FIG_1

FIG_2

FIG_3
This invention relates generally as indicated to a flexible paper tube and more particularly to an inexpensive yet durable spirally wrapped kraft paper tube which can readily be bent or flexed without such tube being destroyed or disintegrating.

Conventional spirally wrapped paper tubes, such as paper straws, mailing tubes, etc., cannot be bent or flexed without the plies separating and such tubes then become substantially useless. Such conventional spirally wrapped paper tubes therefore cannot be employed as covers or sheaths for elongated objects that curve or bend. An example of such objects may be found in the cores, windings, conductors and other cables utilized in oil immersed transformers. Vinyl plastic tubing has heretofore been utilized as sheaths for such transformer components, but it has been discovered that such vinyl will leach out contaminants into the oil especially when such oil obtains high temperatures. Such sheaths for transformer elements serve primarily to space such elements, and for more efficient operation of the transformer, it is desirable to have the oil bath as close as possible to the sheathed element. A vinyl or other plastic tubing, being oil impervious, serves then to space the oil from the element.

It is accordingly a principal object of the present invention to provide a flexible paper tube which will readily conform to curved elements such as transformer rods and the like.

A further principal object is the provision of such flexible paper tube which will readily absorb oil and the like. Another object is the provision of a flexible paper tube which will not leach contaminants when immersed in a hot oil bath. Yet another object is the provision of a flexible paper tube which can be produced at much less cost than similar plastic tubes.

A still further object is the provision of a method of manufacture for such flexible paper tubes by which such tubes can continuously be produced.

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 herein-after fully described and particularly pointed out in the claims, the following description and the annexed drawing 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 drawing:

FIG. 1 is a somewhat schematic top plan view of paper tube winding apparatus illustrating the manner in which a tube in accordance with the present invention may be produced;

FIG. 2 is a schematic end elevation of such apparatus as seen from the bottom in FIG. 1; and

FIG. 3 is a greatly enlarged radial section of a wall of a flexible paper tube in accordance with the present invention.

Referring now to the annexed drawing and more particularly to FIGS. 1 and 2, there is illustrated a holder 1 including a chuck 2 in which is positioned a highly polished fixed mandrel 3 projecting axially therefrom and terminating at 4. About such mandrel 3 there is wrapped strips 6, 7, 8 and 9 of biaxially creped kraft paper. Such strips will be fed to the mandrel at predetermined lead angles from spools of such strips and will be drawn from such spools or storage rolls by power driven winding belt 11 wrapped about the finished tube 12 on the end of the mandrel 3. Such strips of creped kraft paper are then spirally wrapped upon the mandrel to form the spirally wound paper tube indicated at 12. A rotating flying knife 13 may be employed to sever the tube 12 into sections of the desired length.

The illustrated tube winding apparatus is generally conventional and forms no part of the present invention. However, it will be understood that the spiral of the wrappings of the finished tube 12 have a lead which is dependent on the lead angle of the strips 6 through 9 being drawn onto the mandrel by the flexible winding belt 11. For the purposes of the present invention, the lead angle may be from 40 to 70 degrees.

The four strips 6 through 9 will form the respective plies of the finished tube 12 and may hereinafter be referred to as plies 6 through 9 forming the inner, the two intermediate, and outer plies, respectively, of the finished tube 12.

The inner ply 6 is trued over a wax applicator 15 so that the inner surface 16 of such inner ply will readily slide on the polished mandrel 3. A glue applicator 17 of conventional variety applies a coating to the entire width of the inner ply 6 indicated at 18 so that the exterior side of the inner ply will be covered with such adhesive. The first ply 6 is preferably wider than the intermediate plies 7 and 8 and in the illustrated embodiment, forming a ¾ inch tube, may be approximately 1¾ inches in width. The ply 6 will be wound such that it will be lapped upon itself to form a lap of approximately ¼ inch. However, the second and third plies 7 and 8, respectively, will be approximately 1 inch in width and will be wrapped such that they will form a butt joint for the second and third spirally wrapped plies of the finished tube. The second and third plies are run dry or without any application of adhesive. The fourth or outside ply 9 is approximately 1¼ inches wide or the same width as the inside ply 6 and is passed through adhesive applicator 20 which applies a coating of adhesive 21 to one edge only thereof and approximately ¼ inch in width. Such adhesive coating is applied to the inner side of the outside ply 9. The outside ply 9 is wrapped upon the third ply 8 such that it will lap upon itself approximately ¼ inch and be adhered to itself at such lap spiral joint only by the layer of adhesive 21 applied to the edge thereof. Such outside ply will not be then adhesively secured to the next inner ply.

Referring now to FIG. 3, it will be seen that the finished tube 12 comprises an inside ply formed of the strip 6 which is lapped upon itself as indicated at 24 and, of course, adhered to itself at such lap by the coating of adhesive 18 applied thereto. Such coating of adhesive 18 also adheres the entire exterior surface of the inner ply to the second ply formed of the strip 7. The second ply is butted as indicated at 25 and will adhere to the first ply because of the coating 18 thereon. The third ply is also butted as indicated at 26 and is run dry, i.e., not adhesively secured to either the second or fourth ply. The outside ply or strip 9 is lapped upon itself approximately ¼ inch as indicated at 27 and the coating of adhesive 21 secures such lapped portions together. The finished tube then comprises an inner ply 6 of spirally wrapped biaxially creped kraft paper lapped upon itself, a layer of adhesive 18 between the inner ply and the second ply 7, a second ply 7 butted as indicated at 25, a third ply 8 butted as indicated at 26 and not adhesively secured either to the second or fourth plies,
and finally an outside ply 9 which is lapped upon itself and secured together at such lap only by the adhesive layer 21.

Such biaxially creped kraft paper which forms the plies of the tube may be formed from plain kraft paper, a dark brown paper, or usually made from sulphate pulp, by binding such paper with adhesive on a drum and creping it diagonally off a first creping knife. Such diagonally creped paper is then bound again on a second drum and cross-creped with a second knife. Reference may be had to U.S. Patents Nos. 2,071,347, 2,159,087, 2,161,092, 2,404,334 and 2,567,967 for examples of such biaxially creped kraft paper and methods of making the same. Such paper may have up to 65% biaxial stretch, i.e., in directions both laterally and longitudinally of the strip. The particular lie of the crepe axis is, however, not particularly important but such paper should be creped in directions normal to each other.

The first ply preferably is .004 inch thick before creping. Such paper preferably has a stretch in any direction of approximately 50% and may now be .010 inch thick. Desirable is to use a width of strip as possible to obtain the four in it that will have the smallest radius of curvature when the tube is bent to conform to a curved transformer core rod or the like. Both the second and third plies may be .012 inch thick before creping and have 65% stretch in both directions while being .006 inch thick after creping. While in the illustrated preferred embodiment, the second and third plies are shown run dry and butted, it will be understood that they may be lapped as the first and fourth plies. The fourth ply may be of the same thickness as the first. The fourth ply is, of course, only adhered to itself on the lap by the adhesive coating 21.

The finished tube may then have a wall thickness of approximately 1/8 of an inch and will soak up oil between the adjacent convolutions of the helix formed by the coating 21 adhering the lapped portions of the outside ply or strip 9 together. In this manner, the tube is particularly useful as an insulator and separator for oil immersed transformer elements. The exterior helix of glue or adhesive 21 which adheres the strips 9 together at the spiral wrapped seam may be spaced axially apart approximately 1 inch and this then permits the exterior of the tube readily to stretch and flex to conform to curved transformer elements and the like. It will be appreciated that the lead and spacing of the relatively narrow band of adhesive 21 can affect the flexibility of the tube in that every time you have a glue line in the tube you rigidify the same.

The adhesive employed is preferably a polyvinyl acetate base glue with a small amount of plasticizer such as polyvinyl alcohol. Also, polyether resin film type adhesives may be employed. It has been discovered that animal glues, rubber base glues, epoxides and cellulose acetate glues are unsuitable for the present invention especially if the finished product is to be immersed in hot oil.

All of the seams of the finished tube are preferably axially staggered or offset to provide a higher strength tube. The spacing of such seams may, of course, depend upon the width of the strip employed and it is normally desirable to use a width of strip as possible to obtain a staggered helix angle to obtain a more flexible tube. The width of the ply paper strips is normally 50 to 70% of the circumference of the mandrel. The steepest spiral or greatest lead obtains the maximum flexibility and the greater the lead, the greater the flexibility. However within the confines of strip size and handling feasibility, a 40 to 70 degree lead angle has been found desirable and will afford a tube of requisite flexibility.

It will be appreciated that the two inner plies may be omitted should a smaller thickness tube be desired. Also, if the thickness of the tube is desired to be greater, more than two inner plies may be employed. In the production of smaller diameter tubes, such as the size of a soda straw, the two middle plies need not be employed. In such smaller tubes, only a two ply tube can be employed with

the inner ply lapped upon itself and adhesively secured to itself only on the lap. The outside ply is also lapped upon itself between the lapped seam of the inner ply and also only adhered on the lap. For example, a 3/8 inch width of strip may be employed having a 3/8 inch lap. In such smaller tubes, the amount of lap of the outside ply will not be as great as the amount of lap of the inside ply and thus the helix or thin layer of adhesive on the outside of the tube will be smaller in width. This then permits the outside ply to have greater stretchability in its outer portion 10 where it may represent a slightly larger radius of curvature than inside the ply.

The illustrated embodiment utilizing four plies has been found quite satisfactory for tubes down to approximately 1/4 inch in diameter. However, for 1/8 inch diameter tubes, it is extremely difficult to wind four plies of heavy material on such a small mandrel. A 1/8 inch diameter tube, in a transformer element sheath use, need not have a very large wall thickness in that for the smaller elements less current and voltage will be employed. The following are two examples of ways of manufacturing such small or 1/8 inch diameter tube:

**Example 1**

Three plies of 10 mil biaxially creped kraft paper material:

First ply lapped and glued all over;

Second ply, same material, butted and not glued;

Third ply, same material, lapped and glued on lap only.

Such tube affords a wall thickness of approximately 1/32 of an inch and is very flexible.

**Example 2**

Two plies of 10 mil biaxially creped kraft paper material:

First ply lapped and glued on lap only;

Second ply, lapped and glued on lap only.

This latter example provides a tube having a wall thickness of .020 inch and the tube is also very flexible.

It will now be seen that there is provided a flexible paper tube which can be made to the desired thickness and which can be employed to sheath curved elongated elements such as transformer rods simply by sliding the tube thereover. Such paper tube not only readily conforms to the enclosed element, but will also absorb or soak up oil without in any way deleteriously affecting such oil and the operation of the transformer. Moreover, it will be appreciated that such flexible paper tube can be produced very inexpensively.

Other modes of applying the principle of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims or the equivalent of such be employed.

We, therefore, particularly point out and distinctly claim as our invention:

1. A spiral wound flexible, bendable paper tube capable of absorbing oil comprising an inner ply of biaxially creped kraft paper, a coating of adhesive on the exterior surface of said inner ply, an intermediate ply of biaxially creped kraft paper, an exterior ply of biaxially creped kraft paper lap sealed to itself, and adhesive securing together the lapped portions only of said exterior ply.

2. A spiral wound flexible, bendable paper tube capable of absorbing oil comprising an interior ply of biaxially stretchable creped kraft paper lap sealed to itself, adhesive securing together the lapped portions of said interior ply, an exterior ply of biaxially stretchable creped paper lap sealed to itself, and adhesive securing together the lapped portions of said exterior ply.

3. A spiral wound flexible, bendable paper tube capable of absorbing oil comprising an inner ply of biaxially creped kraft paper lap sealed to itself, a coating of adhesive on the exterior surface of said inner ply, a second ply of biaxially creped kraft paper adhesively secured to
said inner ply, a third ply of biaxially creped kraft paper, an exterior ply of biaxially creped kraft paper lap sealed to itself, and adhesive securing together the lapped portions of said exterior ply, said third ply being unsecured to said second ply and said exterior ply.

4. A spiral wound flexible paper tube as set forth in claim 3 wherein said adhesive on the exterior of said inner ply and securing together the lapped portions of said exterior ply comprises a polyvinyl acetate base glue having a small amount of polyvinyl alcohol plasticizer therein.

5. A spiral wound flexible paper tube as set forth in claim 3 wherein said inner and exterior plies are wound from strips of such biaxially creped kraft paper wider than the strips of such paper employed to form said second and third plies.

6. A spiral wound flexible, bendable paper tube capable of absorbing oil comprising an interior ply of biaxially creped kraft paper lap seamed to itself and adhesively secured along such lapped seam, an intermediate ply of the same material spirally wound and not joined to itself, and an exterior ply of the same material lap seamed to itself and adhesively secured in such spiral form on such lap only.

7. A spiral wound flexible paper tube as set forth in claim 6 wherein such adhesive comprises a polyvinyl acetate base glue having a small amount of polyvinyl alcohol plasticizer therein.

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