METHOD OF PRODUCING STRIP MATERIAL

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Filed Apr. 14, 1958, Ser. No. 728,346

2 Claims. (Cl. 29—420.5)

The present invention relates to the continuous production of metal strip as such, or as a composite strip of which one component is produced according to my process and another component is a metal strip of preferably a porous or fibrous strip. Composite strips which include such a porous or fibrous component and the metal strip applied thereto by my method are adapted for use as improved thermal or vapor barriers, or in electric condensers, for example.

The present application is a continuation-in-part of my prior pending applications, Serial No. 334,130, filed January 30, 1953, and Serial No. 356,819, filed May 22, 1953 now abandoned: the former application being related to a copending application, Serial No. 45.881, filed August 12, 1948, and now Patent No. 2,659,400, this last application being a continuation-in-part of Serial No. 548,023, filed August 4, 1944, and now abandoned in view of its continuation in application Serial No. 152,412, now Patent No. 2,701,775. The present application is also related to my copending applications Serial No. 324,020, filed December 4, 1952, now Patent No. 2,870,689 Ser. No. 336,227, and Serial No. 744,777, the last being filed April 29, 1947, and now abandoned.

The present application is primarily directed to the spraying of molten metal onto a porous base material or sheet and to the manner and treatment thereof, particularly to form a highly polished speculum finish or effect.

One object of the present invention is to provide a method by which an elongated metal strip of desired uniform characteristics is continuously produced by spray discharging at constant temperature and under the influence of constant pressure molten metal against a uniformly moving heated base member of which base member the spray deposited layer either becomes a part, as aforesaid, or from which base member the spray deposited layer may be continuously removed as a separate metallic strip.

Another object of this invention is to provide a method of continuously producing metallic strip of the character referred to by spray discharging of molten metal without the usual gaseous blast as is required in conventional metal spraying processes.

Still another object of this invention is to provide a spray method of continuously producing metallic strip wherein vaporization of the sprayed metal particles is achieved without requiring a separate gaseous blast for the breaking up of the particles as discharged through a spray nozzle.

Another object of this invention is to produce finer grained and/or finer and smaller particles by spray depositing metals than has heretofore been obtainable in the spray projection of metal particles.

With reference to the formation of metal impregnated porous sheets or fabrics, these have been previously made by spraying metal against a porous band, such as 40 mesh cotton gauze, thin paper, or asbestos, and usually the molten metal is sprayed from a stationary spray gun onto such band as the latter is moved past the gun. In order that the sprayed particles will adhere to the porous band, the metal particles should be plastic when deposited and should also be uniformly distributed so as to substantially uniformly coat the band. However, it has been difficult to coat wide bands by the methods known heretofore; and, in fact, prior processes have been used to coat only narrow bands, such as 3 or 4 inches wide. Furthermore, the temperature of the deposited particles must be held within very close limitations to have the desired plasticity when deposited so as to interlock on, and adhere to, the fibers of the porous band. Hence, previous types of porous sheets of this class have not been uniform and have been expensive to manufacture.

Hence, it is another object of this invention to avoid and overcome the foregoing and other difficulties with prior types of processes for producing porous sheets for use as thermal or vapor barriers or as electrodes and to provide an improved method of obtaining uniform sheets characterized by its ability to be used with any type of metal particle deposit apparatus.

Another object of the invention is to utilize suction in depositing metal particles on a base sheet.

Another object of the invention is to provide a method of uniformly covering a wide base with metal particles which are integrally bonded to each other and to the base.

Another object of the invention is to control the temperature and velocity of the metal particles as they are in transit towards the moving base sheet.

Yet another object of the invention is to roll out, spread, or press the metal particles, while in plastic condition, against and into a porous base sheet.

A further object is to provide a control for the deposit of metal particles on a base sheet.

A further object is to accelerate the deposit of metal particles on a base band.

Still other objects of the invention are to secure uniform plasticity in and velocity of metal particles as they are being deposited on a base; to form an oxide coating on the particles as they are deposited; and to collect the unused metal particles in the stream in an economical manner.

Other objects and advantages of the present invention will become apparent as the following description proceeds.

To the accomplishment of the foregoing and related ends, the invention, then, comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principle of the invention may be employed.

In said annexed drawings:

Fig. 1 is a diagrammatic view of apparatus embodying and for practicing the principles of the invention;

Figs. 2 and 3 are similar views of modified apparatus for use in practicing the invention;

Fig. 4 is a side elevation view, partly in section, showing schematically one form of apparatus for performing the present process wherein the spray deposited metallic strip constitutes one component of a composite strip;

Fig. 5 is a cross-section view of a somewhat enlarged scale along the line 5—5, Fig. 4;

Fig. 6 is a fragmentary view showing a modified apparatus for the continuous production of a metallic strip as such;

Fig. 7 is a fragmentary view of still another apparatus for continuously producing metallic strip;

Fig. 8 is a cross-section view of the lower end portion of one type of spray nozzle which may be employed.
for securing a fine division of sprayed metal without requiring a gaseous blast; Fig. 9 is a view similar to Fig. 8 except illustrating a different form of spray nozzle also for achieving fine subdividing of molten metal without requiring a gaseous blast; Fig. 10 is a bottom plan view of the Fig. 9 spray nozzle as viewed along the line 9—10, Fig. 9; Fig. 11 is a cross-section view illustrating one manner of producing metal of thicknesses only a few millimeters or less by my process in instances where the distribution of the sprayed particles is the most concentrated at the center of the spray cone and progressively less concentrated around the periphery thereof; and Fig. 12 is a diagrammatic view of modified apparatus for use in practicing the invention. Now referring in detail to the drawings, a base sheet 10 is provided which passes from a storage roll 11 around an idler roll 12 to a wind-up roll 13, which may be driven in a conventional manner. The sheet 10 may be made from cotton cards, canvas, porous paper, fiber glass, etc., or the sheet could be made from cotton cards with cellulose acetate fiber therein with the latter sheet material usually being rolled while heated prior to its use in accordance with the teachings of this invention. In all events, the sheet 10 is impregnated with metallic particles from the reservoir 16 and is provided with a metal supply and their functioning is no part of the present invention. The nozzles deliver a gas blast which has liquid, or plastic metallic particles therein that are to be deposited on the base sheet. This particle stream cannot be released immediately adjacent the sheet 10 or it would not deposit in the form of a porous layer, as is desired. Hence, the nozzles 14 and 15 are spaced from the sheet 10 with the spacing shown in the drawings being exemplary only. Due to such travel, the plastic metal particles in the blast cool rapidly, partly due to the expansion of the carrier gas and partly to striking the atmosphere. As hereinafter explained, the nozzles can operate without air blast. As a salient feature of the invention, a suction is provided to aid in depositing the metal particles on and in the sheet 10. The amount of suction can be varied quite easily to provide an effective regulator for controlling the conditions of deposit of the metal particles. The suction at 16 and 17, respectively, are positioned in opposition relation to the nozzles 14 and 15, and they connect to a conventional suction generator, as a fan. Use of the idler roll 12 permits the sheet 10 to be doubled back between the nozzles and suction tubes, as shown in Fig. 1. The suction set up on the sheet should be sufficient that it accelerates movement and deposit of the particles, and the effect of the suction may be enhanced, if desired, by providing extensions on the suction tubes. The extensions (not shown) could be placed between the doubled portions of the base sheet in alignment with the nozzles and even have sections telescoped over the ends of the nozzles, if desired. As a further feature of the invention, heating means, such as induction coils 18, are placed between the doubled sections of the sheet 10 in alignment with the nozzles and suction tubes. The coils 18 have a high frequency electrical current supplied to them by any conventional source so as to set up a heating field therebetween sufficient to heat small conductive particles substantially instantaneously as they pass therethrough. Ordinarily, the metal particles will be at an elevated temperature when they reach the coils 18 which then would at least maintain their temperature at a desired level. By use of suction as an aid in depositing metal particles on the base sheet 10, combustion of such sheet, if combustible, is prevented due to the excellent temperature control effected. The coils 18 are usually kept at a temperature of the deposited particles which should be sufficiently plastic and be moving at such a high velocity as to spread somewhat over the sheet on impact. Deposit of the particles by suction also permits them to be originally propelled by a low pressure gas, which then would be used for other purposes. However, in some instances, no propellant gas is required when employing nozzles of the type shown in Figs. 8 and 9, for example. To aid in securing the metal particles P to and in the sheet 10, it may pass between pairs of rolls 19, 20 and 21 which may compress the sheet 10 slightly to aid in integrating the metal particles with the sheet. The pairs of rolls at least flatten the metal particles extending furthest from the sheet and serve to bond the metal particles and sheet together firmly. The pairs of rolls 19, 20 and 21 have a high frequency electric current supplied thereto by pairs of leads 23, 22 and 24 connected thereto and to a source of such energy. These rolls 19, 20 and 21 may be formed from any desired material which is not electro-conductive and may comprise a ceramic or a dielectric material with the high frequency coil or plates means or other device being positioned therebetween to wind up a high frequency field therebetween. Hence, the combined pressure set up by the rolls and the plasticizing effect set up by heating the deposited particles produces a permanent bond between the metal particles and the base sheet and/or fibers thereof. The bonding is especially important for the first metal deposited on and in the sheet so that the rolls 19 are of especial value, while the rolls 20 and 21 may be omitted, when desired. However, in this respect, it is emphasized that the feature of heating the deposited metal while it is being passed through the rolls is very important, because under these conditions it is possible to roll down and spread out the metal deposited on a fibrous base, for example, that is, the metal can be spread out and readily distributed due to being heat softened without breaking or splitting or unduly straining the base, even though the latter is relatively plastic. This manner, a spreading out of the metal deposited can be attained independently of a corresponding spreading or stretching of the base material. The material deposited by the invention usually is aluminum, but other materials or mixtures of materials such as magnesium, tantalum, aluminum oxide, etc., could be used. The metal particles are preferably a material such as porosity or filler particles such as boron acid or particles or fibers of a synthetic thermoplastic like cellulose acetate in some instances. The metal particles deposited could be in particle form prior to such deposit action and the case could be carried by a vibrating screen and usually be started toward the base sheet by gravity or a suction action. Also, the particles could be mixed with a carrier gas in a cyclonic mixer and passed therefrom to the base sheet. In such modifications, the particles could be heated in any desired manner as by passing through additional coils, like coils 18, prior to deposit on the base sheet. If the base sheet 10 is to be used in making porous electrodes, production of the desired porosity is expedited by placing aluminum oxide, mica, or other non-conduc- tive tubing within the bases of the coils 18 and having the metal particles flow through such coils. The tubing now will prevent the particles from depositing on the coils. Fig. 2 of the drawings show how two base sheets 30 and 31 can have metal particles P sprayed between them to aid in bonding the sheets together and in metal impregnating them. The sheets pass between a pair of rolls 32 immediately after the particles strike the sheets. Suction tubes 33 and 34 are provided to aid in the particle
deposit, as hereinbefore explained. As in the apparatus of Fig. 1, the rolls 32 may have high frequency current supplied thereto, if desired, and a temperature control coil may also be provided between the sheets 30 and 31 as hereinbefore explained. The conical base of rolls 30 and 31 forms a right therebetween and metal particles deposit in the bight as well as on the adjacent portions of the base sheet.

Apparatus for coating opposite sides of a base sheet 40 is disclosed in Fig. 3. Nozzles 41 and 42 are provided to deposit against opposite surfaces of the sheet 40, while suction tubes 43 and 44, respectively, are aligned with the nozzles. Again, heating rolls and coils may be used if desired.

The suction depositing action helps to distribute, uniformly, the metal particles being deposited and permits any of several types of metal deposit means to be used so that wide base sheets can be uniformly covered with metal both laterally and longitudinally of the base sheet. Such uniformity is extremely desirable in making condensers and a uniform capacity sheet which can be efficiently and rapidly produced, is provided by the invention.

By heating the metal particles, such as aluminum, in transit in the air, an oxide coating or film is formed on such particles. This reduces the cost of and time required to finish the resultant sheet since it normally has an insulating film formed therein before being ready for use, such as an anode in an electrolyte. The partially oxide coated metal also may be processed and electroformed at lower current cost than unoxidized metal. The oxide film on the surface of the metal particles is punctured on deposition and impact permitting the molten or plastic material of each particle to make good, low resistance electrical and intimate physical contact with the porous base sheet, resulting in a flexible, porous layer of particles if kept thin enough, preferably about .010 inch in thickness, but not over .125 inch.

According to my invention, the same sheet may be doubled back on itself any desired number of times, or the other sheets may be led past a nozzle behind the sheet adjacent the nozzle so that the greatest possible percentage of the metal particles passing through the first sheet or layer can be deposited on one of the sheets, or layers. Multiple sheets may also be metallized simultaneously. Metal particles passing into the suction tubes can be recovered for re-use in any conventional manner. Their removal from the coating zone by the suction action avoids the health and safety hazard which would be created if the metal particles would be allowed to remain in the atmosphere adjacent the depositing apparatus.

Referring now to Figs. 4 and 5, the apparatus there shown comprises a molten metal supply crucible 51 into which molten metal or solid metal particles may be continuously or intermittently supplied as through the charging passage 52. The metal in said crucible 51 is heated to molten condition or is maintained in molten condition by means of the high frequency induction coil 53 or equivalent heating means associated with said crucible. Leading from said crucible is a discharge conduit 54 to which the intake port of a pump 55 or the like is connected, the molten metal displaced by said pump being discharged under desired pressure through the spray nozzle 56. The metal flowing through the spray nozzle at desired pressure is maintained at a desired temperature and fluidity as by means of the high frequency induction heating coil 57 therearound. Obviously, other heating means may be employed, such as electric resistance heaters, hot fluid circulated through the passage in the nozzle, or equivalent heating means. The crucible 51 is also provided with another passage 58 through which gas under pressure or inert gas may be admitted; and, when pressure gas is employed, the pump 55 may, in some instances, be omitted so long as the pressure gas is uniform and the static head of metal in said crucible is maintained constant so as to secure uniform spraying.

The molten metal from the spray nozzle 56 is sprayed into an enclosure 59 which is preferably maintained under partial vacuum as by means of the passage 60 connected to a suitable vacuum source. Within said enclosure is a supply roll 61 of strip material 62 which, for example in the production of electrodes for electric condensers, comprises paper or other porous or fibrous filament batts, cords, yarn, or gauze of refractory material such as asbestos or quartz. In order to prevent spraying off the edges of said strip 62, a folding device 64 is provided which folds under the opposite edge portions of said strip 62 as best shown in Fig. 5. Inasmuch as the strip 62 is at a temperature at or above the melting point of the sprayed metal, the sprayed particles will immediately coalesce and when solidified, there is produced a metallic strip 65 of the desired porosity; and, if desired, the composite sprayed layer 65 and strip 62 may be passed between squeeze rollers 66 when hot and then the composite strip 65—62 is wound onto a take-up roll 67. Thus, it can be seen that metal strip is produced continuously so long as molten metal is supplied into crucible 51 and a base strip 62 is moved in the spray field. The member 68 serves as a support for the strip 62 while being sprayed. In most instances, it will be desired to heat the sprayed particles in transit from the spray nozzle 56 to the base strip 62 in order to maintain the particles in molten condition at the time that they impinge upon said base strip, and for this purpose, a high frequency coil 69 has been found to be the most efficient especially when arranged as to encircle the spray field in uniformly spaced relation therearound. In some instances, an electric or gas furnace may be employed.

Where composite strip is desired, the base 62 may be heated to a temperature above the melting point of the metal if the base is composed of refractory fibers or if a bonded metal coating is desired on said base. A subsequent coating of a more porous nature may be applied after a first bonding coalescing molten metal particulate bonding spray.

In instances where it is desired to produce metallic strip as such, it is preferred to employ an endless highly polished metal band 70 as in Fig. 6, which passes over guide rolls 71 and 72 and is driven by one of them so that at least one stretch of said band moves under the spray at a uniform linear speed. Again the process is conducted under a partial vacuum in an enclosure 61 and a suitable stripper 73 is provided to separate the spray deposited layer 74 from said band 76, whereupon the spray deposited layer may pass through pinch rolls 75 and be continuously wound around a take-up roll 76. It is also contemplated to perform my unique process by means of an apparatus such as illustrated in Fig. 7 wherein a rotary drum 80 is provided against which the spray is directed and from which drum the spray deposited layer 81 may be continuously removed with the spray deposited layer passing or not between pinch rolls 82 and being wound on a take-up roll 84. The drum surface, therefore, in effect, constitutes an endless band corresponding to band 70 as shown in Fig. 6; and, as in the Fig. 4 apparatus, a base strip as is shown in Fig. 7 extends across said drum and the spray directed against said base strip. In such instance, the edges of the base strip may again be folded under to prevent spraying onto the opposite edge portions thereof.

One important feature of my process as herein disclosed, is that it is not required to employ an atomizing gas or gaseous blast for the subdividing of the molten metal. In the spray nozzle disclosed in Fig. 8, the molten metal is caused to flow through several small passages 85 which converge so that the streams issuing there-
from will collide with one another and thereby effect a breaking up of the molten metal into very small particles. For example, when spraying molten aluminum at a temperature of 1800° F. and at a pressure of 30 to 90 p.s.i. through .005" passages, the average particle size will be under 10 microns.

The spray nozzle illustrated in Figs. 9 and 10 includes an orifice plate 99 which has an orifice 91 therethrough terminating in an oblong groove 92 on its outlet face which is effective to break up the stream into fine particles and to spread the same in the form of a relatively narrow fan. Here again, no gaseous blast is required in order to break up the molten metal into extremely fine particles suitable for the practice of the present invention. In instances where the sprayed particles are not uniformly distributed in the spray field, uniform thickness metal strip may be produced by having, for example, three spray nozzles staggered relative to the path of the base strip so that the aggregate of the three non-uniform deposits over the width W will be of uniform thickness. Obviously, instead of providing several spray nozzles, as foresaid, it is possible to obtain the same results with one nozzle by successively passing the base strip 96 under different portions of the spray cone. For further reference, attention is directed to the Robert M. Brennan Patent No. 2,187,544 which was granted on May 27, 1935, and which discloses an apparatus and method by which uniform thickness spray deposited layers of metal are produced.

The present invention also concerns the vaporization of metal for the production of elongated metal strip, again without requiring a gaseous blast. In order to effect extremely fine division of the molten metal, the same is super-heated and discharged into a space maintained at a pressure (usually a partial vacuum) at which the super-heated metal will vaporize and, in effect, the vaporized metal will condense upon the base strip. For this purpose, the space into which the super-heated molten metal is discharged is preferably maintained under a partial vacuum so that the extent of super-heating need not be as great as when the space is at normal atmospheric pressure or at some super-atmospheric pressure; and directional deposition is achieved as well as increased production.

My process as herein disclosed, is applicable with virtually all metals and alloys, among which are included for example, titanium, nickel, copper, lead, aluminum.

A distinctive feature of this invention resides in that particulate metal may be deposited onto, or intercalated in a fibrous base which base is maintained at an elevated temperature equal to, or in excess of the melting point of the deposited particulate molten metal during the time of deposition or thereafter with the result that the particles of molten metal coalesce with the fibers of the base material and join, and bond the fibers together to produce a very strong material when thereafter the deposited molten metal particles are solidified. This material is strength retaining up to the melting point, or softening point, of the molten particulate material deposited and coalesced with the fibrous base material.

The methods of associating the fibrous material and the molten particulate material are, for example, described in my copending application U.S. Serial No. 324,020, filed December 4, 1932, and also in my application U.S. Serial No. 43,881, filed August 12, 1948, now Patent No. 2,539,490.

According to this invention, any kind of fibrous material may be used so long as it will withstand the temperatures involved which are equal to or in excess of the melting point of the molten material applied thereto for bonding and making a strong fabric. The particulate molten material may be, for example, applied in continuous layer form to the fibers while molten or solid and fused and coalesced thermally immediately or subsequestly and then chilled to solidify and effect the bonding action. Such a layer may be applied by spraying, spreading, or by other means, but in any case, the metal particles are thermally coalesced at least in sufficient number to establish bond between substantially all the fibers associated therewith.

A series of applications of particulate bonding material may be made of varying density, or similar density with reference to particle distribution. One method is to sparsely deposit metal particles on or in the fibrous base and then thermally coalesce them by melting the particles and simultaneously heating the fibrous base to equal or exceed the melting point of the metal particles and therefor solidify the metal particles by cooling the same with the fibrous base. Such procedure need not necessarily produce a conductive strip material but it does produce a strip material much stronger than the fibrous base. The fibrous base is preferably moved at a uniform rate during the application of the metal particles thereto and such base is constantly heated to coalesce the metal particles at or near the point of application and thereafter cooled to solidify the metal particles.

Melted or sintered metal particles may, of course, be applied in continuous conductive layer form also as can readily be understood either in a single or multiple operation.

By having the base and the applied metal particles at, or above the melting point of the metal particles and then chilling the composite material, a material at least several times as strong in tensile compared to the fibrous base alone is produced.

Material so produced may be conductive throughout if the applied particles are welded together and abutting, or it may be conductive in some areas and non-conductive in others, depending upon the density and pattern and distribution. In any case, a fabric is made according to this invention which is gas tight as strong as the untreated fibrous base material and capable of withstand temperatures while retaining its great strength up to the heat softening point of the bonding particulate material.

Initial or subsequent layers of particulate bonding materials may be applied to one side only of a refractory fibrous base layer so that a continuous composite coherent conductive layer which is non-porous and impervious may be produced in continuous strip form. Non-porosity in the applied metallic layer is produced by heating the applied metallic layer beyond its melting point while associated with the fibrous base layer. No material may be used which will withstand the temperatures involved without objectionable change or the fibrous base material may be kept cool by contact with heat-extracting surfaces.

Referring now to Figure 12, still another manner of practicing the present invention is illustrated. In this case, a porous sheet 100 of the type hereinafter described is advanced from a roll 101 between rollers 102 and then in succession around idler rollers 103, 104, 105, 106, and 107. It will be noted that the sheet 100 is doubled back on itself as in Figure 1 and particularly that the two lengths 100a and 100b travel an angularly reversing path to define two lengths of the sheet moving in substantially opposite directions and traveling in planes which form an acute angle at the adjacent ends of the lengths 100a and 100b. Heated gas passes through tubes 108 and 109 to draw molten metal from a ceramic spray tube 110 and a ceramic crucible 111 which are heated by the resistance heaters 112. The gas from tubes 108 and 109 atomizes and sprays the resulting molten particles against a length 100c of the sheet 100. Preferably some of the molten metal particles are smaller than some of the openings in the porous sheet 100, so that such particles pass through and coat the contiguous surface of the succeeding length 100d. This simplifies the necessary apparatus very much, reducing the requirement by one-half.
because the indicated single spray apparatus can be used to coat both sides of a fabric using apparatus and methods herein disclosed.

A similar spraying nozzle arrangement indicated at 113 sprays molten metal between the adjacent or inwardly directed surfaces of lengths 100a and 100b. In this instance, the desired open angular relation of these lengths, the molten metal particles are spread into an elongated form as they strike the surfaces, thereby facilitating the deposition of a smooth, more uniform layer or coat.

A plenum chamber 114 may enclose the spraying operations as just described with suitable openings to pass the sheet 100 through the sides thereof as indicated. Use of the chamber 114 is preferred since it permits an inert atmosphere to surround the spraying and deposition operation, and this in combination with the rolling hereinafter described has been found to provide a highly polished speculum finish or effect on the resulting laminate. Such a laminate may then be used as a thermal or vapor barrier or heat or light reflector. The inert atmosphere may be a non-oxidizing one with respect to the metal being sprayed as by using an inert gas, or the atmosphere may be a partial vacuum, in which case the sides of the strip 100 remote from the spraying tube 110 are at a greater vacuum if the foregoing described advantages of "suction" deposition are desired.

In any event, the sheet 100 is finally passed between polishing and burnishing rolls 115 and then between reducing and densifying rolls 116. The latter may be powered to draw the sheet 100 through the path described. Thereafter a heating coil 117 anneals the metal coated strip before it is collected on a take-up roll 118. It is possible to have the polishing follow the annealing, but in general it is desirable to anneal after the rolling. The plenum chamber 114 and the rolls therein as well as the various parts contacting the porous base, as the latter moves through the plenum chamber, may be suitably cooled by various refrigeration apparatus known in the art. In the case of a combustible base material, cooling assists in preventing the charring, combustion, or melting thereof.

Because of the multi-passes of the sheet 100 before a bath of sprayed molten metal, there is not only a more uniform deposition and a covering of both phases of a porous or fibrous base, but a greater economy since the molten particles which penetrate a first length of the sheet and normally would be lost are captured by the second or reversing length or pass. There may be three or even four dozen layers of a porous base material such as un woven fabrics or parallel filaments used in place of the sheet 100. In a like manner, the porous base material may be in felt or very thin batt form and composed of yarns, cords, threads, filaments, fibers or batts of textile matter either in a woven or nonwoven state. I have used paper and also a woven gauze-like cellulose material having a laminate thereon of un woven cotton batt. I have also used an un woven material of cellulose fibers which are substantially all longitudinal and provided with spaced apertures of a diamond configuration. This material is known in the trade as key-back material.

Further, instead of paper, cellulose, or textile material, I can use a metallic porous base such as, for example, one made from metallic filaments, metallic cloth, or metallic gauze. Additionally, the base material may be composed of resinous materials, particularly the thermosetting resins such as phenol-formaldehyde, urea-formaldehyde, resorcinol formaldehyde, the silicones, and the like which are shaped in any of the physical forms above mentioned.

In the case of an aluminum deposition using an orifice in a spray nozzle of one-sixteenth of an inch orifice and air heated at 900° F. and at 60 p.s.i. pressure, I can spray 30 pounds per hour of aluminum and deposit it onto a base material continuously and uniformly both laterally and longitudinally by using an overlapped spray such as that described in connection with Figure 11. The porous sheet of the type previously mentioned travel at the rate of 150 feet per minute. Following the metal deposition, the laminate was capable of being rolled to a 50 percent reduction without splitting the fibrous backing sheet. In the case of a 0.010 inch deposit thickness, it is desirable to keep the deposit within an accuracy of plus or minus 0.001 inch. This is attainable with the overlap sprays. The overlapped sprays are each uniform and not only produce a uniform spray pattern, but in addition deliver a uniform amount of metal per unit of time and at a uniform temperature.

It is also desirable in many cases to anneal the laminate as indicated. This can be accomplished without burning the base material even though the latter may be cellulose, because such material is passed through the annealing cycle so rapidly and preferably protected by an inert atmosphere that it does not char. However, if it is desired to remove the base material conditions are altered so that combustion is possible. The cellulose strip may also be removed by a solution or mechanical means or with an open flame. Annealing may also be accomplished with a surface flame of oxygen, hydrogen, or acetylene oxygen wherein the material is passed rapidly through this flame to effect the annealing.

Other forms embodying the features of the invention may be employed, change being made as regards the features herein disclosed, provided those stated in any of the following claims or the equivalent of such features be employed.

I therefore particularly point out and distinctly claim my invention:

1. A method of producing a metal strip comprising spraying molten metal onto one side of a porous base to deposit a film of such metal onto the base, and simultaneously maintaining a pressure on the opposite side of such base at a value less than the pressure on such one side of the base to attract the sprayed molten metal to the base and to retain the sprayed molten metal to the base during solidification thereof.

2. A method of producing a laminate strip comprising spraying particles of molten metal through an inert atmosphere, moving a porous base material into the path of the spraying and at a substantially uniform rate to deposit the molten metal particles as a substantially uniform film on one side of the base material, and simultaneously maintaining a sub-atmospheric pressure on the reverse side of such base material at a value less than the pressure on such one side of the base material to attract the particles to the material and cause the particles to impregnate the porous material before solidifying.

3. A method of producing laminate strip comprising spraying particles of molten metal through an inert atmosphere, moving a porous base material into the path of the spraying and at a substantially uniform rate to deposit the molten metal particles as a substantially uniform film on one side of the base material, and simultaneously maintaining a sub-atmospheric pressure on the reverse side of such base material at a value less than the pressure on such one side of the base material to attract the particles to the material and cause the particles to impregnate the porous material before solidifying.

4. A method as defined in claim 3 wherein such inert atmosphere is a partial vacuum and such reverse side of the base material is maintained at a greater vacuum.

5. A method as defined in claim 3 wherein such spray of molten metal particles is heated in transit during the movement of such particles through the inert atmosphere and toward the porous base material to aid in maintaining such particles in a molten condition at the time of such deposition.

6. A method as defined in claim 3 wherein such porous
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base material is fibrous and further including the step of maintaining such fibrous base material at a temperature at least equal to the melting point of the metal of such particles to aid in coalescing the metal with the fibers and thereby bond the fibers together to improve the strength of the resulting laminate.

7. A method of producing a thermal and vapor barrier comprising spraying particles of molten metal through an inert atmosphere, moving a porous base material into the path of the spraying and at substantially a uniform rate to deposit the molten metal particles as a substantially uniform film on one side of the base material, simultaneously maintaining a sub-atmospheric pressure on the opposite side of such base material, and rolling the metal coated base material to impart a highly polished speculum finish.

8. A method as defined in claim 7 further including the step of annealing the metal coated base material prior to rolling.

9. A method as defined in claim 7 further including heating the metal coated base material simultaneously with such rolling to spread the metal deposited on the base material relatively thereto without fracturing such base material.

10. A method of producing laminate strip comprising moving a porous sheet through a reversing path to define two lengths of the sheet, spraying molten metal against the surface of one length, and passing some of the molten metal through such length and against the surface of the other length to deposit the molten metal on both sides of the porous sheet.

11. A method of producing laminate strip comprising moving a porous sheet through a reversing path to define two spaced lengths of the sheet moving in opposite directions, spraying molten metal particles against the surface of one length, accelerating the movement of the metal particles passing through such one length by suction means toward the second length, and simultaneously heating and compressing and polishing the deposited metal particles against the sheet to impart a highly polished speculum effect.

12. A method of making an improved thermal and vapor barrier comprising moving a porous sheet through an angularly related reversing path to define two lengths of the sheet moving in substantially opposite directions and forming an acute angle at their adjacent ends, spraying molten metal particles having a size smaller than at least some of the openings in such porous sheet toward an outwardly directed surface of one length, passing some of the molten metal through such one length and against the surface of the other length to deposit the molten metal on both sides of the porous sheet, further spraying molten metal between the inwardly directed surfaces of such lengths and toward such acute angle to spread the particles so sprayed into an elongated form upon striking such inwardly directed surfaces and aid in coating the porous sheet with a metal layer, rolling the metal coated sheet to reduce the thickness thereof, and then annealing the rolled sheet to impart a highly polished speculum effect.

References Cited in the file of this patent

UNITED STATES PATENTS

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