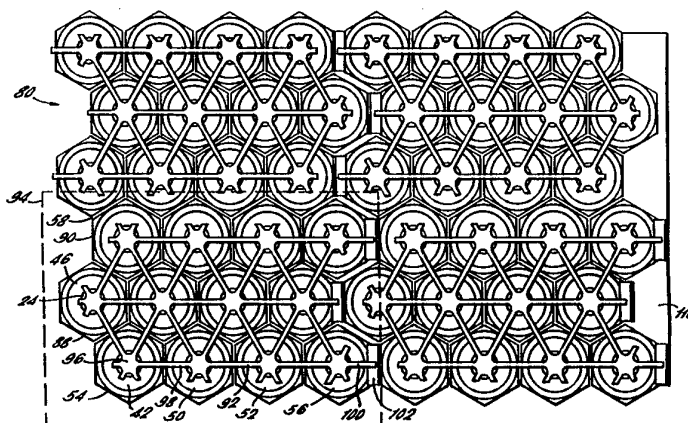




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(54) Title: IMPROVEMENTS RELATING TO BATTERIES**(57) Abstract**

There is provided a battery of electric cells comprising means (58, 60) to separate at least two of said cells, wherein the separating means (58, 60) comprises a refractory fibrous web (58) impregnated with a cured refractory binder (60). There is also provided a method of assembling a battery of electric cells comprising the steps of impregnating a refractory fibrous web (58) with a refractory binder (60), arranging the refractory fibrous web (58) so as to separate at least two of said cells, and curing the refractory binder (60). There is also provided a method of assembling a battery of electric cells comprising the steps of applying a cementing material (58, 60) to a surface of a first cell, subsequently bringing a second cell into contact with the cementing material (58, 60) applied to the first cell, and curing the cementing material (58, 60) so that the cells adhere together. There is also provided a battery of electric cells comprising three or more cells or strings of cells cemented together in parallel, spaced-apart relationship and including means (92) for interconnecting the cells or strings of cells in parallel, said parallel interconnecting means (92) comprising a lattice place (92) having three or more nodes (96) each connected to a corresponding terminal of a respective cell or string of cells.

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IMPROVEMENTS RELATING TO BATTERIES

The Government of the United States has rights in this invention pursuant to Contract No. 54-5324 awarded by the U.S. Department of Energy.

The present invention relates to batteries of electric cells and to methods of their construction. Many forms of battery are known from a single cell to arrangements comprising a plurality of as many interconnected cells as are necessary to give a required energy storage capacity and/or output potential.

Batteries can be categorised into two main types; primary batteries which have a relatively short life and which are discarded when exhausted; and secondary batteries which are rechargeable when exhausted and which therefore can have a relatively long life. This difference is reflected in the uses to which the two categories of battery are put. Primary batteries are used in torches, radios and toys whereas secondary batteries are used for starting automobiles, powering electric vehicles and providing standby power for buildings and telephone exchange equipment. Both primary and secondary batteries of dry alkaline type are known, as are secondary batteries of lead acid type. Recently secondary batteries of sodium sulphur type have been developed possessing the advantages of light weight, high storage capacity and rapid rechargability. Batteries of this type also have the advantage that the constituent materials of sodium and sulphur are abundant and cheap.

Unlike conventional lead acid batteries in which a liquid electrolyte such as dilute sulphuric acid separates two solid electrodes, in a sodium sulphur battery a solid electrolyte of beta alumina

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separates two liquid electrodes respectively of sodium and sulphur respectively.

A typical sodium sulphur cell is shown in Figure 1 to comprise a solid electrolyte cup 10 of beta alumina surrounded by a pressed steel case 12 in the form of a right circular cylinder. The cup 10 is adapted to contain the sodium electrode 14 while the space between the cup 10 and the case 12 is occupied by the sulphur electrode 16 although it will be appreciated that the two electrodes may have their locations reversed. The open end of the cup 10 is closed by an insulating disk 18 of alpha alumina whereas by contrast the case 12 is closed by an annular steel disk 20.

The case 12 serves as a terminal for the sulphur electrode 16 while the sodium electrode 14 surrounds an elongate metal current collector 22 disposed coaxially with the case 12 and which extends out through the insulating disk 18 to be welded to a central terminal disk 24. Since sulphur is essentially non conducting, a means of increasing the conductivity has to be provided and this is generally achieved by forming the sulphur electrode 16 as a carbon fibre mat impreganted with sulphur.

In use, the cell is maintained at a temperature in excess of approximately 300°C so that both the sodium and sulphur electrodes 14 and 16 are in a liquid state. At this temperature the atomic structure of the still solid beta alumina is such that it acts as a selective ion filter. Thus when the cell is discharging, sodium ions pass from the sodium electrode 14 through the electrolyte 10 and

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react with the sulphur electrode 16 to form sodium sulphide. The chemical energy of this reaction is converted directly into electrical energy. However when the cell is charged, sodium and sulphur are regenerated from the sodium sulphide by the conversion of electrical energy back into chemical energy.

To provide a sodium sulphur battery capable of, for example, powering a vehicle, it is necessary for about 3000 of the cells described to be assembled in arrays of series connected arrangements of cells with the arrangements in each array connected in parallel and each of the arrays connected in series.

WO89/00344 (CHLORIDE SILENT POWER) discloses various constructions of battery each comprising one or more arrays of single cells or series arrangements of cells disposed between a pair of mild steel bus plates. In these constructions the bus plates serve the dual purpose of connecting the cells or series arrangements of cells in parallel whilst at the same time providing the battery with sufficient rigidity to prevent the cases of adjacent cells from coming into contact with each other as a result of a vibration and causing unwanted short circuit paths. To increase the rigidity of the battery constructions the bus plates are clamped together by means of a plurality of tie rods.

UK Patent Application No. 9025525.8 (CHLORIDE SILENT POWER) describes a battery construction in which at least one of the electrically conductive structural members is made from a composite material comprising a layer of copper sandwiched between two layers of steel. Using this construction it has been

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possible to provide batteries having a significantly reduced weight which is of particular benefit to those batteries designed for use in cars or which are required to be portable for other reasons.

According to a first aspect of the present invention there is provided a battery of electric cells comprising means to separate two of said cells, wherein the separating means comprises a refractory fibrous web impregnated with a cured refractory binder.

Advantageously the separating means may be interposed between the cells.

Advantageously the separating means may cement the cells together.

Advantageously the refractory fibrous web may comprise a woven cloth and preferably may comprise alpha alumina fibre cloth, or calcia fibre cloth.

Advantageously the cells may contain sodium and the refractory binder have a curing temperature below the melting point of sodium. Preferably the refractory binder is water glass.

Advantageously the battery may comprise two or more rows of cells or of strings of cells, adjacent rows of cells or of strings of cells being separated by said separating means. Preferably the battery comprises insulating strips separating adjacent cells or strings of cells of a common row, the insulating strip preferably being formed of a refractory fibrous web impregnated with a cured refractory binder. In a battery having at least three rows of cells or of

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strings of cells, said separating means preferably comprises a single length of the refractory fibrous web interposed between successive pairs of adjacent rows. Alternatively, in a battery having at least three rows of cells or of strings of cells, said separating means may comprise separate lengths of the refractory fibrous web interposed between each pair of adjacent rows.

Advantageously the battery may comprise means for interconnecting cells or strings of cells in parallel. In a battery comprising two or more rows of cells or of strings of cells, said parallel interconnecting means preferably comprises a lattice plate having three or more nodes each connected to a corresponding terminal of a respective cell or string of cells. Each node of the lattice plate is preferably connected to each adjacent node and from which it is also preferably equally spaced.

Advantageously the battery may comprise means for interconnecting cells or of strings of cells in series. In a battery comprising two or more lattice plates, said series interconnecting means preferably comprises a conductive strip connected between two lattice plates which are themselves respectively connected to correspondingly opposite terminals of separate groups of cells or strings of cells.

Advantageously the cells of the battery may be arranged to form a block and the block have a wrapping comprising a refractory fibrous web impregnated with a cured refractory binder. Preferably the wrapping substantially encloses the block.

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According to a second aspect of the present invention there is provided a method of assembling a battery of electric cells comprising the steps of impregnating a refractory fibrous web with a refractory binder, arranging the refractory fibrous web so as to separate at least two of said cells, and curing the refractory binder.

Advantageously the refractory fibrous web may be interposed between the cells.

Advantageously after the refractory binder has been cured the impregnated refractory fibrous web may cement the cell together.

Advantageously the refractory fibrous web may be impregnated with the refractory binder by immersion in a quantity thereof. Preferably the refractory fibrous web is passed around one or more rollers while immersed in the refractory binder. Preferably the refractory fibrous web is scraped after being withdrawn from the refractory binder to remove excess binder from the web.

Advantageously the cells may be interconnected in series to form a plurality of strings of cells and the refractory fibrous web interposed between at least two of the said strings.

Advantageously the cells or strings of cells may be arranged in two or more rows and the refractory fibrous web interposed between adjacent rows. Preferably each row of cells or of strings of cells is assembled separately. Preferably each row of cells or of strings of cells is assembled by interposing an insulating strip between adjacent

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cells or strings of cells, the insulating strips being preferably formed by impregnating a refractory fibrous web with a refractory binder which is cured during the assembly of each row of cells or strings of cells. Each row of cells or of strings of cells is preferably assembled in a forming apparatus so that the assembled row has at least one predetermined dimension. Preferably the cells or strings of cells are assembled from a block comprising three or more rows of cells or of strings of cells and a single length of the refractory fibrous web is interposed between successive pairs of adjacent rows. Alternatively, if the cells or strings of cells are assembled to form a block comprising three or more rows of cells or of strings of cells, separate lengths of the refractory fibrous web may be interposed between each pair of adjacent rows. Where the cells or strings of cells are assembled to form a block, the block is preferably assembled in a forming apparatus so that the assembled block has at least one predetermined dimension.

Advantageously after the refractory binder has been cured at least two of said cells or strings of cells may be interconnected in parallel. Preferably the cells or strings of cells are interconnected in parallel by means of a lattice plate having three or more nodes each connected to a corresponding terminal of a respective cell or string of cells.

Advantageously after the refractory binder has been cured at least two of said cells or strings of cells may be interconnected in series. In a battery comprising two or more lattice plates, the cells or strings of cells are preferably interconnected in series by means of a conductive strip connected

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between two lattice plates which are themselves respectively connected to correspondingly opposite terminals of separate groups of cells or of strings of cells. Preferably the conductive strip is interposed between two cells or strings of cells and is separated therefrom by insulating strips. Preferably the two cells or strings of cells comprise adjacent cells or strings of cells of a common row and the conductive strip is interposed between the two during the assembly of the row, the insulating strips being preferably formed by impregnating a refractory fibrous web with a refractory binder which is cured during the assembly of the row of cells or of strings of cells.

Advantageously after the cells or strings of cells have been interconnected a length of a refractory fibrous web may be impregnated with a refractory binder, the battery wrapped in the impregnated fibrous web and the refractory binder cured.

According to a third aspect of the present invention there is provided a method of assembling a battery of electric cells comprising the steps of applying a cementing material to a surface of at least a first cell, subsequently bringing a second cell into contact with the cementing material applied to the first cell, and curing the cementing material so that the cells adhere together.

Advantageously the cementing material may separate said first and second cells and, in one example, the cementing material comprises a paste including a binding agent and a coarse particulate filler, the filler being electrically insulating and

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effective to prevent electrical contact between said first and second cells.

Advantageously the cells may be interconnected in series to form a plurality of strings of cells and said first and second cells comprise corresponding cells of respective strings.

Advantageously the cells or strings of cells may be arranged in two or more rows and said first and second cells comprise corresponding cells of adjacent rows. Preferably each row of cells or of strings of cells is assembled separately. Preferably each row of cells or of strings of cells is assembled by interposing insulating strips between adjacent cells or strings of cells, the insulating strips preferably comprising a cementing material which is cured during the assembly of each row of cells or strings of cells. Each row of cells or of strings of cells is preferably assembled in a forming apparatus so that the assembled row has at least one predetermined dimension. Preferably the cells or strings of cells are assembled to form a block comprising three or more rows of cells or of strings of cells and the block is assembled in a forming apparatus so that the assembled block has at least one predetermined dimension.

Advantageously after the cementing material has been cured at least two of said cells or strings of cells may be interconnected in parallel. Preferably the cells or strings of cells are interconnected in parallel by means of a lattice plate having three or more nodes each connected to a corresponding terminal of a respective cell or string of cells.

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Advantageously after the cementing material has been cured at least two of said cells or strings of cells may be interconnected in series. In a battery comprising two or more lattice plates, the cells or strings of cells are preferably interconnected in series by means of a conductive strip connected between two lattice plates which are themselves respectively connected to correspondingly opposite terminals of separate groups of cells or of strings of cells. Preferably the conductive strip is interposed between two cells or strings of cells and is separated therefrom by insulating strips. Preferably the two cells or strings of cells comprise adjacent cells or strings of cells of a common row and the conductive strip is interposed between the two during the assembly of the row, the insulating strips preferably comprising a cementing material which is cured during the assembly of the row of cells or of strings of cells.

Advantageously after the cells or strings of cells have been interconnected the cells or strings of cells may be coated with a cementing material which is subsequently cured.

According to a fourth aspect of the present invention there is provided a battery of electric cells comprising three or more cells or strings of cells cemented together in parallel, spaced-apart relationship and including means for interconnecting the cells or strings of cells in parallel, said parallel interconnecting means comprising a lattice plate having three or more nodes each connected to a corresponding terminal of a respective cell or string of cells.

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Advantageously each node of the lattice plate may be connected to each adjacent node from which it is also preferably equally spaced.

Advantageously the battery may comprise means for interconnecting cells or strings of cells in series said series interconnecting means preferably comprising a conductive strip connected between two lattice plates which are themselves respectively connected to correspondingly opposite terminals of separate groups of cells or of strings of cells.

The invention also provides a battery of electric cells comprising three or more cells or strings of cells in parallel spaced-apart relationship, and cementing means holding the cells or strings of cells together, the cementing means comprising a cured cementing paste containing a coarse particulate filler which is electrically insulating and prevents electrical contact between adjacent cells cemented together, the cementing paste being applied only in a layer to the surfaces of the cells at least where adjacent cells are cemented together.

An embodiment of the present invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a perspective view of a typical sodium sulphur cell in which part of the cell has been broken away for the sake of clarity;

Figure 2 is a plan view of a fully assembled battery in accordance with a first aspect of the present invention;

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Figure 3 is a lateral side view of two typical sodium sulphur cells disposed in end to end relationship;

Figure 4 is a perspective view of a string of four sodium sulphur cells;

Figure 5 is a perspective view of a row of four strings of sodium sulphur cells;

Figure 6 is a schematic view of an apparatus for use in impregnating a refractory fibrous web with a refractory binder;

Figure 7 is a schematic view of a forming apparatus for use in the assembly of a row of cells or of strings of cells.;

Figure 8 is a schematic view of a forming apparatus for use in the assembly of a block of cells or of strings of cells in accordance with a first method;

Figure 9 is a schematic view of a forming apparatus for use in the assembly of a block of cells or of strings of cells in accordance with a second method;

Figure 10 is a plan view of a lattice plate for use in interconnecting cells or of strings of cells in parallel;

Figure 11 is a perspective view of a connector for use in interconnecting cells or of strings of cells in series; and

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Figure 12 is a schematic view of the connector of Figure 11 being incorporated during the assembly of a row of strings of cells.

Referring initially to Figure 2, the illustrated battery can be seen to comprise a block 80 of series arrangements of cells 42, 50, 52 and 56 of which only the uppermost cell 46 is visible. The series arrangements of cells or strings 42, 50, 52 and 56 are disposed in parallel, spaced-apart relationship and are separated from each other by means of a cementing material 58. The cementing material 58 cements the strings 42, 50, 52 and 56 together and provides the block 80 with its required rigidity.

Within the block 80 groups of strings are connected together in parallel by means of pairs of lattice plates 92 to form an arrays 94 of parallel-connected strings. These arrays 94 are in turn connected together in series by means of a plurality of series connectors 102 and an end plate 110.

Considering now each string in more detail, Figure 3 illustrates two sodium sulphur cells connected in series. The two cells 26 and 28 are of the same general construction as those previously described with reference to Figure 1 and are disposed in end to end relationship with the central terminal disk 24 of the lower cell 26 adjacent a bottom surface 30 of the upper cell 28. The two cells 26 and 28 are separated by an annular spacer member 32 of insulating ceramic or porcelaine material in order to prevent electrical contact from being established between their respective cases 12. A conductive

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metal strip 34 is arranged to extend across the bottom surface 30 of the upper cell 28 to which it is welded at each of its ends 36 and 38. At its centre the strip 34 is formed so as to extend downwardly through an aperture 40 in the spacer member 32 toward the lower cell 28 where it is welded to the central terminal disk 24. In this way the metal strip 34 provides the necessary electrical connection between the central terminal disk 24 of one cell and the case 12 of the other.

Clearly larger strings of cells can be provided by arranging the required number of cells in end to end relationship with an annular spacer member 32 interposed between each pair of adjacent cells and with electrical contact established between the two by means of a metal strip 34 welded in the manner described. One such larger string 42 is shown in Figure 4 to comprise four sodium sulphur cells 26, 28, 44, and 46 disposed in end to end relationship with the uppermost cell designated by reference numeral 46. An insulating strip 48 is arranged to extend parallel to the string 42 and adhere to it so that a second string 50 of a similar number of cells may be placed along side the first without the cases 12 of the corresponding cells of the two strings coming into electrical contact with each other. A second insulating strip 48 may then be arranged to extend parallel to the second string 50 and adhere to it so that a third string 52 again of a similar number of cells may be placed along side the other two. In this way it is possible to arrange strings of cells in rows of any desired length. One such row of strings 54 is shown in Figure 5 to comprise four strings 42, 50, 52 and 56 each containing four cells 26, 28, 44 and 46.

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The insulating strip 48 used to separate adjacent strings of cells may comprise any insulating material capable of operating at the elevated temperatures of the battery. Preferably the insulating material is also capable of cementing adjacent strings together. In one such embodiment the insulating strip comprises a refractory fibrous web 58 impregnated with a refractory binder 60 such as water glass. This has the advantage that once the binder 60 has been cured the insulating strips 48 provide the row of strings 54 with sufficient rigidity to enable the row to be handled as an integral unit.

The fibrous web 58, which may take the form of a woven cloth such as alumina fibre cloth, is preferably impregnated with the binder 60 by a process of immersion. A suitable apparatus for performing this process is shown in Figure 6 to comprise a bath 62 containing a sufficient quantity of the binder 60 to immerse two rollers 64 and 66. A roll of dry and as yet unimpregnated fibrous web 68 is disposed adjacent to the bath 62 and is drawn into the binder 60 to pass around the rollers 64 and 66. The action of passing the web 58 around the rollers 64 and 66 ensures that the binder 60 is pressed between the fibres of the web whereafter the impregnated web is drawn out of the bath 62 to pass between the opposed blades of a scraper system 70. The scraper system 70 removes any excess binder 60 from the web 58 before the web then passes over a further roller 72. Lengths may be cut from the web 58 to form the insulating strips 48.

In order to facilitate the assembly of a row of strings 54 such as that shown in Figure 5 a forming

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apparatus may be used comprising a base plate 74 mounted for relative vertical movement between two substantially perpendicular sidewalls 76 and 78. As can be seen from Figure 7, the side walls 76 and 78 are spaced apart by a distance slightly greater than the diameter of one of the strings and it is this spacing that determines the linearity of the assembled row.

In use a first string of cells 42 is placed on the base plate 74 between the two side walls 76 and 78. A strip 48 of the refractory fibrous web 58 impregnated with the as yet uncured refractory binder 60 is then arranged to overlie the first string 42 in such a way that it covers the cases 12 of each of the cells 26, 29, 44 and 46 that make up the string. A second string 50 is then arranged on top of the insulating strip 48 and pressed down to ensure a good adhesion between the insulating strip 48 and the two strings 42 and 50 that it separates.

To increase the number of strings contained in the row 54 a second insulating strip 48 is arranged to overlie the second string 50, again in such a way that it covers the cases 12 of each of the cells 26, 28, 44 and 46 that make up the string. A third string 52 is then pressed down on to the second insulating strip 48 to ensure that the second insulating strip adheres to both the second string 50 and the third string 52. By repeating this process a row 54 may be assembled comprising any desired number of strings.

Finally, once the row has been assembled of the required number of strings, the refractory binder 60 contained within the insulating strips 48 is allowed

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to cure and go hard. When the binder has cured the row of strings 54 is removed from the forming apparatus and possesses sufficient rigidity to enable it to be treated as an integral unit.

To assemble the block of strings 80 shown in Figure 2 rows of strings 54 are arranged adjacent one another in mutually parallel spaced relationship separated by a layer of insulating material. Again the insulating material may comprise any material having the appropriate properties and capable of operating at the elevated temperatures of the battery. As with the assembly of an individual row of strings 54, the insulating material is preferably also capable of cementing adjacent rows together. In one such embodiment the insulating material comprises a refractory fibrous web 58 impregnated with a refractory binder 60 such as water glass.

To facilitate the assembly of the block a second forming apparatus may be used comprising a base plate 82 mounted for relative vertical movement between two substantially perpendicular side walls 84 and 86. The space between the side walls 84 and 86 is preferably adjustable as this determines one of the external dimensions of the block 80 and, as will be readily apparent to those skilled in the art, if the spacing can be made sufficiently narrow then the same forming apparatus can be used to facilitate the assembly of blocks 80 as can be used to facilitate the assembly of rows 54.

Referring to Figure 8 it will be seen that to assemble a block of strings 80 using the forming apparatus a first row 54 is initially placed on the base plate 82 between the two side walls 84 and 86. A layer of the refractory fibrous web 58 impregnated

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with the as yet uncured refractory binder 60 is then arranged to overlies the row 54 in such a way that it covers the cases 12 of each of the cells 26, 28, 44 and 46 of each of the strings 42, 50, 52 and 56 contained within the row 54. A second row of strings 88 is then arranged on top of the layer of the refractory fibrous web 58 and pressed down to ensure a good adhesion between the web 58 and the two rows 54 and 88 that it separates.

To increase the number of rows contained in the block 80 a second layer of the refractory fibrous web 58 is arranged to overlies the second row 88, again in such a way that it covers the cases 12 of each of the cells 26, 28, 44 and 46 of each of the strings 42, 50, 52 and 56. A third row of strings 90 is then pressed down on to the second layer of the refractory fibrous web to ensure that the web 58 adheres to both the second row 88 and the third row 90. By repeating this process a block of strings 80 may be assembled comprising any desired number of rows.

Finally, once the block 80 has been assembled of the required number of rows, the refractory binder 60 contained within the layers of the refractory fibrous web 58 is allowed to cure and go hard. When the binder has been cured the block 80 is removed from the forming apparatus and possesses sufficient rigidity to negate the use of the steel bus plates common to prior art batteries of this type.

An alternative method of assembling a block of strings 80 is shown in Figure 9. In this method the separate layers of refractory fibrous web 58 that separate adjacent rows 54, 88 and 90 are replaced by

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a single length of refractory fibrous web that follows a serpentine path through the block 80. The web is still used to separate adjacent rows and cement them together but is wrapped around the last string in each row before being folded back on itself to pass along the opposite side of the same row. This method of assembly has the advantage that by using a single length of web the resulting block 80 has an increased rigidity.

Using either of the foregoing methods and by employing a forming apparatus it is possible to assemble a block of cells 80 having pre-determined external dimensions irrespective of tolerance variations in the individual cells or strings of cells. This enables large numbers of battery units to be produced all having the same dimensions and enables each battery to be interchangeable with any other battery.

With the block 80 deriving its rigidity from the cured refractory binder 60 contained within the refractory fibrous web 58 used to separate adjacent strings of cells, the strings may be electrically interconnected by means of a plurality of lightweight connectors. One such lightweight connector is shown in Figure 10 to comprise a lattice plate 92 and is used to interconnect groups of strings in parallel to form an array 94. Each lattice plate 92 comprises a pattern of interconnected nodes 96 each of which is connected to its immediate neighbours by means of an individual fret 98. These frets 98 are all of substantially the same length and divide the lattice plate 92 into a plurality of equilateral triangles having a node 96 at each corner. Along one side of the lattice plate 92 the peripheral nodes 96 are each

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provided with a respective tab portion 100 that projects substantially perpendicularly to a line defined by alternate of the said peripheral node.

In use two lattice plates 92 are employed to interconnect a group of strings in parallel. The first lattice plate is disposed so that each of its nodes 96 can be welded to the central terminal disk 24 of the uppermost cell 46 of a respective one of the strings that form part of the array 94 while the second lattice plate is disposed so that each of its nodes is welded to the bottom surface 30 of the lowermost cell 26 of the same group of strings. By interconnecting groups of strings in this way a block of strings 80 may be divided into a number of arrays of parallel-connected strings of cells 94.

The arrays of parallel-connected strings 94 may themselves be connected together in series by means of one or more of the series connectors 102 shown in Figure 11. Each connector 102 comprises a lightweight elongate metal connecting strip 104 having one of a pair of oppositely directed flanges 106 and 108 disposed at either end.

In use the connectors 102 are incorporated into the block 80 during the assembly of individual rows 54. Thus, as can be seen from Figure 12, the elongate connecting strip 104 is arranged to extend parallel to the fourth string 56 of a particular row of strings and is prevented from coming into electrical contact with the cases 12 of the cells 26, 28, 44 and 46 making up the string by means of an insulating strip 48 interposed between the two. A second insulating strip 48 (not shown) is then arranged to overlies the connecting strip 104 of the

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connector 102 before a further string (also not shown) is pressed against the second insulating strip thereby sandwiching the connector 102 between the fourth string 56 and the said further string. Later, when the block 80 has been fully assembled and the binder 60 has been cured, the series connectors 102 are used to interconnect correspondingly opposite lattice plates 92 of adjacent arrays 94 by welding the respective tab portions 100 of the lattice plates concerned to one or other of the oppositely directed flanges 106 and 108.

Thus in summary and referring back to Figure 2, the assembled battery can be seen to comprise a plurality of series-connected strings of cells 42, 50, 52 and 56 of which only the uppermost cell 46 of each string is visible. These strings are arranged in rows 54, 88, and 90 and the rows arranged to form a block 80 in which each string is separated from its neighbours by a refractory fibrous web 58 impregnated with a cured refractory binder 60. Within the block 80 groups of strings are connected together in parallel by means of lightweight lattice plates 92 to form arrays 94 and the arrays are themselves connected together in series by means of a plurality of series connectors 102. An end plate 110 serves to interconnect the correspondingly opposite lattice plates 92 of two arrays of parallel-connected strings 94 disposed in a side by side relationship in a manner analogous to one of the series connectors 102. Since the rigidity of the block 80 does not depend on the rigidity of the end plate 110 the end plate, like the lattice plate 92, may be made of any lightweight electrically conductive material.

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Finally, in order to provide the block 80 with a still greater rigidity the whole may be wrapped to a greater or lesser extent in one or more sheets of the impregnated refractory fibrous web 58 and allowed to undergo a further curing process.

It will be apparent to those skilled in the art that whilst the battery has been described as an assembly of strings of a number of cells, the battery may equally comprise an arrangement in which there is only one cells in each "string".

It will be apparent to those skilled in the art that whilst the battery has been described as an assembly of sodium sulphur cells, the battery may equally comprise cells of any desired type.

It will also be apparent to those skilled in the art that whilst the refractory fibrous web has been described as interposed between the cells, the cells may equally be separated by an alternative distribution of the web.

In one alternative to the above described arrangement, the cells are cemented together yet insulated from one another by a cementing paste comprising a binder and a coarse particulate filler. The filler is electrically insulating and serves to keep adjacent cells separate to prevent electrical contact. The cementing paste is applied to a surface of at least one of the cells to be bonded together before the second of the cells is brought into contact and the paste allowed to cure. This operation conveniently takes place in a forming apparatus as described above. Thus the block of cells is built up in a fashion similar to that

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described above with reference to impregnated refractory fibrous web material.

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CLAIMS

1. A battery of electric cells comprising means to separate at least two of said cells, wherein the separating means comprises a refractory fibrous web impregnated with a cured refractory binder.
2. A battery in accordance with claim 1, wherein the separating means is interposed between the cells.
3. A battery in accordance with claim 1 or claim 2, wherein the separating means cements the cells together.
4. A battery in accordance with any preceding claim, wherein the refractory fibrous web comprises a woven cloth.
5. A battery in accordance with any preceding claim, wherein the refractory fibrous web comprises alumina fibre cloth.
6. A battery in accordance with any preceding claim, wherein the cells contain sodium and the refractory binder has a curing temperature below the melting point of sodium.
7. A battery in accordance with any preceding claim, wherein the refractory binder is water glass.
8. A battery in accordance with any preceding claim and comprising two or more rows of cells or of strings of cells, adjacent rows of cells or of strings of cells being separated by said separating means.

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9. A battery in accordance with claim 8 and comprising insulating strips separating adjacent cells or strings of cells of a common row.
10. A battery in accordance with claim 9, wherein the insulating strips are formed of a refractory fibrous web impregnated with a cured refractory binder.
11. A battery in accordance with any of claims 8 to 10 having at least three rows of cells or of strings of cells, said separating means comprising a single length of the refractory fibrous web interposed between successive pairs of adjacent rows.
12. A battery in accordance with any of claims 8 to 10 having at least three rows of cells or of strings of cells, said separating means comprising separate lengths of the refractory fibrous web interposed between each pair of adjacent rows.
13. A battery in accordance with any preceding claim and comprising means for interconnecting cells or strings of cells in parallel.
14. A battery in accordance with claim 13 when dependant on any of claims 8 to 12, wherein said parallel interconnecting means comprises a lattice plate having three or more nodes each connected to a corresponding terminal of a respective cell or string of cells.
15. A battery in accordance with claim 14, wherein each node of the lattice plate is connected to each adjacent node.

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16. A battery in accordance with claim 15, wherein each node of the lattice plate is equally spaced from each adjacent node.

17. A battery in accordance with any preceding claim and comprising means for interconnecting cells or strings of cells in series.

18. A battery in accordance with claim 17 when dependant on any of claims 14 to 16, wherein said series interconnecting means comprises a conductive strip connected between two lattice plates which are themselves respectively connected to correspondingly opposite terminals of separate groups of cells or of strings of cells.

19. A battery in accordance with any preceding claim, wherein the cells are arranged to form a block and the block has a wrapping comprising a refractory fibrous web impregnated with a cured refractory binder.

20. A battery in accordance with claim 19, wherein the wrapping substantially encloses the block.

21. A method of assembling a battery of electric cells comprising the steps of impregnating a refractory fibrous web with a refractory binder, arranging the refractory fibrous web so as to separate at least two of said cells, and curing the refractory binder.

22. A method in accordance with claim 21, wherein the refractory fibrous web is interposed between the cells.

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23. A method in accordance with claim 21 or claim 22, wherein after the refractory binder has been cured the impregnated refractory fibrous web cements the cells together.

24. A method in accordance with any of claims 21 to 23, wherein the refractory fibrous web is impregnated with the refractory binder by immersion in a quantity thereof.

25. A method in accordance with claim 24, wherein the refractory fibrous web is passed around one or more rollers while immersed in the refractory binder.

26. A method in accordance with claim 24 or claim 25, wherein the refractory fibrous web is scraped after being withdrawn from the refractory binder to remove excess binder from the web.

27. A method in accordance with any of claims 21 to 26, wherein the cells are interconnected in series to form a plurality strings of cells and the refractory fibrous web is interposed between at least two of the said strings.

28. A method in accordance with any of claims 21 to 27, wherein the cells or strings of cells are arranged in two or more rows and the refractory fibrous web is interposed between adjacent rows.

29. A method in accordance with claim 28, wherein each row of cells or of strings of cells is assembled separately.

30. A method in accordance with claim 29, wherein each row of cells or of strings of cells is assembled

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by interposing an insulating strip between adjacent cells or strings of cells.

31. A method in accordance with claim 30, wherein the insulating strips are formed by impregnating a refractory fibrous web with a refractory binder which is cured during the assembly of each row of cells or of strings of cells.

32. A method in accordance with any of claims 29 to 31, wherein each row of cells or of strings of cells is assembled in a forming apparatus so that the assembled row has at least one predetermined dimension.

33. A method in accordance with any of claims 28 to 32, wherein the cells or strings of cells are assembled to form a block comprising three or more rows of cells or of strings of cells and a single length of the refractory fibrous web is interposed between successive pairs of adjacent rows.

34. A method in accordance with any of claims 28 to 32, wherein the cells or strings of cells are assembled to form a block comprising three or more rows of cells or of strings of cells and separate lengths of the refractory fibrous web are interposed between each pair of adjacent rows.

35. A method in accordance with claim 33 or 34, wherein the block is assembled in a forming apparatus so that the assembled block has at least one predetermined dimension.

36. A method in accordance with any of claims 21 to 35, wherein after the refractory binder has been

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cured at least two of said cells or strings of cells are interconnected in parallel.

37. A method in accordance with claim 36, wherein the cells or strings of cells are interconnected in parallel by means of a lattice plate having three or more nodes each connected to a corresponding terminal of a respective cell or string of cells.

38. A method in accordance any of claims 21 to 37, wherein after the refractory binder has been cured at least two of said cells or strings of cells are interconnected in series.

39. A method in accordance with claim 38 when dependent on claim 37, wherein the cells or strings of cells are interconnected in series by means of a conductive strip connected between two lattice plates which are themselves respectively connected to correspondingly opposite terminals of separate groups of cells or of strings of cells.

40. A method in accordance with claim 39, wherein the conductive strip is interposed between two cells or strings of cells and is separated therefrom by insulating strips.

41. A method in accordance with claim 40, wherein the two cells or strings of cells comprise adjacent cells or strings of cells of a common row and the conductive strip is interposed between the two during the assembly of the row.

42. A method in accordance with claim 41, wherein the insulating strips are formed by impregnating a

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refractory fibrous web with a refractory binder which is cured during the assembly of the row of cells or of strings of cells.

43. A method in accordance with any of claims 36 to 42, wherein after the cells or strings of cells have been interconnected a length of a refractory fibrous web is impregnated with a refractory binder, the battery is wrapped in the impregnated fibrous web and the refractory binder is cured.

44. A method of assembling a battery of electric cells comprising the steps of applying a cementing material to a surface of at least a first cell, subsequently bringing a second cell into contact with the cementing material applied to the first cell, and curing the cementing material so that the cells adhere together.

45. A method in accordance with claim 44, wherein the cementing material separates said first and second cells.

46. A method in accordance with claim 45, wherein the cementing material comprises a paste including a binding agent and a coarse particulate filler, the filler being electrically insulating and effective to prevent electrical contact between said first and second cells.

47. A method in accordance with any of claims 44 to 46, wherein the cells are interconnected in series to form a plurality of strings of cells and said first and second cells comprise corresponding cells of respective strings.

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48. A method in accordance with any of claims 44 to 47, wherein the cells or strings of cells are arranged in two or more rows and said first and second cells comprise corresponding cells of adjacent rows.

49. A method in accordance with claim 48, wherein each row of cells or of strings of cells is assembled separately.

50. A method in accordance with claim 49, wherein each row of cells or of strings of cells is assembled by interposing insulating strips between adjacent cells or strings of cells.

51. A method in accordance with claim 50, wherein the insulating strips comprise a cementing material which is cured during the assembly of each row of cells or of strings of cells.

52. A method in accordance with any of claims 49 to 51, wherein each row of cells or of strings of cells is assembled in a forming apparatus so that the assembled row has at least one predetermined dimension.

53. A method in accordance with any of claims 48 to 52, wherein the cells or strings of cells are assembled to form a block comprising three or more rows of cells or of strings of cells and the block is assembled in a forming apparatus so that the assembled block has at least one predetermined dimension.

54. A method in accordance with any of claims 44 to 53, wherein after the cementing material has been

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cured at least two of said cells or strings of cells are interconnected in parallel.

55. A method in accordance with claim 54, wherein the cells or strings of cells are interconnected in parallel by means of a lattice plate having three or more nodes each connected to a corresponding terminal of a respective cell or string of cells.

56. A method in accordance with any of claims 44 to 55, wherein after the cementing material has been cured at least two of said cells or strings of cells are interconnected in series.

57. A method in accordance with claim 56 when dependant on claim 55, wherein the cells or strings of cells are interconnected in series by means of a conductive strip connected between two lattice plates which are themselves respectively connected to correspondingly opposite terminals of separate groups of cells or of strings of cells.

58. A method in accordance with claim 57, wherein the conductive strip is interposed between two cells or strings of cells and is separated therefrom by insulating strips.

59. A method in accordance with claim 58, wherein the two cells or strings of cells comprise adjacent cells or strings of cells of a common row and the conductive strip is interposed between the two during the assembly of the row.

60. A method in accordance with claim 59, wherein the insulating strips comprise a cementing material

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which is cured during the assembly of the row of cells or of strings of cells.

61. A method in accordance with any of claims 54 to 60, wherein after the cells or strings of cells have been interconnected the cells or strings of cells are coated with a cementing material which is subsequently cured.

62. A battery of electric cells comprising three or more cells or strings of cells cemented together in parallel, spaced-apart relationship and including means for interconnecting the cells or strings of cells in parallel, said parallel interconnecting means comprising a lattice plate having three or more nodes each connected to a corresponding terminal of a respective cell or string of cells.

63. A battery in accordance with claim 62, wherein each node of the lattice plate is connected to each adjacent node.

64. A battery in accordance with claim 63, wherein each node of the lattice plate is equally spaced from each adjacent node.

65. A battery in accordance with any of claims 62 to 64, and comprising means for interconnecting cells or strings of cells in series.

66. A battery in accordance with claim 65, wherein said series interconnecting means comprises a conductive strip connected between two lattice plates which are themselves respectively connected to correspondingly opposite terminals of separate groups of cells or of strings of cells.

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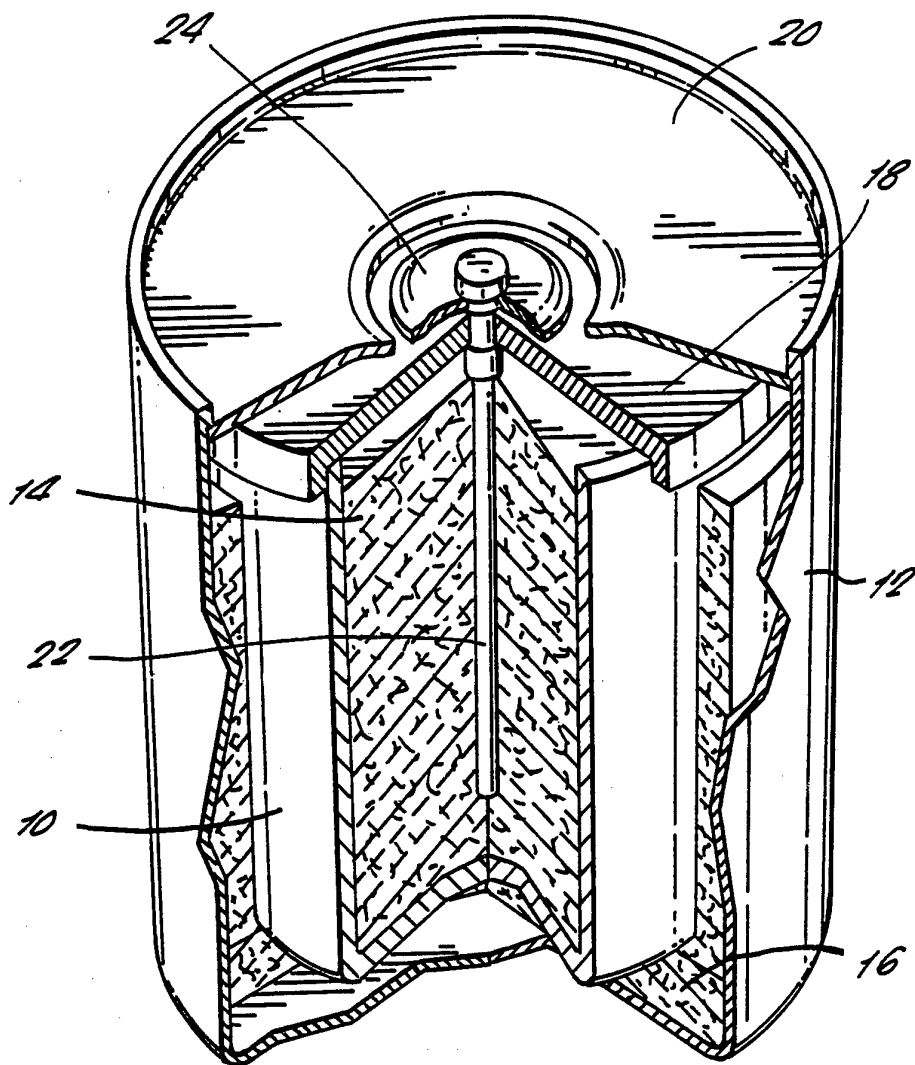
67. A battery of electric cells substantially as herein described with reference to the accompanying drawings.

68. A method of assembling a battery of electric cells substantially as herein described with reference to the accompanying drawings.

69. A battery of electric cells comprising three or more cells or strings of cells in parallel spaced-apart relationship, and cementing means holding the cells or strings of cells together, the cementing means comprising a cured cementing paste containing a coarse particulate filler which is electrically insulating and prevents electrical contact between adjacent cells cemented together, the cementing paste being applied only in a layer to the surfaces of the cells at least where adjacent cells are cemented together.

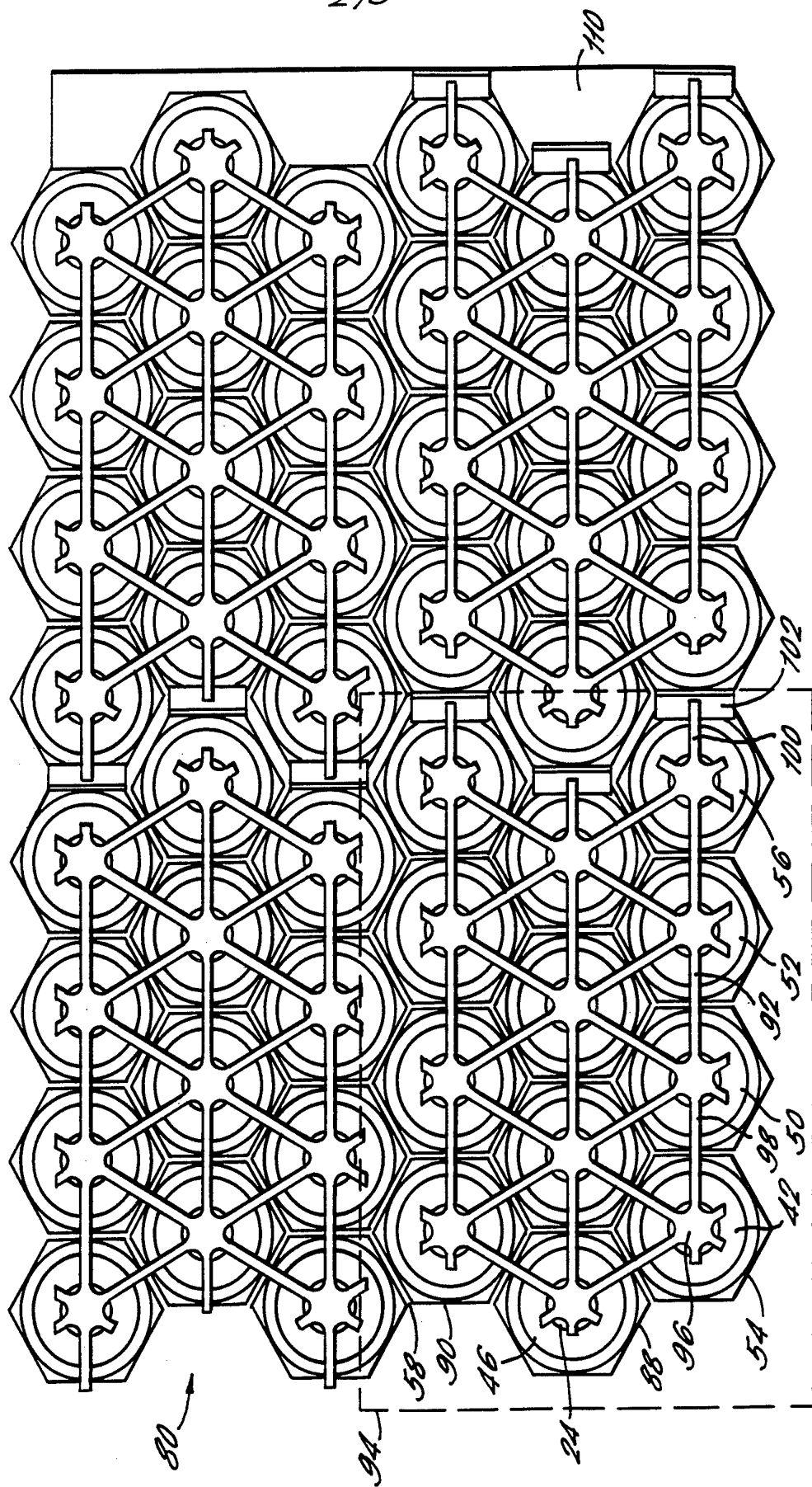
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FIG. 1.



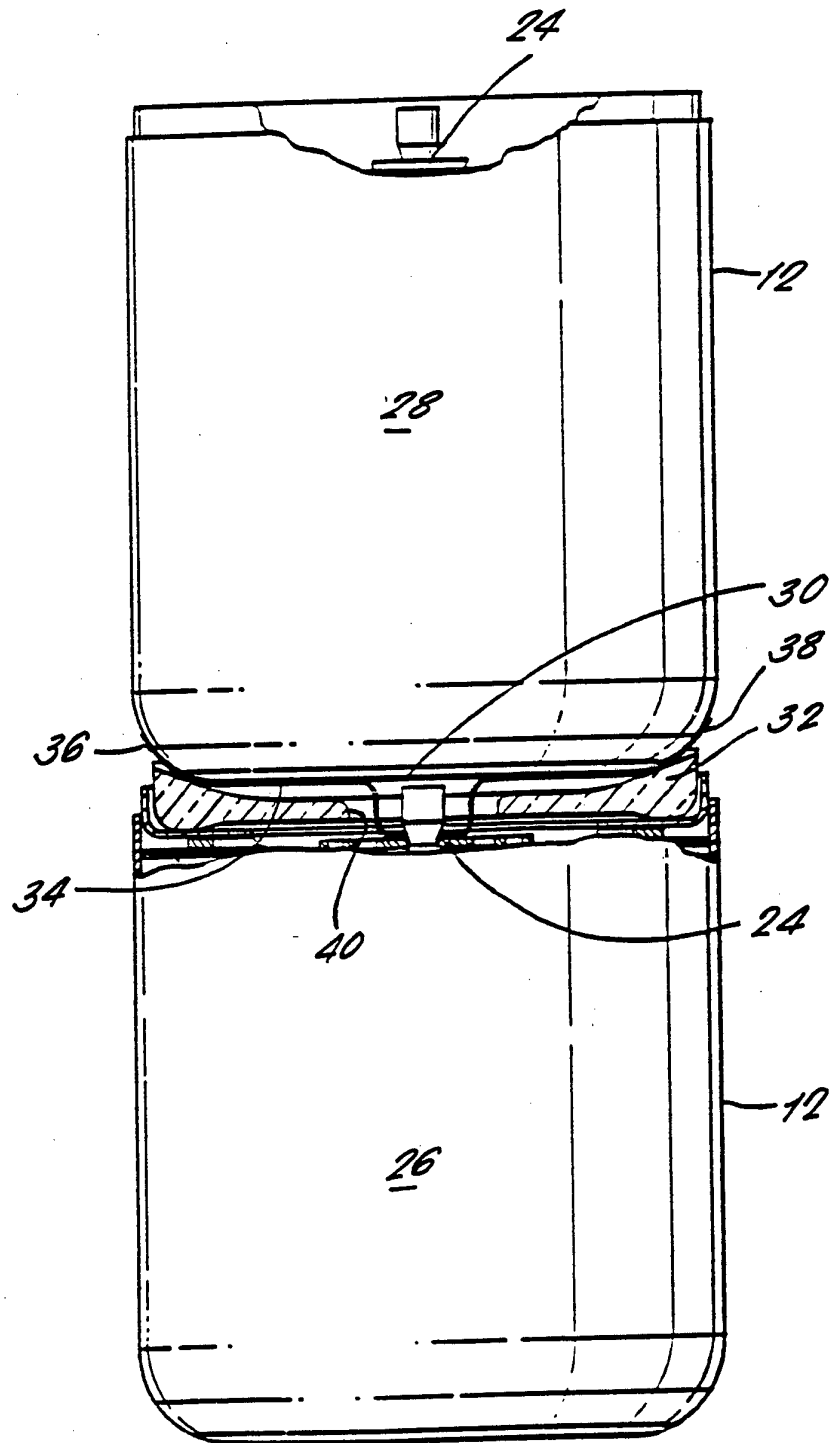
2/9

FIG. 2.



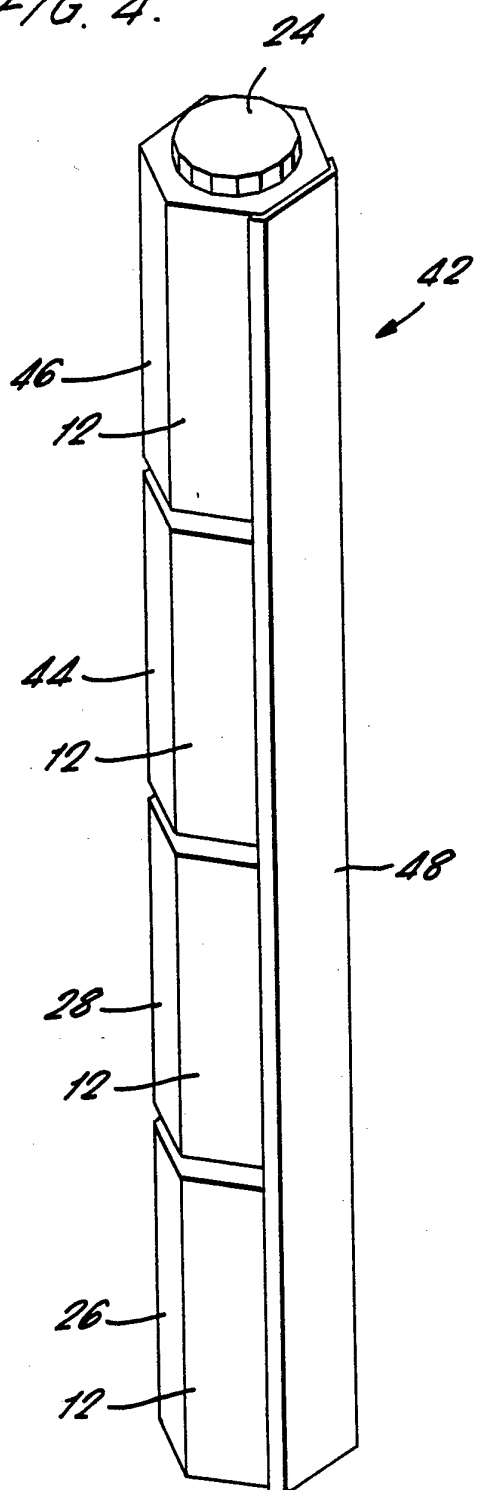
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FIG. 3.



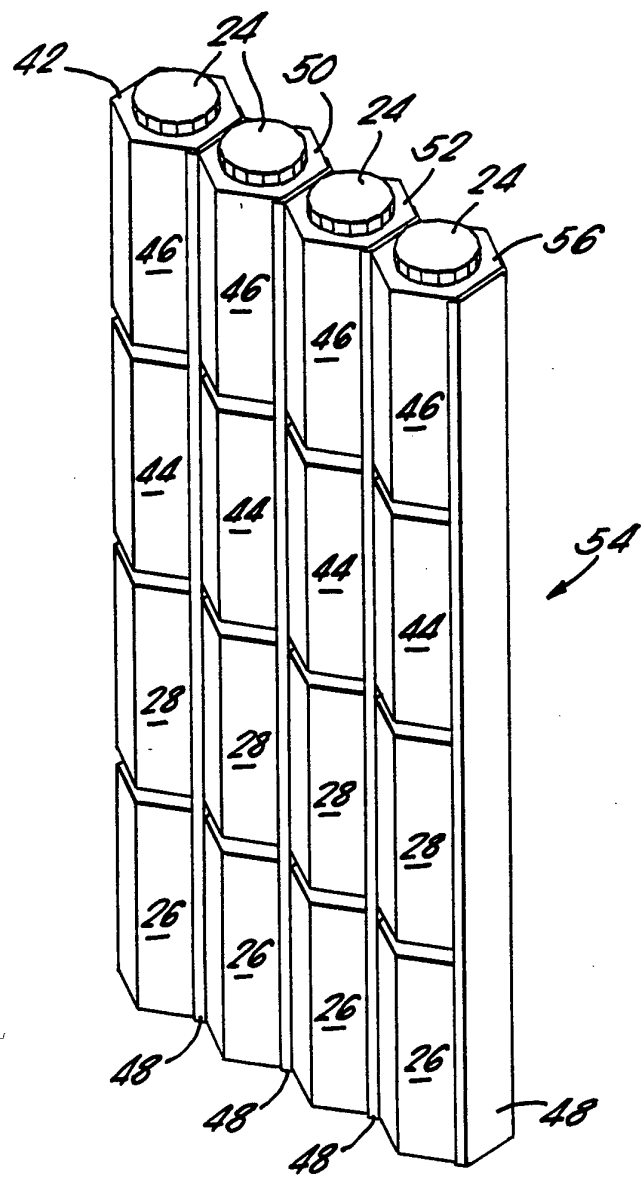
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FIG. 4.



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FIG. 5.



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FIG. 6.

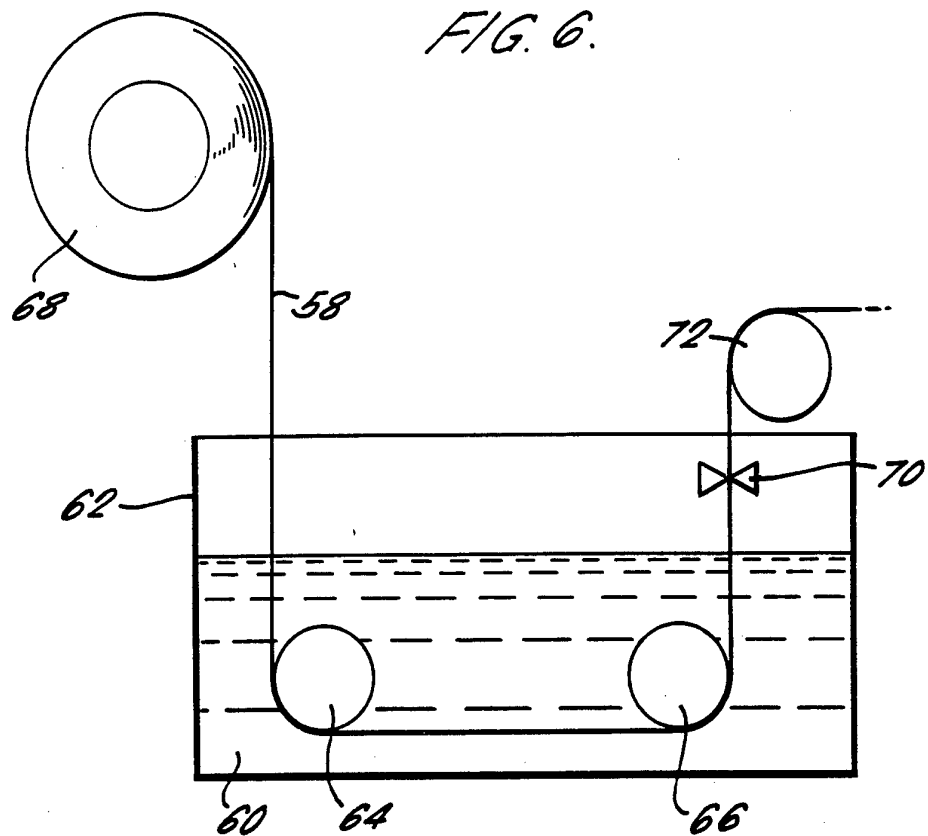
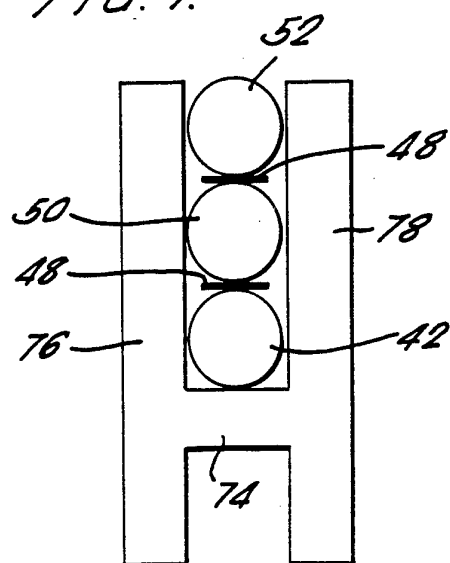


FIG. 7.



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FIG. 8.

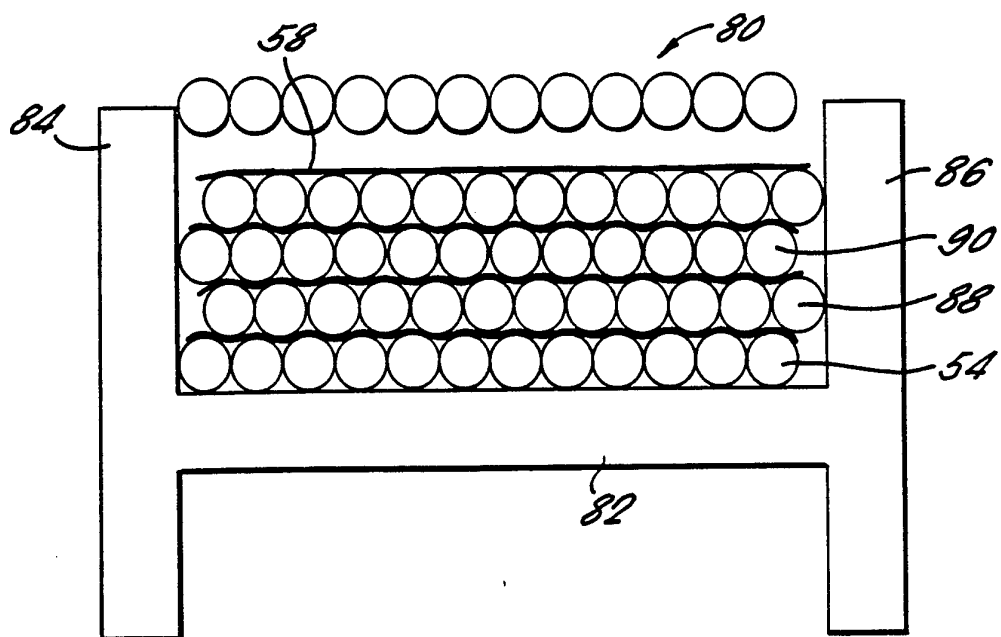
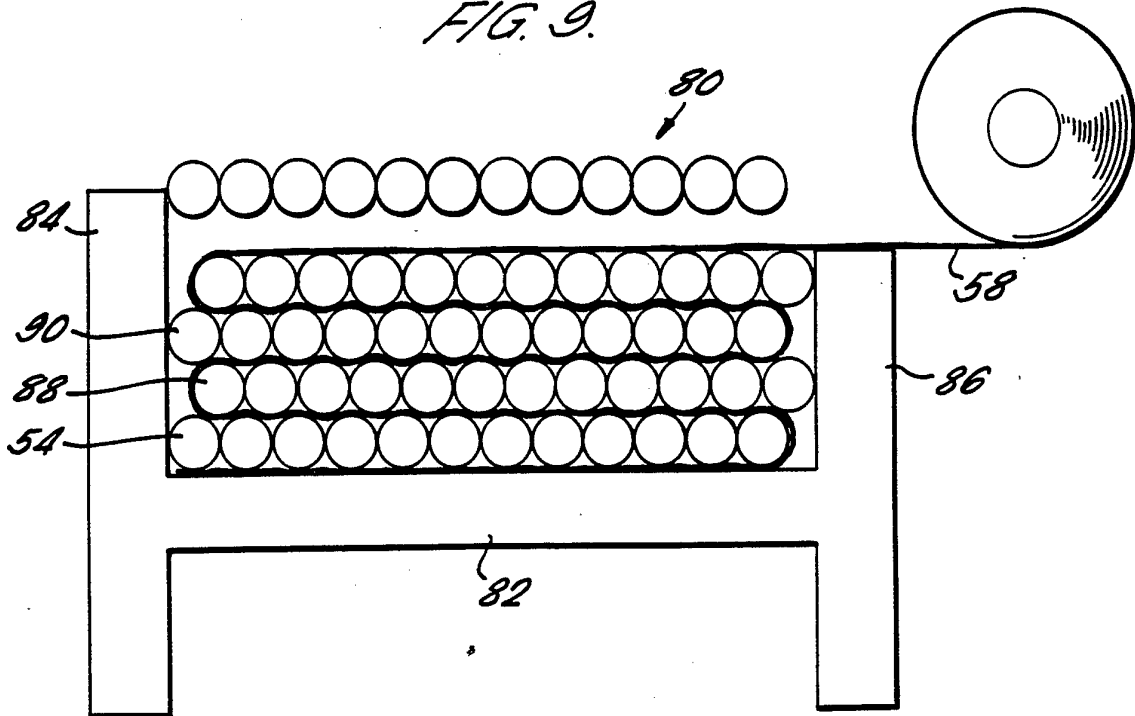


FIG. 9.



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FIG. 10.

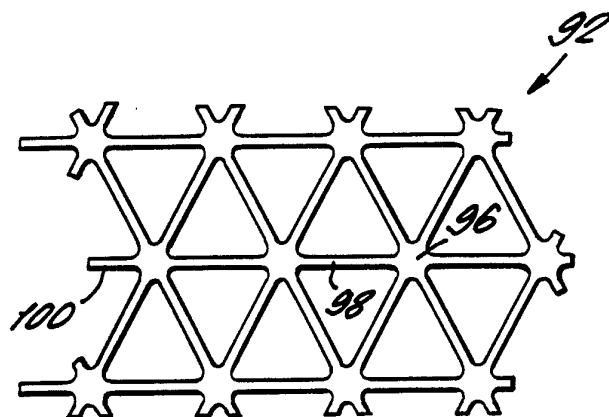
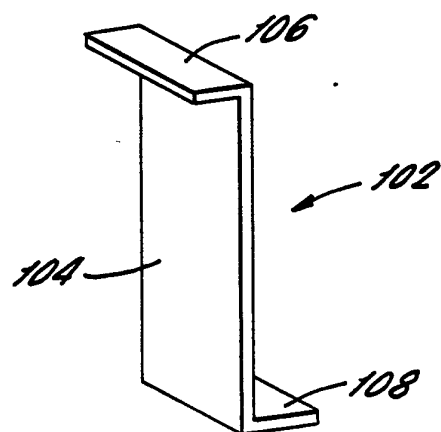
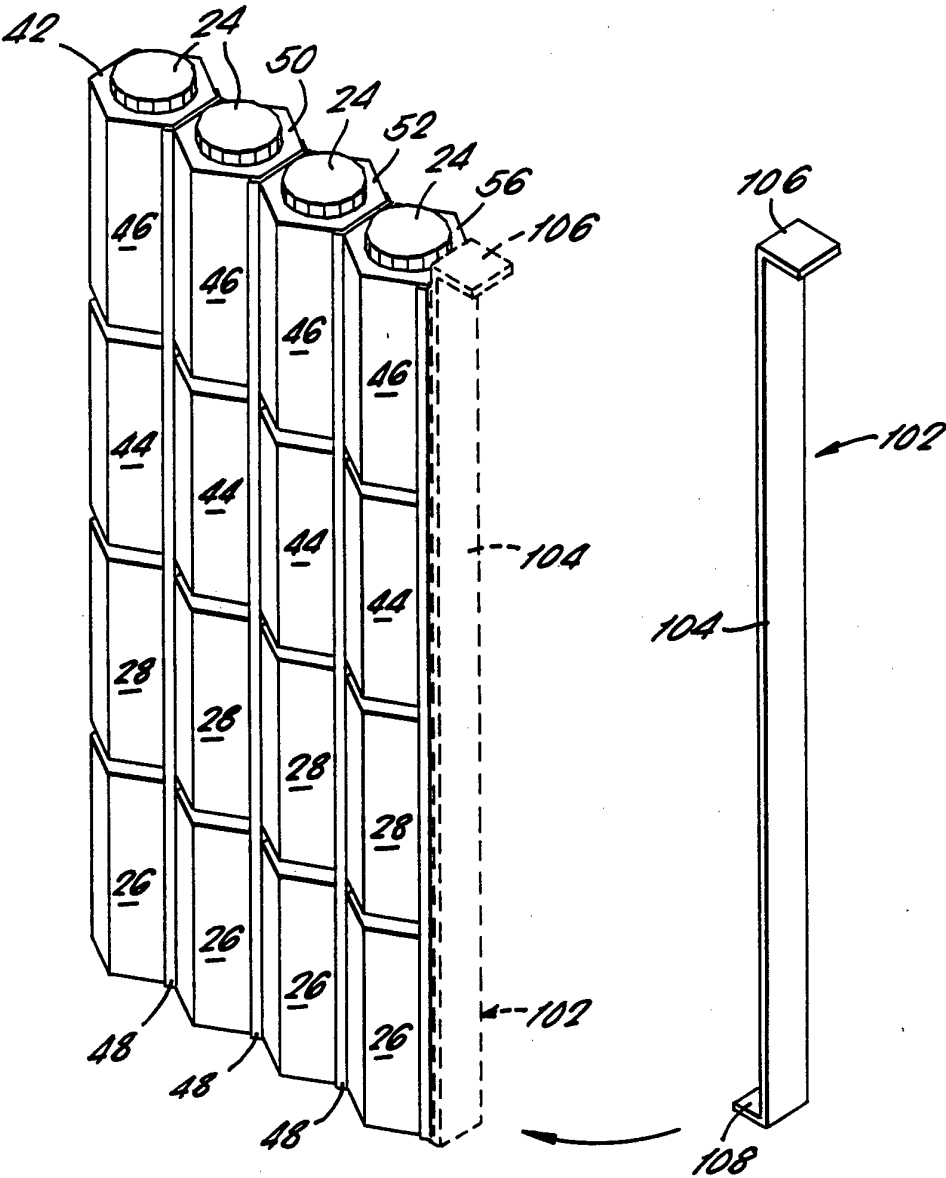


FIG. 11.



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FIG. 12.



INTERNATIONAL SEARCH REPORT

Inter. Application No
PCT/GB 93/02326

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 H01M2/10 H01M2/22

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)
IPC 5 H01M

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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

2 March 1994

Date of mailing of the international search report

09.03.94

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

De Vos, L

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 93/02326

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X	US,A,3 314 823 (RODOLFO RODRIGUEZ BALAGER) 18 April 1967 see column 1, line 35 - line 40 see column 3, line 17 - line 27 see claims 1-6 ---	1,3,21
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Y	EP,A,0 454 015 (ABB PATENT GMBH) 30 October 1991 ---	44-46
X	DE,C,545 616 (BATTERIEN- UND ELEMENTE-FABRIK SYSTEM ZEILER AKT.-GES.) 18 February 1932 *WHOLE DOCUMENT* ---	44
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A	US,A,2 329 856 (EDUARD SALATHÉ) 21 September 1943 *WHOLE DOCUMENT* ---	13,14,62

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Inter. Application No

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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DE-C-545616		NONE	
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US-A-3784411	08-01-74	NONE	