

Jan. 27, 1959.

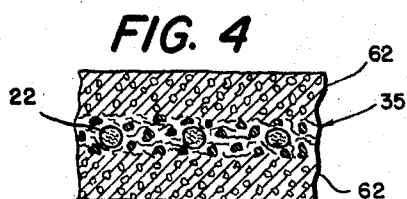
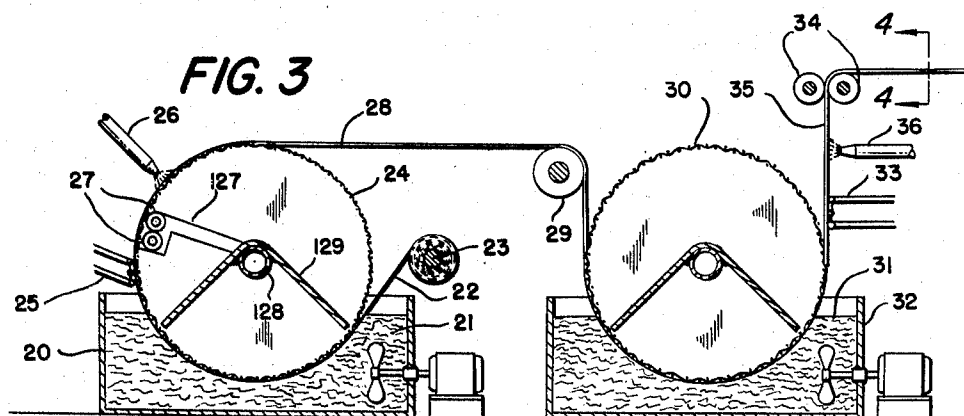
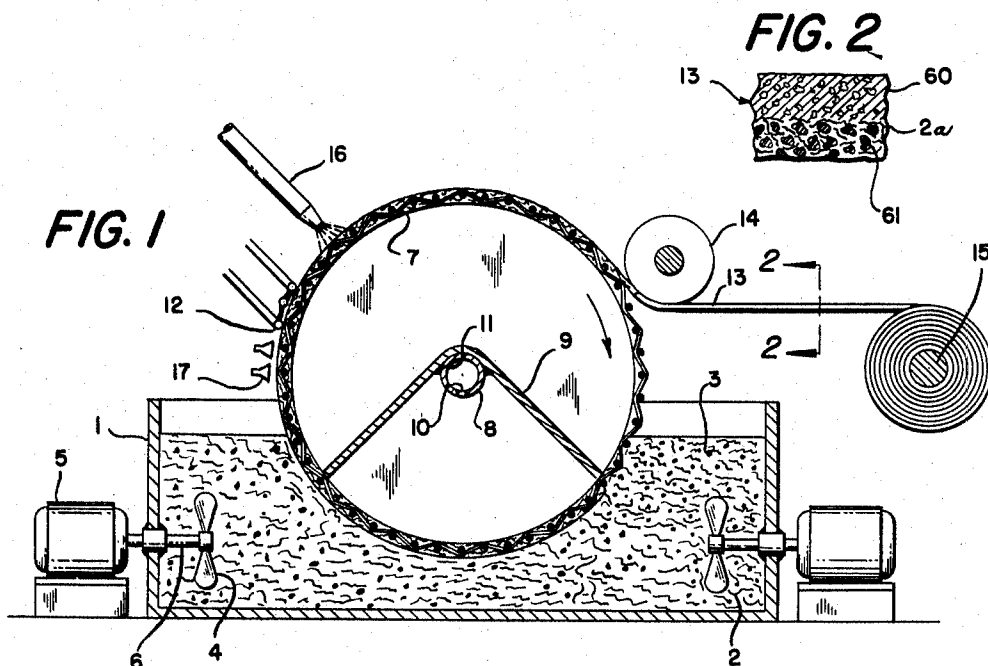
J. B. BRENNAN

2,870,689

METHOD OF PRODUCING STRIP MATERIAL

Filed Dec. 4, 1952

2 Sheets-Sheet 1



INVENTOR.
JOSEPH B. BRENNAN
BY *Oldham & Oldham*
ATTORNEYS

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J. B. BRENNAN

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2 Sheets-Sheet 2

FIG. 5

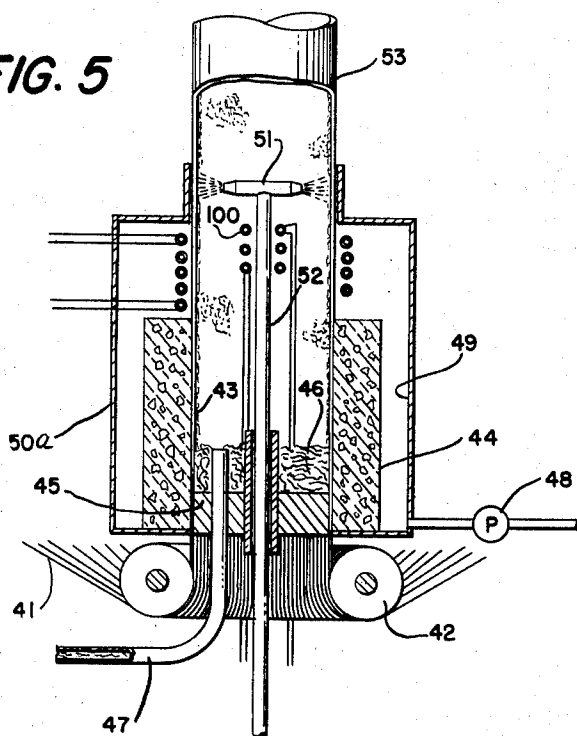


FIG. 6

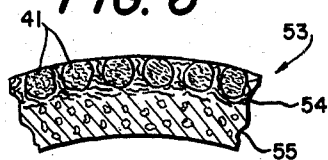


FIG. 7

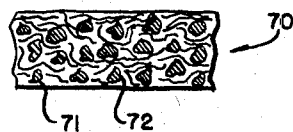


FIG. 8

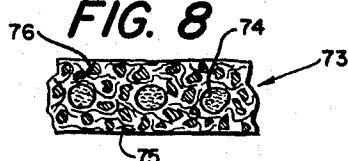


FIG. 9

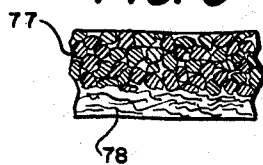


FIG. 10

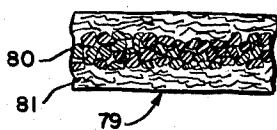


FIG. 11

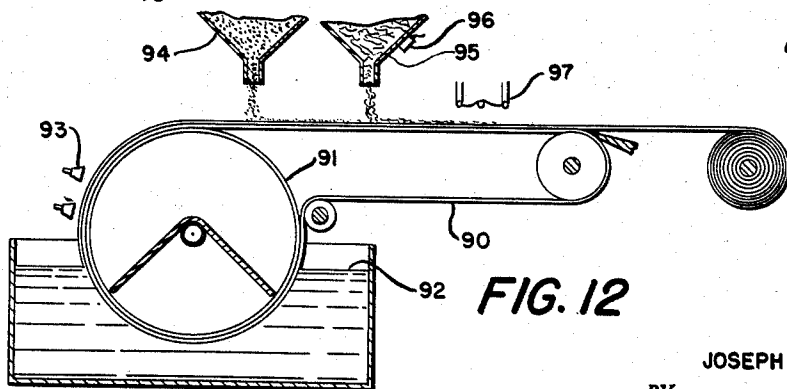
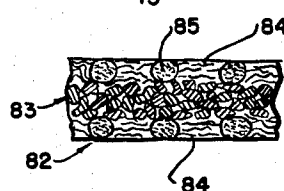


FIG. 12

INVENTOR.

JOSEPH B. BRENNAN

BY

Oldham & Oldham

ATTORNEYS

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2,870,689

METHOD OF PRODUCING STRIP MATERIAL

Joseph B. Brennan, Cleveland, Ohio; Helen E. Brennan, executrix of the estate of said Joseph B. Brennan, deceased

Application December 4, 1952, Serial No. 324,020

9 Claims. (Cl. 92—41)

This invention relates to the production of strip materials, and especially to strip material and methods of producing continuous strips of materials suitable for use as electrodes and spacers in electrolytic condensers, batteries, or the like, and wherein preferably heat-resisting insulating refractory fibers, such as those made from glass or quartz, are bonded together by a suitable medium and then have a coating of metal applied onto one or both surfaces of the refractory fibrous strip.

Heretofore, the strips for use as electrodes and spacers in electrolytic condensers or the like have been made in various manners. Paper base strips have been used in some instances, and porous metal coatings have been spray deposited thereon in one well known method for making this kind of electrodes. Various other processes for producing the electrodes have heretofore been suggested and I have found that one type of fibers which have desirable properties for use in forming electrodes of this type are refractory fibers, and especially various types of glass or quartz fibers or alumina silica fibers. When attempting to make a refractory fiber paper or mat, it has been difficult to obtain a bond between the fibers in order to produce sufficient interlock and bond between adjacent fibers so as to produce a strong self-supporting fibrous mat or sheet therefrom. It will be understood that suitable fiber sheets of this type should be very thin, such as approximately .001 inch to .005 inch in thickness.

Accordingly it, has been very difficult to produce continuously, heretofore, any type of refractory fiber strips when using vitreous or ceramic fibers in making up the strips and have the resultant strip used in the production of electrodes or as dielectric spacers.

The general object of the present invention is to provide a new method of continuously producing dielectric conductive strip material suitable for use in the production of electrodes of the class referred to hereinabove.

Another object of the invention is to continuously produce a porous electrode strip using refractory fibers as a component therein and/or thereabout, and wherein such fibers are bonded together by a suitable medium, such as coherent metal particles.

Yet another object of the invention is to continuously produce a unitary strip which can be used as a dielectric layer alone, or around a metal layer, or as a conductive layer with dielectric thereover, or as a layer which is conductive on one side and non-conductive on the other side.

A further object of the invention is to deposit or build a layer of refractory fibers which has metal particles distributed throughout the refractory fibers in conductive relationship and with the resultant sheet of material being adapted to be subjected to a sintering operation and/or to an induction heating action by which the metal particles can be fused sufficiently to aid in bonding the refractory fibers to each other to produce a self-supporting conductive strip therefrom.

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The foregoing and other objects and advantages of the invention will be made more apparent as the specification proceeds.

For a better understanding of the invention, reference should be had to the accompanying drawings, wherein:

Fig. 1 is a vertical section of representative apparatus for practicing one embodiment of the method of the invention;

Fig. 2 is a fragmentary, enlarged section on line 2—2 of Fig. 1;

Fig. 3 is a vertical section of diagrammatically illustrated apparatus for practicing a modification of the method of the invention;

Fig. 4 is a fragmentary, enlarged section on line 4—4 of Fig. 3;

Fig. 5 is a section through additional apparatus for practicing yet another method of the invention;

Fig. 6 is a fragmentary, enlarged section through a tubular electrode structure on line 6—6 of Fig. 5, made in accordance with a method of the invention; and

Figs. 7 through 11 are all enlarged, fragmentary sections of modified electrodes of the invention.

Fig. 12 is another apparatus for practicing a modification of the method of the invention.

One method of the invention comprises providing a suspension of refractory pulp fibers and metal particles, depositing refractory pulp fibers and metal particles into a method or strip structure, heating the metal particles in the matted fiber and particle structure to fuse the metal particles which when cool bond the refractory fibers together into a self-supporting fibrous strip, and rolling the self-supporting fibrous strip upon a storage reel or otherwise processing the strip so produced.

In a modification of the method of the invention, the fibrous material deposited upon a foraminous drum or otherwise formed into a mat, may have longitudinally-extending reinforcing filaments and/or cords present therein, and the fibrous material with or without reinforcing cords therein can be bonded together by means of spray-deposited molten metal particles which cool in contact with fibers to bond them together and with the fibrous mat being either preheated or cooled, as desired, so that the deposit of metal placed thereon can either be cooled immediately upon contact with such fibers, or may be thermally aided in penetrating into and bonding the fibrous mat, as desired.

One embodiment of apparatus for practicing one method of the invention is shown in Fig. 1 and it includes a suitable container or tank 1 in which a suspension 2 of refractory pulp fibers 2a is positioned. Additionally, usually metal particles 3 may also be present in the suspension of the fibers 2 with such suspension normally being provided in a suitable fluid, such as water, although an air suspension of the material may be used. The suspension 2 usually is agitated by conventional means such as a plurality of propellers 4 present in spaced portions of the suspension 2. The propellers 4 usually connect to drive motors 5 by means of shafts 6 so that the propellers 4 will be rotated rapidly to aid in maintaining a substantially uniform suspension within the tank 1.

The deposit of the fibers 2a and metal particles 3 into a continuous strip is aided or produced by the use of a suitable screen-covered or porous ceramic drum 7, such as is used in conventional paper-making apparatus. This drum 7 usually is journaled upon a tubular shaft 8 in a conventional manner and suitable means (not shown) are provided for rotating the drum 7 at a desired rate so that a continuous strip or mat of the material can be built up on the drum 7 contacting the suspension 2. Preferably, suction is used to aid in depositing the material on the surface of the rotating drum 7 so that a

fixedly positioned shield 9 is secured to and carried by the shaft 8 and bridges over substantially the entire arc of the drum 7 below the surface of the suspension 2. Furthermore, the tubular shaft 8 is provided with holes 10 which communicate with a bore 11 of such shaft 8 and suitable suction generating means (not shown) connect to the bore 11, so that a desired degree of constant suction can be created within the enclosure formed by the shield 9 and the bridged arcuate portion of the drum 7.

The fibrous material deposited upon the periphery of the drum 7, below the surface of the suspension 2, may be bonded together to form a self-supporting strip by suitable means, such as a high frequency induction heating coil 12. This coil 12 is positioned adjacent the periphery of the drum 7 as it moves from the suspension 2 and is connected to a suitable source of high frequency electrical energy so that the metal particles 3, deposited with the refractory fibers 2a on the surface of the drum 7, can be dried and sintered or fused so that the metal particles as they cool will bond themselves and will bind the various fibers together to aid in forming a continuous strip or sheet 13 from the fibers and metal particles. The metal particles 3 in the strip will fuse together to form a conductive structure, as they are present in the fibrous strip in contacting relation to each other.

A suitable deposit of spray-deposited metal may also be deposited on the strip 13 by a conventional metal spray gun 16. After the sprayed metal has solidified, it strengthens the strip 13 which may pass over an idler roll 14 as it is drawn from the surface of the drum 7 and be led to a conventional windup roll 15 for storage thereon.

If desired, the strip 13 may be subjected to a cooling action immediately following the heating action produced by the high frequency induction coil 12. It is generally preferable to dry the matted fibers as they move from the suspension 2 so that any conventional heating means, such as infra-red heaters 17, may be positioned immediately adjacent the drum 7 at the portion thereof immediately above the surface of the suspension 2 so that the fibrous material leaving such suspension can be dried prior to further processing thereof.

Preferably, the refractory fibrous pulp material used in the practice of the invention are made from glass, quartz, or ceramic fibers and a high melting temperature glass which is substantially free from iron or lead is preferably employed. The vitreous fibers should have average diameters not greater than about .0005 inch, and the fibers may be of suitable length such as from about 1/10 of an inch to 1 inch in length, or longer. The glasses used in making the fiberglass may be composed principally of oxides of silicon, boron, and aluminum, and are resistant to the action of electrolytes over long periods of time. Borosilicate glass fibers, alumina-silica fibers, quartz glass fibers, and other high melting temperature ceramic fibers may be used in producing the fibers used in the practice of the invention. When metal particles are used in the fibrous pulp suspension, such particles are preferably of one to ten microns in dimension. The invention is adapted for use with low melting point metals, such as aluminum, but may also be used with very high melting point metals, such as titanium and nickel and iron, since these fibers will withstand temperatures above 2300° F. without losing their permanent strength.

In one specific example of a vitreous fiber pulp suspension used in the practice of the invention, approximately one ounce of glass fibers and one ounce of metal particles (aluminum) were present per gallon of water in the suspension provided and this resulted in the deposit of a desired fibrous mat upon the forming drum 7.

A modified method of the invention is shown in Fig. 3 wherein a tank 20 is shown which has a suspension 21 of refractory fibrous material therein, and wherein a plurality of longitudinally extending parallel positioned textile cords or filaments 22 are provided to be embedded

in the fibrous strip to be produced. These cords 22 may be carried by one or more suitable rolls 23 adjacent the tank 20. A drum 24, like the drum 7 referred to hereinbefore, is provided and is rotated slowly through the suspension 21 with about 1/3 of the periphery of the drum 24 being below the surface of the suspension 21 at any given time. This suspension 21 has dielectric ceramic fibers therein and may have metal particles or other suitable particles therein, as desired, for use in bonding the fibers deposited upon the surface of the drum 24 together after such deposited fibers and the mat made therefrom are moved out from below the surface of the suspension 21. Suitable heating means, such as a high frequency coil 25, are provided adjacent the portion of the drum 24 as it leaves the suspension 21 so that if metal particles are present in such deposited fibers as can be heated by induced electrical currents, then such coil 25, which has high frequency electrical energy supplied thereto, will produce a rapid heating action in the particles in the deposited fibrous material. Thereafter, a conventional spray nozzle 26 may be used for depositing suitable film-forming metals upon the surface and/or in the interstices of the fibrous mat on the drum 24. Such metals may be sprayed by means of a molten metal spray gun or other conventional apparatus which can be used to deposit porous metal layers upon and in the fiber mat on the drum. The degree of penetration of the sprayed molten metal into the fibrous strip layer or mat on the drum can be regulated by maintaining the fibrous layer at a temperature which will chill the deposited metal on deposition and lessen the penetration thereof, so that suitable cooling means, such as cooling rolls or drums or fluid sprays 27 may contact the foraminous drum on the inner surface thereof for cooling the fibrous layer during spray deposit of metal thereon, if desired. Such drums or sprays 27 may have cooling fluid circulating therein and may be supported on brackets 127 carried by a tubular shaft 128 or a shield 129. The penetration of the sprayed metal can further be controlled by the velocity of the sprayed metal particles, as well as by control of the temperature of the particles so that the specific operating conditions will depend largely upon the type of product desired.

Woven gauze of textile cords may also be used in place of the parallel cords 22 described above. Furthermore, the porosity of the deposited layer is regulated by using more or less metal density in the spray of metal so that the deposit of the finely-divided spray of particles can be further varied by regulation of the amount of particulate metal contained therein.

Spray-deposit or sintering of metal on the fibrous materials on the drum 24 produces a self-supporting strip 28 which can be removed from the surface of the drum 24 shortly after deposit of sprayed metal particles thereon as such particles normally will solidify at once after deposit.

In order to build up an additional thickness of material upon the strip 28, it may next pass over a guide roll 29 and then be led around the periphery of a drum 30 like the drum 24. The drum 30 extends into and down below the surface of a suspension 31 contained in a tank 32. The suspension 31 may be of the same composition as the suspension 21, or it may have only dielectric fiber therein, and suction means may be used in both the drums 24 and 30 for aid in depositing fibrous material upon the drum 24 or the surface of the strip 27 exposed to the suspension 30, respectively. Thereafter, the laminated strip can be brought before additional heating means, such as a high frequency electrical coil 33, and be drawn out of engagement with the drum 30 by a pair of guide rolls 34 between which the laminated strip 35 is drawn. The strip 35 is made from the strip 28 by the deposit of an additional layer of metal thereon by a spray nozzle 36 which deposits metal onto the surface of the fibers deposited on the strip 28 while passing through the suspension 31.

If desired, the strip 28 can be twisted about its longitudinal axis when passing from the drum 24 to the drum 30 so that fibers can be deposited upon the metal-covered surface of the strip originally produced on the drum 24, rather than having the additional fibers deposited in the tank 31 be applied to the initial fibrous surface of the strip 27, as shown in Fig. 3.

Yet another modified type of apparatus of the invention is shown in Fig. 5 which apparatus is adapted to perform another modified method of the invention. This apparatus is adapted to produce a continuous tubular product which may be a composite fabric, a conductive strip material, a tubular fibrous dielectric sheet, or a composite conductive member with fibrous insulation thereon. A plurality of fibrous textile cords 41 are led from suitable reels or bobbins to pass over guide sheaves or pulleys 42 and into a bore 43 of a foraminous or perforate sleeve 44 at circumferentially spaced portions thereof. The sleeve 44 may be made from porous ceramic or metal or other suitable material and sufficient cords 41 are provided to position them in closely spaced relation within the bore 43. A stopper 45 is positioned in the bottom of the bore 43 to retain an aqueous fibrous suspension 46, like the suspension 3, within the bore 43. Such fibrous suspension 46 is supplied by a tube 47 that extends through the stopper 45 and connects to a suitable source of the suspension. The cords 41 are pulled past the stopper 45 which permits free movement of the cords and suction is set up on the foraminous sleeve 44 by a suitable vacuum pump 48 connected to a chamber 49 having a wall 50a in which the foraminous sleeve is positioned to aid in depositing fibers on the cords 41. The chamber 49 may be sealed around the ends and outer surface of the sleeve 44 if desired. Sufficient fibers, or fibers and metal particles, are accreted on the cords 41 to build a tubular structure therefrom. The sleeve or former 44 is, for example, electrically heated to dry the cords 41 and fibers as they move along the sleeve and pass from the sleeve 44. A spray head 51 is positioned within the foraminous sleeve bore 43 by a conduit 52 so that molten metal or metal powder such as aluminum, for example, may be sprayed onto the cords and fibers to provide a tubular strip or structure 53 which has a porous conductive metal inner layer. The spray head 51 may be a centrifuge, if desired, and the conduit 52 then would be rotated by conventional means. One suitable centrifuge of such type is shown in my co-pending application Serial No. 318,616, filed November 3, 1952, now Patent 2,816,826.

The fibrous suspension 46 may also be centrifugally deposited with or without metal particles therein on the travelling cords 41.

Fig. 6 shows an arc of the structure 53 which has the longitudinally extending cords 41 therein with fibers 54 from the suspension 46 forming a layer therewith. A porous metal inner layer 55 bonds the fibers and cords together as such metal penetrates into the fibrous layer to solidify therein and form a composite structure therewith. Suitable means (not shown) pull the structure 53 from the sleeve 43 at a desired rate.

The foraminous sleeve 44 and associated apparatus may be longitudinally split and is suitably secured together to provide a sealed structure the parts of which can be disassembled for repair or cleaning purposes.

Any suitable molten material may be deposited by the spray head and aluminum or nickel or titanium usually would be deposited when making an electrode of the class described while plastics or/and resins may be used if dielectric sheet or tube is to be produced. Wires may be used in place of some or all of the cords 41, if desired.

High frequency electrical heating means 100 may surround the conduit 52, which may be made from a ceramic, to maintain the temperature of the molten material therein, if desired.

The member 53 may be used when in tubular form, or

it may be split longitudinally, or it may be collapsed upon itself, as desired.

The tubular structure 53 when flattened would retain the metal layer on the interior thereof to make an insulated, conductive condenser material for use in either electrolytic, or electrostatic condensers. By slitting the tubular structure 53 longitudinally, it can be flattened to be used as a composite electrode and separator strip, as desired.

In practicing the method disclosed in Fig. 1, it may be desirable, in some instances, to apply a more protracted heating action than is indicated in Fig. 1, and a heating chamber may even be associated with a portion of the periphery of the drum 7 to give a sintering action on the metallic particles 3 included in the fibrous mat built up or accumulated upon the surface of the screen drum 7. Thus, a self-supporting, strong strip of material could be built up on the drum 7 merely by use of the glass fibers and metallic particles originally deposited as a mat on the drum, wherein the metallic particles are present in sufficient quantity, to bond the matted fibers together.

It also is possible to use the method of Fig. 1 when higher melting temperature metallic particles are used in the suspension 2 than the low melting metals set forth hereinbefore. Thus, small particles of nickel, iron or titanium may be used in the suspension 2 and then the mat produced usually should be subject to high frequency electrical induction heating thereafter, as such type of heating effectively renders the metal particles in the fibrous mat sufficiently sintered or fused that they would bond to the glass fibers to secure such fibers together into a strong, self-supporting mat for use as an electrode of the type referred to hereinabove. The induction heating does not affect the glass ceramic fibers in the mat in an injurious manner. Then when such metal particles cool and solidify, the glass ceramic fibers are still in contact with the sintered or fused metal particles so that a desired bonding action is obtained. The strip material so produced may be further built up by a sprayed-metal layer deposited thereon, as desired.

In some instances, it may be desirable to use suction action on more of the periphery of the drum of the apparatus than is indicated in the drawings and has been referred to before. Thus, a suction action may be set up within the drums at the zone thereof at which sprayed metallic substances, or other materials, are being deposited upon the fibrous mat on the drum surface. Of course, if desired, the rolls 27 referred to as the cooling rolls may in some instances have heating fluid supplied thereto so that such rolls would give a heating action upon the fibrous mat on the surface of the drum contacted by such rolls when the temperature of such mat is to be elevated prior to deposit of other material thereon.

In the spray deposit of metallic particles in accordance with this invention, and especially in the methods disclosed in Figs. 1 and 3, it may be desired to superheat the metal particles in transit, and such action may be secured by the use of high frequency coils placed in encompassing relation to the sprayed metal particles in transit. Furthermore, the sprayed metal particles may be bounced off heated rotating discs placed adjacent the periphery of the screened drums to aid in heating such metal particles and thereby obtaining a vaporization of the metal in transit to further finely divide the metal particles prior to deposit upon the fibrous mat on the surface of the drum.

The invention also could be practiced by the spray deposit of thermo-plastic dielectric materials, such as polyvinyl chloride, vinylidene chloride, or urea-formaldehyde compounds, for example, by the spray nozzle 36 shown in Fig. 3 so that such dielectric material would reinforce and aid in insuring the production of a dielectric sheet or film upon one surface of the strip material produced. After an electrode strip of the invention has thermo-

plastic materials deposited thereon, it may be desired to cool such strip of material by exposure to the atmosphere before it is pulled from its support, or by a positive cooling action prior to moving the strip so produced from the surfaces of the screen drum.

Reference now is particularly directed to the cross-sections of typical types of electrodes and dielectric separators or similar articles that may be prepared by the processes of the invention. Thus, in Fig. 2 a strip 13 is shown which has a conductive porous metal layer 60 on one surface thereof, whereas the metal particles 3 in the original suspension 2 have been fused together to bind a porous, conductive metal body 61 in the electrode 13 and with a plurality of the glass or other ceramic fibers 2a being heterogeneously positioned with and intimately bonded to the metal body 61. In Fig. 4, the electrode 35 is shown and it has a porous metal layer 62 on each outer surface thereof produced by the spray-deposit of molten aluminum, for example, on the base strip provided. The reinforcing cords 22 are clearly shown in Fig. 4, which brings out the preferred lateral spacing of such cords with relation to each other.

The cords 22 may be made from any suitable textile material such as cotton, or glass, or ceramic filaments or fibers. If metal particles are present in the original suspensions 21 and 31 from which the electrode 35 has been prepared, then the body of such electrode will be made from not only the fibers included in such original suspensions but with porous metal structure obtained when the original metal particles are fused together into bonded conductive relationship with each other by the heating or sintering action performed thereon.

In Fig. 7, an electrode strip 70 is shown, wherein ceramic fibers 71 are bonded together by a porous metal particulate conductive metal body 72, which electrode could be produced by the method disclosed in Fig. 1, by omitting the spray nozzle 16 and the porous spray metal deposit produced thereby. Likewise, an electrode 73, Fig. 8, may be produced by the general method as disclosed in Fig. 1, by omitting the spray nozzle 16 and the porous spray-metal deposit produced thereby. The electrode 73 may be produced by the general method as disclosed in Fig. 3, when the nozzles 26 and 36 are eliminated and the resultant electrode strip has longitudinally extending cords 74 therein, which aid in securing ceramic fibers 75 together in combination with the metal particles 76 present in the electrode 73 and in contacting, bonded relationship to each other to form means for securing the cords 74 and fibers 75 together.

Fig. 9 shows a slightly different type of a composite structure, wherein a porous metal layer 77 is provided, which layer is bonded to a ceramic fiber layer 78. This type of a structure could be produced by apparatus as shown in Fig. 12 of the drawings and described herein-after, or it may be formed in accordance with the method as indicated in Fig. 1 and wherein the inductive heating coil 12 will be moved to a top portion of the drum 7 and metallic particles would be deposited on the fibrous mat produced on the drums 7 below the surface of the suspension 2. There would be no spray nozzle 16 required, and the high frequency heating action should be sufficient to fuse or sinter the metal particles together and bond them to each other and to the fibrous mat on the surface of the drum, so that an integral, self-supporting electrode strip can be produced therefrom.

A special electrode strip 79 is shown in Fig. 10 and it comprises a porous metal center structure or strip 80 with a surface layer of dielectric ceramic fibers 81 being integrally bonded to each of the opposed surfaces of this metal layer 80 so that a porous metal structure is provided that has spacers therefor integrally bonded thereto. The layers of dielectric fibers may preferably extend over the edges of 80 also. A layer of gauze parallel fibers may be bonded inside the metal layer 80.

Fig. 11 shows yet a different type of an electrode 82,

wherein a central porous, particulate metal body layer 83 is provided and it has a fibrous dielectric surface layer 84 bonded to each surface thereof. These fibrous layers 84 both have longitudinally extending reinforcing cords 85 in laterally spaced portions thereof.

Fig. 12 shows yet another modification of the method and apparatus of the invention, wherein a continuous porous or screen belt 90 which is made from vitreous or fibrous or textile gauze material not affected by ordinary heating operations is led over the surface of a paper-making type of screen drum 91 and into a suspension of the ceramic fibers 92. As in the apparatus referred to before, fibers from the suspension 92 will be deposited on the surface of the drum 91 and suitable heating means 93, are positioned adjacent the surface of the suspension 92 for drying the fibrous mat on the surface of the drum 91 as it moves from the suspension 92. Thereafter, the belt 90 preferably is moved from the surface of the drum 91 and passes below a hopper 94 in which desired metal particles may be retained and be fed uniformly therefrom for building up a desired uniform thickness, even layer of metal particles on the fibrous mat on the belt. Next the belt 90 may pass below a hopper 95 in which ceramic fibers may be received and be suitably agitated therein as by a vibrator 96 so that such fibers can be deposited in a uniform thickness layer on the upper surface of the metal particles previously deposited on the belt 90. The belt 90 then passes adjacent to a high frequency heating coil 97 which is supplied with a suitable source of high frequency electrical energy so that the metal particles which are deposited by the hopper 94 can be sintered and/or fused to each other to form a conductive, porous layer therefrom, and to bond the fibrous layers on both surfaces of such metal particle layer thereto, so that the structure that is disclosed in Fig. 10 can be obtained.

It should be noted that when reinforcing cords or gauze like the cords 22 shown in Fig. 3 are used to reinforce the fibrous layer or mat of ceramic fibers, these fibers may have the reinforcing cord either positioned under the fibrous layer, in the fibrous layer, or on top of such fibrous layer, depending upon the time at which the cords 22 are brought into contact with the surfaces of the drum 24, when referring to the embodiment of the invention shown in Fig. 3. Preferably, these parallel cords or gauze are in the portion of the fibrous layer that is directly bonded to the sintered or spray-deposited porous metal layer built up on the fibrous layer to form an electrode therefrom.

It will be realized that by use of refractory vitreous fibers in making electrode strips in accordance with the invention, such fibers will not be charred or burned by any sintering action, or by the spraying of molten metal particles thereon. Likewise, in the operative article such as a condenser made by use of the electrode strips, the fibrous material will not be burned or charred in any way when in normal operation and when subjected to corona or scintillation or arcing actions or effects. Thus, the electrode strips will have good operative characteristics and properties and will not break down easily when in service.

The fiber layer as accreted without the molten particulate binder is too frail for easy production removal from the former on which the layer is deposited, but with the deposition of the molten particulate layer is easily removed without fracture.

The addition of the parallel cords to the accreted layer by particulate metal bonding increases the strength of the strip to all desired limits in use due to the fused attachment of the metal particles to the accreted fibers and to the parallel cords. The purity of the refractory fibers initially is advantageous in that they contain a minimum of conductive particles and their dielectric

strength is uniform and they are the most inert refractory fibers available to electrolytes.

One particularly desirable method of forming an electrode is by the general process disclosed in Fig. 3, wherein the longitudinally extending reinforcing cords would be embedded in the fibrous mat produced on the surfaces of the drum 24. In such instances, no metallic particles would be present in the suspension 21, wherein the spray nozzle 26 is used to produce a porous metal layer on only one side of the fibrous mat. The porous metal layer should be narrower in width than the fibrous layer, and the composite electrode strip would not be subjected to the lamination action of the suspension 31. Thus, the strip 28 would pass directly to a windup roll from the screen drum 24. By making the fibrous mat or layer wider than the coherent metallic layer, good edge spacing is provided in the resultant electrode which is of unitary construction and has its separator as an integral part thereof. The assembly of the electrode into the end item is facilitated by superimposing the dielectric fibrous layer onto a porous conductive metallic layer due to the unitary nature of the separator and porous electrode.

It may be desirable in some instances to take two electrodes of the general type shown in Fig. 9, and preferably wherein reinforcing cords have been included in the fibrous layer of the electrode, and place the metal layers of the two electrodes into face-to-face or contacting relationship. Then the laminated electrode could be passed to suitable welding means, either of the roller or spot type, in order to weld the two metal layers together, so that a high capacity, high strength electrode could be produced and which would be covered with fibrous dielectric material on the exposed outside surfaces thereof.

The invention also may be used to make a composite electrode from particles of titanium by bonding particulate titanium to a fibrous layer such as can be produced by use of the drums 7 or 24 in Figs. 1 and 3 of the drawings. The titanium particles would be deposited upon this fibrous layer and usually the metal particles would then be subjected to a sintering action, preferably in non-reactive argon atmosphere, to bond the metal particles to each other and to the fibrous mat or base layer. This sintering temperature for titanium would be about 1000° C. and the ceramic or glass fibers used in the base must be made from suitable materials, as described hereinbefore, and which are not affected permanently by exposure to such temperatures.

If an impervious strip is to be produced, the particulate metal layer in the strips can be completely fused by suitable H. F. inductive heating, so that an impervious metal layer is produced and such layer is intimately bonded to the fibrous layer.

This is a continuation-in-part of my co-pending application, Serial No. 249,525, now Patent 2,757,426.

While several complete embodiments of the invention have been disclosed herein, it will be appreciated that modification of these particular embodiments of the invention may be resorted to without departing from the scope of the invention as defined in the appended claims.

I claim:

1. A method of making continuous fibrous strip or the like comprising continuously suction-depositing refractory pulp fibers from a fluid suspension thereof to build a continuous porous mat therefrom on a former, and continuously spraying molten conductive particles onto the strip on the former to solidify thereon and therein to bond the fibers together into a self-supporting conductive strip and thereafter continuously removing strip from the former.

2. A method of continuously making a fibrous strip or the like comprising continuously suction-depositing dielectric fibers from a fluid suspension thereof to accrete a continuous porous mat on a former advancing through

the slurry, and spraying a particulate porous metal layer on the fibers thereon to bond the fibers together into a self-supporting strip and removing said so bonded strip from said former.

3. A method of continuously making a porous particulate conductive composite strip comprising continuously drawing a plurality of parallel cords made from dielectric material through a suspension of pulp fibers, continuously suction depositing pulp fibers on the cords to build a porous mat therefrom, continuously spraying molten metal particles onto one side of the mat to provide a conductive porous metal coating thereon, depositing additional pulp fibers on the sprayed surface of the strip, and spraying molten metal particles on such second layer of pulp fibers to provide a porous metal coating thereon.

4. A method of making a porous particulate conductive composite strip comprising continuously depositing high melting temperature vitreous fibers to build a porous mat therefrom, continuously spraying molten metal particles onto the mat to provide a porous conductive metal coating thereon and to bind the fibers together into a strip, depositing additional vitreous fibers on the unsprayed surface of the strip, and spraying molten metal particles on such second layer of fibers to provide a porous conductive metal coating thereon bonded to the additional vitreous fibers and the first metal coating wherein the second sprayed conductive metal coating is in electrical conductive relation to the first sprayed conductive metal coating.

5. A method of making a porous particulate conductive composite strip comprising drawing a plurality of parallel cords made from dielectric material through a suspension of pulp fibers, suction depositing pulp fibers on the cords to build a porous mat therefrom, spraying molten metal particles onto one side of the mat to provide a porous conductive metal coating thereon, and to make a strip therefrom, depositing additional pulp fibers on the sprayed surface of the strip, and spraying molten metal particles on such second layer of pulp fibers to provide a porous conductive metal coating thereon.

6. A method of making an electrode for an electrolytic condenser, or the like, comprising drawing a plurality of non-conductive cords over a rotating foraminous drum through a suspension of refractory pulp fibers, suction depositing refractory pulp fibers on the cords while on said drum to build a porous mat therefrom, and spray-depositing metal particles onto one side of the strip to provide a porous metal coating thereon.

7. A method of making a porous, particulate conductive composite strip, comprising positioning a plurality of non-conductive cords in longitudinal alignment in the form of a tube, drawing the cords through a refractory fiber suspension and accreting fibers thereon, and thereafter depositing molten metal particles on the fibers to provide a porous conductive metal layer bonded to the fibers and cords.

8. A method of making a dielectric strip comprising positioning a plurality of non-conductive cords in longitudinal alignment, continuously drawing the cords through a refractory dielectric fibrous suspension and depositing a layer of fibers thereon, and depositing molten particles on the fiber deposition to solidify such particles in and on the fibers and cords to bond them together.

9. A method of continuously producing conductive fibrous strip material comprising attaching a layer of stranded fibrous non-conductive textile material to an accreted layer of dielectric refractory fibers by spray depositing molten metal particles on and through the stranded fibrous textile material superimposed on the layer of fibers whereby the molten metal particles bond the textile layer and the accreted fibrous layer together.

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