

**"STACKING METHOD AND STACKING UNIT TO FORM A STACK OF
ELECTROCHEMICAL CELLS OF AN ELECTRIC BATTERY"**

Cross-Reference to Related Applications

5 This Patent Application claims priority from Italian Patent Application No. 102021000009644 filed on April 16, 2021, the entire disclosure of which is incorporated herein by reference.

Technical Field of the Invention

10 The present invention relates to a stacking unit and to a stacking method for forming a stack of electrochemical cells of an electric battery.

State of the Art

15 A parallelepipedal (planar) electric battery comprises a stack of electrochemical cells (i.e. of devices capable of converting electric energy into chemical energy or vice versa) superimposed one on top of the other.

20 Each electrochemical cell that is part of a stack is typically composed of four superimposed layers: a first layer which constitutes a cathode, a second layer which constitutes a separator, a third layer which constitutes an anode, and a fourth layer which constitutes a further separator (and thus similar to the second layer). In the stack all the electrochemical cells are identical to one another except
25 the last cell (i.e. the terminal cell or the most external cell) which is placed last on top of the stack and which is shaped differently being devoid of the first layer which constitutes a cathode (i.e. the last cell is composed of only three superimposed layers: separator, anode and again
30 separator).

 Patent applications No. US20200185753A1 and No. EP2879223A1 describe some examples of a stacking unit for forming a stack of electrochemical cells of an electric battery.

Subject and Summary of the Invention

The object of the present invention is to provide a stacking method and a stacking unit for forming a stack of electrochemical cells of an electric battery, said method
5 and said machine allowing operating at a high operating speed (typically measured as number of stacks formed in the time unit) simultaneously ensuring a high working quality and a reduced number of rejections.

According to the present invention, a stacking method
10 and a stacking unit for forming a stack of electrochemical cells of an electric battery are provided, according to what claimed in the appended claims.

The claims describe preferred embodiments of the present invention forming integral part of the present
15 description.

Brief Description of the Drawings

The present invention will now be described with reference to the accompanying drawings, which illustrate a non-limiting example embodiment thereof, wherein:

- 20 • Figure 1 is a schematic and perspective view of a stack of electrochemical cells of an electric battery;
- Figure 2 is a schematic and cross-section view of an electrochemical cell of the stack of Figure 1;
- Figure 3 is a schematic and cross-section view of
25 a terminal (external) electrochemical cell of the stack of Figure 1;
- Figure 4 is a schematic view, with details removed for clarity, of a stacking unit which is adapted to form the stack of Figure 1 and is manufactured in accordance with the
30 present invention;
- Figure 5 is a schematic view of a feeding drum of the stacking unit of Figure 4; and
- Figures 6 and 7 are two different schematic views of a transfer conveyor of the stacking unit of Figure 4 with

respective cam actuation systems in evidence.

**Detailed Description of Preferred Embodiments of the
Invention**

5 In Figure 1, reference numeral 1 indicates, as a whole, a stack of electrochemical cells 2 (i.e. devices capable of converting electric energy into chemical energy and/or vice versa) of an electric battery.

10 In other words, the electric battery comprises the stack 1 of electrochemical cells 2 to which electric terminals and electronic control and management circuits are connected.

By way of example, a stack 1 can be composed of 25-35 (or more) electrochemical cells 2 superimposed one on top of the other. In particular, not limitedly, the electrochemical cells 2 can be of radial type (i.e. with the terminals 15 arranged on a same side of the cell 2 and thus of the stack 1) or of axial type (i.e. with the terminals arranged on opposite sides of the cell 2 and thus of the stack 1).

According to what illustrated in Figures 2 and 3, each electrochemical cell 2 which is part of a stack 1 is 20 typically composed of four layers 3-6 which are superimposed (as illustrated in Figure 2): a first layer 3 which constitutes a cathode, a second layer 4 which constitutes a separator, a third layer 5 which constitutes an anode, and a fourth layer 6 which constitutes a further separator (and 25 thus similar to the second layer 4). In the stack 1 all the electrochemical cells 2 are identical to one another except the last electrochemical cell 2 (i.e. the terminal electrochemical cell 2 or the most external electrochemical cell 2 illustrated in Figure 3) which is placed last on top 30 of the stack 1 and which is shaped differently being devoid of the first layer 3 which constitutes a cathode (i.e. the last electrochemical cell 2 is composed of only three layers 4, 5 and 6 which are superimposed: separator, anode and again separator).

Figure 4 illustrates, as a whole, a machine 7 for producing electric batteries each comprising a stack 1 of electrochemical cells 2.

The machine 7 comprises a production unit A (of known type and schematically illustrated) in which a continuous belt 8 of electrochemical cells 2 seamlessly arranged one after the other is produced; in the belt 8 both standard electrochemical cells 2 (i.e. provided with all four layers 3-6), and terminal or external electrochemical cells 2 (i.e. devoid of the layer 3 which constitutes a cathode) can be found since the production unit A is adapted to produce both (in order to produce a terminal electrochemical cell 2 it is sufficient to inhibit the feeding of the layer 3 which constitutes a cathode). Furthermore, the machine 7 comprises a stacking unit B which receives the belt 8 from the production unit A, transversally cuts the belt 8 for separating the single electrochemical cells 2 from the belt 8 (i.e. for "*singularizing*" the electrochemical cells 2), and then stacks the electrochemical cells 2 for forming the stacks 1.

Preferably, the continuous belt 8 of cells comprises a plurality of cells 2 (for example mono-cells, bi-cells or half-cells) whose separators, i.e. the second layer 4 and the fourth layer 6 are continuous.

In some non-limiting cases, also the layers 3 and 5, i.e. the electrodes, are continuous. In other non-limiting cases, the layers 3 and 5, i.e. respectively cathode and anode, are already discretized so that adjacent cells 2 on the continuous belt 8 (in which the continuity is given by the layers 4 and 6 of the separators and the cell 2 by the layers 3 and 5 which are superimposed in an aligned and alternated manner with the layers 4 and 6) are separated from one another by an intermediate space in which the sole separator layers 4 and 6 are superimposed.

In the latter case, the stacking unit B receiving the belt 8 from the production unit A transversally cuts the belt 8 at the abovementioned intermediate space so as to separate the single electrochemical cells 2 from the continuous belt 8.

Finally, the machine 7 comprises a working unit C (of known type and schematically illustrated) which receives the stacks 1 from the stacking unit B and performs final works on the stacks 1.

The stacking unit B comprises a feeding roller 9 which is rotatably mounted for rotating with a continuous law of motion (i.e. with a law of motion that provides for advancing at a constant speed without alternating motion phases and rest phases) around a rotation axis 10 which is horizontal and perpendicular to the plane of the sheet.

The feeding roller 9 receives the belt 8 at an input station S1 from the production unit A; preferably, upstream of the feeding roller 9 (i.e. between the feeding roller 9 and the production unit A) a compensating device 11 is arranged in which the belt 8 forms a loop having variable length for keeping a tension of the belt 8 constant.

The stacking unit B comprises a feeding roller 12 which is rotatably mounted for rotating with a continuous law of motion around a horizontal rotation axis 13, is arranged next to the feeding roller 9, and receives the belt 8 from the feeding roller 9 at a transfer station S2. The feeding roller 12 is coupled to a cutting device 14 (provided, in the illustrated embodiment, with two different cutters) which is configured to separate a single electrochemical cell 2 from the continuous belt 8; at the feeding roller 12, the continuous belt 8 is thus singularized and becomes a succession of single electrochemical cells 2 separate from one another. The single electrochemical cells 2 leave the feeding roller 12 at a gripping station S3, as it will be

better described in the following.

The timing of the continuous belt 8 with respect to the cutting device 14 in order to ensure that the transverse cut of the belt 8 always occurs in the correct position is performed by means of optic sensors (typically cameras) which, by detecting the position of specific references, determine the exact position (step) of the continuous belt 8 and can thus consequently adjust the advancement of the continuous belt 8.

According to a preferred embodiment illustrated in Figure 5, the feeding drum 12 comprises two suction seats 15, each of which is mounted on the feeding drum 12 so as to be movable with respect to the feeding drum 12, and is configured to retain a single electrochemical cell 2 (initially still connected to the rest of the continuous belt 8 and subsequently separated from the rest of the continuous belt 8 by a transverse cut performed by the cutting device 14). In particular, each suction seat 15 is movable with respect to the feeding drum 12 so as to move (with a maximum stroke limited in the order of millimeters) along an alignment direction D parallel to the rotation axis 13. The feeding drum 12 further comprises a sensor device 16 for detecting a position of the electrochemical cell 2 carried by a suction seat 15; i.e. the sensor device 16 allows verifying the correct alignment of the electrochemical cell 2 carried by a suction seat 15. Finally, the feeding drum 12 comprises an actuator device 17 (for example an electric stepper motor) which is configured to move each suction seat 15 with respect to the feeding drum 12 and along the alignment direction D depending on a detection performed by the sensor device 16 and to arrange (if necessary) the electrochemical cell 2 carried by the suction seat 15 in a desired position (i.e. to correctly align the electrochemical cell 2 correcting any position

errors).

Preferably, the sensor device 16 comprises a camera which frames the periphery of the feeding drum 12 and thus optically detects the actual position of an electrochemical cell 2 carried by a suction seat 15; in this regard, on the outer surface of the suction seat 15, visible reference notches could be printed which define the desired position of the electrochemical cell 2 and provide the sensor device 16 with visible references for evaluating the correct positioning of the electrochemical cell 2.

In the embodiment illustrated in Figure 5, each suction seat 15 is movable with respect to the drum 12 only along a single alignment direction D parallel to the rotation axis 13. According to a different embodiment, each suction seat 15 is movable with respect to the drum 12 also along a further circumferential alignment direction (i.e. perpendicular to the alignment direction D). According to a further embodiment, each suction seat 15 is movable with respect to the drum 12 also rotating around an alignment axis perpendicular to the alignment direction D (and thus perpendicular to the rotation axis 13).

According to what illustrated in Figure 4, the stacking unit B comprises three forming containers 18 (but the overall number thereof could obviously be different), each of which is configured to receive in succession the single electrochemical cells 2 which are arranged successively one on top of the other for forming the stack 1 inside the forming container 18. In particular, each forming container 18 has the shape of a box which is open at one end (through which the single electrochemical cells 2 are progressively inserted in the forming container 18) and is delimited by a flat and movable bottom wall and by a rectangular and fixed side wall; as the single electrochemical cells 2 are inserted in a forming container 18, the bottom wall (which initially

is in a completely lifted position) lowers increasing the internal volume of the forming container 18 and keeping always on the same plane the position in which to insert the following electrochemical cell 2.

5 The stacking unit B comprises a drum 19 which supports the three forming containers 18 and is rotatably mounted around a rotation axis 20 (parallel to the rotation axis 10 and thus horizontal) for moving each forming container 18 along a circularly shaped transfer path P1 which passes
10 through a release station S4 in which each forming container 18 standing still in rest receives in succession the electrochemical cells 2. In particular, each forming container 18 is rigidly mounted on the drum 19 by means of a corresponding support arm devoid of hinges; consequently,
15 each forming container 18 blindly follows the rotation movement of the drum 19 without ever carrying out any movement with respect to the drum 19. The drum 19 is brought into rotation around the rotation axis 20 by an actuator device 21 (normally a dedicated electric motor) with a step
20 law of motion (i.e. a law of motion that provides for a cyclical alternation of motion phases and rest phases). The rotation of the drum 19 moves each forming container 18 along the transfer path P1 and through: the release station S4 (in which each forming container 18 standing still in rest
25 receives in succession the electrochemical cells 2), through a fastening station S5 (in which a complete stack 1 is subjected to a fastening for clamping and stabilizing the stack 1) and finally through a transfer station S6 (in which a formed and fastened stack 1 leaves the corresponding
30 forming container 18 towards the working unit C). In other words, the actuator device 21 moves each empty forming container 18 into the release station S4 and keeps the forming container 18 in the release station S4 until a completion of the stack 1 inside the forming container 18.

At the fastening station S5, a fastening device 22 is arranged which is configured to perform the fastening of a stack 1 carried by a forming container 18 standing still in rest in the fastening station S5.

5 The stacking unit B comprises a transfer conveyor 23 which supports and moves a plurality of gripping heads 24 (eight gripping heads 24 in the embodiment illustrated in the accompanying figures, but the number thereof could be different), each of which is adapted to receive and retain
10 (typically by means of suction) a single electrochemical cell 2. The transfer conveyor 23 cyclically advances each gripping head 24 along a circular transfer path P2 which passes through the gripping station S3 (configured to feed a single electrochemical cell 2 to the gripping head 24) and
15 which thus passes through the release station S4 (arranged along the transfer path P2 downstream of the gripping station S3 and configured to make the gripping head 24 release a single electrochemical cell 2 into the forming container 18 standing still in rest in the release station S4).

20 The transfer conveyor 23 comprises a drum 25 which is rotatably mounted around a rotation axis 26 (parallel to the rotation axis 10 and thus not vertical, preferably horizontal) and supports the gripping heads 24 for advancing the gripping heads 24 along the circularly shaped transfer
25 path P2. Furthermore, the transfer conveyor 23 comprises an actuator device 27 (typically a dedicated electric motor) which brings the drum 25 into rotation around the rotation axis 26 with a continuous law of motion (i.e. with a law of motion which provides for advancing at a constant speed
30 without alternating motion phases and rest phases).

According to what better illustrated in Figures 5 and 6, the transfer conveyor 23 comprises a plurality of arms 28, each of which at an inner end is hinged to the drum 25 so as to rotate, with respect to the drum 25, around a

rotation axis 29 parallel to the rotation axis 26 and at an outer end supports a corresponding gripping head 24 in a rotatable manner around a rotation axis 30 parallel to the rotation axis 29.

5 A cam actuation system 31 (illustrated in Figure 6) is provided which drives the rotation of each arm 28 around the corresponding rotation axis 29 by exploiting the rotation movement of the drum 25 around the rotation axis 26. Similarly, a cam actuation system 32 (illustrated in Figure
10 7) is provided which is separate from and independent of the cam actuation system 31 and drives the rotation of each gripping head 24 around the corresponding rotation axis 30 by exploiting the rotation movement of the drum 25 around the rotation axis 26.

15 According to what illustrated in Figure 6, the cam actuation system 31 comprises two fixed cams 33 and 34 which are arranged around the rotation axis 26 and a series of trolleys 35, each of which is integral with a corresponding arm 28 and is provided with a pair of cam follower rollers
20 36 which couple to the respective fixed cams 33 and 34.

 According to what illustrated in Figure 7, the cam actuation system 32 comprises a fixed cam 37 arranged around the rotation axis 26, a plurality of cam follower rollers 38 which are coupled to the fixed cam 37, and a plurality of
25 leverages 39, each of which transmits the motion from a corresponding cam follower roller 38 to a corresponding gripping head 24. In particular, each leverage 39 comprises, among the various components, a final arm 40 which is hinged to the corresponding gripping head 24 in an eccentric
30 position with respect to the rotation axis 30.

 According to what illustrated in Figure 4, two control stations S7 and S8 are provided which are arranged one after the other along the transfer path P2 and are configured to control the compliance of an electrochemical cell 2 carried

by a gripping head 24, i.e. to control that the electrochemical cell 2 meets the nominal specifications.

The control station S7 comprises an optic control device 41 (normally comprising a camera) which performs an optic control of an electrochemical cell 2 carried by a gripping head 24. In the embodiment illustrated in the accompanying figures, the optic control device 41 acquires (at least) a digital image of the electrochemical cell 2 and such digital image is analyzed for determining the outward (visible) characteristics of the electrochemical cell 2.

The control station S8 comprises a control device 42 which performs an electric control of an electrochemical cell 2 carried by a gripping head 24; in particular, the control device 42 performs an electric resistivity (conductivity) measurement. In the embodiment illustrated in the accompanying figures, the optic control device 42 comprises (at least) a tip electrode 43 and an actuator device 44 which moves the tip electrode 43 between a passing position (illustrated in Figure 4) in which the tip electrode 43 is relatively far from a gripping head 24 which transits through the control station S8 and an operating position (not illustrated) in which the tip electrode 43 is in contact with an electrochemical cell 2 carried by a gripping head 24 which transits through the control station S8. For example, the actuator device 44 comprises a five-bar linkage which at one end supports the tip electrode 43. The law of motion impressed by the actuator device 44 on the tip electrode 43 allows keeping, for a certain time, the tip electrode 43 coupled to an electrochemical cell 2 carried by a gripping head 24 which transits through the control station S8; contextually, the gripping head 24 that transits through the control station S8 is kept facing the tip by means of a combination of a rotation (driven by the cam actuation system 31) of the corresponding arm 28 around the rotation axis 29

and of a rotation (driven by the cam actuation system 32) of the gripping head 24 around the rotation axis 30.

A rejection station S9 is provided which is arranged along the transfer path P2 downstream of the control station S8 and is configured to pick up a faulty electrochemical cell 2 (i.e. recognized as faulty by the controls performed in the control stations S7 and S8) carried by a gripping head 24 for removing the faulty electrochemical cell 2 from the gripping head 24 and to send the faulty gripping head 24 towards an ejection conveyor 45 of the rejects. The rejection station S9 comprises a suction gripping head 46 adapted to receive and retain an electrochemical cell 2, and an actuator device 47 which supports the gripping head 46 and is configured to move the gripping head 46 between the rejection station S9 in which the gripping head 46 picks up an electrochemical cell 2 carried by a gripping head 24 which transits through the rejection station S9 and an ejection station S10 at an input of the ejection conveyor 45.

For example, the actuator device 47 comprises a deformable articulated quadrilateral which at one end supports the gripping head 46. The law of motion impressed by the actuator device 47 on the gripping head 46 allows keeping, for a certain time, the gripping head 46 coupled to an electrochemical cell 2 carried by a gripping head 24 which transits through the rejection station S9; contextually, the gripping head 24 that transits through the rejection station S9 is kept facing the gripping head 46 by means of a combination of a rotation (driven by the cam actuation system 31) of the corresponding arm 28 around the rotation axis 29 and of a rotation (driven by the cam actuation system 32) of the gripping head 24 around the rotation axis 30.

According to a preferred (but not binding) embodiment illustrated in Figure 4, the stacking unit B comprises an exchange station S11 which is arranged along the transfer

path P2 (downstream of the rejection station S9), and a storage unit 48 which is arranged at the exchange station S11 and is suitable for temporarily storing an electrochemical cell 2 in such a way that each gripping head 24 carrying an electrochemical cell 2 upon passing through the exchange station S11 may yield the electrochemical cell 2 to the storage unit 48 or each empty gripping head 24 upon passing through the exchange station S11 may pick up an electrochemical cell 2 from the storage unit 48.

According to a preferred (but not binding) embodiment illustrated in Figure 4, the stacking unit B comprises an exchange station S12 which is arranged along the transfer path P2 (downstream of the exchange station S11), and a storage unit 49 which is arranged at the exchange station S12 and is adapted to temporarily store an (a terminal) electrochemical cell 2 in such a way that each gripping head 24 carrying a terminal electrochemical cell 2 upon passing through the exchange station S12 may yield the terminal electrochemical cell 2 to the storage unit 49 or each empty gripping head 24 upon passing through the exchange station S12 may pick up a terminal electrochemical cell 2 from the storage unit 49.

The two storage units 48 and 49 are structurally identical to one another and each one comprises a drum 50 which is rotatably mounted around a rotation axis 51 parallel to the rotation axis 26 and has a plurality of suction seats 52 which are uniformly distributed around the rotation axis 51 and are suitable for housing respective electrochemical cells 2; an actuator device 53 is provided which brings the drum 50 into rotation around the rotation axis 51 with a step law of motion for varying the suction seat 52 facing the exchange station S11. Preferably, each drum 50 has a polygonal (hexagonal in the non-limiting embodiment illustrated in the accompanying figures) cross-section in

such a way that the side surface of the drum 50 is formed by a succession of flat walls each of which constitutes a corresponding suction seat 52. According to a different embodiment not illustrated, each drum 50 has a circular cross-section and consequently the suction seats 52 are no longer flat but have a cylindrical shape.

Finally, the machine 7 comprises a control unit 54 which superintends the operation of the entire machine 7 and thus the operation of the three units A, B and C which compose the machine 7.

In use, the storage unit 48 is always and only used for stocking standard electrochemical cells 2 (i.e. provided with all four layers 3-6), whereas the storage unit 49 is always and only used for stocking terminal or external electrochemical cells 2 (i.e. devoid of the layer 3 which constitutes a cathode).

In use, the production unit A is cyclically driven for producing a sequence of terminal or external electrochemical cells 2 (i.e. devoid of the layer 3 that constitutes a cathode) which are thus all stored in the storage unit 49 (obviously not more than six terminal or external electrochemical cells 2 since the storage unit 49 has at the most six suction seats 52 in the non-limiting embodiment illustrated in the accompanying figures); in other words, when necessary (typically every three-six stacks 1 produced), the production unit A is driven for producing a sequence of terminal or external electrochemical cells 2 which are all stocked in the storage unit 49.

In use, the storage unit 48 is normally kept half full (i.e. half empty) in such a way that it always has the possibility to both receive an electrochemical cell 2 from a gripping head 24 which passes through the exchange station S11, and yield an electrochemical cell 2 to a gripping head 24 which passes through the exchange station S11.

The modes with which the stacking unit B makes a stack 1 of electrochemical cells 2 in a forming container 18 initially empty and standing still in rest in the release station S4 are described in the following.

5 Initially, the drum 19 carries out a rotation step for moving an empty forming container 18 from the transfer station S6 (into which the forming container 18 has released a formed and fastened stack 1) to the release station S4.

Contextually, the drum 25 of the transfer conveyor 23
10 continues moving the gripping heads 24 along the transfer path P2 for cyclically passing through: the gripping station S3 in which the gripping heads 24 receive the standard and singularized (and possibly correctly aligned) electrochemical cells 2 from the feeding drum 12, the control
15 stations S7 and S8 in which the standard electrochemical cells 2 are controlled, the rejection station S9 into which a possible faulty standard electrochemical cell 2 is rejected, through the exchange stations S11 and S12, and finally through the release station S4 in which the standard
20 electrochemical cells 2 are released in succession inside the forming container 18 standing still in rest for forming the stack 1. When the stack 1 is almost complete, a gripping head 24 arrives empty at the exchange station 12 (either because it has not picked up a standard electrochemical cell
25 2 in the gripping station S3 or because it has yielded the standard electrochemical cell 2 to the storage unit 48 in the exchange station S11) so as to be able to receive in the exchange station 12 a terminal or external electrochemical cell 2 from the storage unit 49 and thus arrive at the
30 gripping station S3 with the terminal or external electrochemical cell 2 which is released into the forming container 18 standing still in rest and thus complete the forming of a stack 1.

It is important to observe that a gripping head 24 can

arrive empty at the exchange station 12 because it has not picked up a standard electrochemical cell 2 in the gripping station S3; obviously in this case the feeding drums 9 and 12 (which are located downstream of the gripping station S3) must be suitably slowed down (or also stopped for an instant) so as "to skip a turn", i.e. prevent a standard electrochemical cell 2 that is not picked up by the gripping head 24 from arriving at the gripping station S3. Generally, it is sufficient to slow down only the feeding drums 9 and 12 (which are small and thus have a reduced inertia) since the compensating device 11 allows compensating the (temporary) speed difference between the production unit A and the feeding drums 9 and 12.

The storage unit 48 containing the standard electrochemical cells 2 allows decoupling what occurs in the gripping station S3 from what occurs downstream of the gripping station S3 and in particular in the rejection station S9; in this manner, regardless of whether or not a standard electrochemical cell 2 is found faulty and thus rejected into the rejection station S9, it is always possible to choose to have, downstream of the rejection station S9, an empty gripping head 24 (because it has left its standard electrochemical cell 2 at the storage unit 48) or a full gripping head 24 (because it has picked up a standard electrochemical cell 2 at the storage unit 48).

Similarly, the storage unit 49 containing the terminal or external electrochemical cells 2 allows decoupling what occurs in the gripping station S3 from what occurs downstream of the gripping station S3 and in particular in the rejection station S9; in this manner, regardless of whether or not a terminal or external electrochemical cell 2 is found faulty and thus rejected into the rejection station S9, it is always possible to have, downstream of the rejection station S9, a gripping head 24 containing a terminal or external

electrochemical cell 2 at the right moment (i.e. for completing a stack 1 being formed in the forming container 18); in fact, it is always possible to free (to empty) a gripping head 24 leaving the standard electrochemical cell 2 initially carried by the gripping head 24 in the storage unit 48 and thus immediately after make the gripping head 24 pick up a terminal or external electrochemical cell 2 from the storage unit 49.

Substantially, thanks to the presence of the storage unit 49, it is no longer necessary to form a single terminal or external electrochemical cell 2 in the assumed correct position with the risk that an unpredicted and unpredictable (and totally random) rejection of standard electrochemical cells 2 or of the terminal or external electrochemical cell 2 does not make a terminal or external electrochemical cell 2 arrive in the gripping station S3 at the right moment (i.e. when it is necessary "to close" an almost complete stack 1); in fact, thanks to the presence of the storage unit 49, it is possible to decouple the production of the terminal or external electrochemical cells 2 from the forming of the stacks 1, i.e. it is possible to dedicate temporal windows to the production of an array of terminal or external electrochemical cells 2 which are temporarily stocked in the storage unit 49 for being used one at a time when necessary and exactly when necessary.

In other words, in order to make the stacks 1 of electrochemical cells 2 the gripping heads 24 are cyclically advanced along the transfer path P2 for receiving in the gripping station S3 single electrochemical cells 2 and subsequently for releasing the single electrochemical cells 2 into a forming container 18 standing still in rest in the release station S4. Each stack 1 is composed of a plurality of standard electrochemical cells 2 and of a single terminal electrochemical cell 2 which is arranged last on top of the

stack 1 and concludes the formation of the stack 1; in the storage unit 49 a series of terminal electrochemical cells 2 are thus previously stored and, when the stack 1 being formed in the forming container 18 has received all the standard electrochemical cells 2, the gripping head 24 advances empty through the exchange station S12 for receiving from the storage unit 49 a terminal electrochemical cell 2 (in a "*just in time*" manner) which is released immediately after into the forming container 18 standing still in rest in the release station S4.

Consequently, a series of terminal electrochemical cells 2 are produced, periodically and together (i.e. one after the other), said series of terminal electrochemical cells 2 advancing all together (i.e. one after the other) towards the gripping station S3 for being picked up by the gripping heads 24 and then released into the storage unit 49 (in this manner the storage unit 49 is filled with terminal electrochemical cells 2 to be subsequently used one at a time in view of the forming of future stacks 1). A series of standard electrochemical cells 2 sufficient for the production of several stacks 1 are thus produced without interruption since in order to complete each stack 1 a corresponding terminal electrochemical cell 2 stored in the storage unit 49 (i.e. previously prepared for being in the right place at the right time) is used. Consequently, a number of standard electrochemical cells 2 is produced without interruption, said number being substantially an integer multiple of the number of terminal electrochemical cells 2 stored in the storage unit 49. Actually, the number of standard electrochemical cells 2 produced is slightly increased with respect to the exact integer multiple of the number of terminal electrochemical cells 2 stored in the storage unit 49 for keeping into account possible rejections (by using an average of rejections); if during the stacking

it is observed that the number of rejections is different from what envisaged (i.e. different from the average) it is possible to reprogram the number of standard electrochemical cells 2 to be produced and/or the storage unit 48 can be used for storing exceeding standard electrochemical cells 2 or for receiving lacking standard electrochemical cells 2.

As mentioned in the foregoing, it is possible to store in the storage unit 48 a standard electrochemical cell 2 carried by a gripping head 24 for making the gripping head 24 empty when a terminal electrochemical cell 2 has to be released into the release station S4; i.e. the gripping head 24 is emptied from the standard electrochemical cell 2 in the storage unit 48 for allowing the empty gripping head 24 to pick up immediately after a terminal electrochemical cell 2 from the storage unit 49.

Obviously, from time to time, a standard electrochemical cell 2 is picked up from the storage unit 48 so as to prevent the complete filling of the storage unit 48 advancing an empty gripping head 24 through the exchange station S11 (associated with the storage unit 48). A gripping head 24 is advanced empty through the exchange station S11 because a standard electrochemical cell 2 picked up by the gripping head 24 in the gripping station S3 has been rejected upstream of the exchange station S11; alternatively a gripping head 24 is advanced empty through the exchange station S11 because the gripping head 24 has not received any standard electrochemical cell 2 in the gripping station S3 (for example because the feeding assembly arranged upstream of the gripping station S3 has been slowed down so as to prevent the gripping head 24 from receiving any standard electrochemical cell 2 in the gripping station S3).

According to a different embodiment not illustrated, the storage unit 48 is absent and only the storage unit 49 is thus present which is used always and only for stocking

terminal or external electrochemical cells 2 (i.e. devoid of the layer 3 that constitutes a cathode), or for stocking both standard electrochemical cells 2 (i.e. provided with all four layers 3-6), and terminal or external
5 electrochemical cells 2 (i.e. devoid of the layer 3 that constitutes a cathode). According to a further embodiment not illustrated, both storage units 48 and 49 are absent.

It is important to observe that along the entire transfer path P2, each gripping head 24 continuously carries
10 out a series of movements with respect to the drum 25 which are due to a combination of a rotation around the rotation axis 29 (driven by the cam actuation system 31) and of a simultaneous rotation around the rotation axis 30 (driven by the cam actuation system 32); these movements of each
15 gripping head 24 with respect to the drum 25 allow the gripping head 24 to interact in the stations S3, S7, S8, S9, S11, S12 and S4 with optimum modes also operating at high speed; for example, before approaching a station S3, S7, S8, S9, S11, S12 or S4, the arm 28 of a gripping head 24 can
20 rotate around the corresponding rotation axis 29 for anticipating the advancement movement of the drum 25 (i.e. in the same rotation direction of the drum 25) and thus in the station S3, S7, S8, S9, S11, S12 or S4 the arm 28 can rotate in opposite direction (i.e. opposite the rotation
25 direction of the drum 25) for keeping (for a brief period) the gripping head 24 still or almost still.

The embodiments described herein can be combined with one another without departing from the scope of protection of the present invention.

30 The above-described stacking unit B has numerous advantages.

Firstly, the above-described stacking unit B allows operating at a high operating speed (typically measured as number of stacks 1 formed in the time unit) especially thanks

to the continuous law of motion of the transfer conveyor 23.

Furthermore, the above-described stacking unit B allows ensuring a high working quality assuring both an accurate compliance control of each single electrochemical cell 2, and a very precise positioning of each single electrochemical cell 2 in a forming container 18 at the moment of making a stack 1.

Finally, the above-described stacking unit B allows rejecting all and only the faulty electrochemical cells 2, i.e. allows always using all the electrochemical cells 2 compliant with the specifications annulling the rejection of electrochemical cells 2 compliant with the specifications; this result is obtained thanks to the presence of the storage units 48 and 49 which allow decoupling the forming act of the stacks 1 from the production act of the electrochemical cells 2 thus having the possibility of compensating the unpredicted and unpredictable (and totally random) presence of faulty electrochemical cells 2 to be rejected.

LIST OF THE REFERENCE NUMERALS OF THE FIGURES

20	1	stack
	2	electrochemical cell
	3	layer
	4	layer
	5	layer
25	6	layer
	7	machine
	8	belt
	9	feeding roller
	10	rotation axis
30	11	compensating device
	12	feeding roller
	13	rotation axis
	14	cutting device
	15	suction seat

16 sensor device
17 actuator device
18 forming container
19 drum
5 20 rotation axis
21 actuator device
22 fastening device
23 transfer conveyor
24 gripping head
10 25 drum
26 rotation axis
27 actuator device
28 arm
29 rotation axis
15 30 rotation axis
31 cam actuation system
32 cam actuation system
33 fixed cam
34 fixed cam
20 35 trolleys
36 cam follower roller
37 fixed cam
38 cam follower roller
39 leverage
25 40 arm
41 control device
42 control device
43 tip electrode
44 actuator device
30 45 ejection conveyor
46 gripping head
47 actuator device
48 storage unit
49 storage unit

	50	drum
	51	rotation axis
	52	suction seats
	53	actuator device
5	54	control unit
	A	production unit
	B	stacking unit
	C	working unit
	S1	input station
10	S2	transfer station
	S3	gripping station
	S4	release station
	S5	fastening station
	S6	transfer station
15	S7	control station
	S8	control station
	S9	rejection station
	S10	ejection station
	S11	exchange station
20	S12	exchange station
	D	alignment direction
	P1	transfer path
	P2	transfer path

C L A I M S

1) Stacking method for forming a stack (1) of electrochemical cells (2) of an electric battery; the stacking method comprises the steps of:

5 cyclically advancing at least one gripping head (24) suitable for receiving and retaining an electrochemical cell (2) along a transfer path (P2) by means of a transfer conveyor (23);

10 feeding, at a gripping station (S3) which is arranged along the transfer path (P2), a single electrochemical cell (2) to the gripping head (24); and

15 releasing, at a release station (S4) which is arranged along the transfer path (P2) downstream of the first gripping station (S3), from the gripping head (24) a single electrochemical cell (2) into a forming container (18) configured to receive in succession the single electrochemical cells (2) which are arranged successively one on top of the other to form the stack (1);

20 wherein the stack (1) comprises a plurality of standard electrochemical cells (2) and a single terminal electrochemical cell (2) which is arranged last on top of the stack (1) and concludes the formation of the stack (1);

the stacking method is **characterised by the fact that** it comprises the further steps of:

25 previously storing at least one terminal electrochemical cell (2) in a first storage unit (49) arranged at a first exchange station (S12) located along the transfer path (P2);

30 advancing, when the stack (1) being formed in the forming container (18) has received all the standard electrochemical (2) cells, the empty gripping head (24) through the first exchange station (S12) to receive from the first storage unit (49) a terminal electrochemical cell (2); and

releasing, at the release station (S4), from the gripping head (24) the terminal electrochemical cell (2) into the forming container (18).

2) Stacking method according to claim 1 and comprising
5 the further steps of:

producing, periodically and one after the other, a series of terminal electrochemical cells (2);

advancing, one after the other, all the terminal electrochemical cells (2) towards the gripping station (S3);

10 feeding, one at a time and at the gripping station (S3), each terminal electrochemical cell (2) of the series of terminal electrochemical cells (2) to the gripping head (24); and

transferring, one at a time and at the first exchange
15 station (S12), each terminal electrochemical cell (2) to the first storage unit (49) so as to fill the first storage unit (49) in view of the formation of future stacks (1).

3) Stacking method according to claim 2 and comprising the further steps of:

20 producing without interruption a series of standard electrochemical cells (2) sufficient for the production of several stacks (1); and

using to complete each stack (1) a corresponding terminal electrochemical cell (2) stored in the first storage
25 unit (49).

4) Stacking method according to claim 3 and comprising the further step of producing without interruption a number of standard electrochemical cells (2) that is substantially an integer multiple of the number of terminal electrochemical
30 cells (2) stored in the first storage unit (49).

5) Stacking method according to any one of claims 1 to 4, wherein the first exchange station (S12) is located along the transfer path (P2) downstream of the gripping station (S3) and upstream of the release station (S4).

6) Stacking method according to any one of claims 1 to 5 and comprising the further steps of:

checking the compliance of each electrochemical cell (2) carried by the gripping head (24) in at least one control station (S7, S8) that is arranged along the transfer path (P2) upstream of the first exchange station (S12); and

rejecting a non-compliant electrochemical cell (2) carried by the gripping head (24) at a reject station (S9) that is arranged along the transfer path (P2) between the control station (S7, S8) and the first exchange station (S12).

7) Stacking method according to any one of claims 1 to 6 and comprising the further step of storing, in a second storage unit (48) arranged at a second exchange station (S11) which is located along the transfer path (P2) upstream of the first exchange station (S12), a standard electrochemical cell (2) carried by the gripping head (24) to make the gripping head (24) empty when a terminal electrochemical cell (2) is to be released at the release station (S4).

8) Stacking method according to claim 7 and comprising the further step of picking up, from time to time, a standard electrochemical cell (2) from the second storage unit (48) to prevent the complete filling of the second storage unit (48) by advancing the empty gripping head (24) through the second exchange station (S11).

9) Stacking method according to claim 8, wherein the gripping head (24) is advanced empty through the second exchange station (S11) because a standard electrochemical cell (2) taken from the gripping head (24) in the gripping station (S3) has been rejected upstream of the second exchange station (S11).

10) Stacking method according to claim 8, wherein the gripping head (24) is advanced empty through the second exchange station (S11) because the gripping head (24) has

not received any standard electrochemical cell (2) in the gripping station (S3).

11) Stacking method according to claim 10 and comprising the further step of slowing down a feeding unit arranged upstream of the gripping station (S3) to prevent the gripping head (24) from receiving any standard electrochemical cell (2) in the gripping station (S3).

12) Stacking method according to any one of claims 7 to 11, wherein the second storage unit (48) is used to store only standard electrochemical cells (2) and the first storage unit (49) is used to store only terminal electrochemical cells (2).

13) Stacking unit (B) for forming a stack (1) of electrochemical cells (2) of an electric battery and implement the stacking method according to any one of claims 1 to 12.

14) Stacking unit (B) according to claim 13 and comprising:

a forming container (18) configured to receive in succession the single electrochemical cells (2) which are arranged successively one on top of the other to form the stack (1);

at least one first gripping head (24) configured to receive and retain an electrochemical cell (2);

a transfer conveyor (23) supporting the first gripping head (24) for cyclically advancing the first gripping head (24) along a first transfer path (P2);

a gripping station (S3), which is arranged along the first transfer path (P2) and is configured to feed a single electrochemical cell (2) to the first gripping head (24); and

a release station (S4), which is arranged along the first transfer path (P2) downstream of the first gripping station (S3) and is configured to release, from the first

gripping head (24) a single electrochemical cell (2) into the forming container (18);

5 wherein, the transfer conveyor (23) comprises a first drum (25) which is rotatably mounted around a first rotation axis (26) so as to move, with a continuous motion, the first gripping head (24) along the first circularly shaped transfer path (P2).