

[54] **METHOD OF MULTICELL BATTERY
PRODUCTION USING POCKETED
CONTINUOUS STRIP**

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[51] Int. Cl. **H01m 1/02**

[58] Field of Search..... 136/83 R, 111, 175

[56] **References Cited**

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[57]

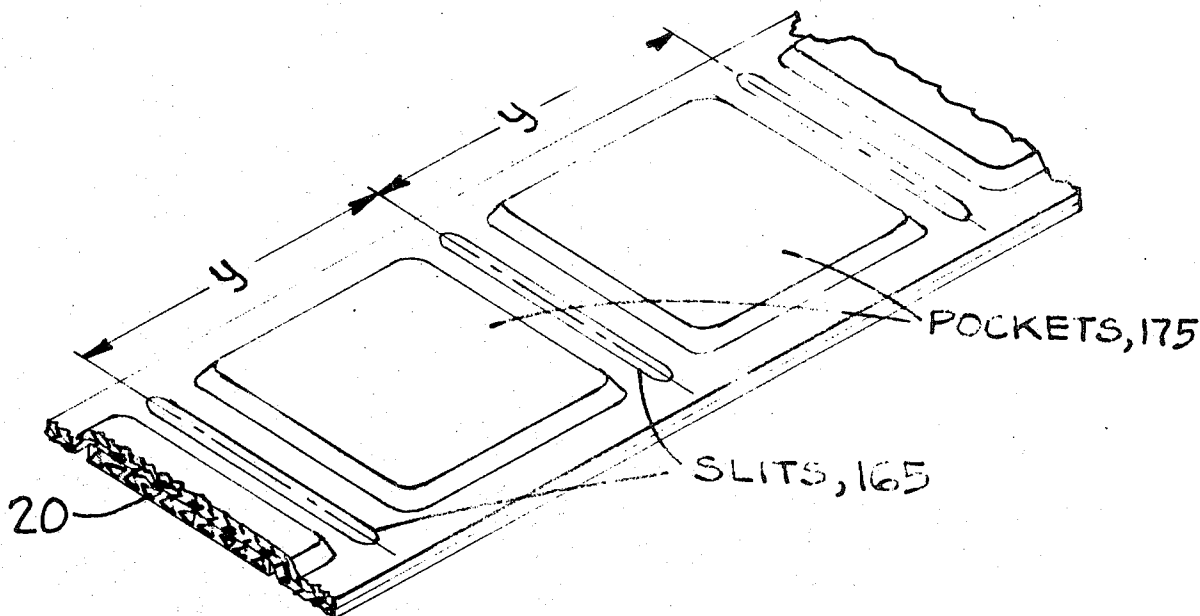
ABSTRACT

A method of constructing multicell batteries utilizes a continuous web comprising a plurality of structurally connected continuous Zones at least one of which comprises a continuous strip of metal. Deposits of electrodes are placed along the Zones of the continuous web after which the web is cut to structurally disconnect the continuous Zones from each other. Pockets are then indented in a Zone comprising a continuous strip of metal, the indenting being done in a manner which results in the pocketed Zone having the same relative longitudinal length after the indenting as it had before the indenting. Finally, the pocketed Zone is collated into an assembly of battery components which includes at least one other continuous Zone from the web.

The indenting may be preceded by the cutting of a slit partially across the Zone to be pocketed, in which case the width of the slits is increased but the center lines of the slits remain in fixed relative longitudinal position by the indenting action.

The method is applicable both to webs having metal and plastic laminations and to all metal webs.

8 Claims, 19 Drawing Figures



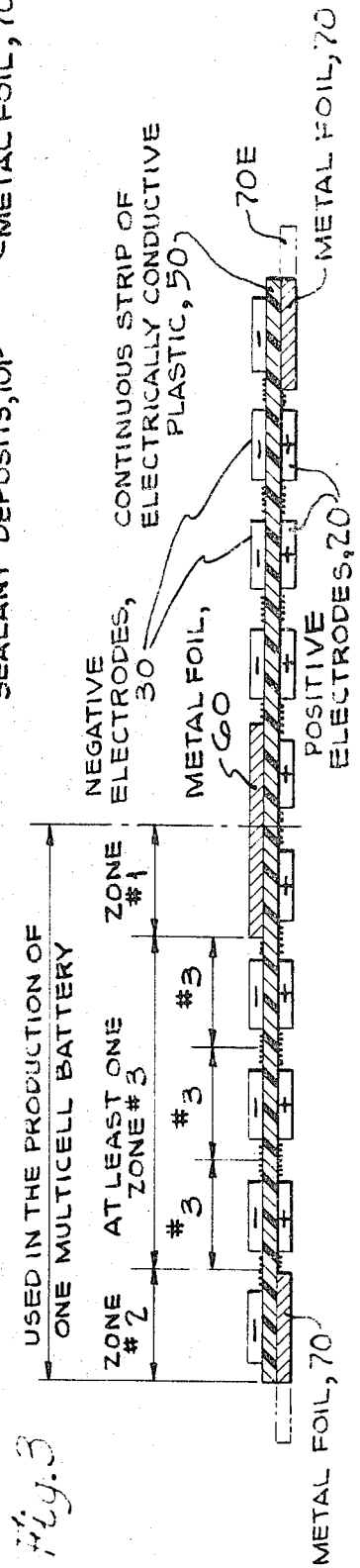
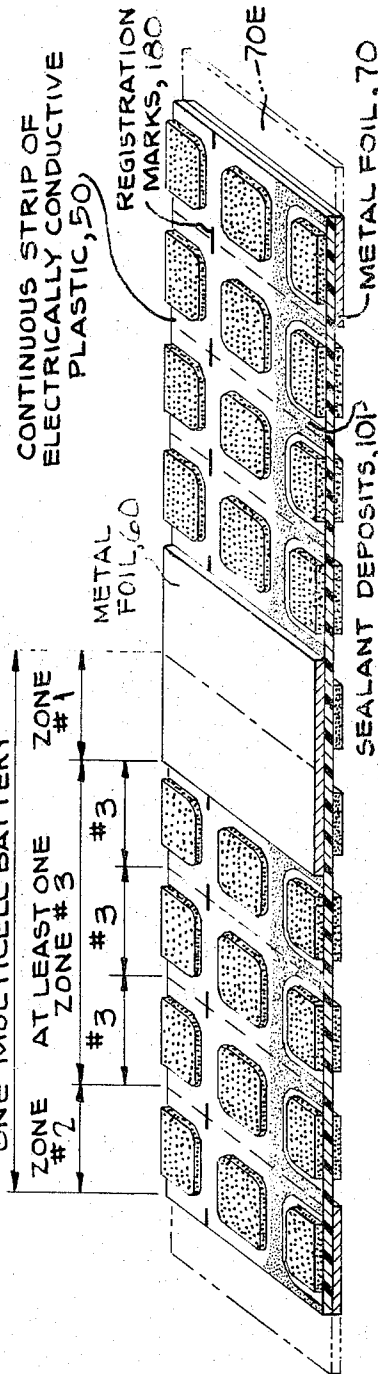
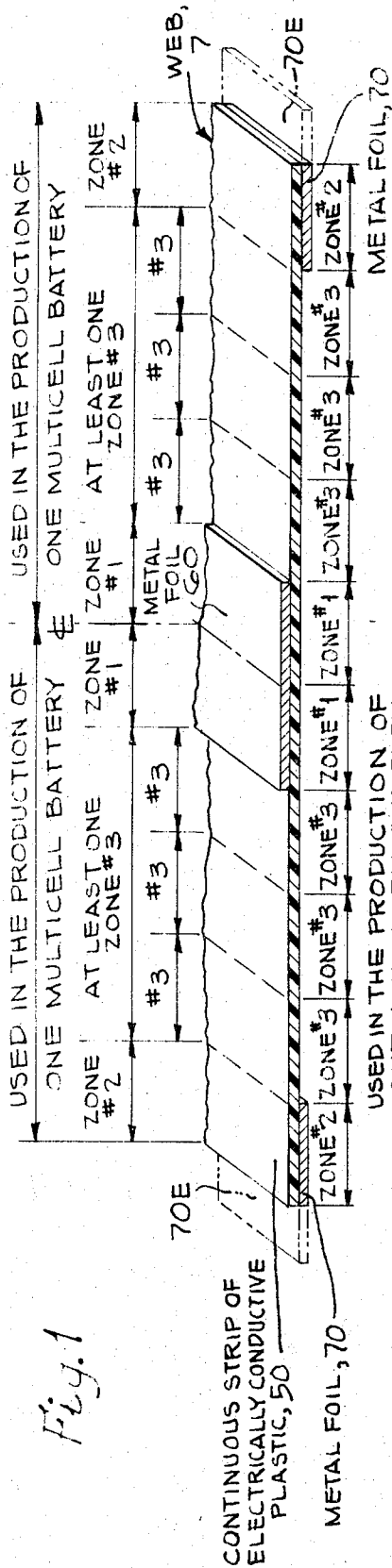


Fig.4

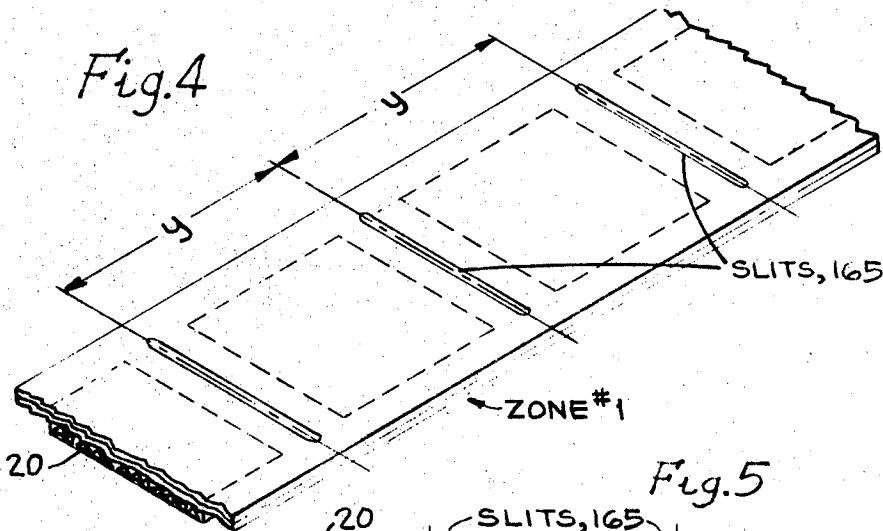


Fig.5

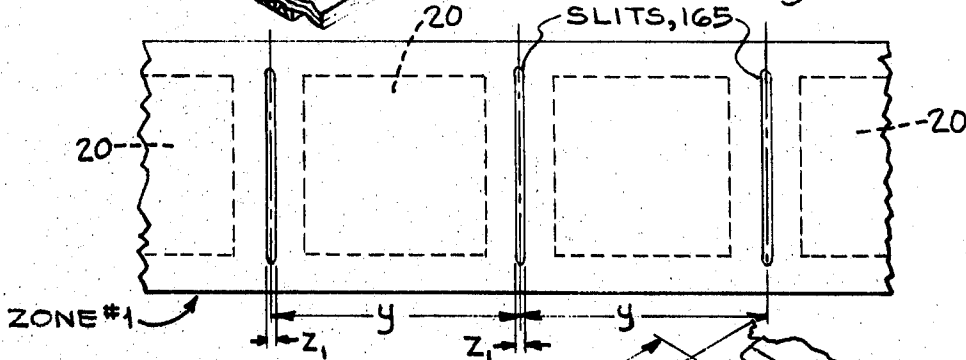


Fig.6

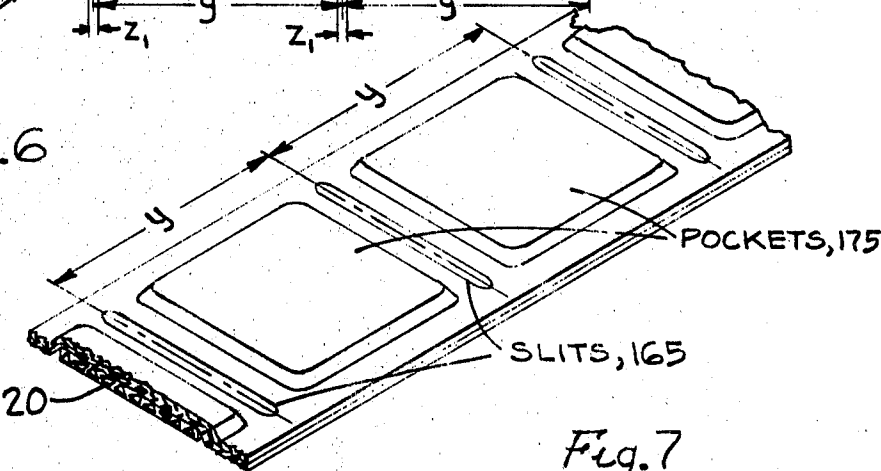
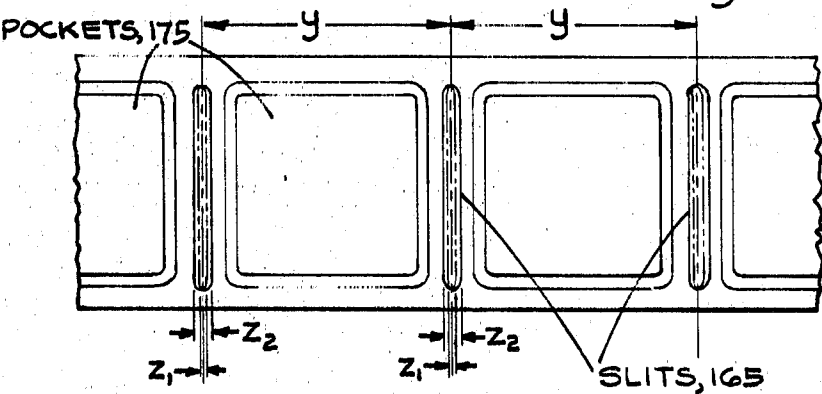


Fig.7



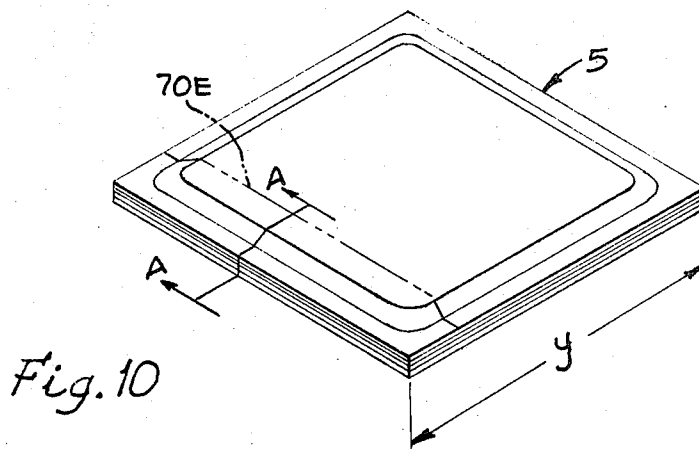
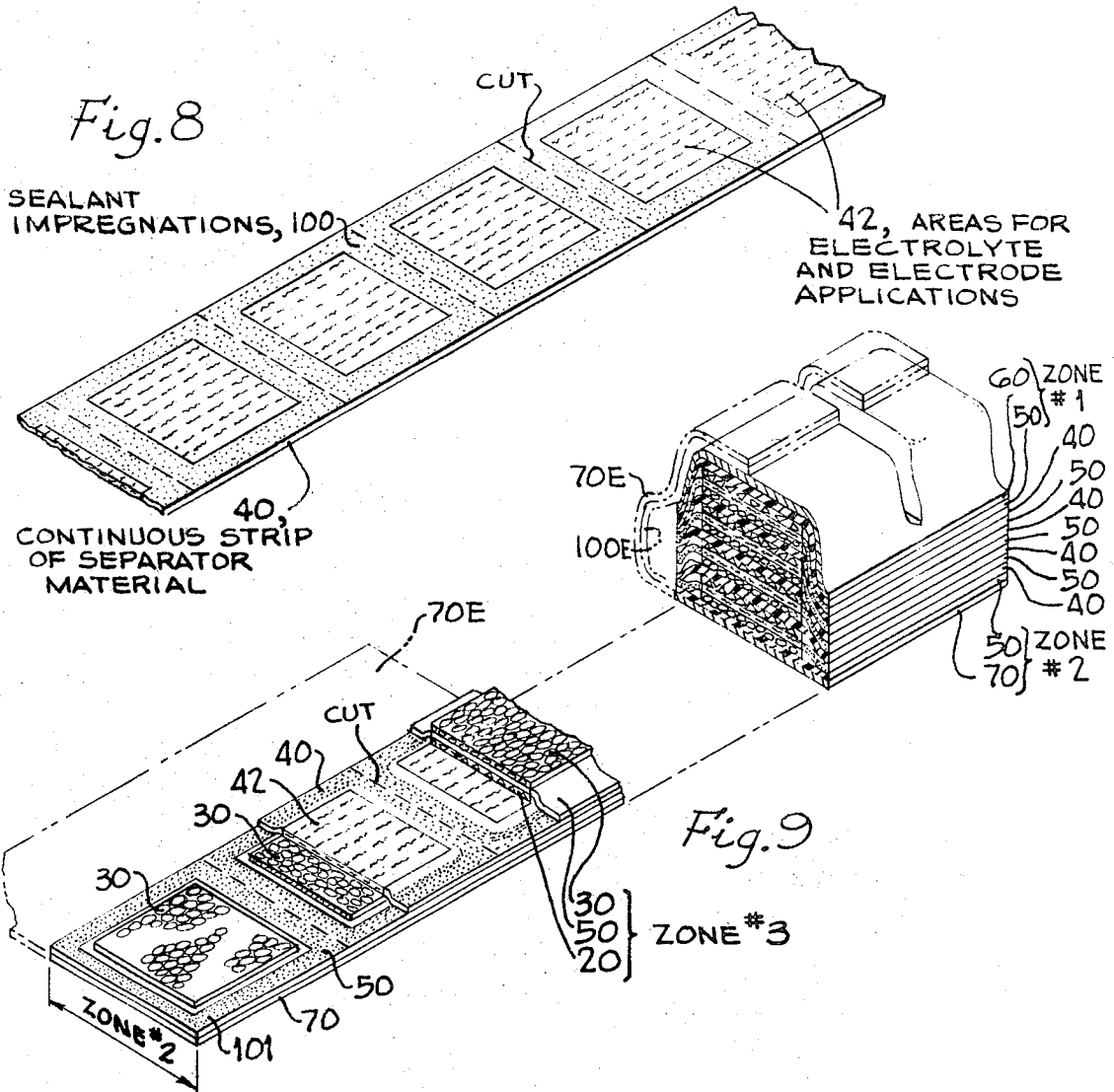


Fig. 11

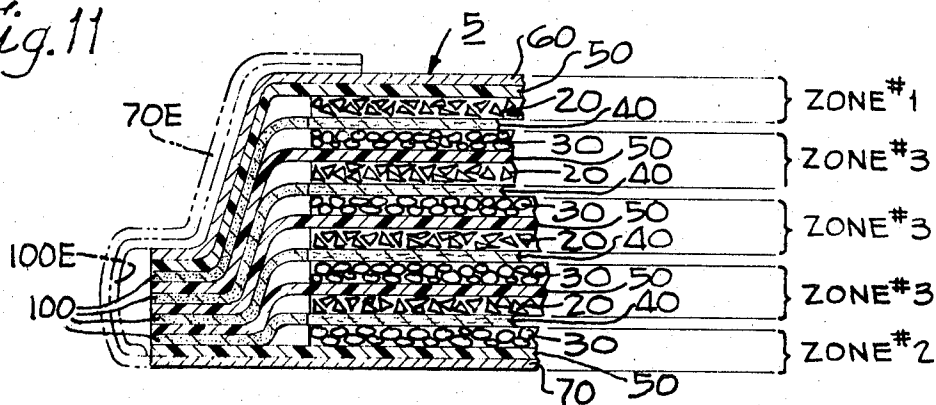


Fig. 14

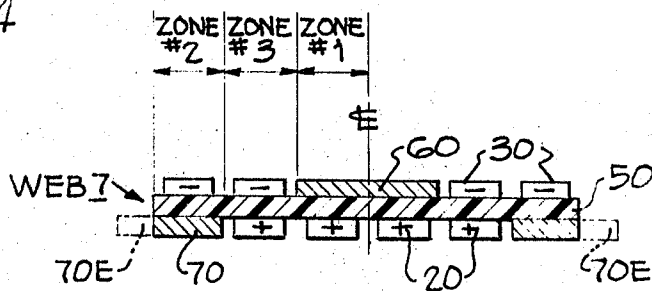


Fig. 15

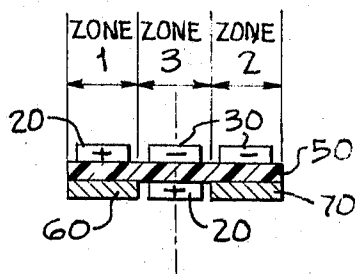


Fig. 12

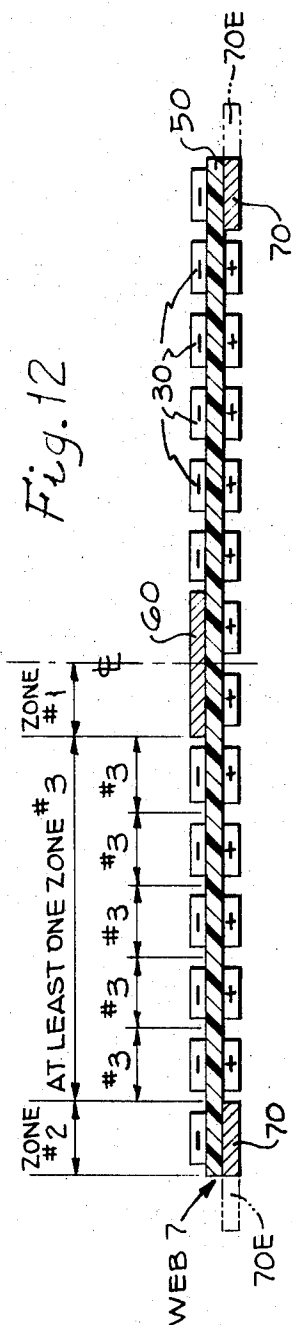


Fig. 13

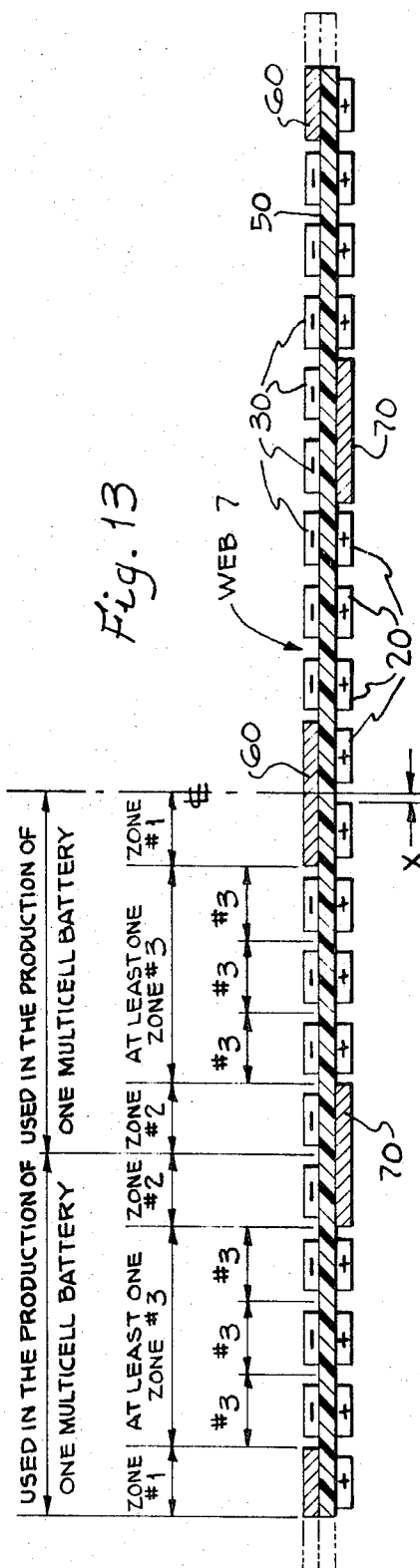


Fig. 16

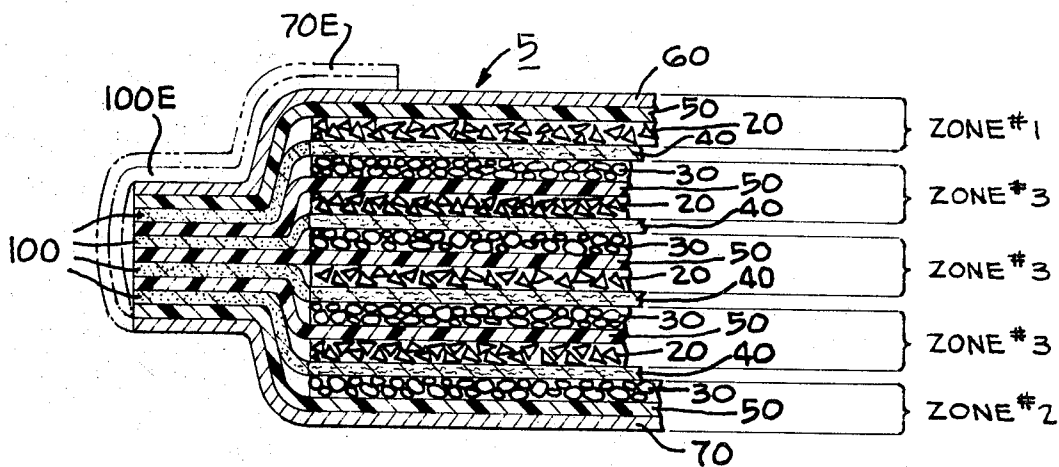
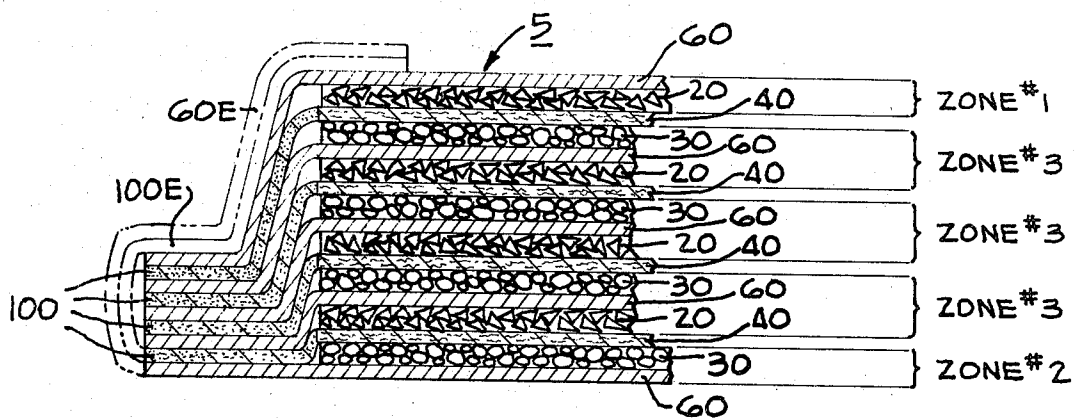
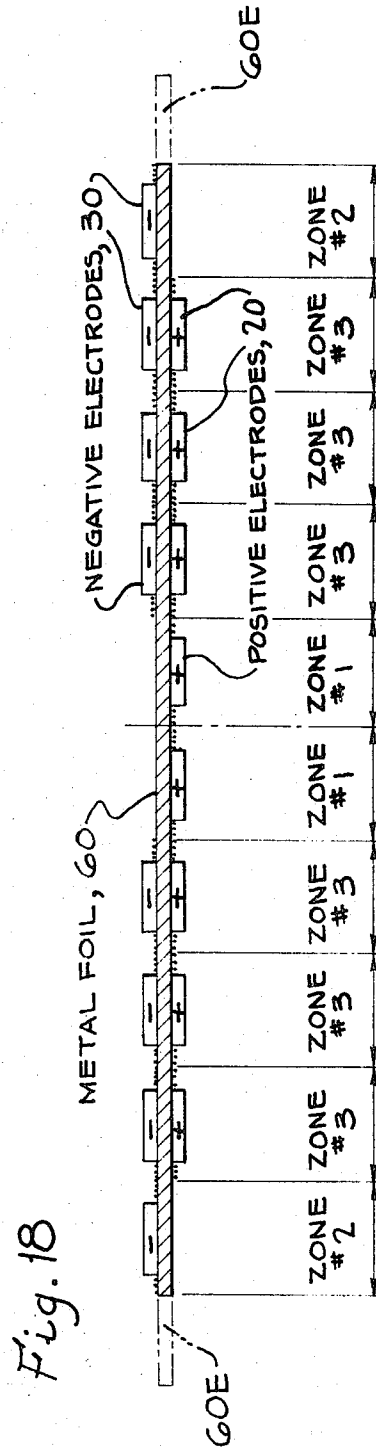
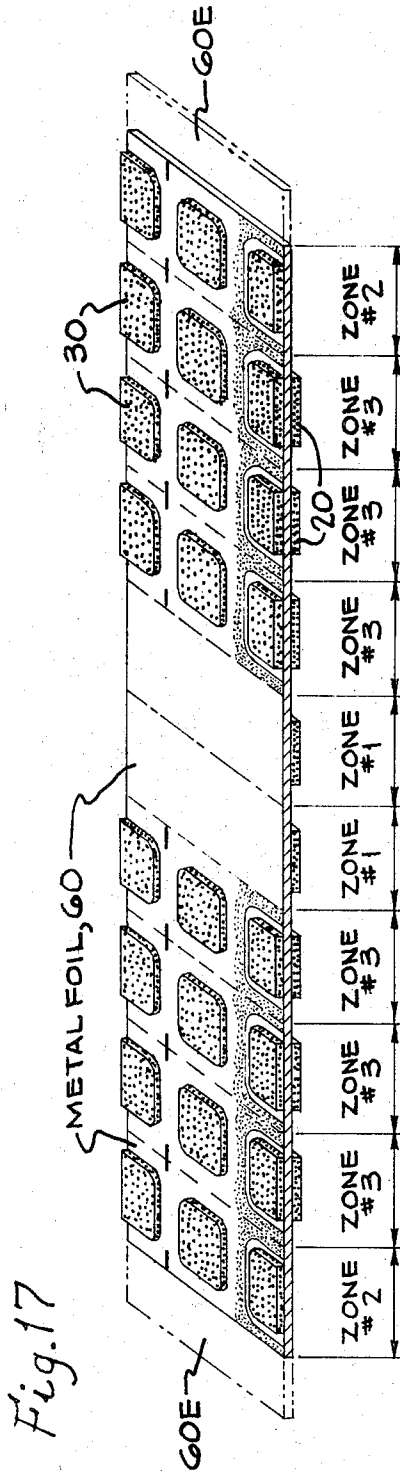


Fig. 19





METHOD OF MULTICELL BATTERY PRODUCTION USING POCKETED CONTINUOUS STRIP

BACKGROUND OF THE INVENTION

U.S. Pat. No. 3,708,349 describes a method of constructing multicell batteries utilizing a continuous web comprising a plurality of structurally connected continuous Zones No. 1, No. 2, and No. 3. At least one of the Zones of the web comprises a continuous strip of metal. Intermittent deposits of positive electrodes are placed along one side of each Zone No. 1; intermittent deposits of negative electrodes are placed along one side of each Zone No. 2; and intermittent deposits of positive and negative electrodes are placed along each Zone No. 3, each deposit of positive electrode being on the other side of a Zone No. 3 from and substantially opposite a deposit of negative electrode. After application of the electrodes the web is cut so that the continuous Zones are structurally disconnected from each other. The Zones are then collated into an assembly of battery components which includes other continuous Zones from the web. Seals are then made around the electrodes on the Zones.

In the collation and sealing together of the battery components one of the Zones may remain in a plane configuration. In other Zones, however, slight deflections must be made so that satisfactory seals may be made around the electrodes. This necessary deflection reaches its maximum in at least one of the outermost Zones in the collation.

In order to maintain proper registration among the continuous Zones during the collating and sealing steps it is necessary to maintain precisely the relative longitudinal position of the electrodes along each Zone with respect to the electrodes along the other Zone. Errors along continuous strips may be cumulative, and the accumulation of individually minor longitudinal errors in the collation will, if repeated successively, result in such misalignment that continued collation and sealing becomes impossible.

With some materials which may be used in batteries, e.g., plastics, fibrous materials, etc., and deflections required in these materials may be achieved by the forces of the production machinery used in the collation and sealing, and the related problem of maintaining proper registration of these materials with respect to other battery components may be resolved by the proper control of tension. These solutions to production problems become inapplicable, however, with battery components comprising continuous strips of metal foils. With such foils it may be necessary to produce any required deflections and to take any steps necessary to maintain proper longitudinal registration before the metal is included in the collation.

SUMMARY OF THE INVENTION

This invention concerns a method of constructing multicell batteries which utilizes a continuous web comprising a plurality of structurally connected continuous Zones at least one of which comprises a continuous strip of metal. The continuous web is cut so that the continuous Zones are continuous strips which are structurally unconnected from each other. Pockets representing the deflections required to permit collation and sealing are indented in a Zone comprising a continuous strip of metal, the indenting being done in a man-

ner which results in the pocketed Zone having the same relative longitudinal length after the indenting as it had before the indenting to assure proper longitudinal registration of the pocketed Zone with respect to other battery components. The pocketed Zone is then collated into an assembly of battery components which includes at least one other Zone cut from the web.

Preferably intermittent deposits of electrodes are applied along the continuous web before the web is cut to structurally disconnect the Zones. The web is defined as comprising at least one Zone No. 1, at least one Zone No. 2, and at least one Zone No. 3 and the electrodes are applied as follows: intermittent deposits of positive electrodes are placed along one side of each Zone No. 1; intermittent deposits of negative electrodes are placed along one side of each Zone No. 2; and intermittent deposits of positive and negative electrodes are placed along each Zone No. 3, each deposit of positive electrode being on the other side of a Zone No. 3 and substantially opposite a deposit of negative electrode. After the web is cut, pockets are indented around the electrodes in those Zones comprising metal foils which require deflections in the collation.

The indenting action may be preceded by the cutting of a slit partially across the Zone to be pocketed, in which case the width of the slits is increased but the center lines of the slits remain in fixed relative longitudinal position by the indenting action.

The method is applicable both to webs having laminates of plastic and metal and to all metal webs. In webs comprising laminates of plastic and metal, the electrodes are preferably placed in contact with the plastic rather than the metal. When the electrodes are placed on a metal surface of the web, the surfaces of the metal must be selected from metals which are electrochemically nonreactive with respect to the electrodes and electrolyte of the battery.

BRIEF DESCRIPTION OF THE DRAWINGS

As a prelude to a description of the drawings it should be remarked that the thicknesses of the members shown in the drawings have been greatly exaggerated for purposes of illustration. Thicknesses which are typical of those which might actually be used will be given together with other representative dimensions later in this account of the invention.

FIG. 1 illustrates a web containing Zones No. 1, No. 2 and No. 3 in which Zones No. 1 and No. 2 comprise laminates of electrically conductive plastic and metal foils. The web, which is symmetrical about its center line, contains enough Zones No. 1, No. 2 and No. 3 to permit the production of two four-cell batteries.

FIG. 2 illustrates the web of FIG. 1 after the deposits of electrodes have been applied.

FIG. 3 illustrates an end or cross-sectional view of the web shown in FIG. 2.

FIG. 4 shows Zone No. 1 after the web has been cut to structurally disconnect the Zones from one another, after slits have been cut into the Zone No. 1 and before pockets have been indented into Zone No. 1.

FIG. 5 is a plan view of Zone No. 1 at the stage depicted in FIG. 4.

FIG. 6 shows Zone No. 1 after pockets have been indented into Zone No. 1.

FIG. 7 is a plan view of Zone No. 1 at the stage depicted in FIG. 6.

FIG. 8 illustrates a continuous strip of separator material. Patches of adhesive are impregnated into the strip, each patch being in the form of a closed loop. Electrolyte is impregnated into the area of the separator strip inside each loop.

FIG. 9 illustrates the pocketed Zone No. 1 being assembled into multicell batteries.

FIG. 10 illustrates one of the multicell batteries made as shown in FIG. 9 after that battery has been cut from the continuous Zones.

FIG. 11 illustrates a cross-section of the multicell battery shown in FIG. 10.

FIGS. 12, 13, 14 and 15 illustrate alternatives to the web configuration shown in FIG. 3.

FIG. 16, which represents an alternative to the construction shown in FIG. 11, illustrates a battery in which both outer Zones of the battery comprise metal foils in which pockets have been indented.

FIG. 17 shows a web of all metal analogous to the web of metal and plastic laminate shown in FIG. 2.

FIG. 18 illustrates an end or cross-sectional view of the web shown in FIG. 17.

FIG. 19, which is analogous to FIG. 11, illustrates a cross-section of the multicell battery made from the web shown in FIG. 17.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It should be remarked that the thicknesses of the members shown in the drawings have been greatly exaggerated for purposes of illustration. Thicknesses which are typical of those which might actually be used will be given together with other representative dimensions later in the description of this invention.

For simplicity the description of the invention will be divided into four sections. Section 1 will describe the method of making batteries using a web comprising composite continuous strips of plastic and metal foil which is the subject of U.S. Pat. No. 3,708,349. Section 2 will concern the relationship of this invention to the process described in Section 1. Section 3 will describe the application of this invention to an all metal web. Section 4 will be directed to the materials which may be used with the processes described in the other sections.

SECTION 1: WEB COMPRISING LAMINATION OF METAL AND PLASTIC

This section will describe how the present invention may be used with the web comprising a lamination of metal and plastic which is the subject of U.S. Pat. No. 3,708,349.

FIG. 1 illustrates a web 7 which contains enough Zones No. 1, No. 2 and No. 3 to permit the production of two four-cell batteries. The web comprises one continuous strip of electrically conductive plastic 50 and three other continuous strips of metal foil joined thereto, one of these three strips being a metal 60 which is situated in the center of the plastic 50 and the other two strips also being metals 70 which are joined to the side of the plastic opposite metal 60 and which are situated near the edges of the plastic. While the edges of the metal foils 60 and 70 could extend to the edges of their respective Zones, it is preferable to recess them slightly, e.g., 1/16 inch from each edge of the Zone to facilitate cutting or slitting the web apart. While FIG. 1 uses dashed and center lines to demarcate

the boundaries of Zones No. 1, No. 2 and No. 3, it should be understood that those lines are used in the drawings for purposes of illustration only and no such lines are required on an actual web. It will be seen that Zone No. 1 is defined as a composite of a strip of plastic 50 and a metal foil 60, Zone No. 2 is defined as a composite of a strip of plastic 50 and a metal foil 70, and that Zone No. 3 is defined as a continuous strip of plastic 50. In the web 7 shown in FIG. 1, the plastic 50 components of Zones No. 1, No. 2 and No. 3 are all undivided portions of one wide sheet of plastic.

The construction of multicell batteries begins by placing intermittent deposits of positive electrodes 20 along the plastic side of Zone No. 1, by placing intermittent deposits of negative electrodes 30 along the plastic side of Zone No. 2, and by placing intermittent deposits of positive and negative electrodes 20 and 30 respectively along each Zone No. 3 so that each deposit of positive electrode 20 is on the other side of the Zone No. 3 from and substantially opposite a deposit of negative electrode 30. Illustrations of the web 7 after the electrodes have been so deposited are shown in FIGS. 2 and 3. It will be noted that in all cases the electrodes are narrower than and are centered within the Zones onto which they were applied, thus leaving perimeters on the Zones around the electrodes which will be used in the subsequent sealing step.

After the electrodes have been applied the continuous web 7 is cut so that the Zones No. 1, No. 2 and No. 3 are continuous strips which are structurally unconnected from each other. The continuous Zones No. 1, No. 2 and No. 3 are then collated so that at least one Zone No. 3 is between a Zone No. 1 and a Zone No. 2, so that the positive electrodes along Zone No. 1 and the negative electrodes along Zone No. 2 are facing the inside of the collation, and so that a deposit of positive electrode on one Zone is opposite a deposit of negative electrode on an adjacent Zone. A separator and electrolyte would be placed between each adjacent pair of electrodes in the collation and then the Zones would be sealed together around and between the electrode deposits.

An illustration of a separator strip 40 which might be used is shown in FIG. 8. The continuous strip separator material 40 has patches of electrically nonconductive adhesive 100 impregnated therein, with each patch being in the form of a closed loop inside of which is an area 42 of separator material which contains electrolyte. By impregnating the adhesive patches into the separator material first and then adding the electrolyte to the resultant enclosed areas 42, the electrolyte can be confined within those areas and prevented from migrating along the separator strip 40 while at the same time a better, more thorough adhesive impregnation can be obtained in the separator which results in a superior seal in the assembled battery. Such a concept is further described and claimed in U.S. Pat. No. 3,701,690. As one alternative to the technique just described, adhesive patches could be impregnated into the continuous strip of separator material 40 after the electrolyte has been added to the separator. Another step which could be used instead of but which is preferably used in conjunction with the adhesive impregnations in the separator is to apply patches of adhesive 101 around the electrodes on Zones No. 1, No. 2 and No. 3 as shown in FIGS. 2, 3 and 5. By themselves these patches 101 would penetrate the separator strips and produce the

desired seals when the collation of Zones and separator strips was pressed together; a sealing technique of this latter nature used in the production of single cell batteries is illustrated in U.S. Pat. No. 3,494,796. It is preferred, however, to use the patches 101 in combination with the adhesive patches in the separator strip; it has been found that this combination produces a better seal than the other alternatives discussed above which utilize a separator strip.

FIG. 2 also shows a series of dashes 180 being placed across the web between the electrodes. These dashes, which are purely optional, may serve as registration devices used in the production machinery. Such registration marks should be applied to the web before the web is cut.

The collation of Zones No. 1, No. 2 and No. 3 and of the preferred separator strip after the web 7 has been cut to structurally disconnect the Zones is illustrated in FIG. 9. As shown in FIG. 9, the electrolyte impregnated areas 42 inside the patches of adhesive 100 in the separator strip 40 are positioned so that the impregnated areas are between and overlay a positive electrode on one Zone and a negative electrode on an adjacent Zone. The adhesive patches 100 register or mate with the corresponding adhesive patches 101 on the perimeters of the Zones surrounding the electrodes. After the desired number of Zones No. 3 and separator strips 40 have been collated between Zones No. 1 and No. 2 the sealing step is performed. Depending upon the particular sealant 100 which is used, the sealing may be achieved by the application of heat and/or pressure, although other satisfactory sealing techniques may also be used. The resultant multicell batteries may, if desired, be left structurally connected together after the sealing so as to form a chain of multicell batteries which are electrically connected in parallel. Alternatively the collated, sealed continuous strips may be cut so that the resultant multicell batteries are structurally and electrically disconnected from each other; such a discrete battery 5, illustrated in FIG. 10, may be obtained by cutting along the collated sealed continuous strips at the dashed, imaginary "cut" lines shown on the separator strip 40 in FIGS. 8 and 9 with an electrically nonconductive cutting instrument such as a sapphire or ceramic knife, by laser beams or by other suitable techniques. The cutting must be done in a manner so as to avoid producing undesired internal electrical paths within the battery, e.g., so as to prevent the electricity conductive plastic 50 from one Zone from coming into contact with the plastic 50 of another Zone. A portion of the assembled battery is shown in magnified cross-section in FIG. 11.

If desired the web 7 can be constructed so that the finished, assembled battery has one of its terminals wrapped around its edge which overlays the terminal on the opposite side. For some applications of the batteries it may be desirable to have both terminals on the same side of the battery. Many different modifications can be made in the web to achieve this same net result. One such modification is represented by dashed lines and the designation 70E which appear in FIGS. 1, 2 and 3. This optional extension 70E of the metal foil 70 projects beyond the edge of the plastic component of Zone No. 2, is wrapped around the edge of the collation and overlays the metal 60 of Zone No. 1. An electrical insulator must be interposed between the extension 70E and the composite Zone over which it is overlaid; while

a nonconductive adhesive 100E of the same material as adhesive 100 is shown in the drawings for purposes of illustration, other nonconductive securing materials including a variety of hot melts used in the dry battery industry may be used to also secure the extension to the underneath Zone, and other nonsecuring nonconductors such as papers, felts, or films may be interposed between the extension and the Zone. The resultant product having the "wrapped around" terminal is further described, illustrated, and claimed in U.S. Pat. No. 3,734,780. The particular construction shown in FIGS. 1, 2 and 3 utilizes the relatively good longitudinal conductivity of the metal as compared with the conductive plastic to minimize the power losses in conducting current around the edge of the battery. A battery with the "wrapped around" terminal adhered to the negative rather than the positive end of the battery can be obtained with the web 7 of FIGS. 1 and 2 (including metal extensions 70E) by transposing the positive and negative electrodes and therefore in effect transposing Zones No. 1 and No. 2 from the positions shown in FIGS. 1 and 2; such transposition results in the metallic strip of Zone No. 1 being wider than and extending beyond the edge of the plastic strip of Zone No. 1 and being adhered to the metal of Zone No. 2. Another modification of the web which results in the "wrapped around" electrode is the extension of the plastic-metal laminates at the edges of the web, rather than the extension of just the metal 70E as shown in FIGS. 1 and 2. Other modifications of the web which permit the construction of "wrapped around" terminals will be given below in the accounts of alternative web configurations or designs.

While the web 7 which is used with this invention must have at least one Zone No. 1, at least one Zone No. 2, and at least one Zone No. 3, there are numerous web configurations which meet these requirements and which can be used with this invention. FIGS. 12 through 15 illustrate a few of these many different web configurations.

The web 7 shown in FIG. 12 differs from those shown in FIGS. 1, 2 and 3 by having five Zones No. 3 on each side of the center line. Each half of this web contains enough Zones to permit the construction of a six cell battery according to the invention.

The web 7 shown in FIG. 13, which is likewise symmetrical about its center line, contains enough Zones to permit the construction of four four-cell batteries. An optional modification of the web 7, which could be made if a "wrapped around" terminal of metal-conductive plastic composite is desired in the finished batteries, is also illustrated. As part of this optional modification the plastic 50 and metal 60 could be extended at both edges of the web, as shown by dashed extensions 50E and 60E, respectively. An additional aspect of the modification is illustrated near the center of the web by the letter "x", which represents the distance from the edge of the positive electrode 20 to the web centerline or the edge of Zone No. 1; this distance "x" could be increased to include a segment of plastic 50 metal 60 laminate equal in width to 50E and 60E.

FIG. 14 illustrates a web 7 which is symmetrical about its center line. On each side of the center line is one Zone No. 1, one Zone No. 2, and one Zone No. 3; each half of this web contains enough Zones to permit the construction of a two cell battery. The web contains six Zones but only a single strip of electrically conduc-

tive plastic 50. As is true with the web shown in FIG. 1, the web of FIG. 14 has a metal strip 60 which is cut down the middle when the web is cut into unconnected Zones. The optional extensions 70E of metal strips 70 are also shown by dashed lines in FIGS. 14.

A very simple configuration of the web 7 having the essential requirements is shown in FIG. 15. That web has one Zone No. 1, one Zone No. 2 and one Zone No. 3, is symmetrical about its center line, and contains enough Zones to permit the construction of one two-cell battery. The web could, of course, be modified if desired to permit the resultant battery to have a "wrapped around" terminal of either metal or metal-conductive plastic composite.

It was mentioned as a prelude to the description of the drawings that the thicknesses of the battery components shown in the drawings have been greatly exaggerated for purposes of clear illustration. This invention may be used and is particularly useful in the construction of very thin, flat multicell batteries. The dimensions associated with the web, electrodes and separator illustrated in FIGS. 1 through 3, taken from an actual production line design, will serve to illustrate. Referring to FIGS. 1 through 3, the continuous strip of electrically conductive plastic 50 was a total of $27\frac{1}{2}$ inches wide and 2 mils (thousandth of an inch) thick; of this total width, each of the two Zones No. 1 was $2\frac{3}{4}$ inches wide, each of the two Zones No. 2 was $2\frac{3}{4}$ inches wide, and each of the six Zones No. 3 was $2\frac{3}{4}$ inches wide. The metal strip 60 shown in the center of the web was steel and was $5\frac{5}{8}$ inches wide. The metal strips 70 at the two outer edges of the web were also steel and were each $3\frac{3}{4}$ inches wide, of which $2\frac{11}{16}$ inches width was joined to the conductive plastic of Zones No. 2 while the remaining $1\frac{1}{16}$ inches of metal extended outward as extension 70E to provide for a "wrapped around" terminal. Each of the metal strips 60 and 70 was $1\frac{1}{2}$ mils thick. The electrode deposits 20 and 30, which were centered in each of the Zones, were approximately $2\frac{1}{16}$ inches wide. The electrode deposits, which might be as much as 20 to 25 mils or more but would typically be 10 mils or less in thickness, were approximately $2\frac{15}{16}$ inches long (along the length of the Zone) and a space of about $\frac{5}{8}$ inches clear space was provided between the nearest edges of consecutive electrodes. After the electrodes were applied to the web the web was cut by steel slitting wheels to disconnect the Zones from one another. The separator strips 40, which were made from nonwoven polyester fabric, were $3\frac{1}{2}$ mils thick and had areas 42 which were centered about and approximately the same horizontal dimensions as the electrodes.

As is shown in FIG. 11, each plastic, metal and separator member of the assembled battery must be slightly longer and must be deflected slightly more than the other plastic, metal, and separator members beneath it. This slight increase in length of the separators 40 and the plastic members 50 of Zones No. 3 may be achieved by providing enough tension in those members to stretch them by the required amounts. The deflections required in these materials to attain the contour shown in FIG. 11 may be achieved by the forces of the production machinery used in the collation and sealing. The plastic-metal laminate of Zone No. 1, which must be increased in length the greatest amount as shown in FIG. 11, may be indented or pocketed into

the desired shape prior to the collating and sealing steps.

An alternative to the cross-section shown in FIG. 11 appears in FIG. 16. In the alternative illustrated in FIG. 16 the middle Zone of the collation, a Zone No. 3, is not deflected at all while the remaining Zones on each side of the middle Zone are deflected. With this construction there would be a need to pocket both Zone No. 1 and 2 before assembling them into the collation, since both of those Zones contain continuous strips of metal.

The method by which these pockets may be produced, which method is the subject of this application, will be described in the following section.

SECTION 2: THE POCKETING METHOD

In order to maintain proper registration among the continuous Zones during the collating and sealing steps it is necessary to maintain precisely the relative longitudinal position of the electrodes along each Zone with respect to the electrodes along each other Zone. Stated another way, the indenting must be done in a manner which results in the pocketed Zone having the same relative longitudinal length after the indenting as it had before the indenting. Errors along continuous strips may be cumulative, and the accumulation of individually minor longitudinal errors in the collation will, if repeated successively, result in such misalignment that continued collation and sealing becomes impossible.

The problem, therefore, is to provide the necessary deflection in a Zone comprising a continuous strip of metal while at the same time maintaining the relative longitudinal length of the Zone containing the continuous metal strip.

The problem is solved by this invention in a manner which is best illustrated in FIGS. 4 through 11. After the electrodes have been placed onto the web and the web has then been cut into structurally unconnected Zones, Zone No. 1 which contains the continuous strip of metal is indented in a manner which maintains the relative longitudinal length of that Zone. To accomplish this result it may be desirable to cut a slit partially across the Zone and between each consecutive pair of electrodes along that Zone. Zone No. 1 with such slits 165 therein is shown in FIGS. 4 and 5. As shown in FIG. 5, the slits 165 have a width Z_1 before the pockets are indented, with representative dimensions of Z_1 being from about 0.060 inches to about 0.062 inches. The slits 165 may be produced by a composite die which cuts slits by a punch and die arrangement and pockets between the slits in the same stroke with an undersize punch in a die. The longitudinal dimension along Zone No. 1 between the pair of predetermined positions represented by the center lines of the slits is designated by "y", with a representative magnitude of "y" being approximately 3.56 inches (the sum of $2\frac{15}{16}$ and $\frac{5}{8}$ inches, as given in the preceding section). It should be pointed out that as used herein, the word "slit" has the general meaning given to that term by Webster's dictionary, i.e., a long incision or a long, very narrow opening; the term "slit" is not meant to imply any limitation on the process or method of making the long incisions, and different techniques sometimes referred to in certain industries as "slitting", "piercing", "punching", and others may all be used to produce the long, very narrow openings.

Referring now to FIGS. 6 and 7, which show Zone No. 1 after the pockets 175 have been indented, as well as to FIGS. 9, 10, and 11, it will be evident that the total length along Zone No. 1 as measured by following the pocketed contour down the middle of that Zone is in excess of dimension "y" but that the longitudinal distance along Zone No. 1 (disregarding the pocketed contour) between the center lines of consecutive slits has been maintained at dimension "y". This is accomplished by obtaining the stretching which results from the pocketing in the region of Zone No. 1 between the edge of the electrode and center line of the slit. As a result of this stretching the width of the slits 165 is increased from dimension Z_1 to dimension Z_2 , as shown in FIG. 7, with the increase in width typically being from about 0.002 inches to about 0.007 inches with pocket depths ranging from about 0.030 inches to about 0.045 inches, respectively.

The pocketing can be performed without first slitting Zone No. 1 if the Zone can be stretched sufficiently while simultaneously maintaining the distance "y" constant. Unfortunately some of the mechanisms used to produce pocketing do not consistently grip the metal strips in such a manner as to accomplish this result; instead there is a slight slippage of the Zone within the mechanism during the indenting action which results in the distance "y" being reduced rather than being held constant. Where this problem is encountered the slits 165 are useful, for they permit the slippage of the Zone within the indenting mechanism to be offset by a stretching or elongation of the Zone outside the indenting action, with the net result that the desired pocket is achieved while the dimension "y" is held constant.

One other observation should be made to complete the discussion of the pocketing. The indenting mechanism used to produce the pockets must be stationary with respect to the Zone containing the continuous metal strip when the pocketing is occurring. One way in which this result can be obtained is through the use of indenting mechanisms which do not travel longitudinally in the direction of the Zone's travel; in that case a segment of the Zone is brought to a standstill just long enough to undergo pocketing, with take-up loops before and after the pocketing station letting out and taking up, respectively, the continuous Zone as needed for the other production steps. An alternative way to achieve the pocketing is with the use of a rotating, endless belt moving at such a speed that each pocketing mechanism is in a fixed longitudinal position with respect to a segment of the Zone while that segment is being pocketed.

SECTION 3: THE ALL METAL WEB

Sections 1 and 2 described how the present invention may be used with webs comprising a combination of plastic and metal. This Section will describe the relevance of the invention to an all metal web. FIGS. 17, 18, and 19 will be referred to in this Section.

FIG. 17 shows an all metal web which is analogous to the one shown in FIG. 2. Its cross-section, shown in FIG. 18, is analogous to the cross-section shown in FIG. 3. A single metal foil 60 is used, and extensions 60E may be provided if the "wrapped around" terminal is desired in the finished battery.

The cross-section of the finished battery made from the web illustrated in FIGS. 17 and 18 is shown in FIG. 19. Note that FIG. 19 is analogous to FIG. 11. Note,

however, that in FIG. 19 each of the Zones contains a portion of the continuous strips of metal and that only one of these Zones, Zone No. 2, does not require pocketing. Note also that the remaining Zones, Zones No. 3 and Zone No. 1, all require pocketing and each by a unique amount.

Starting with the web shown in FIGS. 17 and 18, the Zones could be assembled into a battery having a cross-section analogous to that shown in FIG. 16. In that case one of the Zones No. 3 would require no pocketing, while the remaining Zones — Zone No. 1, Zone No. 2 and two Zones No. 3 — would require pocketing, the amount of the deflection pocketed into Zone No. 1 being equal to that pocketed into Zone No. 2 and the amounts pocketed into the two Zones No. 3 being equal to each other.

The drawings and the accounts given above in Sections 1 and 2 in this Section thus illustrate the principle that the initial continuous web comprises a plurality of structurally connected continuous Zones; that at least one of these Zones comprises a continuous strip of metal; that the continuous web is cut so that the continuous Zones are structurally unconnected from each other; that pockets are indented in at least one Zone comprising a continuous strip of metal, with the indenting being done in a manner which results in the pocketed Zone having the same relative longitudinal length after the indenting as it had before the indenting; and that the pocketed Zone is collated into an assembly of battery components which assembly includes at least one other Zone cut from the web.

SECTION 4: THE MATERIALS

The process of this invention may utilize a wide variety of materials.

The electrically conductive plastic used in the continuous carrier strip 50 described in Section 1 may be produced by casting, extrusion, calendaring, or other suitable techniques. The conductive plastics may be made, for example, from materials such as polymers loaded with electrically conductive particles and containing various stabilizers and/or plasticizers. The conductive particles may be carbonaceous materials such as graphite or acetylene black, or metallic particles may also be used. Polymers which by themselves are sufficiently conductive may also be used. The conductive plastic, whether loaded or unloaded, must be made from a composition which is compatible with other components of the battery. For batteries using LeClanche and moderately concentrated alkaline electrolytes, the conductive plastic may be made for example, from materials such as polyacrylates, polyvinyl halides, polyvinylidene halides, polyacrylonitriles, copolymers of vinyl chloride and vinylidene chloride, polychloroprene, and butadiene-styrene or butadiene-acrylonitrile resins. For batteries using strongly alkaline electrolytes, polyvinylchloride and polyolefins such as polyethylene and polyisobutylene may be used in the preparation of the conductive plastic. For batteries using acid electrolytes such as sulfuric acid polyvinyl halides, copolymers of vinyl chloride, and vinylidene chloride may be used.

The metal foils used in the production of Zones No. 1 and No. 2 described in Sections 1 and 2 may be made from such metals as steel, aluminum, lead or zinc. These metals are relatively inexpensive, they are good electrical conductors, and they can be obtained in foils of extreme thinness which are substantially free of pin-

holes. The foils of these metals can be purchased in rolls of great length and thus are well suited for use in high speed, continuously operating laminating machinery. These metals may also be laminated to some conductive plastics by the application of heat and pressure without requiring any intermediary adhesives between the layers, or they can be laminated using intermediate adhesives. It should be pointed out that while it may be common in some industries to imply a maximum thickness limitation whenever the terms "foil" or "metal foil" are used, no such limitation is intended as those terms are used herein.

The positive electrodes **20** may each comprise particles of electrochemically positive active material contained in and dispersed throughout a binder matrix. The positive active material conventionally is divided into tiny particles so as to increase the rate at which the electrochemical reactions can occur by increasing the surface area where they occur. The binder increases the electronic conductivity of the electrode, increases the structural integrity within the positive electrode, and adheres the positive electrode to the carrier strip. Since electrolyte must have access to the surface of the active material particles, the electrode must be made sufficiently porous so that the electrolyte may diffuse throughout the electrode rapidly and thoroughly. Preferably the pores in the electrode are produced by the evaporation of liquid during the construction of the electrode; the evaporating liquid may be part of a dispersion binder system in which the solid binder contained in the finally constructed electrode comprises tiny particles of binder material dispersed throughout and not dissolved in the liquid while the electrode is being constructed, or the evaporating liquid may be part of a solution binder system in which the solid binder contained in the finally constructed electrode is dissolved in the liquid which is later evaporated. The porosity of the positive electrodes may be increased as the discharge rate desired in the battery is increased. Electrodes may also be constructed using various combination of the dispersion and solution systems. Alternatively, the pores might be produced by the dissolving of a solid which was present during construction of the electrode or by passing gases through or generating gases within the electrodes at controlled rates during electrode construction. The positive electrodes **20** may, and preferably will, also contain amounts of a good electrical conductor such as carbon or graphite to improve the electrical conductivity between the active material particles themselves generally being relatively poor conductors of electricity. The conductivity of the active material particles together with the conductivity of the binder itself will influence the amounts of conductors added to the electrode. The electrodes **20** may also contain if desired small amounts of additional ingredients used for such purposes as maintaining uniform dispersion of active materials particles during electrode construction, aiding the diffusion of electrolyte through the pores of the finally constructed electrodes, controlling viscosity during processing, controlling surface tension, controlling pot life, or for other reasons.

The negative electrodes **30** may comprise spray or vapor deposits of metals or may comprise tiny particles of metals contained in and dispersed throughout a binder matrix. If the negative electrodes utilize a binder matrix, in general the same considerations regarding

that matrix apply to the negative electrodes as do for the positive electrodes except that no electrical conductor may be needed to achieve desired electrical conductivity between the active material particles since the negative active materials are generally better conductors than are the positive materials. When the negative electrodes utilize a binder matrix, the binder system need not be the same as the one used in the positive electrodes, and even if it is the proportions of binder, active material particles, and other ingredients in the negative electrodes may have a different optimum than the proportions of analogous ingredients in the positive electrode. When the negative electrodes **20** are deposited onto the web in the form of liquid dispersions of active materials and binder, the electrodes should be dried before being further processed. The initial porosity of the negative electrodes may sometimes be less than that of the positive electrodes, since the negative electrode discharge reaction products are sometimes dissolved in the battery electrolyte. The porosity of the negative electrodes may be increased as the discharge rate desired in the battery is increased. The negative electrodes **30** may also comprise thin sheets or foils of electrochemically negative material.

If the positive and negative electrodes **20** and **30** respectively have the active material particles dispersed in a binder matrix as mentioned above, they may be applied onto the continuous strips by such techniques as the rotogravure or reverse roll coating methods used in the printing arts. Such methods are suitable for applying liquids for varying viscosities onto carriers and may be used with modern, high speed rotary production machinery. Where the electrodes are deposited in the form of such liquids, the electrodes should be dried before being further processed; the drying can be achieved by passing the web through appropriate ovens or drying chambers. Other methods of applying the positive electrodes onto the web includes silk screening, stenciling, and flexographic printing techniques; the particular application technique selected will depend not only upon the composition of the electrodes as they are deposited but on such additional factors as the desired thickness of the electrodes, the speed at which the continuous Zones move with respect to the applicators, and others. It is preferred to use this invention with positive and negative electrode compositions which, when placed onto Zones No. 1, No. 2 and No. 3, comprise active material particles dispersed in a binder matrix.

It is necessary to place a separator and electrolyte between each adjacent pair of electrodes in the collation. This requirement may be met in different ways with different materials. One approach is with the use of a continuous strip of separator material **40** such as that illustrated in FIGS. 8 and 9. Such separators may be made from a wide variety of materials including the synthetic fibers, microporous polymer sheets, and cellulosic materials which are conventional in battery construction as well as from woven or non-woven fibrous materials such as polyester, nylon, polypropylene, polyethylene, and glass. Liquid electrolyte solutions could be impregnated into these separator strips or patches of viscous, gelled electrolyte could be applied onto one or both sides of the separator strip. The viscous, gelled electrolytes, which can be made including a wide variety of gelling agents, would contain the needed electrolyte and also adhere or bond to the adjacent electrodes to

produce good conductivity. As another alternative, deposits of viscous, gelled electrolytes could by themselves serve as both separators and as electrolyte if of proper thickness and/or consistency, making a distinct separator such as the member 40 shown in FIGS. 8 and 9 unnecessary. All such alternatives are included within this invention as ways of placing a separator and electrolyte between each adjacent pair of electrodes in the collation.

Several observations should be made in regard to the role of the adhesive patches which provide the seals around the electrodes. As mentioned earlier, preferably these patches may be impregnated into the separator strip before the electrolyte is added to that strip. The adhesive should be applied in liberal quantity so that all of the pores in the separator are completely filled in the area to which the adhesive is applied and so that there is sufficient excessive adhesive to coat and adhere to the other members being sealed by the patches. The adhesives should be electrically nonconductive. The adhesives themselves may be selected from a wide variety of materials including such adhesive cements as catalyzed uncured epoxy resins, phenolic resin solutions, ethylene copolymer hot melts, pressure sensitive elastomer mixtures, thermoplastic resin solutions, and natural gums and resins and their solutions. Faster and more thorough and complete impregnation of the adhesive into the separator may be achieved with many hot melt cements by making the impregnations with heat adhesives. The adhesives which may be used may be ones which attain their adhesive quality for the first time during assembly of the battery as a result of the application of pressure, heat, ultrasonics, or other forms of energy. Where gelled electrolytes are used as the only separators between adjacent electrodes, sealant deposits 101 of the type shown in FIGS. 2 and 3 may be used to achieve the sealing.

While it is preferred to employ the LeClanche electrochemical system (comprising manganese dioxide positive active material, zinc negative active material, and an electrolyte comprising ammonium chloride and/or zinc chloride), the multicell battery 5 of this invention may employ a wide variety of electrochemical systems including both primary and secondary systems. Among the positive electrode materials are such commonly used inorganic metal oxides as manganese dioxide, lead dioxide, nickel oxyhydroxide, mercuric oxide and silver oxide, inorganic metal halides such as silver chloride and lead chloride and organic materials capable of being reduced such as dinitrobenzene and azodicarbonamide compounds. Among the negative electrode materials are such commonly used metals as zinc, aluminum, magnesium, lead, cadmium, and iron. This invention may employ the electrolytes commonly used in the LeClanche system (ammonium chloride and/or zinc chloride), various alkaline electrolytes such as the hydroxides of potassium, sodium and/or lithium, acidic electrolytes such as sulfuric or phosphoric acid, and nonaqueous electrolytes, the electrolytes of course being chosen to be compatible with the positive and negative electrodes.

Among the wide variety of electrochemical systems which may be used in the multicell battery 5 are those in which the positive electrodes comprise manganese dioxide, the negative electrodes comprise metals such as zinc, aluminum, or magnesium, and the electrolyte

substantially comprises an acidic solution of inorganic salts. Another commonly known system useful in the battery 5 is the alkaline manganese system in which the positive electrodes comprise manganese dioxide, the negative electrodes comprise zinc, and the electrolyte substantially comprises a solution of potassium hydroxide. Other aqueous electrolyte systems including those of nickel-zinc, silver-zinc, mercury-zinc, mercury-cadmium, and nickel-cadmium may also be used.

Systems employing organic positive electrodes and acidic electrolytes may also be used, including rechargeable systems using azodicarbonamide compound electrodes and LeClanche electrolyte.

With the all metal web described in Section 3, the surfaces of the web must be selected from metals which are electrochemically nonreactive with respect to the electrodes and electrolyte of the battery. As further described in U.S. Pat. No. 3,706,616, the metal carrier strip used as the web may comprise: (1) a unimetal which is nonreactive to the positive and negative electrodes and to the electrolyte within the battery; (2) a bimetal in which the metal adjacent the positive electrode is nonreactive with respect to that electrode and the metal adjacent the negative electrode is nonreactive with respect to that electrode; (3) and, a trimetal whose outer two layers are non-reactive as in (2). The particular metals employed will depend upon the electrochemical system used in the battery. Metals which are nonreactive in nearly all electrochemical environments in common usage include titanium, tantalum, and gold; these metals and others which are nonreactive in some but not all electrochemical environments may be used. In general, bimetals have the advantage of permitting a wider selection of materials and of permitting a metals selection based upon the idea that the metal on one side of the web may be particularly nonreactive with respect to the positive electrodes while the metal on the other side of the web may be particularly nonreactive with respect to the negative electrodes. Use of trimetals increases the range of possibilities by permitting the interior metal to be selected on the basis of factors such as cost, electrical conductivity, and ease of pocketing while the two exterior metals may be selected primarily on the basis of their electrochemical nonreactivity. Bimetal and trimetal constructions may be obtained by cladding, plating, flame spraying, vacuum deposition, or by any other suitable means.

We claim:

1. A method of constructing multicell batteries utilizing a continuous web comprising a plurality of structurally connected continuous Zones, at least one of the Zones comprising a continuous strip of metal, the method comprising the steps of:

- a. cutting the continuous web so that the continuous Zones are continuous strips which are structurally unconnected from each other;
- b. indenting pockets in a Zone comprising a continuous strip of metal, each pocket being indented between a pair of predetermined positions along the Zone, each pocket being formed while gripping the continuous strip sufficiently to maintain the distance between the pair of predetermined positions constant during the indenting action; and,
- c. collating the pocketed Zone into an assembly of battery components which assembly includes at least one other Zone cut from the web.

2. A method of constructing multicell batteries utilizing a continuous web, the web comprising at least one Zone No. 1, at least one Zone No. 2, and at least one Zone No. 3 which are structurally connected together, at least one of the Zones comprising a continuous strip of metal, the method comprising the steps of:
- placing intermittent deposits of electrodes along the continuous web by
 - placing intermittent deposits of positive electrodes along one side of each Zone No. 1.
 - placing intermittent deposits of negative electrodes along one side of each Zone No. 2, and
 - placing intermittent deposits of positive and negative electrodes along each Zone No. 3, each deposit of positive electrode being on the other side of a Zone No. 3 from and substantially opposite a deposit of negative electrode;
 - cutting the continuous web having the electrode deposits thereon so that the Zones No. 1, No. 2, and No. 3 are continuous strips which are structurally unconnected from each other;
 - indenting pockets in a Zone comprising a continuous strip of metal, each pocket being indented between a pair of predetermined positions along the Zone, each pocket being formed while gripping the continuous strip sufficiently to maintain the distance between the pair of predetermined positions constant during the indenting action;
 - collating the continuous Zones No. 1, No. 2, and No. 3 so that at least one Zone No. 3 is between a Zone No. 1 and a Zone No. 2, so that the positive electrodes along Zone No. 1 and the negative electrodes along Zone No. 2 are facing the inside of the collation, and so that a deposit of positive electrode on one Zone is opposite a deposit of negative electrode on an adjacent Zone;
 - placing a separator and electrolyte between each adjacent pair of electrodes in the collation; and
 - sealing around the electrodes on the Zones.
3. The method of claim 2 in which Zone No. 1 comprises a laminate of electrically conductive plastic and metal foil, Zone No. 2 comprises a laminate of electrically conductive plastic and metal foil, and Zone No. 3 comprises electrically conductive plastic, the electrodes being placed along the plastic sides of Zones No. 1 and No. 2.
4. The method of claim 2 in which each of the Zones No. 1, No. 2, and No. 3 comprises a metal foil the surfaces of which are electrochemically non-reactive with respect to the electrodes and electrolyte of the battery.
5. A method of constructing multicell batteries utilizing a continuous web comprising a plurality of structurally connected continuous Zones, at least one of the Zones comprising a continuous strip of metal, the method comprising the steps of:
- cutting the continuous web so that the continuous Zones are continuous strips which are structurally unconnected from each other;
 - cutting a pair of slits partially across the Zone comprising a continuous strip of metal;

- indenting a pocket between the slits in the slitted Zone, the indenting being done in a manner which results in the width of the slits being increased but the center lines of the slits remaining in fixed relative longitudinal position by the indenting action; and,
 - collating the pocketed Zone into an assembly of battery components which assembly includes at least one other Zone cut from the web.
6. A method of constructing multicell batteries utilizing a continuous web, the web comprising at least one Zone No. 1, at least one Zone No. 2, and at least one Zone No. 3 which are structurally connected together, at least one of the Zones comprising a continuous strip of metal, the method comprising the steps of:
- placing intermittent deposits of electrodes along the continuous web by
 - placing intermittent deposits of positive electrodes along one side of each Zone No. 1,
 - placing intermittent deposits of negative electrodes along one side of each of Zone No. 2, and
 - placing intermittent deposits of positive and negative electrodes along each Zone No. 3, each deposit of positive electrode being on the other side of a Zone No. 3 from and substantially opposite a deposit of negative electrode;
 - cutting the continuous web having the electrode deposits thereon so that the Zones No. 1, No. 2, and No. 3 are continuous strips which are structurally unconnected from each other;
 - cutting a pair of slits partially across the Zone comprising a continuous strip of metals;
 - indenting a pocket between the slits in the slitted Zone, the indenting being done in a manner which results in the width of the slits being increased but the center lines of the slits remaining in fixed relative longitudinal position by the indenting action;
 - collating the continuous Zones No. 1, No. 2 and No. 3 so that at least one Zone No. 3 is between a Zone No. 1 and a Zone No. 2, so that the positive electrodes along Zone No. 1 and the negative electrodes along Zone No. 2 are facing the inside of the collation, and so that a deposit of positive electrode on one Zone is opposite a deposit of negative electrode on an adjacent Zone;
 - placing a separator and electrolyte between each adjacent pair of electrodes in the collation; and,
 - sealing around the electrodes on the Zones.
7. The method of claim 6 in which Zone No. 1 comprises a laminate of electrically conductive plastic and metal foil, Zone No. 2 comprises a laminate of electrically conductive plastic and metal foil, and Zone No. 3 comprises electrically conductive plastic, the electrodes being placed along the plastic sides of Zones No. 1 and No. 2.
8. The method of claim 6 in which each of the Zones No. 1, No. 2, and No. 3 comprises a metal foil the surfaces of which are electrochemically nonreactive with respect to the electrodes and electrolyte of the battery.
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