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(54) APPARATUS FOR FORMING ENVELOPES FOR BATTERY PLATES

(71) We, W. R. GRACE & Co., a Corporation organized and existing under the laws of the State of Massachusetts, United States of America, of 62 Whittemore Avenue, Cambridge, Massachusetts 02140, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to apparatus for forming battery separator envelopes for enveloping battery plates.

In the past it has been the practice to form battery separator envelopes by interconnecting walls of the battery separator through the means of adhesives, hot melts, tape or, when the battery separator material was appopriately sealable, through heat seals and unltrasonic sealing. In all of these instances, using the previous practices, it was usual to either butt the edges of the battery separator together where it was to be joined or to lap them over one another. It has also been the practice in the past to directly cast battery separator tubes or to sew tubes from fabric and then impregnate the fabric.

One prior enveloping method used with the positive plates of lead acid industrial batteries involved placing glass mats over the pasted faces of the battery plate and then wrapping the plate around its narrow dimension with a tape of glass sliver. Then a PVC sheet is wrapped over the tape, overlapped and sealed. The PVC sheet has perforations mechanically poked in it where the paste is and is solid at the edges of the plate to reduce moss or edge shorts. The bottom edge (open edge opposite the battery post) is then inserted into a plastics shield that fits over the rectangular bottom of the PVC wrapping.

In the parent Application No. 28705/76 (Serial No. 1558787) we have disclosed an invention based on the surprising finding that the walls may be spaced from each other and interconnected through a foam member and yet no additional space is lost within the battery and the "free flow" area of the battery separator, i.e. the area available to the battery electrolyte, is not adversely affected.

Accordingly, the patent application provides a battery separator envelope for a battery plate comprising two opposed walls of battery separator secured in spaced apart position by at least one foam member positioned between the walls.

In a preferred type of envelope the edges of the battery separator walls are aligned and the foam member or members extend along a part of the total edge perimeter of the walls.

The battery separator walls will normally be substantially rectangular and the foam member or members preferably extend along at least substantially the entire length of one of the edges of the rectangle, and most preferably along the entire length of one or both of the longer edges of the rectangle. In one preferred construction the battery separator walls are joined between one of the shorter edges of the rectangle by an end wall integral with the two said opposed walls and constructed of the same (battery separator) material. In this construction the two opposed walls are desirably relatively flat (although they may of course be ribbed), rectangular walls extending parallel to and in alignment with one another and are derived from a continuous homogeneous sheet having two folds therein defining with a base position, i.e. an end wall, between the folds. The continuous sheet therefore has much the same shape as the cover on a book with the edge (end) wall extending at an angle of substantially 90° from each of the two main (opposed) walls. Preferably, a foam member (or members) secure the two walls together for at least substantially the entire length of two of their aligned edges, forming a seal with the walls. Thus only a single edge of the envelope is left open for access to the battery plate. Except for a pole connection to the plate, even this could be

substantially closed with a foam member. Venting, of course, would have to be adquate. The battery separator walls are of course mainly or wholly porous and the foam member is desirably in contact with a porous portion of the walls. A strong mechanical bond can be formed between the separator walls and the polymer, as penetration of the pores by the foam provides anchorage. In addition of course, by choice of a suitable synthetic polymer as the main ingredient of the foam, a considerable adhesive effect can be produced Thus, by various means, it is possible to make the foam member serve the function of a seal which is impervious to battery electrolyte. However, the foam member is valuable in its own right as a spacing member even if some other means is used to seal the battery plate from the electrolyte at the edges of the walls of the battery separator and thereby close the envelope.

Of course, an aspect of the invention of the parent application includes a battery plate in position in the battery separator envelope of this invention. In its preferred form the combination contemplates a battery plate having a frame around its periphery enclosing the battery grid which is pasted with battery paste with two outwardly disposed faces exposed for battery electrolyte. A paste support mat preferably covers each of the two pasted faces of the battery plate and the foam member engages and extends through the interstices of at least two opposite edges of each of the support mats.

The parent application also describes and claims a method for forming battery separator envelopes for battery plates. The method basically involves positioning the two walls of battery separator adjacent to one another and spaced from one another and introducing hardenable foam or otherwise placing the active foam member into the space between the adjacent walls and in contact with each of the walls, and hardening the foam. Desirably the foam be one which hardens merely by standing.

The present invention provides apparatus for forming envelopes for battery plates comprising mandrel means arranged to support battery separator sheeting thereagainst with pairs of sheet faces thereof in opposed spaced apart relation, for forming walls of the envelope, a jig arranged to clamp the sheeting against the mandrel means and extrusion means for extruding foam material and arranged to introduce a bending of foam between the spaced apart sheet faces and in contact with them along at least one edge thereof.

The mandrel means may comprise the battery plate that is to be enveloped. Rigid supporting members may be provided along at least one of the outer edges of each of the two faces of battery separator sheeting on their sides opposite the mandrel to prevent the foam from pushing the two walls apart as it fills the channel. The two rigid supporting members are preferably part of the jig and preferably in the form of opposed sheet faces dimensioned to correspond substantially with the size of the battery separator sheet faces (usually rectangular), to be clamped against the mandrel means in alignment with the edges of the separator sheet faces (to support them in parallel spaced apart position against the mandrel to form a firm assembly with them and the mandrel for receiving the foam).

So that the foam member can be applied easily by extruding a foam bead from an extruder die into the channel formed between the edges of the battery separator sheet faces and the mandrel beginning at the base portion of the battery separator sheet, the apparatus of the invention preferably includes a die provided adjacent to a die outlet of the extrusion means, for receiving the jig for movement relative to the die outlet with the edges of the spaced apart sheet faces positioned for receiving foam extrudate. Preferably the sheet faces are substantially rectangular and the guide is arranged to receive the jig for movement in a substantially straight line along the whole length of an aligned edge of a rectangular side of the battery separator sheet faces. In use of the apparatus of the invention, the foam can be tamped firmly into the channel if desired and the surface of the foam exposed at the surface of the channel smoothed by pressing with a flat surface. Thereafter the foam is cooled to solidify it and any flash (surplus foam protruding beyond the edges) is trimmed. Most preferably the foam is made of a synthetic organic polymer compounded with a heat-activated blowing agent before being introduced into the extruder, and is extruded as a hot melt.

Various forms of apparatus of the invention will be described hereinafter with reference to the accompanying drawings, in which:

Figure 1 is an isometric view of the apparatus of the present invention in operation with a small portion of the foam bead cut away adjacent base 23.

Figure 2 is a partial end view of the jig assembly of the present invention showing the active foam member being tamped and smoothed.

Figure 3 is an isometric view of the enveloped battery plate of the present invention with the flash being cut away.

The apparatus of the present invention in a presently preferred form may be briefly outlined as follows: Looking at Figures 1 and 2, a jig 9 is shown having strengthening

bars 10 and 11 along the corresponding opposite upper edges of its outwardly opposite facing two jig sheets or sides 12 and 13. The strengthening members 10 and 11 are spaced slightly below the upper edges of the sides. The strengthening members are T shaped bars for rigidity against flexing when the foam presses outwardly against the corresponding opposed edges of sheets 12 and 13. A mandrel 14 is also shown. The mandrel may be a battery plate. As shown in the Figures the mandrel 14 is a battery plate and 14A of Figure 2 is the battery plate post. A C-clamp 15 is provided for positively securing the open end of the jig in spaced position. The jig itself is a single piece of sheet metal bent medially in a shape much like that of a book cover. The portion joining or hinging the outer sides or covers 12 and 13 is the base or hinge portion 16. The inherent spring nature or bias of the spring metal tends to urge covers 12 and 13 apart.

An extruder 17 is shown in Figure 1 for extruding a foamable polymer throough a narrow throated die 18. The polymer exits at 18A to form a foam bead 19 over the mandrel 14 bridging the outer edges 20 and 21 of a battery separator which is bent in the same general shape as the jig 9. The two sides or sheets 12 and 13 of the jig are sized to correspond with the size of the battery separator sheets to be clamped on the mandrel as shown in Figures 1 and 2 to make it easy to align the top edges of sides 12 and 13 of the jig with edges 20 and 21 of battery separator sheet 22. The battery separator sheet 22 also has a base or fold region 23. The jig 9 when assembled or loaded with a battery separator and mandrel is a loaded jig assembly or a jig assembly 24.

A work table guide 25 is provided adjacent the extruder die outlet 18A for receiving and positioning the jig assembly 24 for movement past the die outlet. A guide bar 26 extends across a medial region of work table or stand 25 and provides a proper spacing for the jig assembly 24 for receiving the foam bead 19 when the jig assembly 24 has its bottom edge securely engaged there against. The upper edge of the work stand 25 stops short of the upper edge of the jig assembly 24 to allow for passage of the C-clamp 15 and the strengthening member 11 thereabove. Thus the flat face of sheet 13 of the jig 9 is engaged against the flat face of the stand 25 so that the assembly will be stable as it is slid across the stand 25 for placement of bead 19.

A second, flat-surfaced, work table or smoothing surface 27 is positioned adjacent the stand 25 and used to press or tamp the foam bead inwardly and against the mandrel to smooth its outer surface and assure an even secure seal and binding with the walls of the battery separator. The only other piece of equipment shown may be seen in Figure 3 and this is the knife 28. Knife 28 is used to trim flash 29 from the edges of the separator 22 after the separator has been removed from the jig assembly.

The present invention also includes a method of forming envelopes for battery plates using apparatus defined above, which comprises positioning the battery separator sheeting against the mandrel means with pairs of sheet faces thereof in opposed spaced apart relation, clamping the sheeting with the jig and extruding the foam material to introduce the foam beading in the manner defined above, and if a removable mandrel means not comprising a battery plate is employed, removing it from the envelope after the foam has solidified. Preferred features are set out below.

To prepare the extruder a synthetic polymer resin, preferably a polyolefin and most preferably polyethylene is compounded with a blowing agent, which is preferably a heat activated blowing agent. The compounded synthetic polymer is fed into an extruder and extruded as a hot melt typically as a temperature in excess of 300°F. at the die outlet. Of course, it is possible to introduce the foaming agent into the synthetic polymer in the extruder in some instances.

The jig assembly is also prepared. First, when the battery separator is sufficiently flexible to fold without being excessively damaged it is preferable to take a sheet of battery separator that is sized appropriately and fold the sheet much like a book cover so that two walls of battery separator that will form two walls of the envelope covering the pasted faces of the battery plate extend from a base portion at an angle of 90°. In the usually preferred form the two separator walls are identical in size and are arranged parallel to each other over the mandrel which may be the battery plate itself. The edges of the walls extend slightly beyond the edges of the mandrel where the walls are to be secured together by the extruded foam beading. This provides a channel above the edge of the mandrel for receiving the foam beading. Of course, the battery separator sheeting could be discrete sheets rather than composed of a single folded sheet. In the presently preferred embodiment, however, a single sheet is folded to form the two walls. If there are ribs present on the battery separator that cross the fold lines it may be highly desirable to remove or break the ribs at the folds to alleviate stresses. This may be done by cold or hot pressing the ribs to mash them down or by crimping the fold enough to bend the rib out of the way without significantly damaging or breaking the separator sheet. The preferred battery separator would be a microporous sheet formed from synthetic polymer resin, preferably

from polyolefin and most preferably polyethylene. The preferred battery separator would be that sold under the registered Trade Mark "DARAMIC" by W. R. Grace & Co. which is made under U.S. Patent 3,351,495.

After the sheet of battery separator has been folded and positioned over the mandrel which is the battery plate in the case shown in Figures 1, 2 and 3, the subassembly is positioned in the jig. It is most convenient to place the base 23 of the battery separator on a flat surface with the leaves or walls 30 and 31 spread apart in the vertical position and to then insert the battery plate edge against the base in centered position with the desired margins at each edge to allow for thickness of foam. Preferably a paste supporting mat is placed over each of the two opposite outwardly pasted faces of the battery plate before the battery plate is positioned in the battery separator. The paste support mat is preferably the same size as the outer edges of the frame of the battery plate. However, the mat does not extend up toward any extensions or projections from the battery plate such as battery poles or posts. The mats have not been shown in the drawings for the sake of clarity. The jig preferably has its hinged portion seated on a flat surface with its sides or leaves 12 and 13 in open position for receipt of the subassembly battery separator and battery plate in the same manner as the battery plate was inserted into the battery separator. The sides of the jig are brought into exact registration with the edges of the battery separator sheeting. The hinged jig is then closed and secured in closed position to hold the separator sheeting against the battery plate or mandrel. This may desirably be done by means such as a C-clamp as illustrated in Figure 1. Having thus positioned the battery plate between the faces of the battery separator sheeting in the desired position and secured the edges of the separator from being pushed outwardly by the foam beading everything is in order for placing the foam in position.

The extruder has previously been placed in operation in one preferred form of this invention and the jig assembly has been prepared and is ready to receive the foam beading. In a preferred form this is done by placing the base 23 of the battery separator at the outlet 18A of the die and moving the assembly to the left as shown facing Figure 1. The speed of movement is determined by the visual observance of foam completely filling the space between the two battery separator sheets 12 and 13 along an edge. The assembly is moved until the foam extends to the tops of the channel walls all the way to along the edge in a straight line. The assembly is moved by sliding it in a straight line along the guide bar 26 with the face of side 13 against the support surface of the table 25. The strengthening bar 10 and the C-clamp are clear of the upper edge of the surface of the support table 25.

Immediately after the beading 19 has been placed, the assembly is positioned with the bead face down against a smooth surface and pressed against the smoothing surface as at 27 in Figure 2. The excess extrudate is thereby forced into the seal. Thereafter, in some instances, the sealed edges may be pressed inwardly very slightly by manual pressure against the edges of the plates 12 and 13 to further assure a positive seal and the elimination of voids remaining after the foam has been tamped and smoothed. Of course, in some applications it may not always be necessary to even press the foam against or with a surface such as surface 27.

After the seal is finished it is cooled and the jig removed. The subassembly battery plate and battery separator are reversed so the still open channel on the opposite side is positioned at the side of the jig adjacent the strengthening bars 10 and 11. The jig is again secured over the subassembly and the procedure is repeated to seal this open channel edge of the walls 12 and 13 beginning again at the base 23. After tamping and squeezing and cooling in the same manner previously described the now sealed subassembly enveloped battery plate is removed from the jig and any flash may be removed by, for example, cutting as illustrated in Figure 3.

A careful study of Figure 2 reveals that the foam not only swells, coming into contact with the walls 20 and 21 of the battery separator, but also penetrates inwardly alongside the battery plate.

The battery plate typically has a frame extending therearound enclosing the battery grid which is pasted with battery paste with two outwardly disposed faces exposed for battery electrolyte. The foam flows around the outer edge of the frame, which acts as a heat sink (in the usual practice of the invention where the frame is not preheated) "freezing" the foam and causing it to pull back very slightly from the edge of the frame leaving a very slight gap. The foam beading engages the edges of the paste support mat extending into or through the interstices of the edges and thereby bonding therewith. It may be recalled that the paste supporting mats are not shown. Figure 2 reveals that this penetration along the edge of the battery plates edge is in good measure due to the spacing of the main wall of the separator from the battery plate by the ribs projecting outwardly and impinging against the battery plate. The ribs 33 and 34 are actually encompassed in the foam. The paste support mats are usually only em-

ployed when the ribs space the back web or main separator surface from the paste. In addition the synthetic polymer actually penetrates right into the pores of the preferred type of battery separator forming a very good mechanical bond even when the pores are the preferred small pores of less than an average of .07 microns. The significant entry and superior mechanical bond in such small pores are truly remarkable. A second preferred embodiment would involve pores averaging up to 2.0 microns. Of course, the invention is also applicable to uses with battery separators having very large pores. The battery separator walls could of course be dissimilar.

When a removable mandrel is used in place of the battery plate it is usually preferable to omit the paste support mats. The removable mandrel is usually longer than the battery plate to facilitate its removal. Of course, the removable mandrel is also preferably smooth-surfaced and made of a material to which the foam will not adhere so that it may be easily removed. It has been found that a preferred mandrel may be made of steel. When hot foam of synthetic polymers such as polyethylene contact the metal it has been found that it is cooled by the metal which acts as a heat sink and the foam shrinks back slightly making the mandrel's removal relatively easy.

In the particular embodiment here depicted in detail a continuous feed and extrusion extruder is used and all set up and handling is to be done off line so that the extruder may be continuously used. If a stop/start operation on each envelope is desired, a ram feed unit would be preferred. Any method may be employed in appropriate circumstances for applying the foam over the mandrel edge between the edges of the battery separator walls 20 and 21 as shown in Figures 1 and 2. It is however preferred that a polyolefin be employed with the blowing agent activated by heat within an extruder. The blowing agent and polyethylene can be dry blended and fed into the extruder hopper in the desired proportions. The extrudate can be directed from an appropriate die opening in a bead into the space between the edges of the battery separator sheets.

Chemical foaming agents are preferred but other foam techniques may be employed. For example, the foam can in certain circumstances be mechanically formed in the extruder by mixing a gas into the polymer under pressure. It is important that the foam expand as it is placed, to ensure proper void-free sealing of the separator.

The extruder illustrated in the present embodiment is a single screw continuous extrusion type. Other types could be used. For discontinuous operation a ram type extruder could be used. With the continuous type extruder it would be contemplated that a number of set ups (jigs and mandrels) would be available and set ups would be done so as to allow for continuous use of the extrudate.

The paste support mat is commonly the glass mat which may include a tape of glass sliver. The common function of the paste support mat is to mechanically reduce shedding of positive material under abusive operating conditions.

By "average pore size" it is meant that the majority of the pores have the recited size as determined by the peak of the pore size distribution as measured by the Desorption Isotherm method using a Micro Meritics Digisorb-Model 2500 with the BET method.

The frame of the battery plate is the outer perimeter of the battery plate. Usually it is the positive battery plate that is enveloped and the negative battery plate is placed in between the enveloped positive battery plates. However, in some instances the negative battery plate is enveloped rather than the positive battery plate. In still other instances a block of several battery plates may be enveloped. For example, two battery plates with a battery separator between them and battery separators on the outsides of the pair of plates may be secured in a jig. This would form two channels, one channel above each battery plate edge. Then an active foam member could be placed on the two channels in the manner previously described. It would also be possible to extrude one wide foam bead and place it in both channels at the same time. The two battery envelopes would be joined through the common battery separator wall separating adjacent positive and negative battery plates. The foam member would extend along the separate channels in two parts each part joined to the same common battery separator wall between the positive and negative battery plates. A further extension of this concept would be eneveloping all of the plates in an element, thus forming a mechanically unitary block or battery cell element. For these purposes, the present invention includes apparatus for forming two or more envelopes with a single extrusion operation, wherein the mandrel means is arranged to support two or more pairs of wall-forming sheet faces of battery separator sheeting in opposed spaced apart relation, and the extrusion means is arranged to introduce a single foam beading between each pair of the sheet faces and in contact with them along at least one edge thereof.

A special embodiment of the invention that saves on the quantity of foam required to form the foam member is provided by shaping the jig so that its upper edges push the edges of the battery separator walls sub-

stantially closer together, narrowing the channel. Thus less foam is required to fill the channel.

The following examples further illustrate the nature and advantages of the present invention.

EXAMPLE I

A positive battery plate for a lead acid battery is enveloped using the process set out below. The battery plate is $16\frac{1}{2}$ inches long (when lying on its side edge as shown in Figure 1) and $5\frac{3}{4}$ inches high with a post extending about 1 inch from one of the short edges. The battery plate is about $\frac{1}{4}$ inch thick. The sheet of DARAMIC battery separator DIJH-334 (a product of W. R. Grace & Co.) is cut to a size of $33\frac{7}{8}$ inches × 6 inches. This separator has ribs such as those illustrated in Figure 2 running the long dimension of the battery separator and spaced $\frac{1}{4}$ inch apart on centre. To form the two walls 30 and 31 and the base portion 23 from the battery separator sheet that is $33\frac{7}{8}$ inches long, the sheet is folded to provide a medial base edge portion 23 that is $\frac{1}{2}$ inch across and two walls one on each side of the base, each of which are $16^{14}/_{16}$ inches long. To relieve rib stress in the area where the ribs fold the $33\frac{7}{8}$ inches long sheet of battery separator is positioned over two bars that have $\frac{1}{8}$ inch diameters and are $\frac{1}{2}$ inch apart on centre with the ribs running across the bars. The battery separator is then hydraulically pressed against the bars with a platen at a pressure of 5 pounds/sq.in. to cold press the ribs and mash them down. The cold pressing forms a line across the battery separator sheet such that when the sheet is turned over with the ribs up and the walls 30 and 31 are lifted by hand they naturally fold where the bars pressed to form the desired book cover shape.

The battery plate with one paste support mat on each face is then seated against the separator base 23 with the post extending away from the base 23. The plate is centered with respect to the other two edges of the battery separator walls 30 and 31. This is most easily done with the base 23 resting on a table or the like.

The subassembly of the battery separator and battery plate are then positioned in the jig 9 with base 23 against the hinge portion 16 of the jig. The edges of the jig exactly conform in size to the edges of the battery separator walls and provide support and protection to the battery separators' edges. After the edges of the separators are aligned with the edges of the jig a C-clamp 15 is engaged on the strengthening bars 10 and 11 to hold the sides 12 and 13 of the jig in position parallel with one another and clamp the battery separator against the mandrel or battery plate 14.

As a separate procedure two parts per hundred of foaming agent, KEMPORE 200 (a product of National Poly Chemical, Inc.) is dry blended with Exxon LD 610 polyethylene (a product of Exxon) in a drum tumbler. This blend is then charged into the hopper of a small extruder ($14\frac{1}{2}$:1 L/D, 2 inch. Royal extruder) and extruded at a barrel temperature of about 400—450°F. through a die made out of $\frac{1}{8}$ inch copper tubing. The polyethylene's density is about 1.00. The density of the foam is about 0.35.

With the extruder operating, the jig assembly 24 is placed as the right hand edge of the slanted table face (looking at Fig. 1) resting on the bar 26 with the back face of sheet 13 flat against the slanted table surface and positioned with the die outlet 18A at the very beginning of the channel opening which is at the base 23 of the battery separator. Then the assembly 24 is slowly moved by sliding it by hand across the surface of the table resting and travelling along bar 26 at such a speed that the extruder outlet supplies a foam bead 19 completely filling the channel space above the plate 14 and between the side edges 20 and 21 of the battery separator. The jig assembly 24 is moved to the left (looking at Figure 1) until it is beyond the die outlet 18A and then quickly lifted and the bead is pushed or tamped inwardly by being pushed down against a flat surface such as a table as shown in Figure 2. This smooths the bead's outer surface so that it does not have ripples bulging outwardly which would consume space within a battery. This also assures complete and uniform contact by the foam throughout the channel dimensions at the edge of the separator. The assembly is then allowed to cool at ambient temperature of about 70°F for a few minutes to complete the formation of the foam member. The C-clamp is then released and the battery separator and the battery plate subassembly are removed from the jig. Any flash is cut from the edges of the battery separator as illustrated in Figure 3.

The subassembly is turned over top to bottom and secured in the jig again with the unsealed edges of the battery separator walls adjacent the strengthening members 10 and 11. This is most easily accomplished with the base 16 of the jig resting against a table. The base 23 of the battery separator of the subassembly is placed against base 16 of the jig and the edges of the separator and of the jig are aligned and the C-clamp is again secured in position. The strengthening members 10 and 11 are thus again adjacent the edge of the separator that is to be filled in with foam bead 19. The process of applying the foamed bead is repeated in exactly the same manner previously described. The bead is then pressed and tamped against a

table surface in the same manner as previously described and afterwards the active foam member is cooled. Then the C-clamp is removed and any flash is cut from the edges of the battery separator as illustrated in Figure 3 and the envelope is thus completed.

As may be seen in Figure 2 the foam extends down along the edge of the battery plate for about $\frac{1}{4}$ of an inch and around the end of the outer rib on each wall. As may be seen the rib spaces the battery separator's main web portion away from the battery plate. The paste support mat (which is not shown) is against the battery plate and in general the foam flows to the outside of this, pushing it more tightly against the battery plate. The foam may extend in thickness of less than $^1/_{32}$ of an inch over the outer edges 20 and 21 of the battery separator walls 30 and 31. In many instances the edges 20 and 21 of the battery separator extend wholly to the table surface 27. The foam should not extend beyond a thickness of $^1/_{32}$ inch because it could interfere with the envelope's insertion into the tight confines of a battery case.

If with great difficulty some of the foam is pulled away from the separator little hair-like fibrils are present on the foam clearly evidencing that the polyethylene is in secure mechanical adhesion with the battery separator which has pores having average pore sizes of about .03 microns. The paste support mats are locked in so securely that they cannot be removed without tearing them and it is very difficult to remove the battery plate from the envelope. This provides good handling qualities to the enveloped battery plate and also should reduce abrasion and other shifting damage to the battery plate and the battery separator during their operation in a battery and during shipping and handling prior to installation in a battery.

EXAMPLE II

The process of Example I is repeated except that a mandrel having the following dimensions is used in place of the battery plate. The mandrel is 18 inches in length, $5^{13}/_{16}$ inches in height and $\frac{3}{8}$ inches thick and made out of stainless steel. The paste support mats are also omitted. In all other respects the process is carried out in exactly the same manner. The foam bead is stopped at the end of the length of the battery separator. After trimming as shown in Figure 3 the mandrel is removed from the envelope and the envelope is then ready for receipt of a battery plate at some future time.

EXAMPLE III

The procedures of Example I and II are combined. One end of the battery separator envelope is sealed as in Example II using a mandrel that is not a battery plate. This seal is cooled and any flash is trimmed to provide an intermediate battery separator envelope. The mandrel is then removed and a battery plate, with the paste support mats over each face, is positioned through the still open side before the battery separator is placed back in the jig 9. Then the procedure continues as in Example I. The paste support mats are bonded with the foam at only one end.

The advantage of the procedure of Example III is that the mandrel may be much lighter than the battery plate and consequently is easier to position and retain in position while the first seal is formed. The battery plate, particularly when covered with paste support mats which can wrinkle up, is more easily inserted through the open side. The already formed seal positions and supports the heavy battery plate in position in the battery separator and while the subassembly is being reassembled for receipt of the second seal to complete a two part foam member. In some instances there is a paste support mat that is folded or wrapped around the battery plate rather than being two discrete sheets or mats. There are other combinations such as discrete paste support mats overwrapped with a wrap-around paste support mat.

WHAT WE CLAIM IS:—

1. Apparatus for forming envelopes for battery plates comprising mandrel means arranged to support battery separator sheeting thereagainst with pairs of sheet faces thereof in opposed spaced apart relation, for forming walls of the envelope, a jig arranged to clamp the sheeting against the mandrel means and extrusion means for extruding foam material and arranged to introduce a beading of foam between the spaced apart sheet faces and in contact with them along at least one edge thereof.

2. Apparatus according to claim 1 for forming two or more envelopes with a single extrusion operation, wherein the mandrel means is arranged to support two or more pairs of wall-forming sheet faces of battery separator sheeting in opposed spaced apart relation, and the extrusion means is arranged to introduce a single foam beading between each pair of the sheet faces and in contact with them along at least one edge thereof.

3. Apparatus according to claim 1 or 2 wherein the mandrel means comprises a battery plate or plates, respectively.

4. Apparatus according to claim 1, 2 or 3 wherein the jig comprises two opposed sheet faces dimensioned to correspond with the size of the battery separator sheet faces, to be clamped against the mandrel means in alignment with the edges of the battery separator sheet faces.

5. Apparatus according to any preceding claim wherein a guide is provided adjacent to a die outlet of the extrusion means, for receiving the jig for movement relative to the die outlet with the edges of the spaced apart sheet faces positioned for receiving foam extrudate.

6. Apparatus according to any preceding claim wherein the two sheet faces of the jig are provided by a single sheet of metal folded in the general manner of a book cover and sprung to bias apart the opposed faces and the jig further comprises strengthening bars provided behind the opposed faces to prevent them from flexing further apart when said foam presses outwardly thereagainst.

7. Apparatus for forming envelopes for battery plates and constructed and arranged substantially as hereinbefore described with reference to and as illustrated in Figure 1, 2 and/or 3 of the accompanying drawings.

8. A method of forming envelopes for battery plates using apparatus claimed in any preceding claim, which comprises positioning the battery separator sheeting against the mandrel means with pairs of sheet faces thereof in opposed spaced apart relation, clamping the sheeting with the jig and extruding the foam material to introduce the foam beading in the manner defined in said preceding claim, and if a removable mandrel means not comprising a battery plate is employed, removing it from the enevelope after the foam has solidified.

9. A method according to claim 8 wherein the method is operated first with a removable mandrel means to introduce foam beading along the longer edge of substantially rectangularly shaped sheet faces and then with mandrel means comprising a battery plate or plates to introduce foam beading along a shorter edge.

10. A method according to claim 8 or 9 wherein the battery separator sheeting employed as the start of the method is an integral sheet folded in the general manner of a book cover, to present two opposed faces aligned at their edges with each other and joined integrally at one edge.

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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

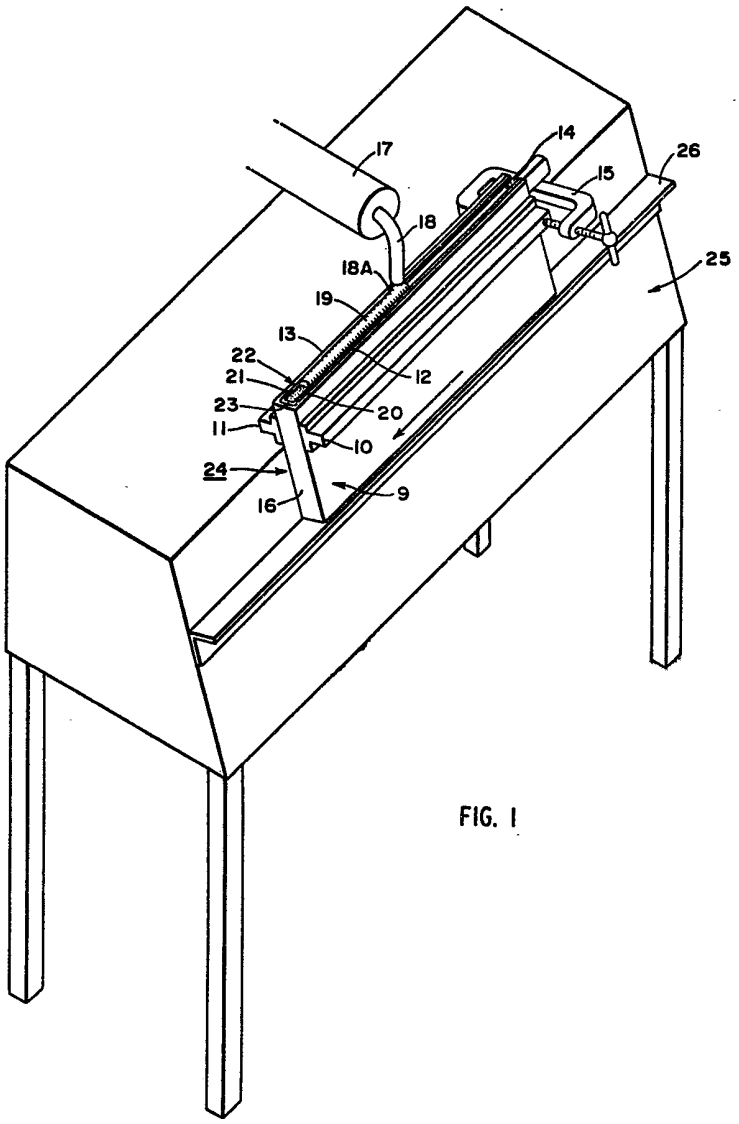
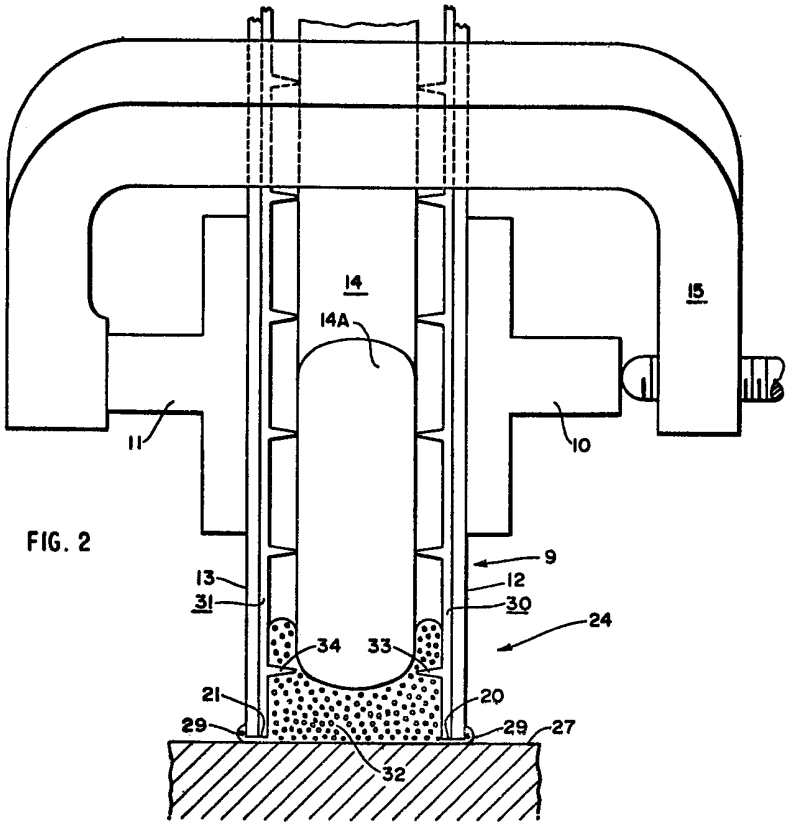


FIG. 1


14
14A
15
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27
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FIG. 2

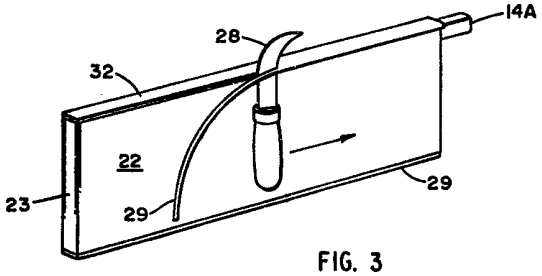
14A
28
32
22
23
29
29

FIG. 3