

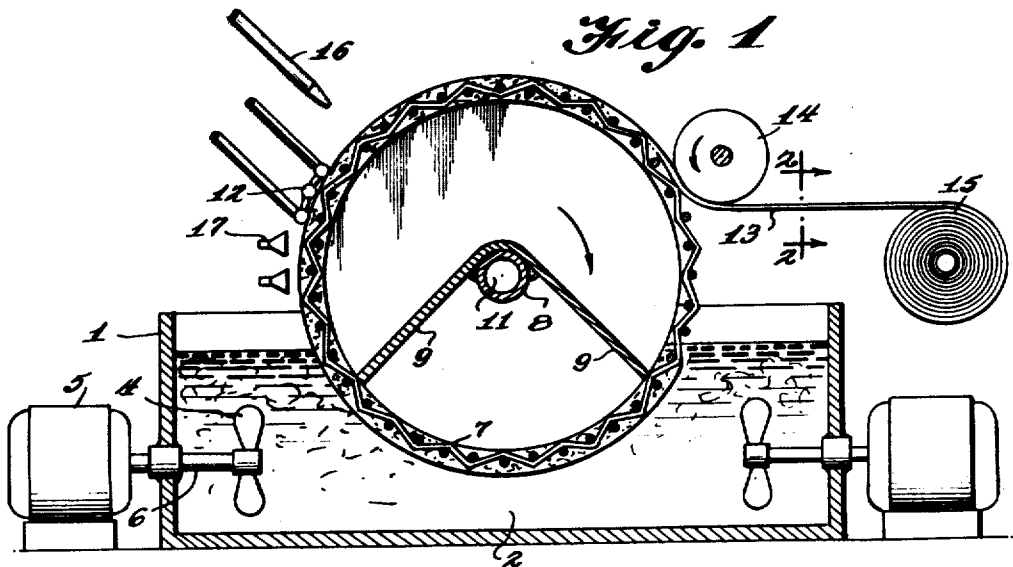
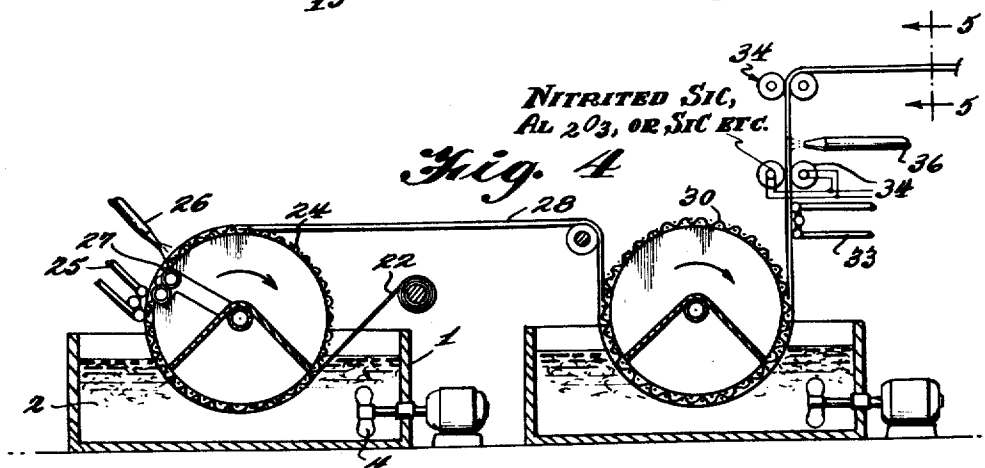
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METHOD OF PRODUCING STRIP MATERIALS

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METHOD OF PRODUCING STRIP MATERIALS

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9 Claims. (Cl. 29—419)

This invention relates to the production of strip materials, and more particularly to continuous production of conductive strips suitable for use in electrolytic condensers, batteries and the like. This application is a continuation-in-part of my applications Serial No. 324,020, filed December 4, 1952, and Serial No. 318,616, filed November 3, 1952, issued as Patent No. 2,816,826 on December 17, 1957. Said application Serial No. 318,616 is a continuation-in-part of my applications Serial No. 548,023, filed August 4, 1944, and Serial No. 722,829, filed January 18, 1947.

The strips of the invention may be generally described as comprising a porous mat of compacted metal fibers integrally bonded or fused at their conductive junctures to improve the conductivity therethrough. Such strips serve admirably as electrodes in electrolytic condensers since they provide a relatively large exposed surface to the electrolyte per unit weight. As a result, condensers prepared using such electrodes have a high capacity per unit electrode mass and are compact in size. The strips are preferably prepared from aluminum fibers, although they may be made using other conducting or non-conducting metal coated materials in fibrous form.

The primary object of my invention is to provide an improved method for continuously producing thin porous conductive strips from metal fibers or non-metallic fibers having an external metal coating.

Another object is to provide such a method which includes the step of fusing or adhering the fibers together at their conductive junctures to provide a strip having a minimum electrical resistance.

These and other objects will become apparent from the following description when read in conjunction with the accompanying drawings, in which:

Figure 1 is an elevational view, partly in section, of apparatus suitable for practicing one embodiment of the method of the invention;

Figure 2 is a cross-sectional view through a strip prepared in accordance with the invention;

Figure 3 is a view similar to Figure 2 showing a fibrous strip which has been sprayed with metal;

Figure 4 is an elevational view, partly in section, showing diagrammatically apparatus for practicing a modification of the method of the invention;

Figure 5 is a cross-sectional view of a strip produced on the apparatus and in accordance with the method of Figure 3; and

Figure 6 is a sectional view through a strip prepared from non-conductive fibers having an external conductive coating.

In one form my invention comprises suction depositing metal fibers on the porous surface of a drum rotating in a fluid suspension of said fibers to deposit a thin mat of felted interlocked fibers. To bond the fibers together to provide a permanent unitary structure or strip, the fibers may be fused by subjection to high frequency induction heating or they may be sprayed using

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a metal spray gun which deposits metal between the interstices of the fibers, thus connecting them together in conductive relationship one with the other.

The fibers employed for producing the strips in accordance with this invention may be made by methods known to those skilled in the art, for example, by cutting off fine shavings from a metallic bar or tube. Filaments are all preferably very fine having a cross-sectional dimension of from .001 to .005 inch. In producing the filaments I prefer to employ a cutting oil or coolant to prevent the metal from overheating. By cooling I have found that it is possible to produce filaments of greater length than if ordinary cutting methods are used.

Another method for preparing fibers suitable for the strip materials of the invention is by centrifuging superheated molten aluminum through tiny orifices equal in diameter to the desired diameter of the fiber, say, up to .005 inch. The surface of the centrifuge through which the metal is extruded should be traveling at about 4,000–5,000 feet per minute, with the temperature of the metal maintained at about 1450° F. The fibers produced will range in length from $\frac{1}{8}$ to $\frac{3}{4}$ inch. Longer fibers may be produced by reducing the speed of the centrifuge, and conversely, shorter fibers can be produced by increasing the speed. In making longer fibers the centrifuge may be equipped with an accumulator for the discharged fibers, which rotates with the centrifuge.

Other fibers suitable for use in the invention may be prepared from textile fibers or other dielectric materials such as glass, quartz or asbestos or synthetic resins such as tetrafluorethylene, having a relatively high melting point. These fibers are coated with a thin layer of metal such as aluminum by spray depositing in vacuo or inert atmosphere, for example, to provide a conductive coating on the external surface thereof.

Fibers of this type are relatively light in weight and may be suspended without particular difficulty in water with or without a wetting agent. If desired, a suitable adhesive may be dissolved in the water to help hold the fibers temporarily in place as they are suction deposited on the surface of the rotating drum. The fibers, after deposition, are permanently bonded to each other, preferably by fusing when pressed between ceramic dielectric members under the influence of high frequency induction coil and/or by spraying metal over the exposed surface of the felted fibers as taught in my pending application Serial No. 300,018, filed July 21, 1952, issued as Patent No. 2,777,929 on April 16, 1956.

It is also desirable to deposit the metallic fibers of the invention on a suitable base material such as a textile fabric made from glass or asbestos fibers, or in some instances it may be desirable to felt the fibers on a gauze material made from metal or from cellulosic fibers. It is also possible to mix non-conductive fibers such as rayon, cotton or the like in with the metal fibers in suspension and deposit the mixture on the surface of the rotating drum. These fibers may then be bonded together by spraying metal on and/or through the surface thereof. The addition of the non-metallic fibers will increase the porosity of the strip material and permit more rapid penetration by the electrolyte.

For strips that are to be used in condensers it may be desirable to provide a non-conductive or dielectric coating over the surface thereof. The strands may be provided with dielectric films in any desired manner known to those skilled in the art, for example, the strip may be subjected to electrolysis as an anode in a suitable film forming electrolyte such as a solution of borax and boric acid. The film forming operation is continued until the leakage current is reduced to the desired low value at

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the maximum forming voltage, which is ordinarily somewhat in excess of the voltage for which the condenser is designed.

It is also well known that the capacity of an electrolytic condenser may be increased by increasing the exposed surface area of the electrode. This may be conveniently done with electrodes made in accordance with my process by etching the electrode to roughen the surface of the fibers and thus increase the exposed area. One convenient method for etching aluminum is described in my prior Patent No. 2,154,027, issued April 11, 1939. The etching not only increases the surface area of the aluminum fibers, but also removes surface impurities therefrom. I have found that aluminum alloy fibers which have been etched may have excellent leakage characteristics even though the purity of the aluminum is below that of the high level usually required for making such condensers. If desired, the fibers may be etched prior to deposition on the drum or accretion thereof.

To improve the physical properties of the strip materials of my invention, particularly the aluminum strip materials, I have found that it is desirable to anneal the metal. This may be done in accordance with conventional procedure using temperatures ranging from 300-400° F. The strength of the metal fibers also may be increased by passing between spaced rolls prior to or after accretion.

Strip materials produced in accordance with the invention, after having been treated to provide a dielectric film on the surface thereof, may be incorporated into condensers as anodes for D.C. or A.C. condensers of the electrolytic type. The electrolyte preferably is a material which is highly viscous. The strip material is wound into a roll and then saturated and impregnated with an electrolyte of this type.

Reference is now made to the accompanying drawings showing suitable apparatus for practicing the process of the invention.

The apparatus shown in Figure 1 includes a container or tank 1 in which a suspension 2 of lightweight aluminum fibers having a mean diameter of, say, .001-.005 inch and a length of 1/8 to 1/2 inch or longer, are suspended. Although the suspension is usually prepared in water, it will be understood that any suitable fluid may be used, including air. In order to keep the fibers thoroughly mixed in the suspending medium, I have provided a plurality of propellers 4 mounted on shafts 6 and driven by suitable electric motors 5. The rotation of these propellers insures uniform distribution of the fibers throughout the suspending medium. The surface of the rotating drum 7 is preferably made from a porous ceramic material which may be covered with a suitable screen. The drum 7 is journaled upon tubular shaft 8 in conventional manner and suitable means (not shown) are provided for rotating the drum at a desired rate so that a continuous strip or mat of felted fibrous material can be built up on the surface of the drum as it advances through the suspension 2. Suction is employed to deposit the material on the surface of the drum. To direct the vacuum to the area of the drum where the deposition will take place, a fixed shield 9 is secured to and carried by the shaft 8 which bridges over substantially the entire arc of the drum below the surface of the suspension 2. A plurality of openings in the tubular shaft 8 communicate with the bore 11 therein so that suction means connected to the bore consistently evacuates the space enclosed by the shield 9. Thus, a constant degree of suction is created across the exposed surface of the drum between the extremities of the shield 9. The fibers are sucked onto the surface of the drum to provide a relatively thin uniform mat of interlocked fibers. A suitable adhesive such as starch, for example, may be dissolved in the liquid suspension to assist the fibers to remain adhered to the surface of the roll until such time as they are subjected to fusion which causes them to become integrally bonded one with the other. Usually,

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however, the fibers are sufficiently rough to cling together without such aid.

Infrared lamps 17 or other heat source may be provided just above the tank 1 to dry the deposited fibers or paper emerging from the suspension. For fusing the fibers at their conductive junctures a high frequency heating coil 12 may be provided. This coil is positioned adjacent the periphery of the drum as it moves from above the suspension 2 just above the heating lamps and is connected to a suitable source of high frequency electrical energy so that the metal fibers can be raised to fusion temperature, thus uniting them into a single self-supporting continuous mat or strip of at least 10 pounds per transverse inch tensile.

Conventional metal spray gun 16 may also be employed for depositing particulate porous metal on the fibers. The metal spray may be used with or without the high frequency induction heating coil 12. In the event the fibers are not previously fused, the metal sprayed onto the surface thereof through the gun 16 will serve this purpose. After the sprayed metal has solidified, it greatly strengthens the strip 13 and increases the capacitance area thereof. The strip is then withdrawn from the roll under the idler 14 and wound up on storage shell 15. The finished strip material will range from .005 to .020 inch in thickness and will have a cross section such as that shown in Figures 2 and 3. In Figure 2 I have shown a strip prepared from metal fibers which have been fused together and in Figure 3 the strip has been bonded into a unitary structure by means of the sprayed metal 20 on the surface and in the interstices of the fibers. These strips are uniformly interstitially porous and uniformly permeable to electrolyte.

A modified method of the invention is shown in Figure 4 which has a tank similar to that shown in Figure 1 containing metal fibers in suspension. In this modification the metal fibers are deposited not directly on the surface of the drum but rather on a textile fabric 22 which is porous in nature and is banded around the surface of the drum. The fabric 22 may be a woven fabric, a fibrous batt, or it may consist of a plurality of parallel closely-spaced individual cords or metallic filaments (non-woven fabric). These cords are preferably made from a dielectric yarn or monofilament or metallic thread or fibers. Strips made in accordance with the process of Figure 3 and Figure 4 could be used directly in a condenser. The drum, high frequency coil and the spray gun may be similar in this version as they are in Figure 1. However, I have also shown cooling rolls mounted against the inner surface of the drum, indicated by the numeral 27. These rolls are provided with cold water or other suitable means for maintaining them at a low temperature in order to conduct heat from the fused fibers which have just been subjected to high frequency induction heating by the element 25. If desired, the surface of the strip may be coated with molten metal by spraying through the spray gun 26. The degree of penetration of the sprayed molten metal into the fibrous strip can be regulated by the amount of suction and/or by maintaining the fibrous layer at a temperature which will chill the deposited metal on the deposition surface and lessen penetration thereof. Consequently, the cooling rolls 27 may be employed with this end in mind as well as for the purpose of pressure ironing or setting the fused fibers immediately after subjection to the induction coil 25.

Apparatus and method for fusing the fibers is taught in my co-pending application Serial No. 300,018, filed July 21, 1952, issued as Patent No. 2,777,929 on April 16, 1956, and this apparatus and method may be used in Figure 3 and Figure 4 and applied to the ceramic rolls 34 of quartz associated with high frequency coils to weld or fuse the metallic elements together as well as to produce uniform gauge material.

In order to build up an additional thickness of fibrous material on the surface of the finished strip 28 being re-

moved from a drum 24, the strip may be passed over a second drum 30 where it is given similar treatment. It should be pointed out that even though the fibrous strip has been sprayed, it is still sufficiently porous so that the suction on the enclosed segment of the roll beneath the surface of the suspension will draw the fibers readily to the surface and hold them there. Additional treating means such as an induction coil 33 for fusing and a spray gun 36 for depositing additional metal on the surface may be provided. The strip manufactured in accordance with the apparatus just described is shown in Figure 5 and has a dielectric textile base 22 and a felted layer of metal fibers 13 overlaid with sprayed metal 20.

In Figure 6 I have shown a modified form of conductive strip made from fibers of dielectric material 38 coated with metal 40. These metal coated fibers are deposited from a suspension just as the metal fibers of Figure 2. The metal coatings 40 of adjacent fibers are in contact to provide a conductive path. Reference may be had to my parent applications Serial No. 318,616, now Patent No. 2,816,826, and Serial No. 324,020, above referred to, for additional suitable methods for making the metal fibers useful in this invention, and particularly, to Serial No. 579,952, filed April 23, 1956, which teaches the method of producing metallic filaments from a continuous annular casting which reconstitutes itself continuously and acts as a holder for a rotating annular casting presenting a constant cutting face to an array of fiber producing cutting tools.

Although I have illustrated preferred embodiments of my invention, it will occur to those skilled in the art that other modifications may be made without departing from the true spirit and scope of the invention, and that it is not my intention to limit the invention other than as necessitated by the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A method of continuously making a conductive strip material which comprises continuously suction depositing metal fibers from a fluid suspension thereof to form a porous mat and continuously integrally bonding the fibers at their conductive junctures to improve the electrical conductivity therebetween.

2. A method of continuously making a conductive strip material for an electrolytic condenser or the like which comprises continuously suction depositing metal fibers from a fluid suspension thereof to form a porous mat and continuously spraying molten metal over the fibers to improve the electrical conductivity therebetween and increase the surface area of the mat.

3. A method of continuously making a conductive strip material for an electrolytic condenser or the like which comprises continuously suction depositing metal fibers from a fluid suspension thereof to form a porous

mat, continuously spraying molten metal over the fibers to improve the electrical conductivity therebetween, and annealing the fused mat.

4. A method for continuously making a conductive strip material for an electrolytic condenser or the like which comprises continuously suction depositing metal fibers from fluid suspension onto a textile base to form a porous laminated mat and continuously integrally bonding the metal fibers at their conductive junctures.

5. A continuous method for preparing a porous conductive strip which comprises suction depositing metal fibers from a constant density fluid suspension thereof on a porous deposition surface advancing through said suspension at a constant rate to form a porous mat and integrally bonding the fibers at their conductive junctures.

6. A method for making a conductive strip from metal fibers which comprises rolling the fibers to increase their strength, suspending said fibers in a fluid suspension, suction depositing said fibers from said suspension to form a porous mat, and spray coating said mat with molten metal to improve the electrical conductivity between the fibers.

7. A method of making a conductive strip for an electrolytic condenser or the like which comprises suction depositing aluminum fibers from a fluid suspension thereof on a porous deposition surface to form a porous mat, fusing said fibers at their conductive junctures in a high frequency inductive field, and spraying molten aluminum over the fibers to improve the electrical conductivity and increase the surface area of the mat.

8. A method of continuously making a fibrous strip or the like comprising continuously suction-depositing metal fibers from a fluid suspension thereof to accrete a continuous porous mat on a former, and depositing a particulate porous metal layer on the fibers to bond the fibers together in a self-supporting strip, and removing said strip from said former.

9. A method for continuously making a reinforced conductive fibrous strip which comprises suction-depositing metal conductive fibers from fluid suspension onto a reinforcing porous base made from non-conductive fibers to form a porous laminated mat, and integrally bonding the metal fibers at their conductive junctures.

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Disclaimer

2,903,787.—*Joseph B. Brennan, Cleveland, Ohio. METHOD OF PRODUCING STRIP MATERIALS.* Patent dated Sept. 15, 1959. Disclaimer filed Apr. 5, 1963, by the assignee, *Armour Research Foundation of Illinois Institute of Technology.*

Hereby enters this disclaimer to claims 1 and 9 of said patent.
[*Official Gazette June 18, 1963.*]

Notice of Adverse Decision in Interference

In Interference No. 91,294 involving Patent No. 2,903,787, J. B. Brennan,
Method of producing strip materials, final decision adverse to the patentee was
rendered June 12, 1963, as to claims 1 and 9.
[*Official Gazette August 20, 1963.*]