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2,930,739

METHOD AND APPARATUS FOR FORMING VALVE METAL FOIL

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2 Sheets-Sheet 1

FIG. 1.

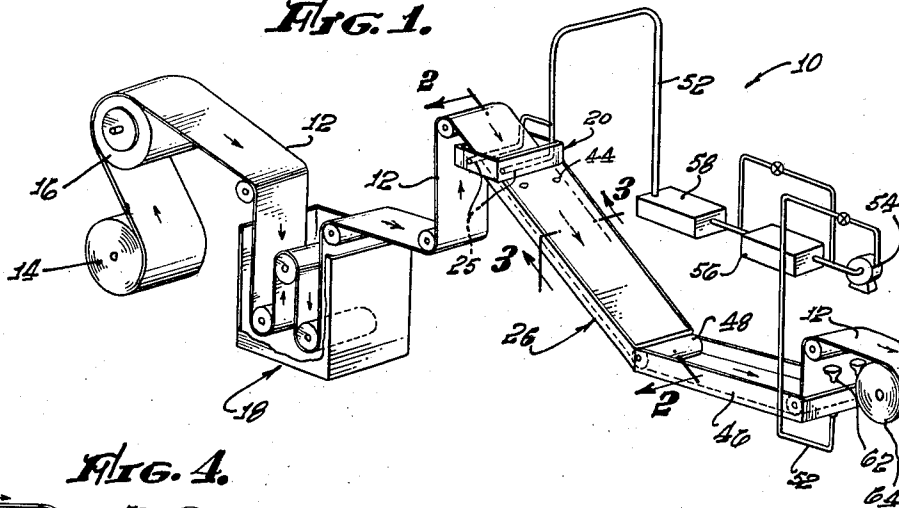


FIG. 4.

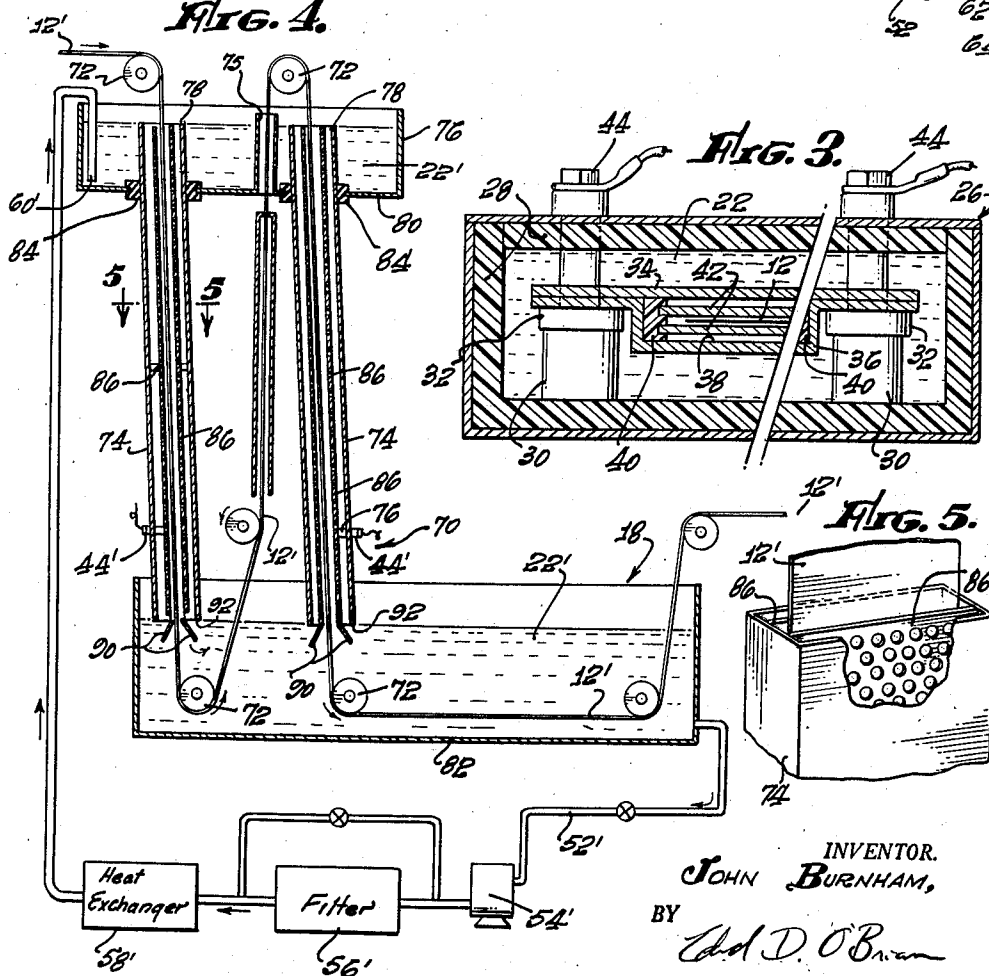


FIG. 3.

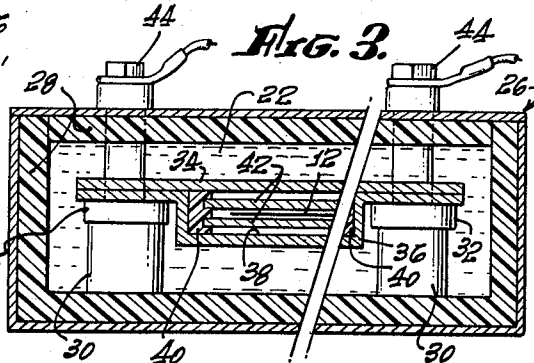
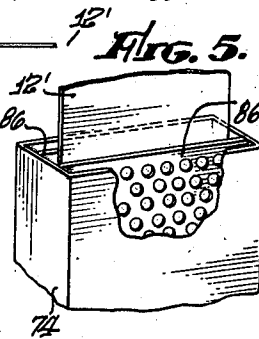


FIG. 5.



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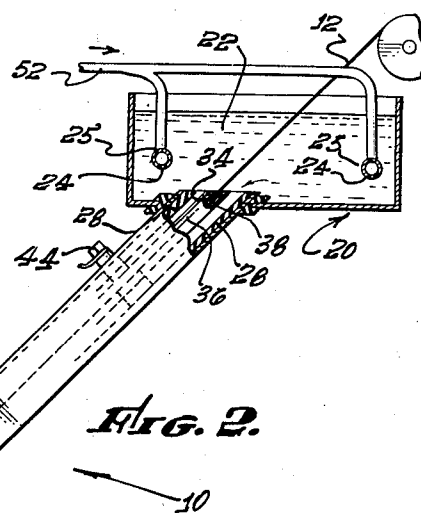
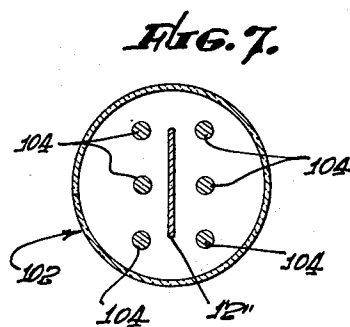
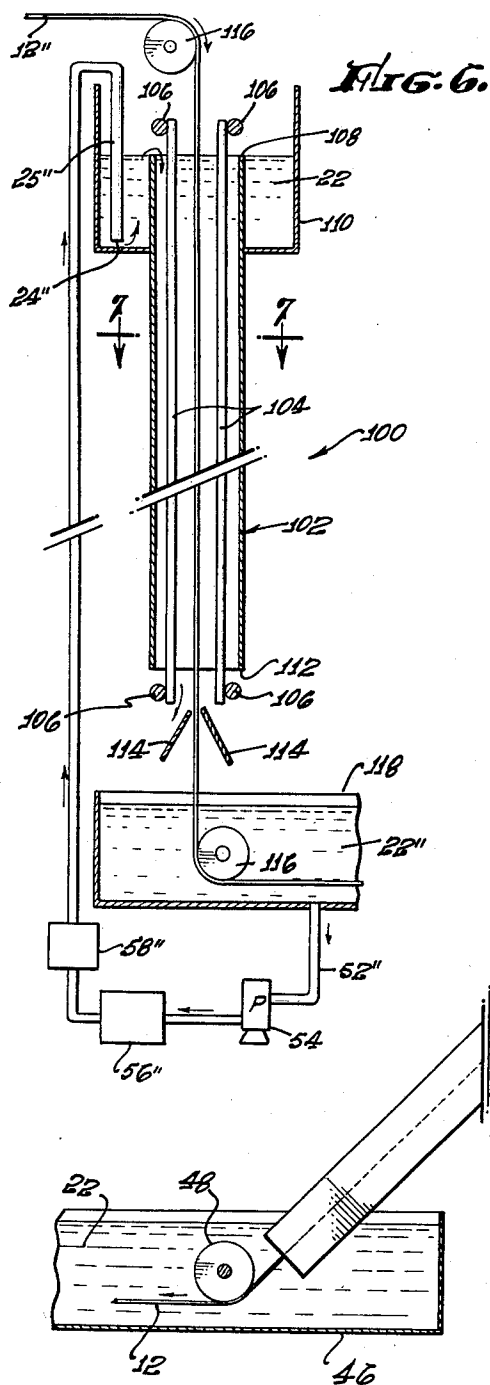
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METHOD AND APPARATUS FOR FORMING VALVE METAL FOIL

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2 Sheets-Sheet 2



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METHOD AND APPARATUS FOR FORMING VALVE METAL FOIL

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12 Claims. (Cl. 204—28)

This invention relates to a new and improved method for forming valve metal foil, and in particular metal foil such as aluminum foil capable of being used in the manufacture of electrolytic capacitors. This invention also relates to apparatus for carrying out this method.

The term "forming" is commonly used in the capacitor industry to designate the formation in an electrolytic bath containing an appropriate electrolyte of an adherent oxide coating having certain electrical properties upon the surface of a valve metal foil serving as an anode. High voltages of up to 800 volts are normally used during this operation. This type of operation is well known, and for this reason it is not considered necessary to describe in this specification the precise electrical characteristics of the oxide film or coating produced upon a metal surface during a forming operation; neither is it considered necessary to describe in this specification the actual use of the so-formed metal foil since this material is readily available in a number of references.

In this specification the terms "valve metal foil" and "aluminum foil" are used interchangeably in describing the method and apparatus of this invention since aluminum foil is virtually the only metal foil used commercially in volume for common electrolytic capacitors of the type employed in radios, television sets and the like. It is to be understood that other valve metals such as tantalum possess satisfactory oxide film-forming qualities, and can also be processed so as to create oxide coated electrodes capable of being used in electrolytic capacitors by employing the method and apparatus of the present invention. For this reason this invention is not to be considered as restricted in scope to the treatment of aluminum foil.

Aluminum foil can be formed utilizing an electrolytic process as briefly indicated in the preceding so as to have an adherent oxide coating in several different manners. The term "still formation" is commonly used to designate formation methods in which the metal foil, the electrolyte, and the inert cathode employed are held in a single position during the creation of an oxide layer. Obviously, such still formation is not suited to high speed continuous production, and for this reason various forming apparatus have been developed in which a metal foil is passed through a series of successive forming baths so as to create an oxide film or coating. In these continuous machines a number of rollers and other means are employed so as to control the path of the metal foil being formed during the forming process itself and so as to periodically remove the metal foil from the electrolyte in order to avoid certain polarization effects.

In spite of the advantageous character of continuous forming operations utilizing a series of forming baths, these continuous forming machines leave a number of factors to be desired. During a part of the forming operation carried out in each bath there is a high rate of electrolytic transfer in the vicinity of the metal foil

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which, coupled with the high concentration of the acid normally used in the electrolyte, and its low conductance, results in certain concentration polarization effects. In general it may be stated that during a concentration gradient lowering the effectiveness of the forming operation is set up in each of the baths utilized which is most apparent just prior to the exit point of the metal foil from each of these baths, even where the foil is washed off or otherwise treated between baths during forming so as to minimize these effects.

Anode polarization of this character is particularly troublesome in any forming operation carried out using an electrolyte containing boric acid and water, regardless of whether the forming is of a still variety or of a continuous category. In conventional forming operations another related "electro-chemical" factor effecting the efficient formation of an oxide coating is the tendency of particles of oxide such as, Al_2O_3 and other impurities present within the electrolyte to accumulate on a cathode forming a high resistance layer interfering with the current and voltage distribution during the forming operation.

An object of this invention is to provide both a method and an apparatus for carrying out the formation of aluminum and other metal foils so as to avoid prior difficulties occurring as a result of concentration polarization effects and as a result of accumulation of impurities upon the cathode employed. A related object of the invention is to provide method and apparatus in which the heat developed as a result of flow of an electrical current during the forming operation can be controlled in order to achieve a number of important results. Such heat is frequently referred to as I^2R heat since it results from both the current flowing and the resistance of the oxide film created during the forming operation, the resistance of the electrolyte between the electrodes, and the resistance of any deposits accumulated upon the surface of the cathode. With the present invention the formation of a high resistance layer upon the cathode surface is effectively prevented by substantially eliminating cathode deposits of impurities. Also, with the invention, any heat developed during a forming operation as a result of the resistance of the electrolyte and the resistance of the oxide metal film itself is effectively controlled so as to avoid the disadvantageous effects of too much heat.

The principle of these effects resulting from high heat accumulation during a forming operation is the creation of a non-uniform or "spotty" oxide coating where parts of the coating have been incompletely formed or oxidized due to the evolution of gas bubbles. Such gas bubbles are created in the usual electrolyte by the vaporization of water within the electrolyte at the anode or metal foil surface by heat present at this point. Heat accumulation resulting from I^2R losses has been an important factor limiting the speed and capacity of conventional continuous forming machines. Thus, many conventional forming machines having a formation voltage of 800 volts can only be operated at a foil speed of 15 inches per minute without boiling to occur. Apparatus of this invention can be operated at approximately ten times this speed without boiling occurring.

Another object of this invention is to provide a method and apparatus in which the use of extensive guide rolls and the equivalent during a forming operation are avoided so that the actual forming operation can proceed unimpeded by contact with such structures. By eliminating means of this category the construction of continuous forming machines of a comparatively inexpensive category is possible in accordance with this invention.

Because of the precise nature of the present invention it is not considered necessary to devote any space to a detailed consideration of various so-called objects of the invention which in reality merely define various specific

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advantages of it. Other objects and advantages of the invention will be fully apparent to those skilled in the art to which this invention pertains from a detailed examination of the remainder of this description, including the appended claims and the accompanying drawings, in which:

Fig. 1 is a diagrammatic view illustrating a forming machine of the present invention;

Figs. 2 and 3 are cross sectional views taken at lines 2—2 and 3—3 of Fig. 1 respectively;

Fig. 4 is a side elevational view, partially in section, of a modified forming machine of the present invention;

Fig. 5 is a cross sectional view taken at line 5—5 of Fig. 4;

Fig. 6 is a view similar to Fig. 4 of a second modified forming machine of the present invention; and

Fig. 7 is a cross sectional view taken at line 7—7 of Fig. 6 of the drawing.

In all figures of the drawings like numerals are used to designate like parts whenever convenient for purposes of illustration and explanation. It is to be understood that these drawings are primarily intended so as to illustrate certain preferred forms of the invention. Obviously the sizes, shapes, and constructional details involved in the various forming machines shown may be changed without departing from the essential nature of this invention. For this reason these drawings are not to be taken as limiting the invention in any respect.

In order to completely understand this invention it may be stated in essentially summary form that both the method and the apparatus described herein involve the use of a forming solution or electrolyte which is caused to travel with respect to a moving valve metal foil being formed, the electrolyte and the foil being moved at different rates with respect to one another so that turbulent flow of the electrolyte occurs. Through the use of such turbulent flow the foil processed is literally "kept in line" in a desired position without the use of guide rolls or the equivalent and is supported throughout the forming operation by the forming solution. By virtue of the nature of the movement employed a number of advantages are achieved.

The fact that the foil is supported by the electrolyte during the forming operation is very important since one of the greatest causes of foil breakage during conventional forming is misalignment of the guide rolls normally employed. During a forming operation carried out in accordance with this invention such guide rolls are eliminated and the formation process is free to proceed unimpeded by contact with any roll surface.

Since, with the invention, a turbulent flow of electrolyte is utilized, it was thought by many competent engineers that various eddy currents within the forming solution would cause the foil to whip back and forth and result in the breakage of foil during its passage through a forming channel. In accordance with this invention it is necessary to simultaneously apply the electrolyte to both sides of the foil being formed in order to equalize at the start of the forming operation the forces applied to the sides of the foil by the electrolyte in order to support it and in order to avoid foil breakage. It is further necessary to employ a forming channel of uniform cross sectional configuration so as to avoid the formation of "baffle" effects which would destroy the balanced status of the forces on the sides of the foil at all times during formation, causing movement of the foil in other than a desired path.

The term "turbulent flow" used in this specification to describe the flow of electrolyte is employed in its conventional sense so as to designate flow conditions which are not characterized by successive layers of the electrolyte flowing with respect to one another in a laminar manner. Although the term "turbulent flow" has a fairly well defined meaning in the engineering profession it is to be understood that there is no one exact set of

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flow conditions at which flow of any liquid changes in an instant from laminar to turbulent and that there is a critical transition range of flow conditions between these two different types of flow. For this reason any electrolyte employed with this invention is preferably caused to move through a forming channel at a sufficient velocity so that the movement of this fluid is well beyond what may be theoretically a limiting value in accordance with various known equations marking the beginning of turbulent flow. By this expedient, any semblance of laminar flow of the electrolyte is avoided, and several important advantages are achieved.

Although it can be stated that laminar flow is avoided in accordance with this invention those skilled in the art to which this specification is directed will recognize that even under turbulent flow conditions a very thin film next to the surface of a foil being formed will flow in a laminar manner. When, however, the principal flow of electrolyte is clearly turbulent, the velocity profile of the flow adjacent to the foil surface is very steep, and this laminar film is extremely thin, and, in effect, is of negligible thickness.

One characteristic of turbulent flow within any closed conduit is that this flow is substantially as the name implies and involves currents of liquid moving at various odd directions throughout the conduit. With such flow, therefore, substantially complete intermixture of the electrolyte employed with this invention takes place during movement through a forming channel, and the accumulation of impurities such as particles of Al_2O_3 upon the surface of the cathode is prevented. A further and important effect of turbulent flow during a forming operation of this invention is the mixing of the catholyte and anolyte so that uniform electro-chemical conditions are achieved in the forming channel. It is obvious from this that anode or concentration polarization in the vicinity of the anode or metal foil is effectively reduced to what is considered to be an irreducible minimum with this invention since the solution at the foil interface is constantly being changed.

Another extremely important effect of the use of turbulent flow with this invention is to reduce the heat built up within the forming channel. By virtue of the fact that the electrolyte moves through a forming channel at a different rate than the metal foil itself it is obvious that any heat built up within the electrolyte is rapidly carried from the forming channel. In effect the entire forming channel employed acts as a heat exchanger in which heat is removed through the electrolyte. By this expedient the heat within the forming channel is never built up to a point where a "spotty" oxide film or coating results due to the evolution of gas bubbles. Since the electrolyte employed with the invention is constantly reused it is normally preferred to utilize an external heat exchanger to keep the temperature of the electrolyte within a working range. Further, it is normally preferred to recirculate electrolyte through a filter so as to remove any particle-like impurities resulting from the forming operation or other factors.

In Fig. 1 of the drawings there is diagrammatically shown a complete forming machine of this invention utilized in placing an oxide coating upon a metal foil 12 obtained from a roll 14. The metal foil 12 as it comes from the roll 14 is caused to pass around a contact roll 16 where it is connected into an electrical circuit so as to act as an anode during the forming operation involved, and then it is passed to a bath 18 where it is cleaned in accordance with known practice. The foil 12 is next passed to a head tank 20 where it is contacted with an electrolyte 22 which flows through periodically spaced openings 24 in inlet pipes 25 on each side of the foil 12 into an enclosed, inclined forming channel 26.

It is noted that the openings 24 are formed in such a manner that the flow of electrolyte through these openings on both sides of the foil 12 is substantially equal.

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Thus, the forces exerted on both sides of the foil 12 are, from the start of the forming operation, equal so as to prevent whipping and tearing of this foil. As is seen in Fig. 3 of the drawings the forming channel 26 is essentially a symmetrical rectangular configuration so as to have identical side structure and is provided with an internal non-conductive coating 28 of rubber or similar material.

Mounted upon one side of this channel are a plurality of spacers 30 of a non-conductive material which serve to support parallel bus-bars 32 of a non-corrosive metal. These bus-bars in turn support metal plates 34 and 36 which are formed also of a metal not attached during a forming operation and which are manufactured so that there is located an internal channel 38 between them. On the edges of this channel non-conductive mounting members 40 serve to support perforated, inert, non-conductive separator plates 42. With this structure the metal foil 12 passes between these separator plates 42 along with the electrolyte 22, and the plates 34 and 36 serve as cathodes to which current is supplied through one or more conventional terminals 44. With this structure the entire assembly can be readily taken down for periodic checking.

At the bottom of the forming channel 26 there is located a surge tank 46 into which both the foil 12 and the electrolyte 22 pass after passing through the forming channel. Here the foil 12 is caused to move around a roller 48 from the path it travelled through the channel 26. Electrolyte is withdrawn from the tank 46 through a pipe 52 and passed through a pump 54, a filter 56, a heat exchanger 58, and thence back into the head tank 20 through the openings 24 located as indicated in Fig. 2 of the drawings at one side of this head tank 20 so that the flow of electrolyte into the head tank does not affect the forces applied to the foil 12 passing through this head tank. If desired, a plurality of equally spaced outlets may be located on both sides of the foil 12 within this head tank in order to minimize forces applied to the foil although this is not considered necessary. From the surge tank 46 the foil 12 travels as indicated in the drawing past drying lamps 62 and then is rolled on to a roller 64 driven by a conventional mechanism (not shown). From this roller the foil may be taken and utilized as desired.

For convenience of explanation in the foregoing description of the forming machine 10 various conventional rollers used to support and convey the foil 12 have not been specifically pointed out since the structure of these rollers is essentially of a known category and since their application is considered obvious from Fig. 1 of the drawings. Further, in order to limit this description to material pertinent to the invention nuts, bolts, supporting stands, electrical connections and the like which are obviously used in creating a structure such as the forming machine 10 have not been specifically illustrated in the accompanying drawing. Such matters of construction are well within the scope of any reasonably competent engineer.

It is not to be assumed from the foregoing that the invention is limited to use with a single metal foil such as the metal foil 12 described. If desired, any number of metal foils can be located parallel to one another so as to pass through the machine 10. A commercial embodiment of the machine is designed to process five foils simultaneously. Thus, the channels 26 and 38 may be of any desired width in order to accommodate any number of parallel foils. Because the electrolyte 22 circulated within the forming machine 10 conducts a current it is normally preferred to insulate the pump 54, the filter 56 and the heat exchanger 58 and the pipe 52 so as to prevent any possibility of a ground connection. Any conventional type of insulating means may be employed for this purpose. The heat exchanger 58 should preferably be for this particular application of the in-

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vention of what may be termed a "closed circuit" variety incorporating within it a refrigeration unit although various conventional types of heat exchangers in which the coolant is insulated from the electrolyte can be employed.

In Fig. 4 of the drawings there is shown a modified forming machine 70 of the instant invention which is similar in construction to the forming machine 10 previously described. This forming machine is adapted to take a series of metal foils 12' from a bath 18 such as is illustrated in Fig. 1 of the drawings and to pass these foils around a roller 72 into the top of a substantially vertical forming channel 74. These foils 12' pass through this forming channel 74, around another roller 72 and through an opening 75 in a head tank 76 to above this head tank 76 where they pass around another roller 72 and down through a second forming channel 74. At the bottom of this second forming channel the foils 12' are conveyed by means of the roller 72 to various drying means (not shown) such as the lamp 62 and to a roller (not shown) similar to the roller 64 shown in Fig. 1.

Within the construction shown in Fig. 4 the upper ends 78 of the forming channels are both located in the same plane adjacent to the top of the head tank 76 and both of these forming channels pass through the bottom 80 of this head tank to within the top area of a surge tank 82. The forming channels 74 are preferably insulated from the material used in manufacturing the head tank 80 by means of non-conductive sealing members 84 completely surrounding the exterior of these two forming channels. It is preferred to manufacture the forming channels 74 in this manner since as indicated in Fig. 5 of the drawings the exterior of each of them is formed in the shape of a rectangle out of a metal which is not affected during a normal forming operation. The exterior of each of the forming channels 74 is designed to be connected into an electrical circuit through the use of a terminal 44' so as to serve as a cathode during forming operation.

Within each of the forming channels 74 there are located on both sides of the metal foil 12' rigid, inert, perforated, non-conductive spacers or separators 86 which may if desired be secured directly to the walls of these channels as indicated. At the bottom of each of the channels 74 within the surge tank there are provided deflecting baffles 90 designed to direct electrolyte 22' away from the foil 12' before the foil 12' is turned. As is indicated in Fig. 4 of the drawings the baffles 90 are located well above the rollers 72 within the surge tank 80 so that the kinetic energy of any electrolyte flowing through the forming channels 74 which is not taken care of by the baffles 90 will be in effect absorbed by the electrolyte within the surge tank 82. Preferably the level of the electrolyte 22' within the surge tank is held at the level of the bottoms 92 of the forming channels 74 through the use of a pump 54' as previously described. This pump is connected through the use of a pipe 52' to a filter 56' and a heat exchanger 58' as previously indicated.

With the machine 70 the upper ends 78 of the forming channels 74 serve in effect as wiers permitting the flow of electrolyte 22' into these forming channels at a controlled rate. This type of structure is considered to be advantageous inasmuch as there is no danger of a thin oxide film prematurely forming on the foil 12' during its travel through the head tank 80 before it enters the forming channels themselves. Thus, the entire travel of the foil 12' through the forming channels 74' is designed so as to obtain maximum effectiveness.

As a specific example of the instant invention, it may be stated that the forming channels 74 illustrated in Fig. 4 of the drawings may be formed so as to have a height of approximately 1" x 24". The spacers 88 employed can be formed out of a phenolic or other non-conductive, non-corrosive material so as to each be approximately 1/8" thick and to each have 1/2" perforations

formed therein so as to remove about 80% of the actual area of these spacers. These spacers can be located approximately $\frac{1}{4}$ " apart. The apparatus 70 constructed in this manner can be used with aluminum foil varying from $\frac{1}{2}$ mil upwards in thickness together with an electrolyte consisting of a saturated solution of boric acid in water. A forming voltage of 750 volts and 1200 amperes may be used with five 3 mil etched aluminum foil strips having a total width of about 13". With these conditions satisfactory results can be obtained with an electrolyte flow rate of approximately 300 gals. per minute. This corresponds to an electrolyte velocity of 3300" per minute which is well beyond the critical Reynold's number for a transition from laminar to turbulent flow. A foil velocity of about 200" per minute can be used in obtaining satisfactory results under these conditions.

It is to be understood that this invention is not limited to the dimensions or the flow rates, currents, etc. indicated in the preceding example inasmuch as these factors may be varied within reasonably wide limits without departing from the essential features of this invention. Forming voltages in excess of 800 volts can be employed, and when such voltages are utilized with apparatus of this invention an exceedingly high current density is employed during the initial part of the forming operation. This in turn results in the production of a large amount of heat, which in turn limits the speed at which a foil can be moved without boiling. Approximately ten times the conventional foil speed can be employed with this invention. Effective results have been achieved utilizing a square inch of foil surface for each 10 kw. of electric power consumed with an electrolyte flow rate exceeding a Reynold's number of 2,200 within an enclosed channel.

If desired, a machine utilizing a forming channel structure such as is employed with the machine 70 can be manufactured so as to utilize a single forming tower instead of two of these towers. The particular structure shown is considered to be advantageous where space limitations prevent the use of a sufficiently long forming channel so as to obtain complete formation of an oxide film having desired electrical properties within a single channel.

In Fig. 6 of the drawing, there is shown another modified forming machine 100 of the present invention. This forming machine is extremely simple in construction and is built about a glass or other similar tube 102. Projecting through this tube so as to be parallel with respect to each other are a series of rods 104 supported at the ends of the tube by means of bus-bars 106. These rods are preferably formed of an inert metal so as to be capable of being used as cathodes during the operation of the machine 100. Around the upper end 108 of the tube 102 there is located a head tank 110 in such a manner that this upper end 108 is a short distance below the surface of the head tank 110. At the lower end 112 of the tube 102 there are mounted baffles 114 adjacent to the rods 104 and two of the bus-bars 106. These baffles are sloped so as to direct a stream of electrolyte 22" away from a metal foil 12" treated within the machine 100. During such treatment a metal foil such as the foil 12" is supplied directly to this machine as indicated in the description of the machine 70. It passes over a roller 116 through the tube 102 between the rods 104 supported on the bus-bars 106 past the baffles 114 into a surge tank 118 located well below these baffles 114. Here the metal foil 12" is passed around another roller 116 and is treated as indicated in the description of the machine 70, and then rolled into a roll for further processing. Electrolyte 22" is circulated in the machine 100 from the surge tank 118 through a pipe 52" as previously described by means of a pump 54" through a filter 56" and a heat exchange unit 58" to an outlet opening 24" located within the head tank 110 adjacent to the bottom thereof beside the tube 102.

With this structure, the upper end 108 of the tube 102

acts essentially as a wiper controlling the flow of electrolyte into the tube 102. This has the advantage, indicated in the preceding discussion, of preventing premature formation of a thin oxide layer outside of the actual forming channel constituted by this tube used with the machine 100. By virtue of the structure shown at the lower end 112 of the tube 102 electrical contact between the electrolyte 22" within the tube 102 and the surge tank 118 is broken by discreet particles of this electrolyte being deflected in essentially a spray form towards the surge tank 118. Because of this break in electrical connection, the pump, filter and heat exchanger, as well as the surge tank 118 need not be insulated as necessary with the machines 10 and 70 previously described, although the pipe 25" leading to the outlet 24" should be formed of a non-conductive material to prevent any chance undesired current flow. Also, the tank 110 should preferably be formed of a similar material. Thus, any convenient type of heat exchanger may be employed without regard to the possibility of contacting a current through a coolant liquid.

It is to be understood that this type of construction employed with the machine 100 so as to handle the electrolyte can be employed with the machines 10 and 70 so as to eliminate the necessity for separately insulating the various parts described. Normally however, this is not preferred since the machines 10 and 70 are designed for large production and separate insulation proves no handicap where such size is involved. It is considered obvious that the structure of the machine 100 can be altered so as to avoid spacing the surge tank from the bottom of the tube 102. If this is done the external electrolyte circuit must be insulated as previously discussed.

It should be noted that in all of the various forms of apparatus of the present invention described and illustrated, the forming channels used are all of uniform cross sectional shape or configuration; and that in all of these constructions the electrolyte is caused to flow with respect to the metal foil in such a manner that the forces on all sides of the metal foil are equal at any point or line along the foil. In essence, it may be stated that in all of the structures involved both the forces and the apparatus on each side of a metal foil are symmetrical or balanced in character.

In the forming machines 10 and 70 the spacers or supports are designed primarily as a safety measure to prevent accidental contact of the metal foils treated with the cathodes employed. Thus in many cases it is possible to dispense with such spacers or supporters without departing from the essential principles of this invention. If desired, such supporters can be employed with the machine 100 although this is not considered necessary. The cathodes used in all of the three forms of apparatus of the invention described are formed and mounted so as to be equally spaced from both sides of a metal foil being treated and so as to provide a uniform current density with respect to the metal foil during a forming operation.

Those skilled in the art will realize from the foregoing description that the process of this invention, as well as the various forms and apparatus for carrying it out, are extremely efficient and effective. As an example of this, reference can be made to the fact that in conventional, continuous forming machines foil speeds of about 5 to 30" per minute are commonly encountered, whereas with this invention foil speeds during forming of as high as 200" per minute can be utilized under equivalent electrochemical forming conditions. No description has been given in this specification of the actual calculation of the critical speeds of electrolyte travel since those skilled in the art to which this invention pertains can readily calculate these speeds utilizing established equations in the Reynold's number designating a transition from laminar to turbulent flow. If desired, any of the machines of the invention can be operated so that the electrolyte

and the metal foil travel from counter current directions during the forming process. Normally it is preferred to utilize vertical or substantially vertical forming channels so as to obtain effective forming. When concurrent metal foil and electrolyte flow are used the electrolyte aids in supporting and transporting the metal foil during the forming operation. An important feature of the invention is that extremely thin aluminum and other foil may be treated in accordance with it without material danger of breakage. Such concurrent movement during forming is especially advantageous with extremely thin foil such as, e.g., 1/2 mil high purity aluminum foil. Any of the species of apparatus described can be operated under the identical, or substantially identical, conditions specified in the specific example given. Because of the fact that this invention is considered to be of essentially a basic category, and because of the fact that a number of modifications may be made from the specific disclosure in this specification without departing from the essential features of it, this invention is to be considered as being limited only by the appended claims.

I claim:

1. A process for placing an oxide film upon a very thin metal foil which process comprises: passing a metal foil having sides consisting of metal selected from the group consisting of aluminum and tantalum in one direction through an enclosed forming channel having cathode means located therein so as to be spaced from both sides of said metal foil, said metal foil being spaced from said channel and said cathode means during movement through said channel; passing an electrolyte through said forming channel in the same direction at a faster rate than the rate at which said metal foil is passed through said channel and at a turbulent velocity while simultaneously passing said metal foil through said channel, said electrolyte being passed through said channel so that the forces exerted on the sides of said metal foil throughout the entire length of said channel are substantially equal on both sides of said metal foil at any point along the length of said metal foil and so that said electrolyte serves to maintain said metal foil in an unburnt condition during movement of said metal foil through said forming channel; and applying current to said cathode means and to said metal foil whereby said metal foil is oxidized in said forming channel, said electrolyte flow at a turbulent velocity causing substantially complete intermixture of said electrolyte within said channel so as to prevent the accumulation of surface impurities on said cathode means, so as to cause uniform electro-chemical conditions within said channel and so as to prevent heat build up within said forming channel.

2. A process as defined in claim 1 wherein said foil and said electrolyte both flow downwardly through said forming channel.

3. An apparatus for placing an oxide film upon a metal foil which comprises: means defining a forming channel having an upper and a lower end; cathode means located within said forming channel; means for conveying metal foil in a straight line through said forming channel so that said metal foil is spaced from said forming channel and said cathode means, said conveying means being located so as to be spaced from said forming channel; means for directly introducing an electrolyte into the upper end of said forming channel simultaneously on both sides of the path of said metal foil so that the forces applied to said metal foil by said electrolyte are equal, said forming channel and said cathode means being of a symmetrical shape with respect to the path of said metal foil whereby the forces applied to both sides of said metal foil are equal at any point along the length of said metal foil; and means for applying an electrical potential to said metal foil and said cathode means whereby said metal foil serves as an anode during the passage of said foil through said forming channel, said surge tank means being located at the lower end of said forming channel, part of said means for

conveying metal foil being located within said surge tank means so as to be spaced from said forming channel, said surge tank means being in communication with said forming channel.

4. An apparatus as defined in claim 3 wherein said cathode means are the walls of said forming channel.

5. An apparatus as defined in claim 3 wherein said cathode means comprise electrical conductors spaced within said forming channel so as to define a separate channel within said forming channel.

6. An apparatus as defined in claim 3 wherein said forming channel is formed of a non-conductive material and wherein said forming channel is located in a substantially vertical direction, and wherein said cathode means comprise vertically spaced rods projecting through said forming channel and extending from each end thereof.

7. An apparatus of the class described for forming an oxide film upon a metal foil consisting of a metal selected from a group consisting of aluminum and tantalum which comprises: a head tank; a forming channel located so as to project in a substantially vertical direction from adjacent to the top of said head tank to beneath said head tank, the top of said forming channel being capable of serving as a wiper; means for conveying a metal foil through said forming channel from the top thereof to the bottom thereof, so that said metal foil is spaced from said forming channel during the movement of said metal foil through said forming channel; means for introducing electrolyte into said head tank so that said electrolyte flows over the top of said forming channel and through said forming channel; cathode means located so as to extend throughout the length of said forming channel, said cathode means and said forming channel having a uniform cross sectional configuration; and means for applying an electrical potential to said metal foil whereby said metal foil is capable of serving as an anode during passage of said metal foil through said forming channel.

8. An apparatus as defined in claim 7 wherein said cathode means are walls of said forming channel.

9. An apparatus as defined in claim 7 wherein said cathode means comprise electrical conductors spaced within said forming channel so as to define a separate channel within said forming channel.

10. An apparatus as defined in claim 7 wherein said forming channel is formed of a non-conductive material and wherein said forming channel is located in a vertical direction and wherein said cathode means comprise vertically spaced rods projecting through said forming channel and extending from each end thereof.

11. An apparatus as defined in claim 7 including means for recirculating electrolyte from the bottom of said forming channel to the top of said forming channel.

12. An apparatus for placing an oxide film upon a metal foil which comprises: means defining a forming channel having an upper and a lower end; cathode means located within said forming channel; means for conveying metal foil in a straight line through said forming channel so that said metal foil is spaced from said forming channel and said cathode means, said conveying means being located so as to be spaced from said forming channel; means for directly introducing an electrolyte into the upper end of said forming channel simultaneously on both sides of the path of said metal foil so that the forces applied to said metal foil by said electrolytes are equal, said forming channel and said cathode means being of a symmetrical shape with respect to the path of said metal foil whereby the forces applied to both sides of said metal foil are equal at any point along the length of said metal foil; and means for applying an electrical potential to said metal foil and said cathode means whereby said metal foil serves as an anode during the passage of said foil through said forming channel; and baffle means located at the lower end of said forming channel so as to be spaced therefrom, said baffle means being located on

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each side of said straight line and being of a symmetrical shape with respect to the path of said metal foil serving to direct the electrolyte passing through said forming channel away from said metal foil.

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