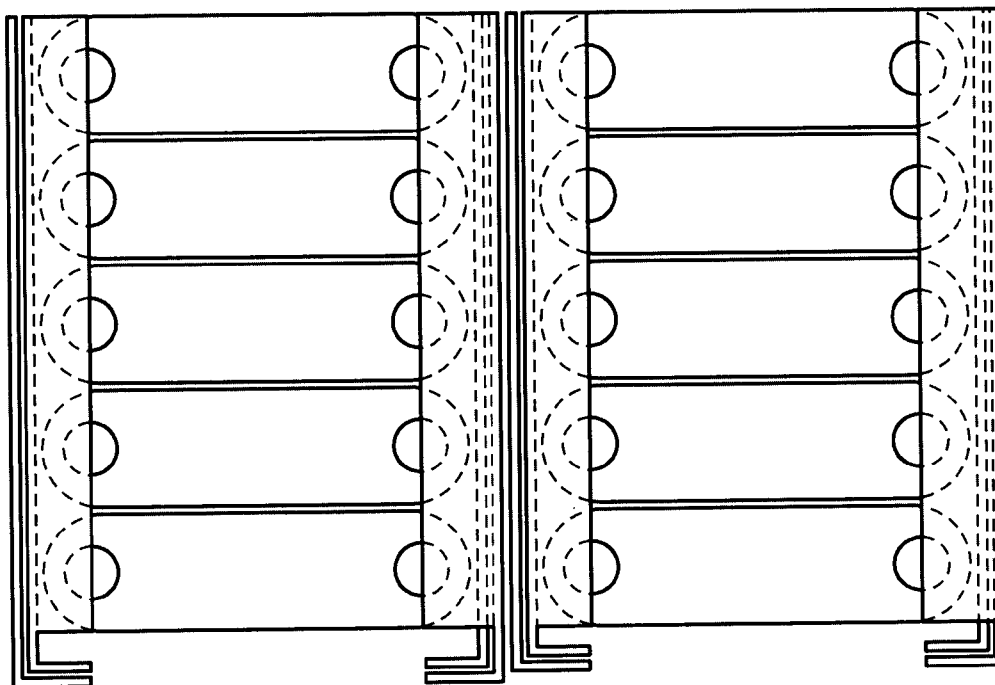


FIG 33

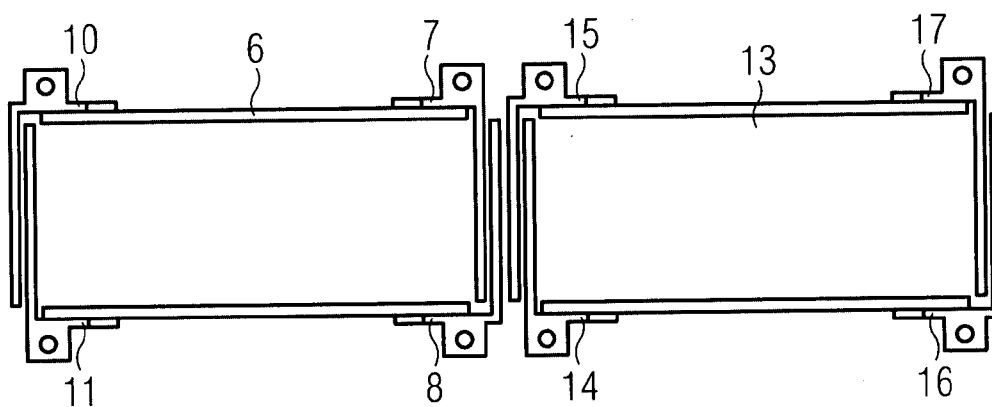


FIG 34

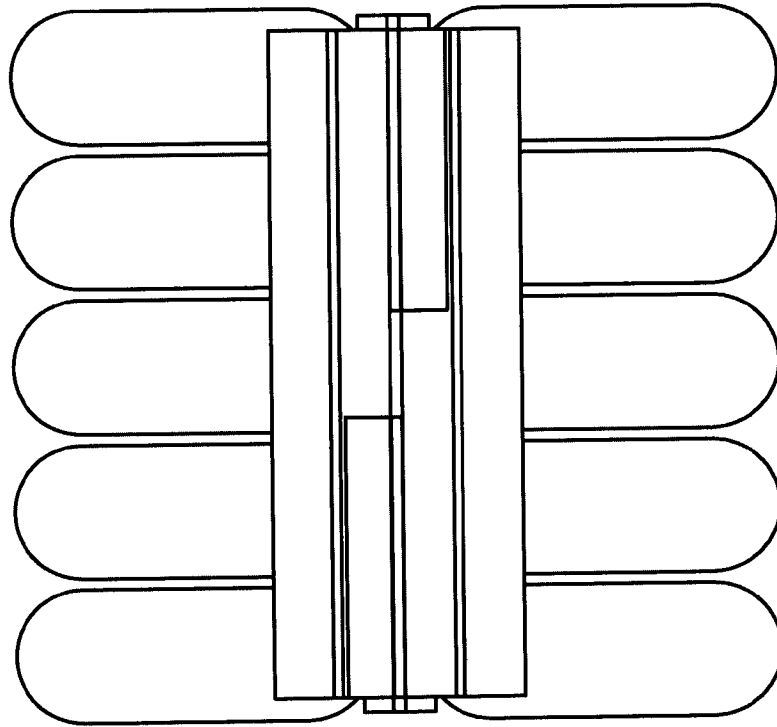


FIG 35

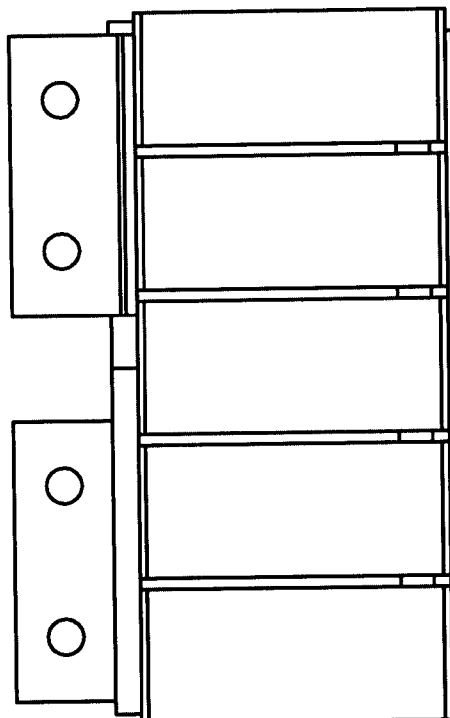


FIG 36

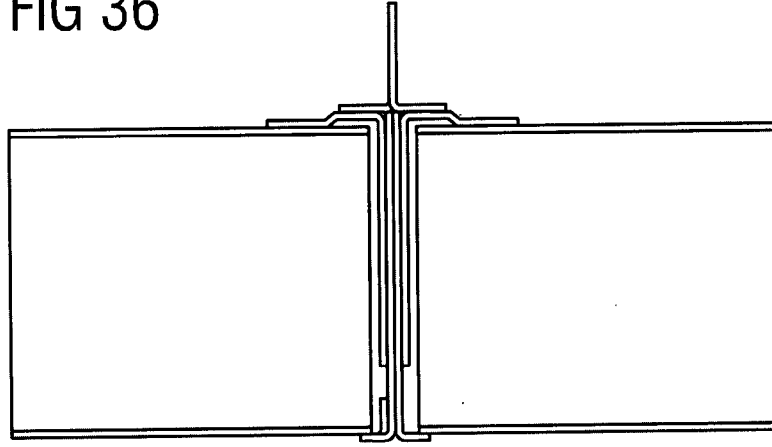


FIG 37

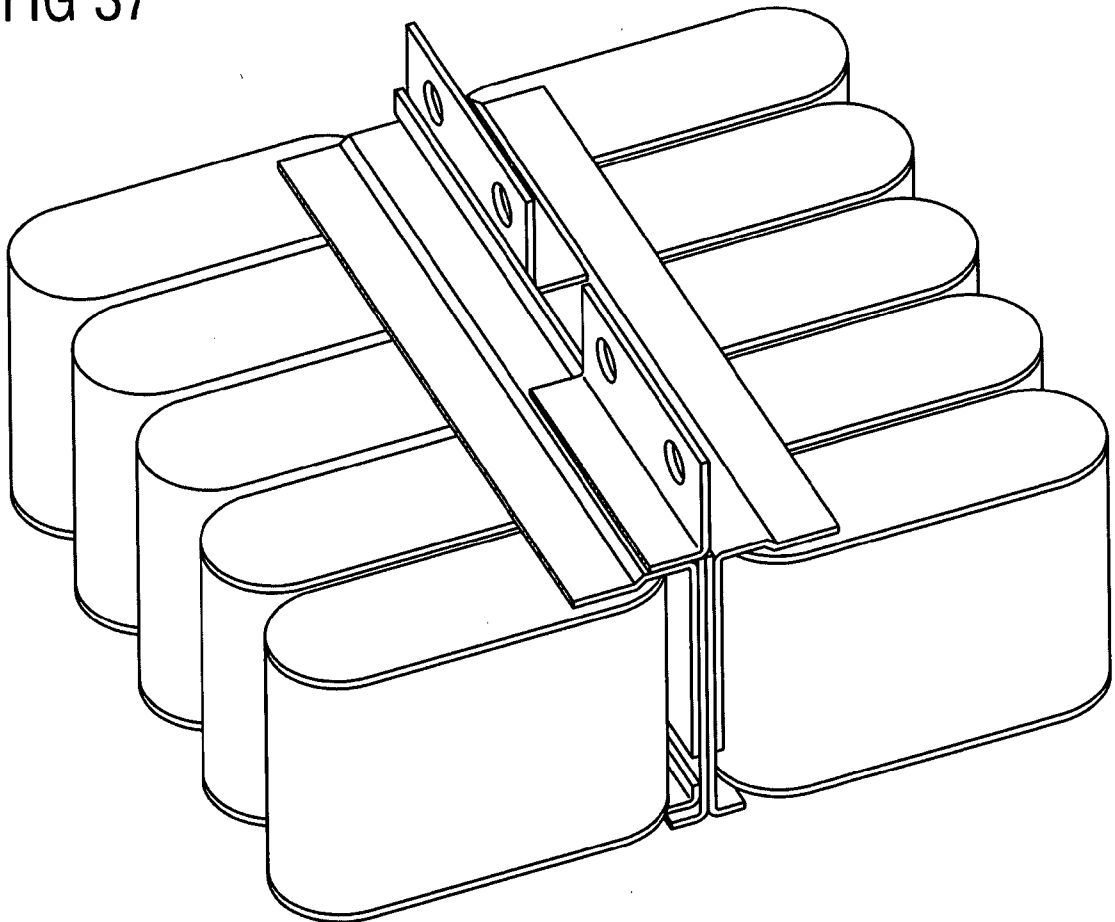


FIG 38

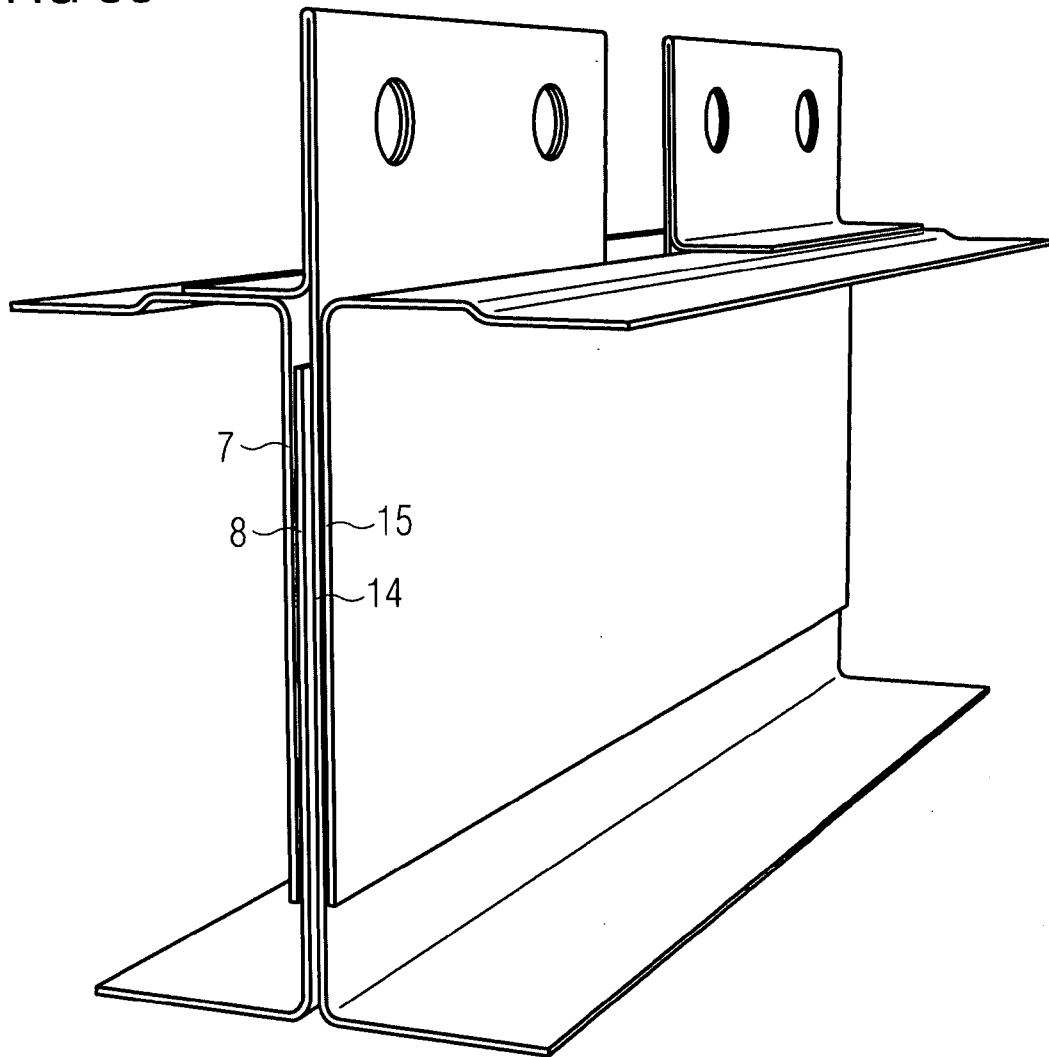


FIG 39

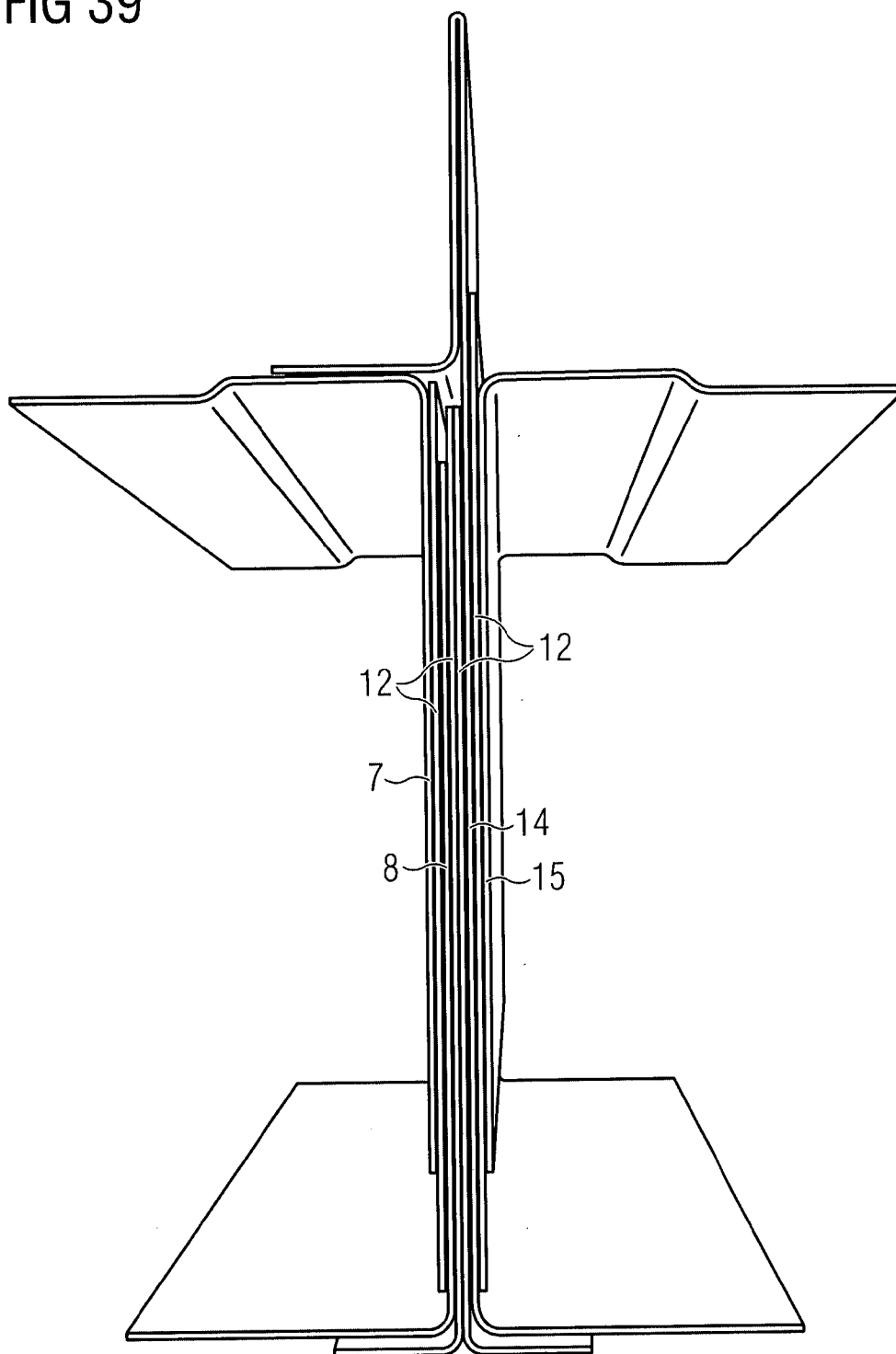


FIG 40

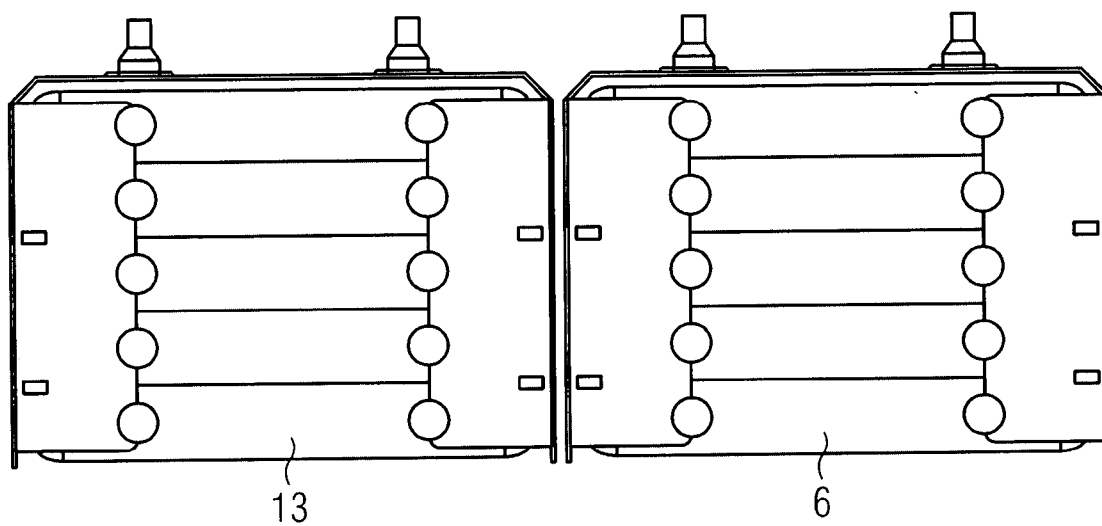


FIG 41

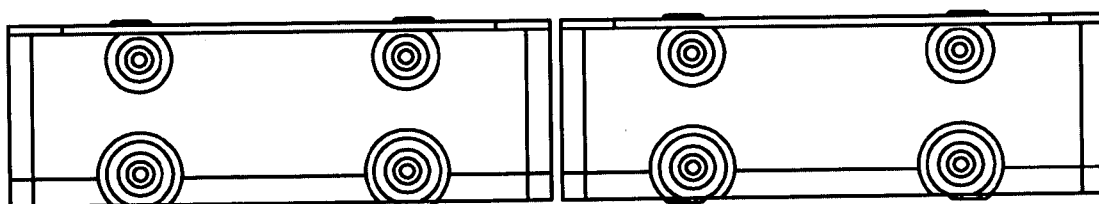


FIG 42

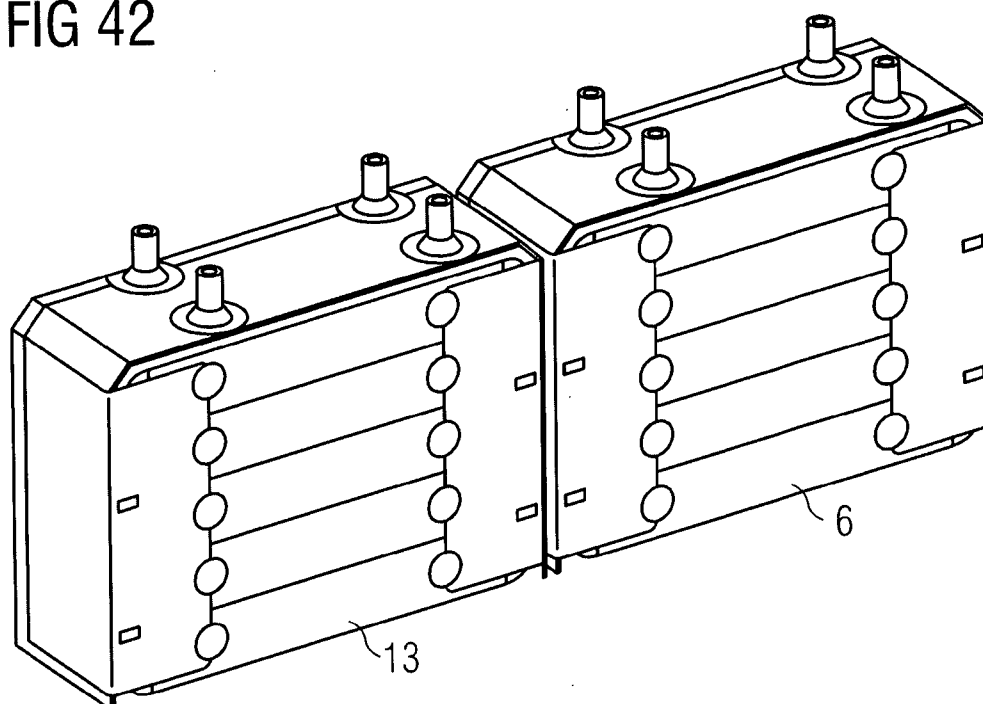


FIG 43

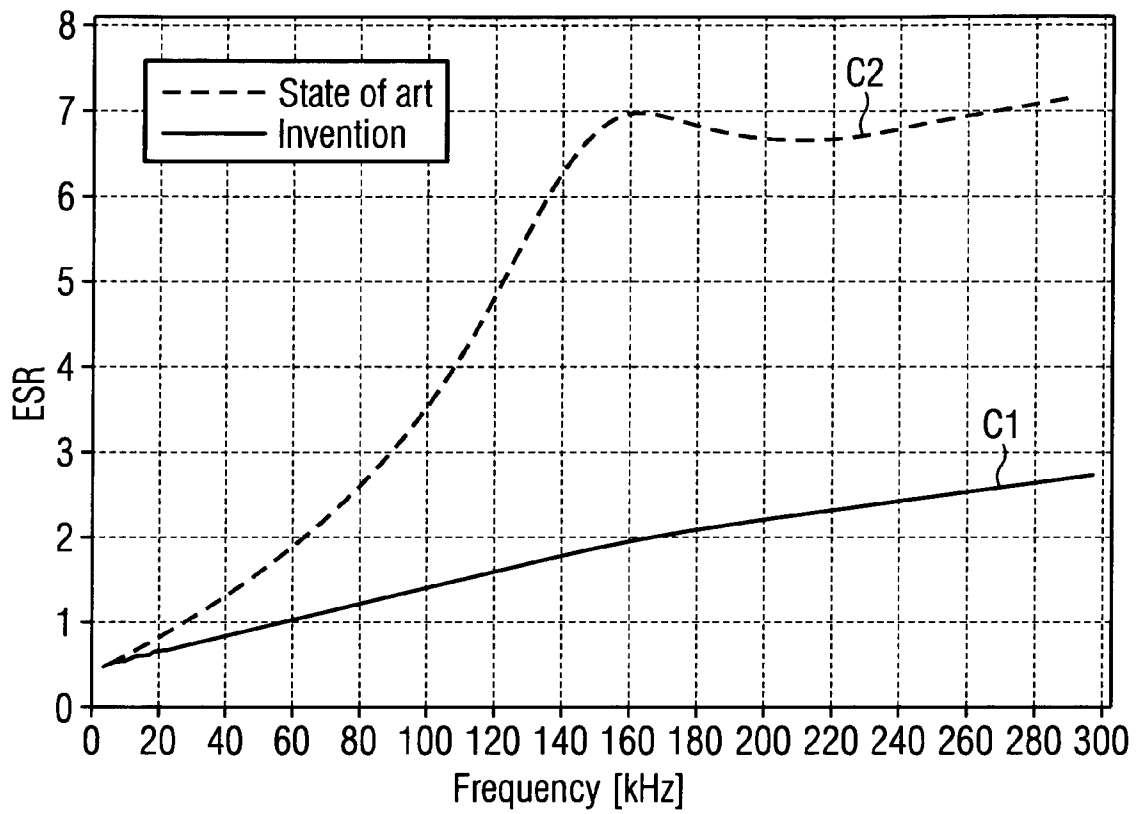


FIG 44

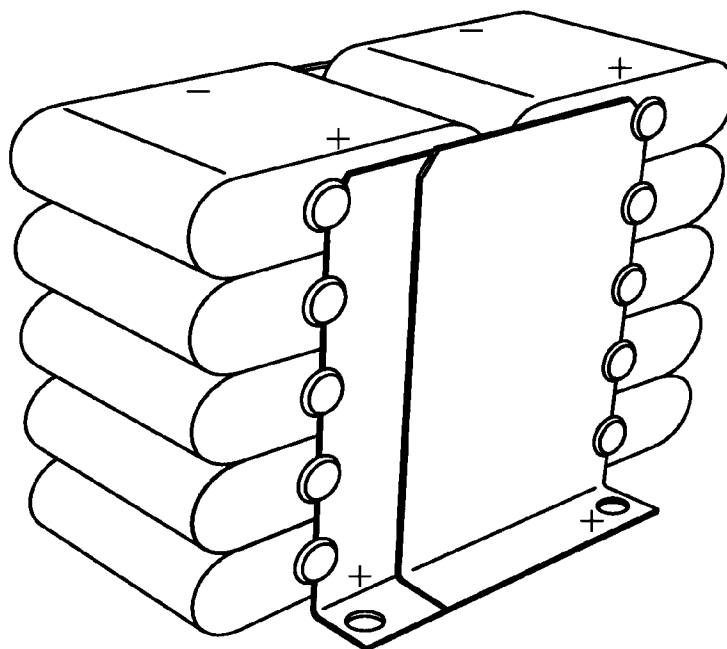


FIG 45

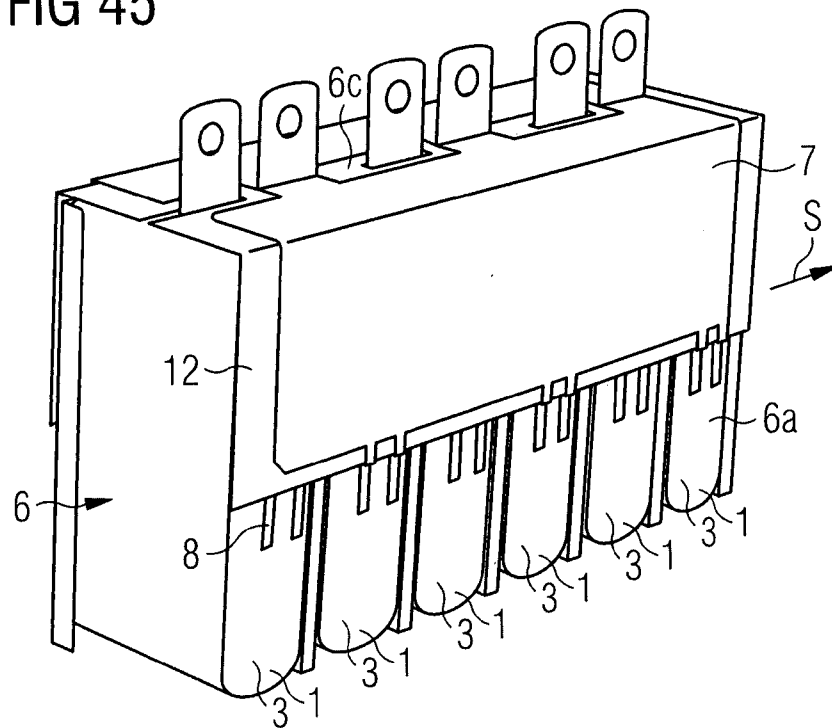


FIG 46

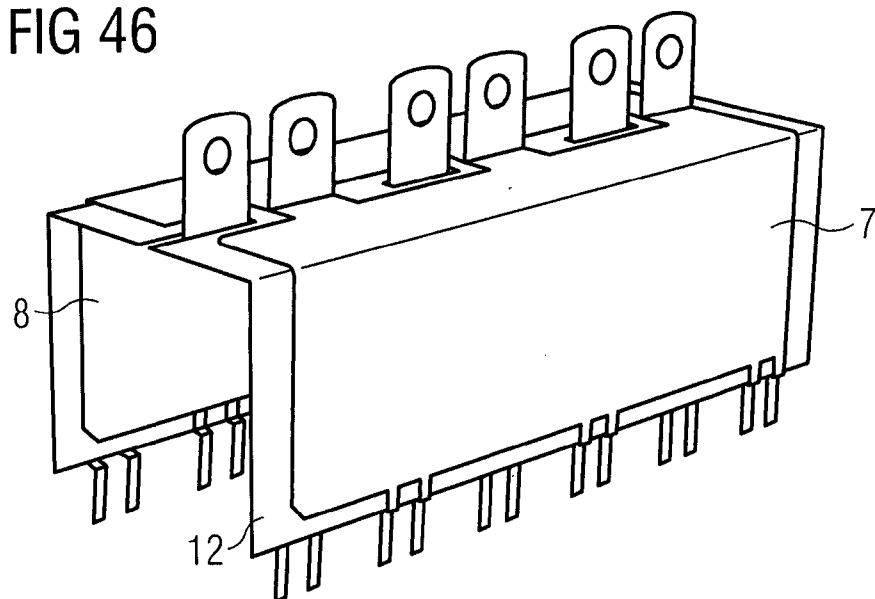


FIG 47

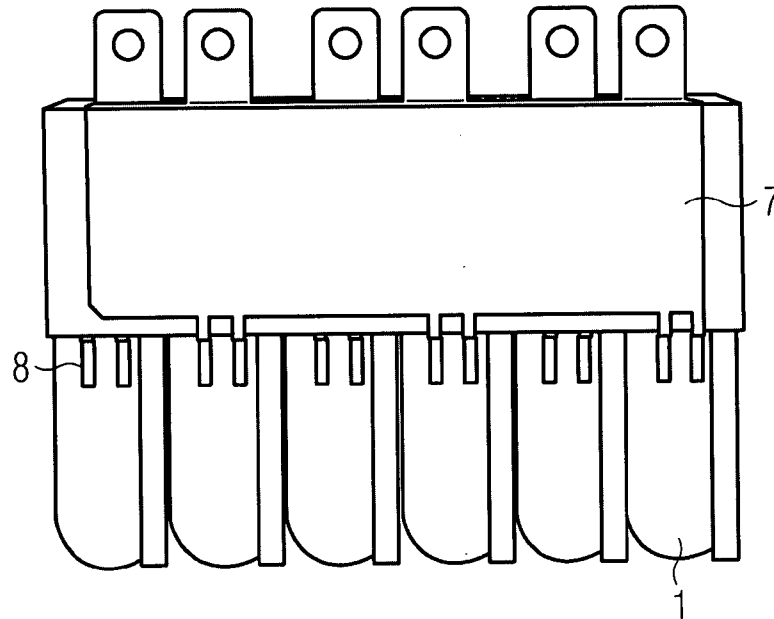


FIG 48

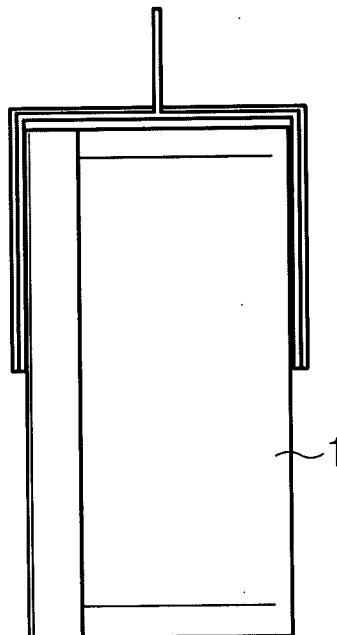


FIG 49

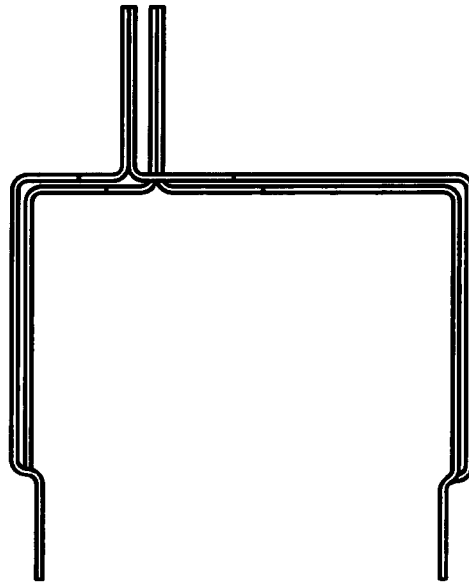


FIG 50

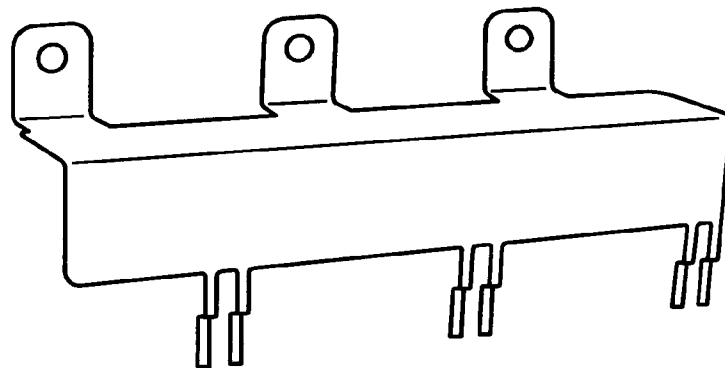


FIG 51

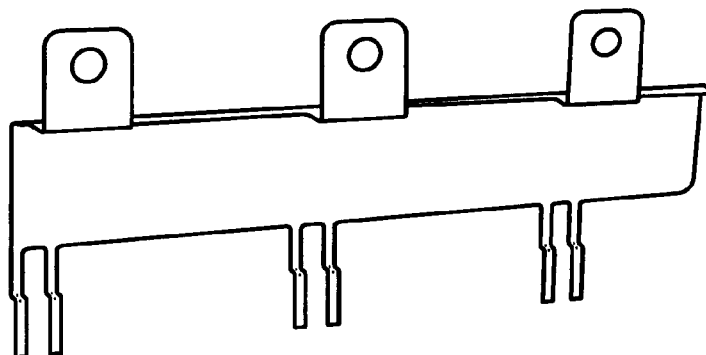


FIG 52

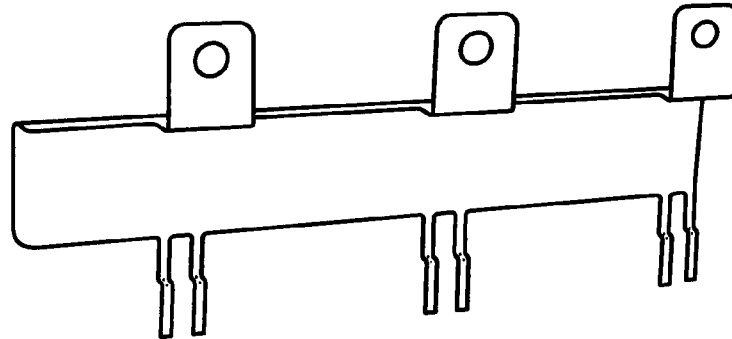


FIG 53

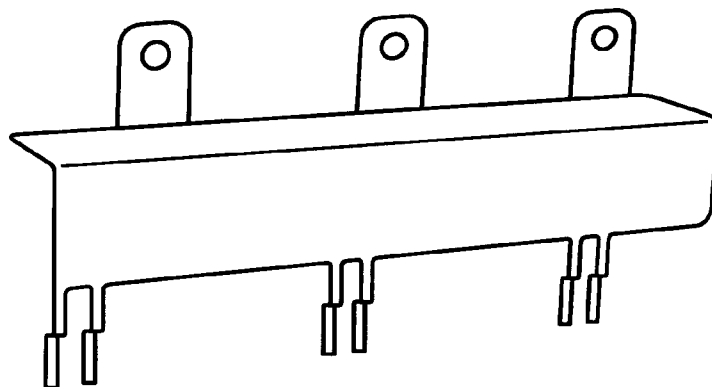


FIG 54

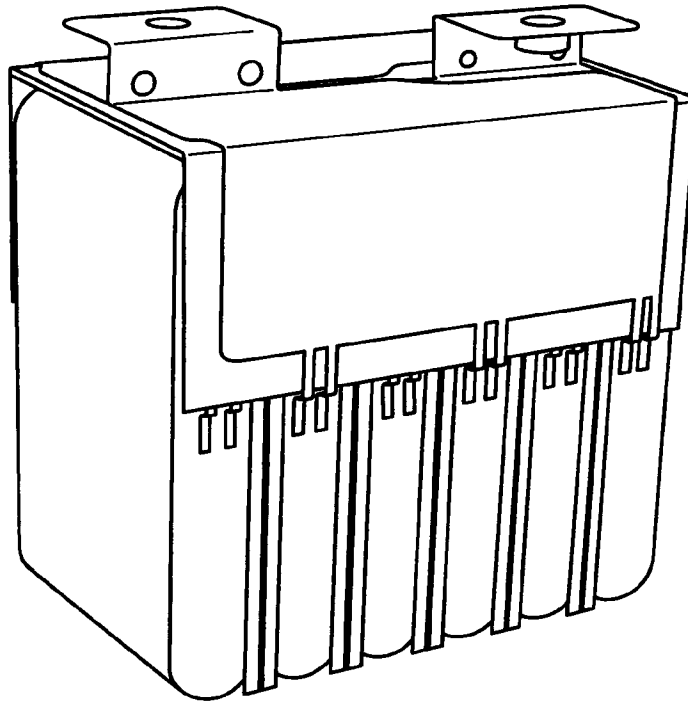


FIG 55

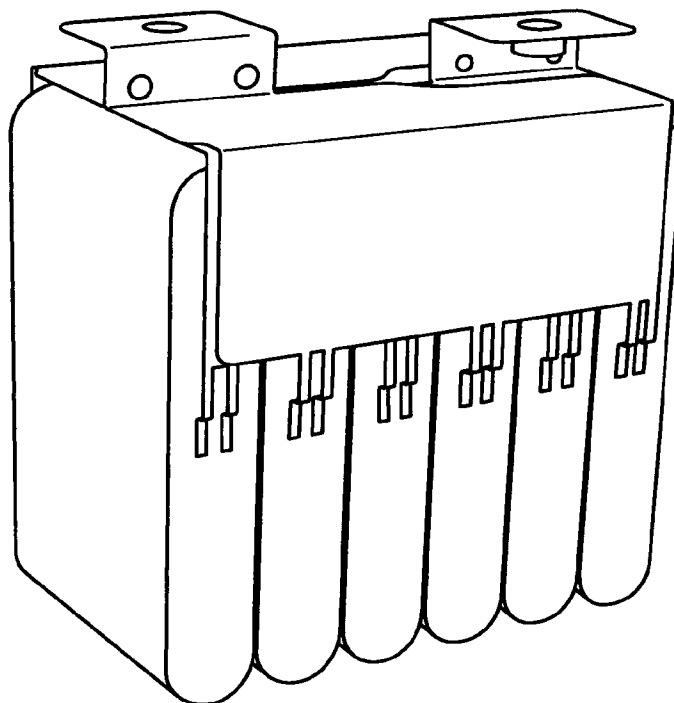


FIG 56

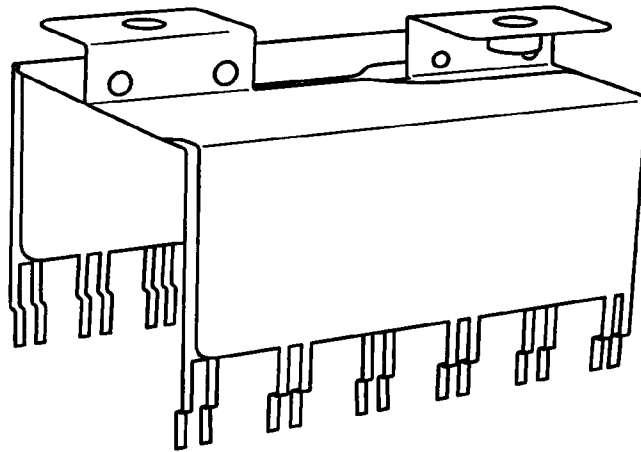


FIG 57

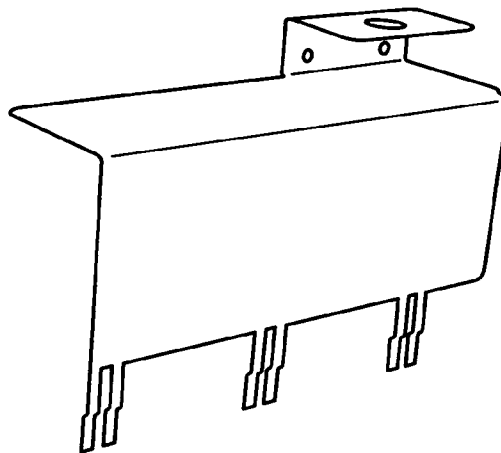


FIG 58

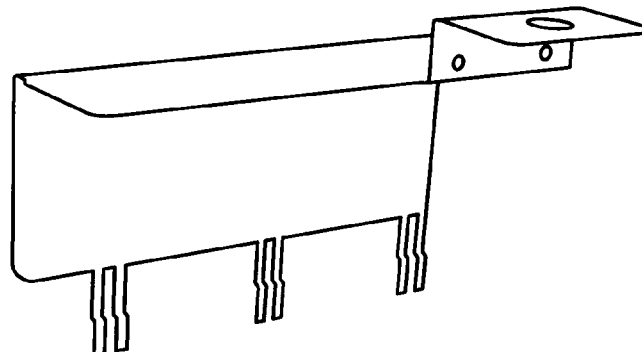


FIG 59

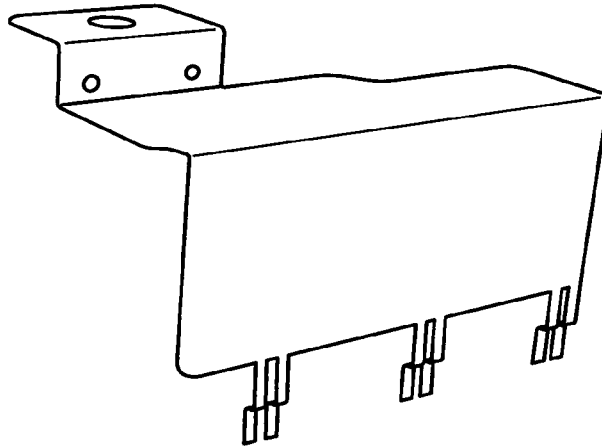


FIG 60

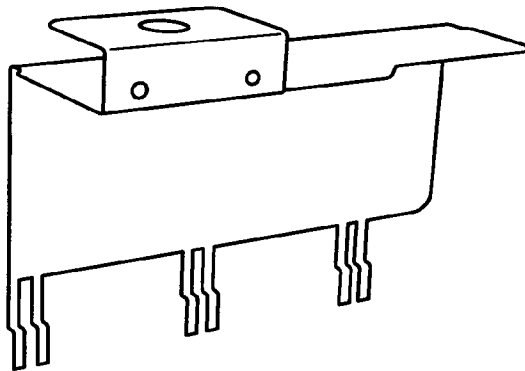


FIG 61

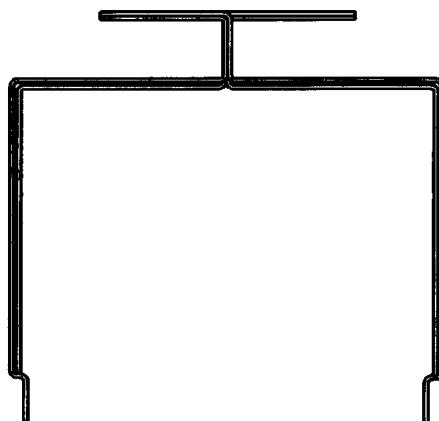


FIG 62

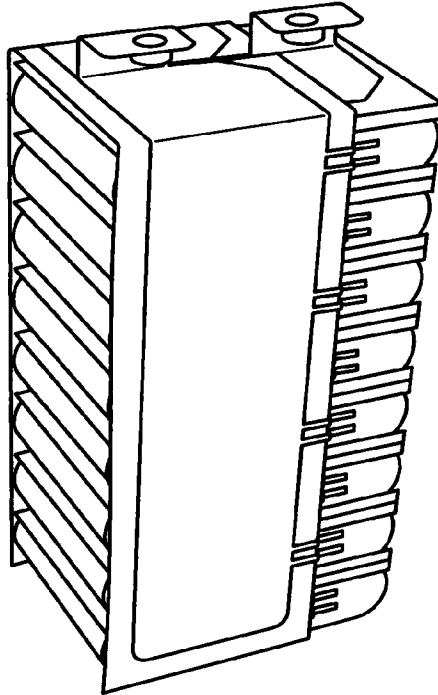


FIG 63

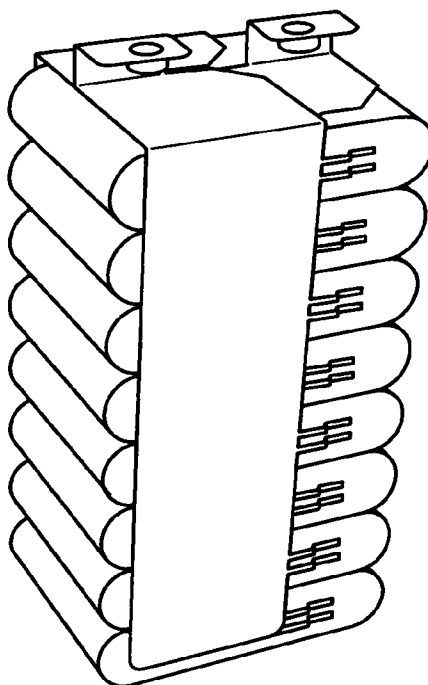


FIG 64

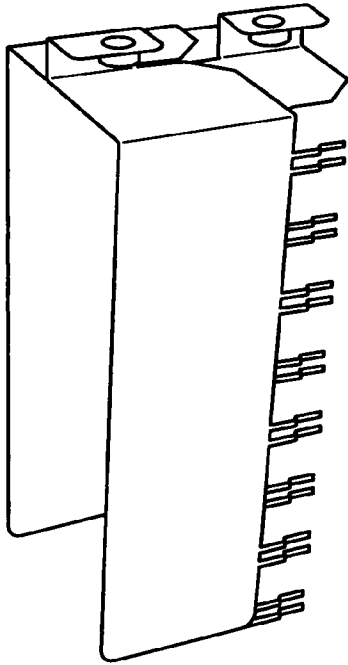


FIG 65

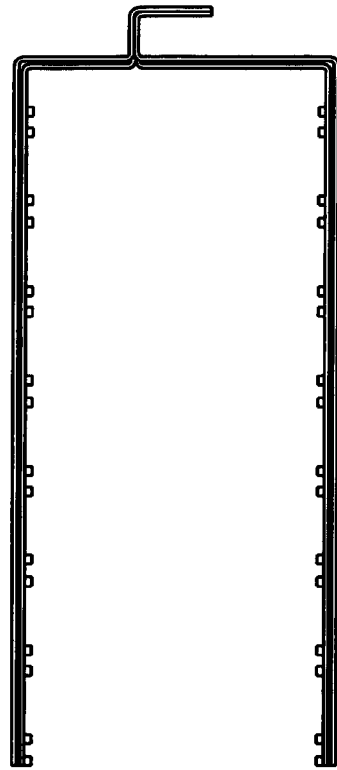


FIG 66

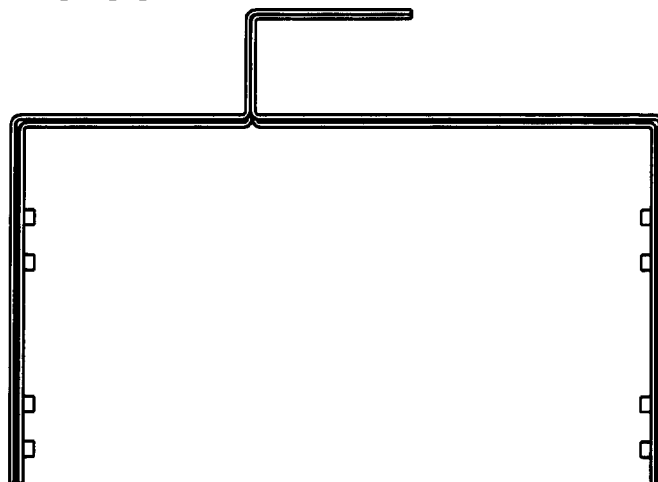


FIG 67

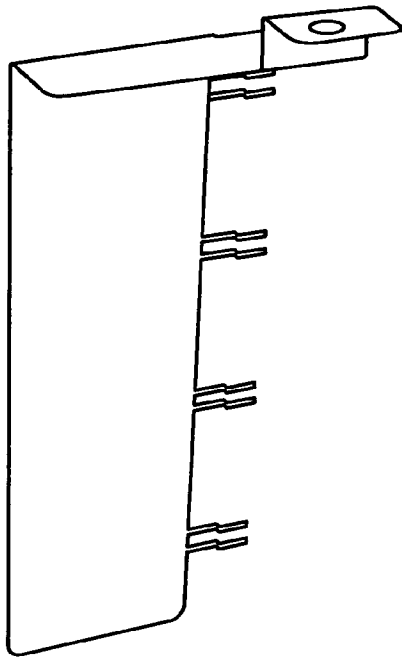


FIG 68

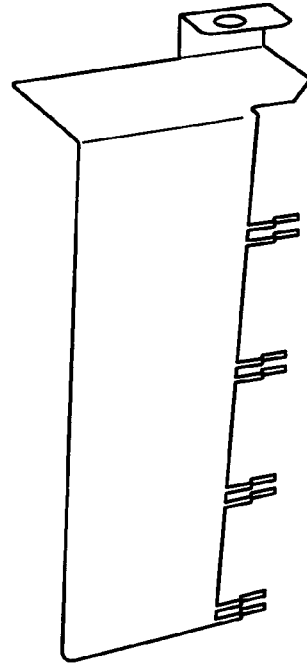


FIG 69

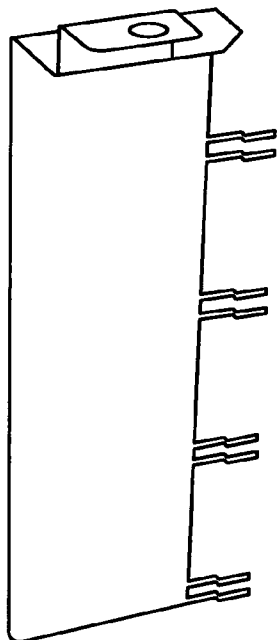


FIG 70

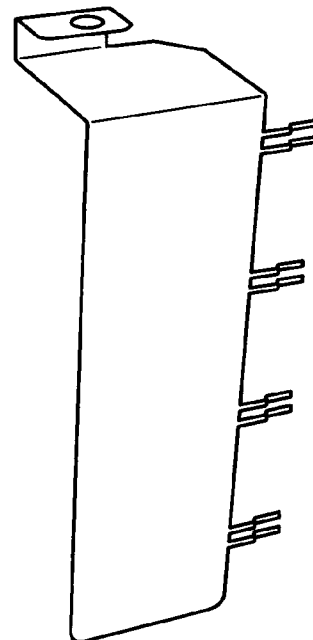


FIG 71

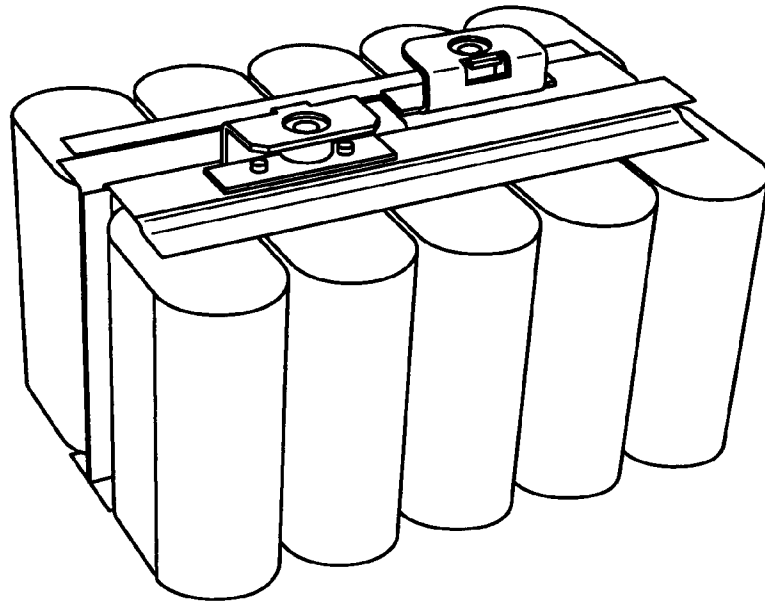


FIG 72

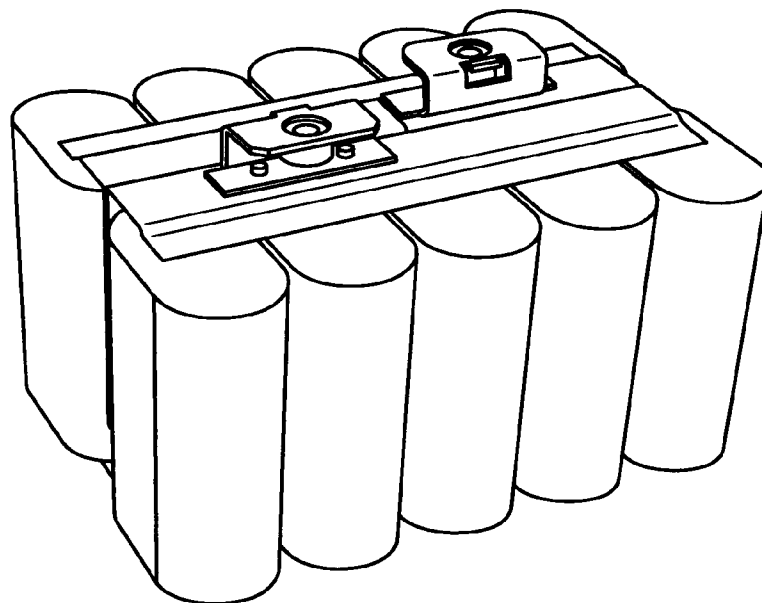


FIG 73

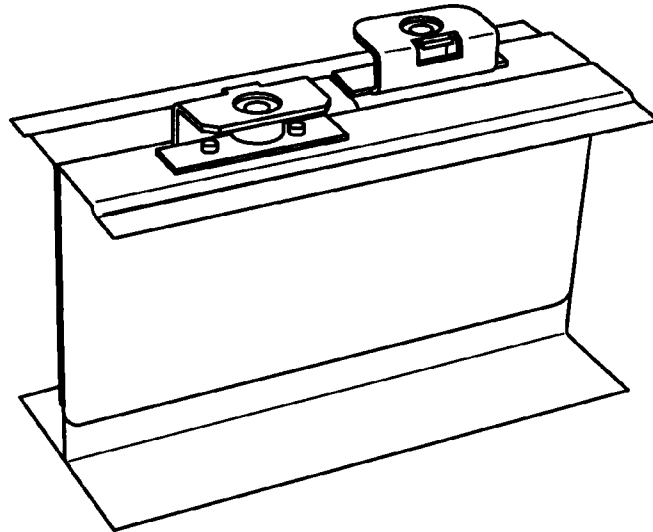


FIG 74

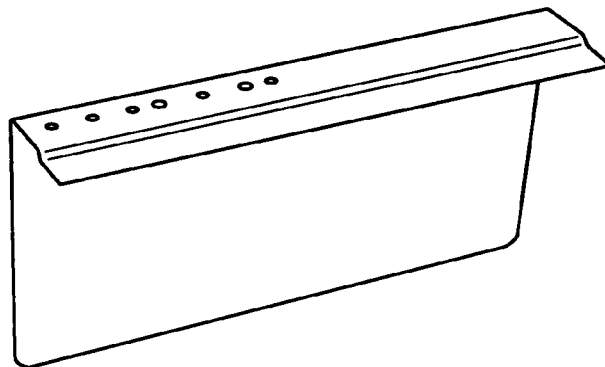


FIG 75

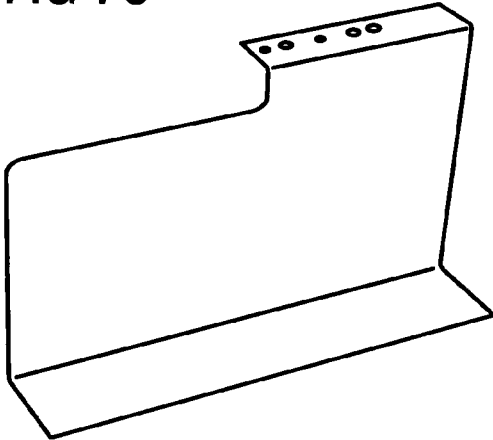


FIG 76

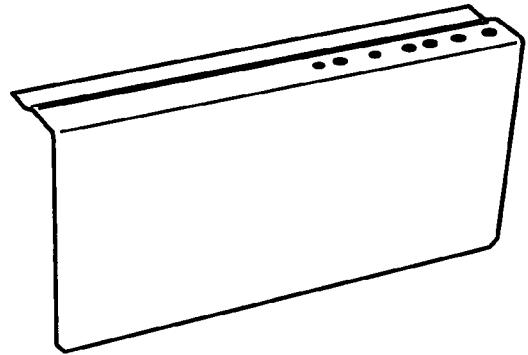


FIG 77

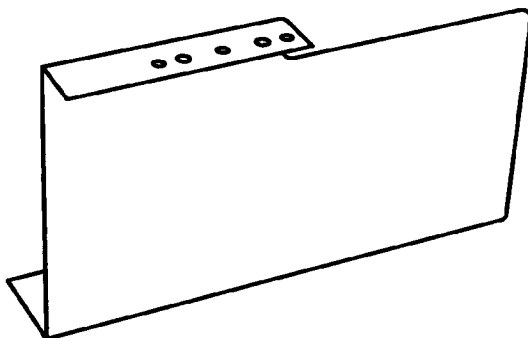


FIG 78

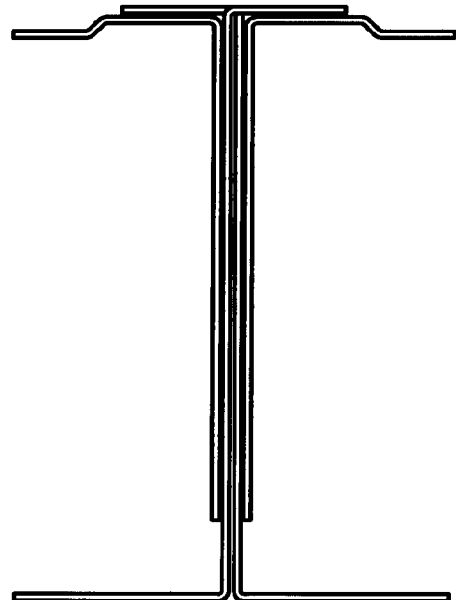


FIG 79

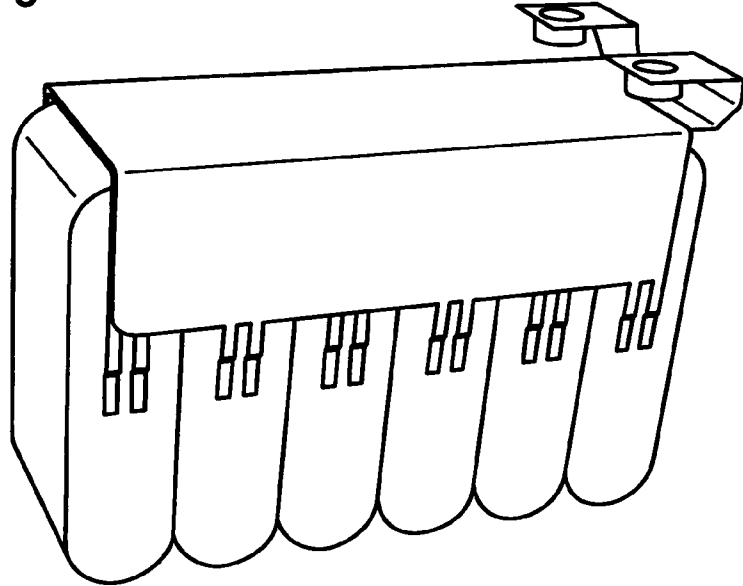


FIG 80

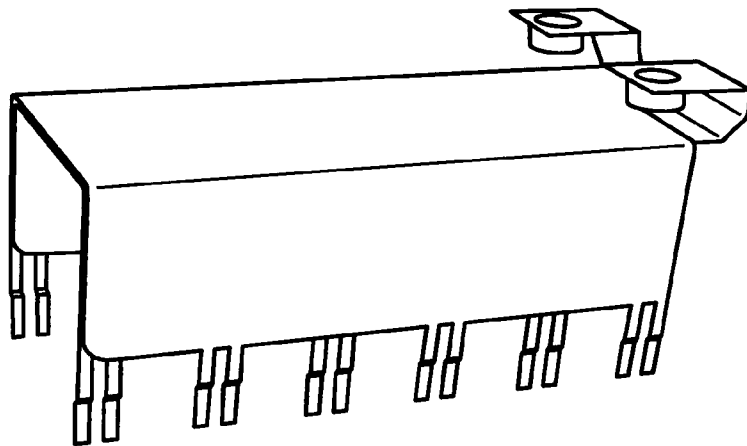


FIG 81

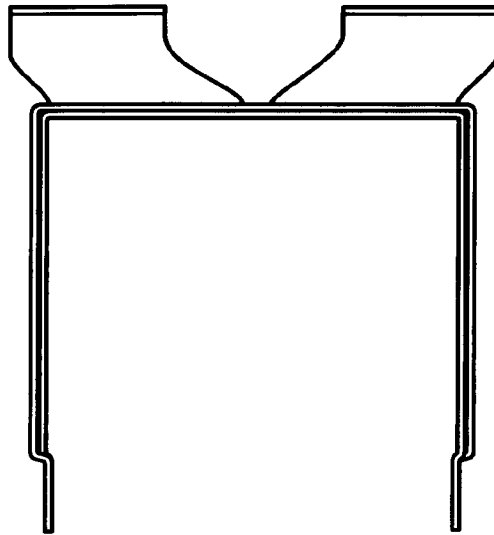


FIG 82

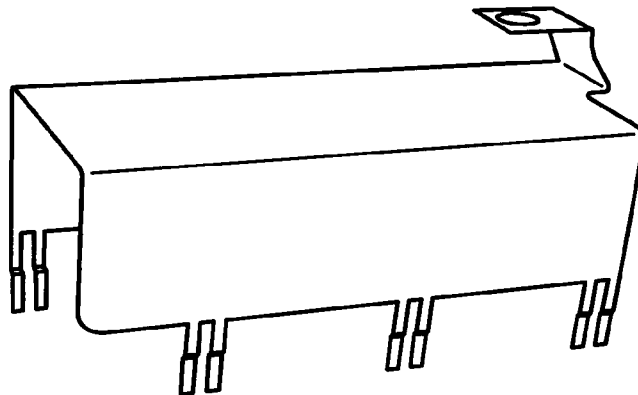


FIG 83

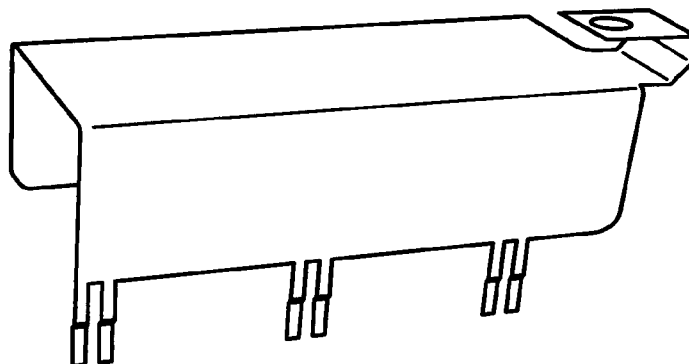


FIG 84

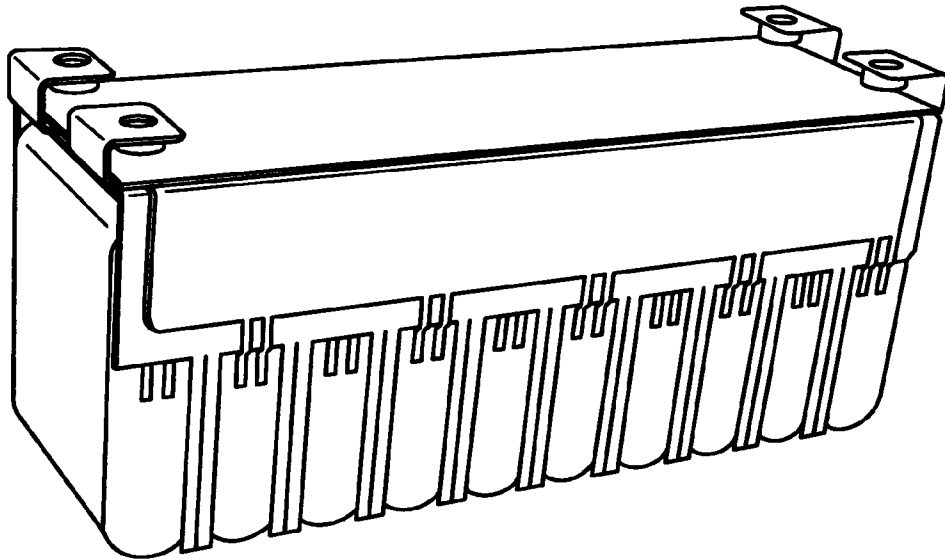


FIG 85

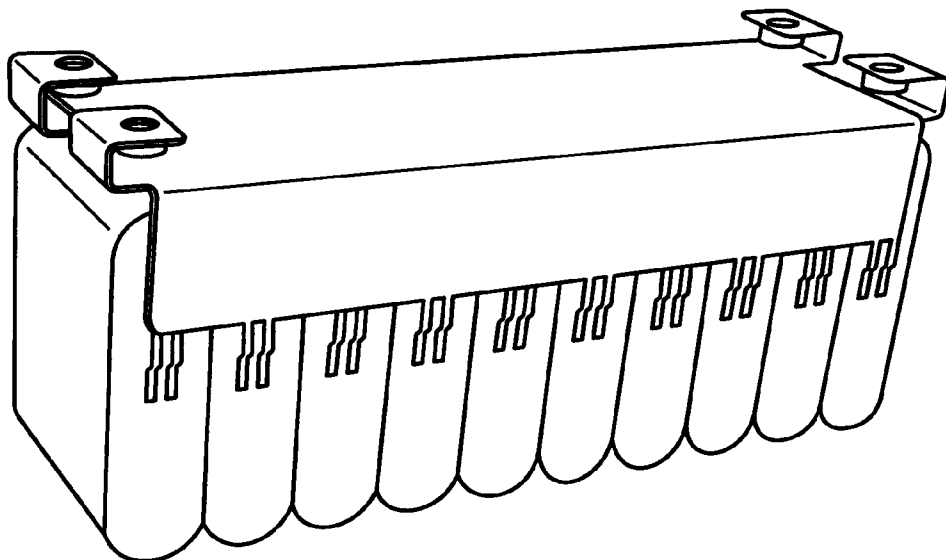


FIG 86

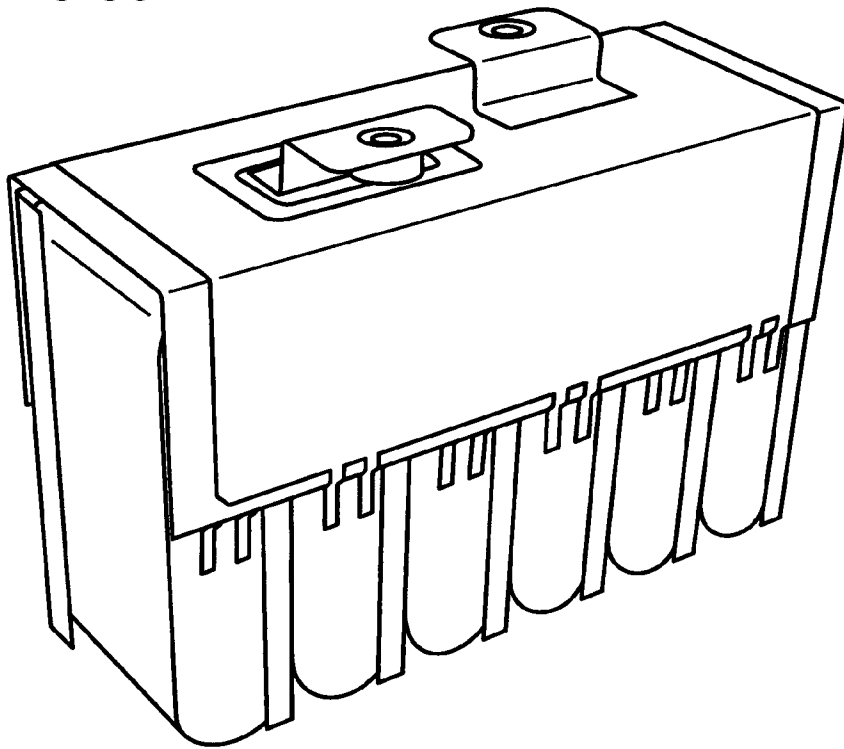


FIG 87

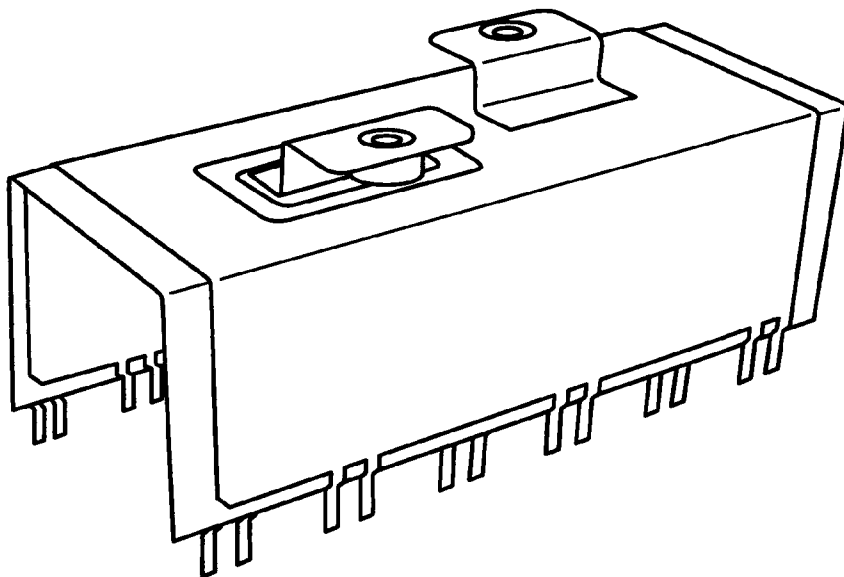


FIG 88

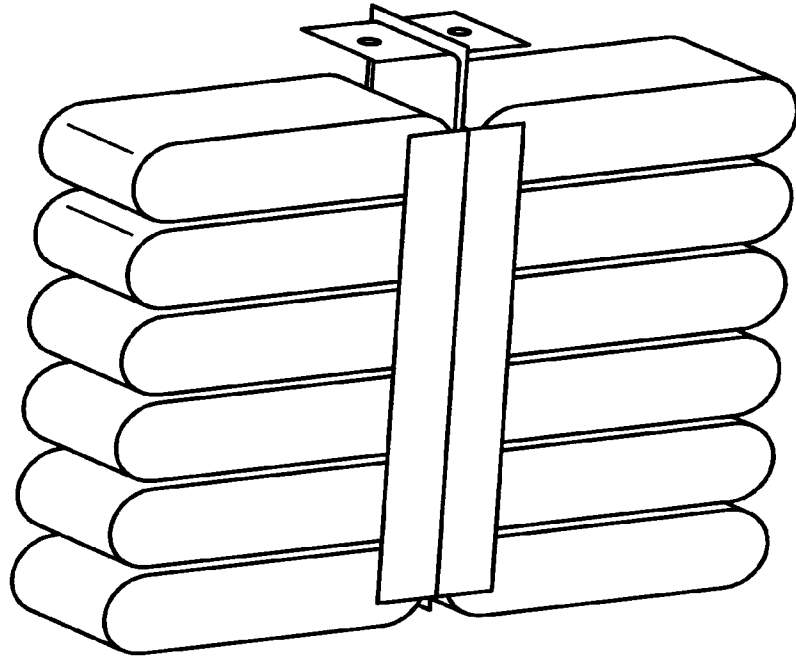


FIG 89

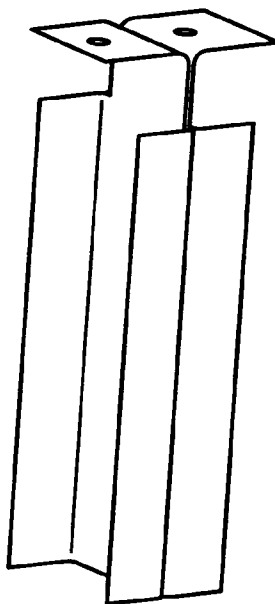


FIG 90

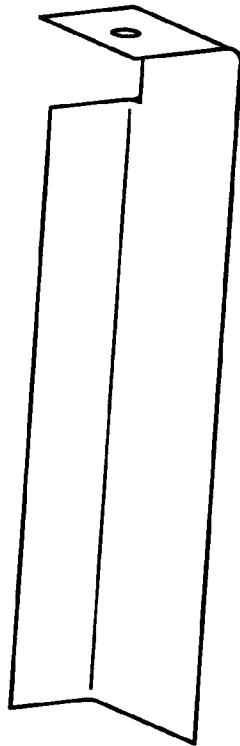


FIG 91

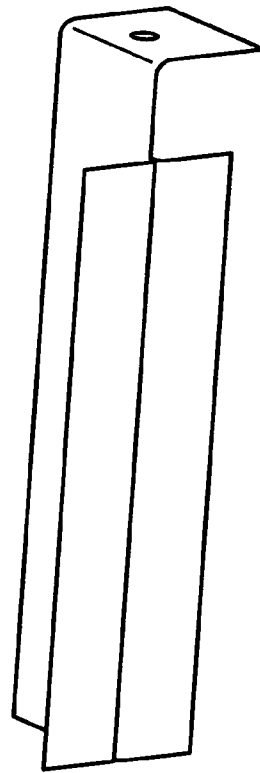


FIG 92

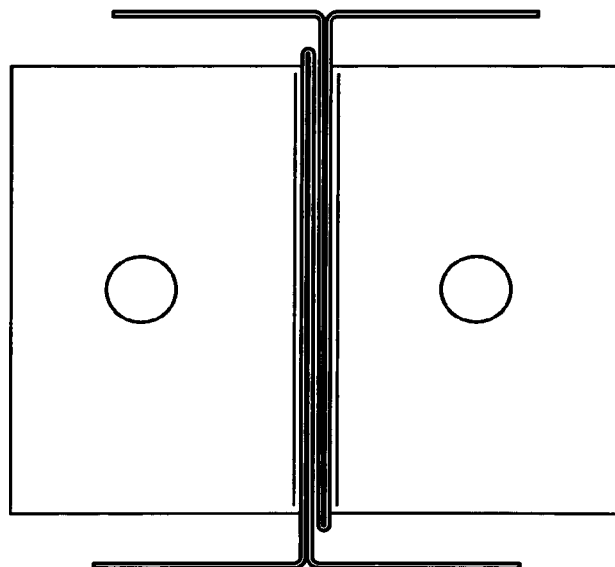


FIG 93

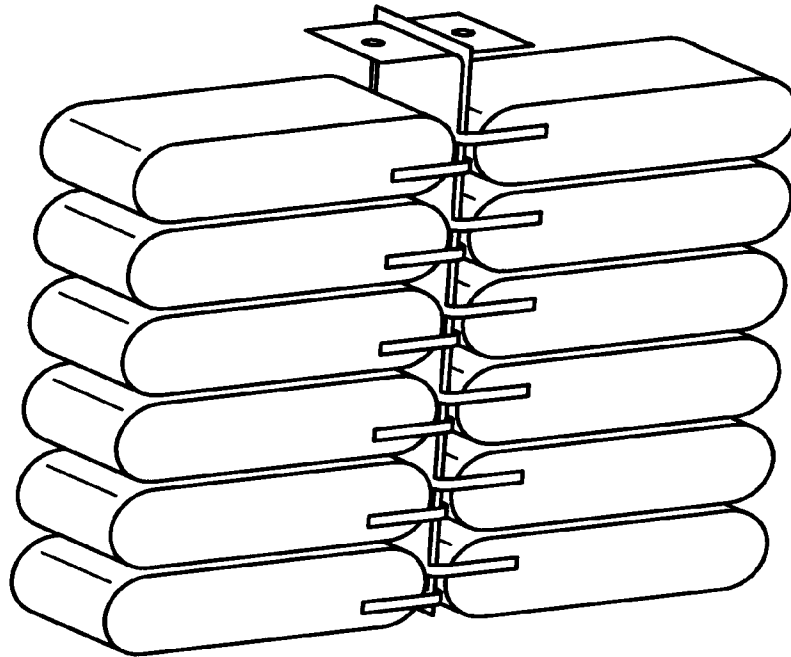


FIG 94

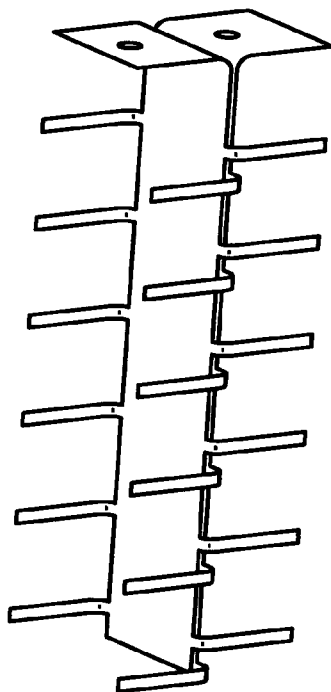


FIG 95

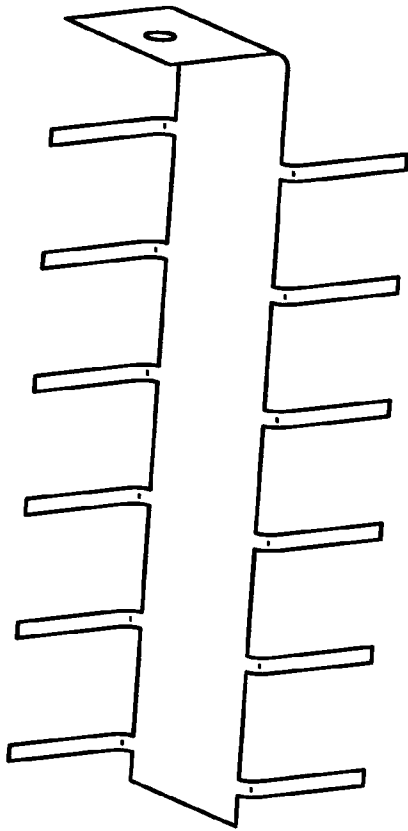


FIG 96

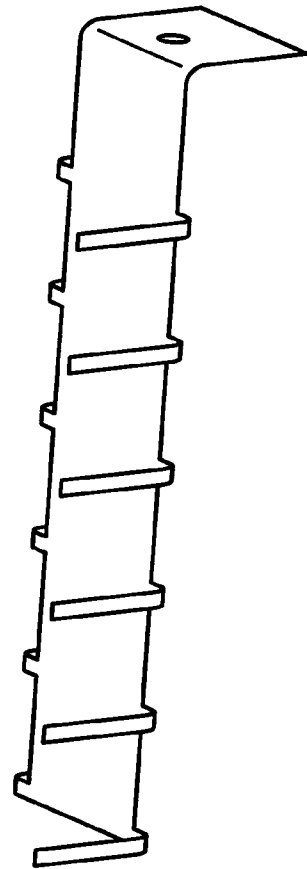


FIG 97

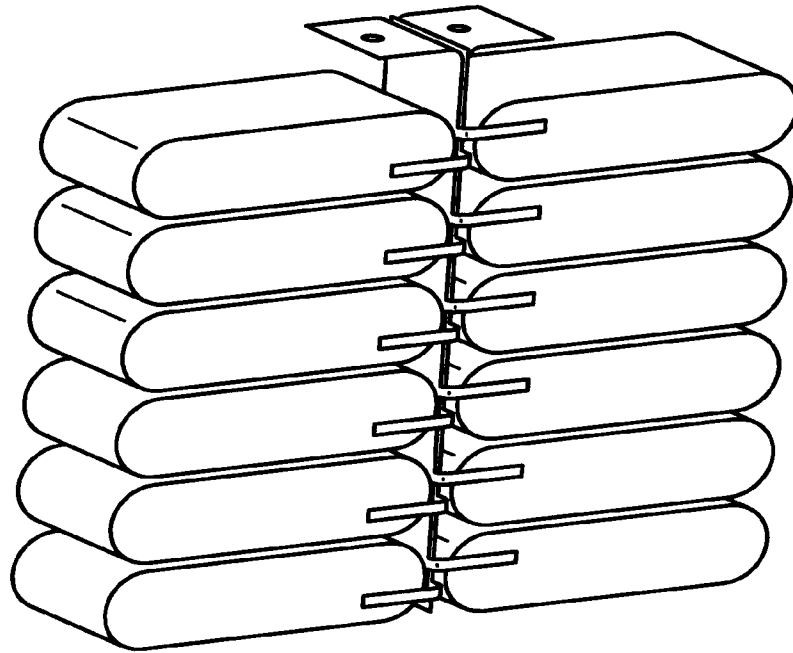
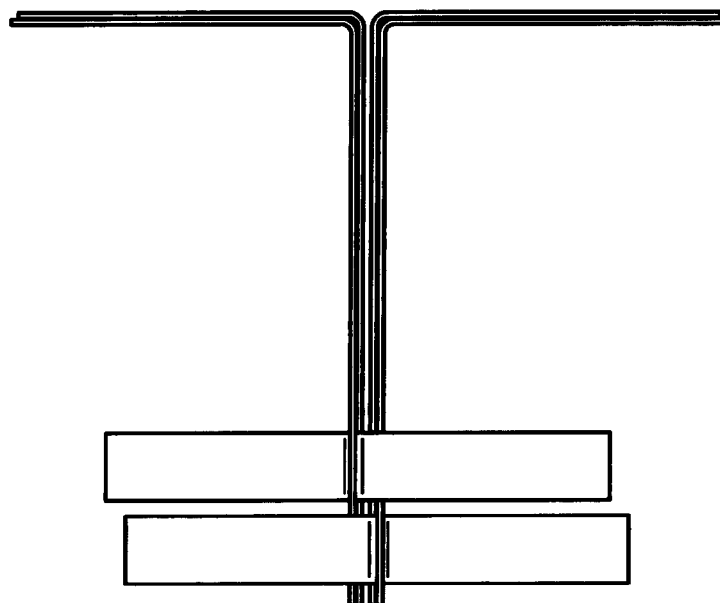


FIG 98



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/082099

A. CLASSIFICATION OF SUBJECT MATTER INV. H01G4/32 H01G4/38 H01G4/40 H01G2/02 H01G2/10 H01G4/18 H01G4/228 H01G4/232 ADD. According to International Patent Classification (IPC) or to both national classification and IPC								
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H01G H02M H02G Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data								
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%; padding: 5px;">Category*</th> <th style="width: 70%; padding: 5px;">Citation of document, with indication, where appropriate, of the relevant passages</th> <th style="width: 20%; padding: 5px;">Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: top; padding: 10px;">X</td> <td style="padding: 10px;"> KR 101 436 787 B1 (NUINTEK CO LTD [KR]) 11 September 2014 (2014-09-11) paragraphs [0005], [0022], [0026] - paragraph [0027]; claim 4; figures 3,1,2 the whole document ----- </td> <td style="text-align: center; vertical-align: top; padding: 10px;"> 1-8, 23-27 </td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	KR 101 436 787 B1 (NUINTEK CO LTD [KR]) 11 September 2014 (2014-09-11) paragraphs [0005], [0022], [0026] - paragraph [0027]; claim 4; figures 3,1,2 the whole document -----	1-8, 23-27
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.						
X	KR 101 436 787 B1 (NUINTEK CO LTD [KR]) 11 September 2014 (2014-09-11) paragraphs [0005], [0022], [0026] - paragraph [0027]; claim 4; figures 3,1,2 the whole document -----	1-8, 23-27						
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.								
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family								
Date of the actual completion of the international search 26 February 2019	Date of mailing of the international search report 08/05/2019							
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Dessaux, Christophe							

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2018/082099

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of Item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-8, 23-27

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-8, 23-27

Claim 1 claims a capacitor assembly comprising at least two winding elements (1), a first busbar (7) and a second busbar (8), wherein the first busbar (7) and the second busbar (8) connect the winding elements (1) in parallel to each other and wherein the first busbar (7) and the second busbar (8) are arranged such that they overlap each other.

2. claims: 9-13

A capacitor stack comprising at least two winding elements (1) arranged in a stack (6). The capacitor assembly comprising a fifth busbar (10) and a sixth busbar (11), wherein the first busbar (7) and the second busbar (8) are arranged on a side (6e) of the stack (6) and the fifth and the sixth busbar (10, 11) are arranged on a side of the stack (6) opposite to the side at which the first busbar (7) and the second busbar (8) are arranged, wherein the fifth busbar (10) is connected to the same poles as the first busbar (7) and the sixth busbar (11) is connected to the same poles as the second busbar (8).

3. claims: 14-20

A capacitor assembly in which the first busbar (7) has a larger thickness in a section between two stacks of capacitors (6, 13) than in a section overlapping a top face (3) or a bottom face (2) of the winding elements (1), and/or wherein the second busbar (8) has a larger thickness in a section between two stacks of winding elements (6, 13) than in a section overlapping a top face (3) or a bottom face (2) of the winding elements (1).

4. claims: 21, 22

A capacitor assembly characterized in that the first busbar (7) comprises two parts (7a, 7b) and the second busbar (8) comprises two parts (8a, 8b). Further, the capacitor assembly forms a DC link capacitor module.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2018/082099

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
KR 101436787	B1	11-09-2014	CN 203895270 U	22-10-2014
			KR 101436787 B1	11-09-2014
			WO 2015102195 A1	09-07-2015
