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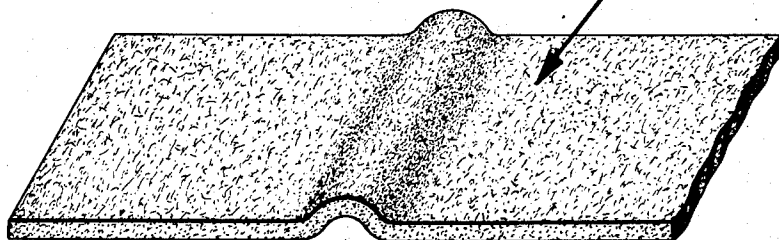
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ELECTRICAL INSULATING MATERIAL

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*FIBROUS SHEET IMPREGNATED
WITH STYRENE POLYMERIZED
BELOW 100° CENTIGRADE*



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ELECTRICAL INSULATING MATERIAL

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This invention relates to electrical insulating material, including the manufacture thereof, an object being to provide an improved method of treating fibrous material such as paper, tape, fabric, silk both natural and artificial, yarn, string and the like with styrene in order to produce insulating material having improved properties which will be hereinafter more particularly referred to.

10 In our British specification No. 454,923 we have described a process of treating electrical insulating material comprising a base of fibrous material, for example paper, in wound form which comprises impregnating the wound material with monomeric styrene with or without a plasticiser, polymerising the monomeric styrene in a closed vessel, unwinding the material whilst the polymerised styrene is soft at an elevated temperature, subjecting the material to treatment for the removal of surplus polystyrene to restore the fibrous texture to the surface and rewinding the material preferably after calendering and preferably after treating with a suitable solvent whereby the material may be readily unwound in subsequent use.

The insulating material produced by carrying out our prior process is quite satisfactory for many purposes but on the other hand the requirements of modern electrical apparatus as regards the properties of the insulating material employed are often such that insulation may be required having certain properties which cannot readily be provided by carrying out our prior process.

35 When dealing with insulating material produced in accordance with our prior process, it is found that after being cooled to room temperature subsequent to the polymerisation and unwinding, the insulating material can only be handled in roll form without risk of adjacent layers of the impregnated material adhering to one another so long as the material is not heated above about 60° C.

The fact that insulating material produced in accordance with our prior process becomes sticky at about 60° C. is rather a disadvantage in some cases, e.g. in the preparation of insulation for cables, because it is often necessary to re-dry the impregnated fibrous material and this is not a practical proposition in view of the length of time involved unless the temperature is raised to about 120° C., and if this temperature were employed in connection with insulating material in accordance with our prior process the adjacent layers of material would adhere to one another,

which is not always desirable. It may be mentioned that humidification of the impregnated fibrous material is almost inevitable in view of the fact that the material must almost always be exposed to the atmosphere for at least a short time and therefore the re-drying is almost always necessary.

Another difficulty with our prior process is that a non-uniform layer of polymer tends to form on the surface of the fibrous material due more particularly to the fact that the rolls of material are unwound at an elevated temperature with the polystyrene in the form of a thick viscous fluid which tends to aggregate into lumps on the surface as the adjacent layers of fibrous material are parted from one another. In order to overcome this difficulty and to produce a substantially uniform product in accordance with our prior process, it is essential to remove the surplus polystyrene and to smooth out the surface of the fibrous material.

These difficulties somewhat limit the application of the insulating material and, therefore, in the past in order to improve the properties thereof we have attempted to adjust the type and amount of plasticiser added to the styrene in such a way as to afford a compromise between the help given in unwinding, by allowing successive layers of the treated fibrous material to be separated from one another, and to the tendency thereby imparted to the material to re-adhere after rewinding. This measure whilst effecting an improvement has in no way overcome the essential difficulties.

We now believe that the above difficulties are caused more particularly by the rather high temperature of polymerisation mentioned in our prior process, viz. 120° C., at which temperature the polymer produced consists of relatively small molecules. We find that the temperature of polymerisation is somewhat critical when dealing with fibrous material treated with monomeric styrene, such that the physical and electrical properties of the finished fibrous material impregnated with polymer are greatly modified by the temperature of polymerisation employed, and an improved product results from the use of a low temperature polymer.

In more detail we have found that if the polymerisation temperature is below 100° C. the insulating material produced offers the desired properties, viz. it may be unwound after polymerisation and is easily re-dried after the almost inevitable humidification without the adjacent layers of fibrous material adhering together, and al-

so the surface layer of polymer is relatively smooth and uniform, which obviates the necessity for carrying out smoothing or like steps.

According to the present invention there is provided a method of treating fibrous electrical insulating material in sheet, tape or like form comprising impregnating the material with monomeric styrene or a mixture containing monomeric styrene and polymerising the styrene at a temperature below 100° C. in order to produce a material having a fine granular surface film of polystyrene which may be heated to 120° C. without becoming sticky.

In accordance with a further feature of the invention there is provided a method of preparing electrical insulation comprising impregnating fibrous material in sheet or tape form with monomeric styrene, polymerising the styrene at a temperature below 100° C., thereafter building up the insulation in the form of a plurality of layers or windings of the impregnated sheets or tapes and then drying the built up insulation by heating to about 120° C. preferably combined with vacuum treatment whereby the adjacent layers or windings do not adhere to one another.

The single figure of the accompanying drawing illustrates a fibrous sheet impregnated with styrene polymerized below 100° C. in accordance with my invention.

The insulating material in accordance with the present invention has advantages other than those mentioned over paper impregnated with polymerised styrene previously produced, for example, the electrical breakdown value thereof is two or three times higher than the material produced in accordance with our prior process. A further advantage is that when monomeric styrene is applied to fibrous material produced in accordance with the present invention a mixture of monomer and polymer of greater viscosity will be provided than is afforded by the high temperature polymer. This feature is of particular importance in the manufacture of insulation for cables, for example, for providing barriers in the form of joints, plugs, or terminations, by utilising the technique described in our co-pending British specification No. 29,224/37 or in insulating cable lengths utilising the technique in our co-pending British specification No. 12,371/37. Another factor in favour of insulating material produced in accordance with the present invention is that trouble due to the development of exothermic heat during polymerisation is reduced which is of importance when dealing with large rolls of the insulating material.

In order to facilitate the provision of a uniform dispersion of styrene, it is preferable to dry a length of the fibrous material and wind the dried material tightly into a roll prior to treatment with styrene, otherwise the shrinkage following drying may well give rise to non-uniformity. When treated in the above manner the surface of the fibrous material after treatment with styrene, polymerisation and separation assumes a fine granular form like very fine glass paper and the apparent thickness of the fibrous material is increased by the granular surface of polystyrene which is about .001 inch thick. As has been explained above, it is not necessary to employ a device to smooth out the surface of the fibrous material, but preferably a calendering operation is carried out. This has the effect of smoothing out any irregularities in the surface. In many cases, however, e. g. in

fibrous material for cable jointing purposes, the nature of the finish is of minor importance and the original finish should suffice and may even be of advantage.

Obviously the fibrous material may be treated when in roll form or in the form of sheets or lengths if desired, but the treatment in roll form is preferable in view of the ease of handling the fibrous material which is preferably a form of paper.

In carrying the invention into effect, a roll of paper may be dried in normal manner i. e. under vacuum and may then at once be plunged into a vessel containing styrene plasticised with monoamyl-naphthalene. From this bath the roll should be carefully unrolled and tightly rewound on to a spindle, it being understood that during the impregnating process it is important to ensure that the paper is maintained in the styrene for a sufficient length of time to become thoroughly impregnated. It is also important to make sure that little or no air is allowed to remain in the paper and that the paper is tightly rewound. The paper may, therefore, be unrolled and rewound all under styrene in which case the paper should be led through about three feet of styrene between unrolling and rewinding or the paper may be rewound in a vacuum chamber. Alternatively, the paper may be unwound above the styrene, led therethrough and rewound under the styrene.

During rewinding the last few turns of paper may be interleaved with styrene impregnated fabric and the roll then placed in a rotatable container in the form of a bomb any excess styrene being allowed to drain off the roll prior to insertion into the container. If desired smoothing rolls may be employed to remove surplus styrene during the rewinding operation in cases in which the rewinding is done in the vacuum chamber. A little surplus styrene should be present in the rotatable container so that the polymerisation is effected in an atmosphere of styrene vapour. Before beginning the polymerisation the container should be evacuated to remove air after which the container will become filled with styrene vapour as described above.

During polymerisation which is preferably effected at between 90° C. and 100° C. the container should be rotated to prevent uneven draining of the styrene, but only a very slow rotation is necessary.

It may here be mentioned that the polymerisation time curve of styrene is at first steep and then bends over sharply to extend almost parallel with the time abscissa, i. e. is asymptotic. In other words the polymerisation starts and continues rapidly until about 80% to 85% polymerisation has been effected after which polymerisation quickly slows down. It is not always desirable to remove the paper from the container with as much as 15% of the impregnant still unpolymerised and therefore the temperature may be raised to above 100° C. for a short time to bring the polymerisation nearer to completion. This has practically no effect on the properties of the resulting insulating material which are determined during the earlier stage of polymerisation at below 100° C. and are merely effected to speed up the lost stages of polymerisation which would otherwise take a considerable time. It is not, however, desirable to take polymerisation to completion in view of the fact that a certain amount of the monomer acts as a plasticiser with bene-

5 ficial results. After polymerisation the paper is removed from the container and unwound in an oven at a temperature of about 180° C., the impregnated fabric assisting in starting the unwinding.

10 Considering now the properties of insulating material in accordance with the invention in rather more detail. A medium density 5 mil paper so produced has been found to be quite pliable at room temperature and capable of being wound into rolls and otherwise handled without difficulty. The elongation is 2.5% as against 2.7-3% for untreated paper, while the tensile strength is about 50% greater than untreated paper.

15 The breakdown value of paper treated according to the invention but with the surface neither smoothed nor calendered has been determined before and after progressive exposure to air of relative humidity over 50%. No discernible change in this value has been detected up to an exposure of 24 hours and the average values obtained during this period are as follows:—

20 Nominal thickness of paper .005", thickness after styrenation .0073" (mean measured total). Mean B. D. V. for single sheet 7.7 k. v. After a week's exposure a sample gave a mean B. D. V. of 6.5 k. v.

25 The power factor at 50 period per second has been determined on 1" strips of paper treated according to the invention whose surface has not been calendered and with progressive exposure to air. The results are given in Table 1.

TABLE 1

Time of exposure, hours	P. F. at 50 periods per second (room temperature)	Relative humidity, percent
0.....	0.0020	50
1.....	.0056	50
2.....	.0082	50
3.....	.0120	50
4.....	.0156	50
5.....	.0198	50

35 On completion of the tests given in Table 1 the tapes were put under vacuum at a temperature of 120° C., in order to determine if it were possible to re-dry them. Table 2 gives the results so obtained:

TABLE 2

Vacuum drying at 120° C.

Time of drying, hours	P. F. at 50 periods per second (room temperature)
0.....	0.037
1.....	.00215
2.....	.00187
3.....	.00174
18.....	.00134

40 These results indicate that it is readily possible to re-dry humidified paper which has been treated according to the invention. Similar results have been obtained after calendering the paper.

45 It will be noted that the power factor at the original room temperature given at the commencement of Table 1 i. e. .002 is of a similar order to the power factor of the material after drying for one hour (see Table 2), and that thereafter the power factor in Table 2 becomes an improvement on the original figure, given in

Table 1. This is in part due to the fact that the original figure in Table 1 was not measured at strictly zero exposure, but the figures indicate that the power factor of the re-dried fibrous material impregnated with polystyrene is at least as good as the power factor of the fibrous material prior to substantial humidification.

Tests have been made on small standard "mica-type" condensers, but with the paper impregnated with polystyrene substituted for the mica and compressed at 120° C., by screwing up the units as tightly as possible. One effect of compressing the papers was to increase the capacity of the unit by the factor 1.84. The first units were made with paper which had been exposed for about an hour. A second series was then made up with fresh paper which was also vacuum dried for 20 hours at 120° C. Results are given in Table 3.

TABLE 3

Frequency, k. c.	Power factor	
	Series 1	Series 2
0.05.....	0.0078	0.0029
1.....	.0083	.0032
10.....	.0110	.0049
100.....	.0173	.0097
1,000.....	.0320	.0204

It may be mentioned that the monomeric styrene utilised in the present process is preferably plasticised, for example, in accordance with the technique set out in our co-pending British specification No. 5,028/37, a particularly satisfactory plasticiser being mono-amyl-naphthalene in any of its various forms with the amyl either in the alpha or beta position and a suitable percentage being 10%.

It will be appreciated that fibrous material produced in accordance with the present invention has many applications as insulating material, for example in insulating cables as described above, in condensers, stress grading devices such as stress cones, condenser bushings and the like.

What is claimed is:

1. A method of treating fibrous electrical insulating material in sheet, tape or like form comprising impregnating the material with an impregnant predominantly consisting of monomeric styrene and polymerising the styrene in a closed vessel in the presence of styrene vapor at a temperature below 100° C. but at least substantially as high as 90° C. in order to produce a material having a fine granular surface film of polystyrene which may be heated to 120° C. without becoming sticky.

2. A method of treating fibrous electrical insulating material in sheet, tape or like form comprising drying the fibrous material, immersing the material in an impregnant predominantly consisting of monomeric styrene, placing the impregnated material in wound form in a rotatable container and polymerising the styrene at a temperature below 100° C. but at least substantially as high as 90° C. while rotating the container, and subsequently unwinding the impregnated and polymerised fibrous material at an elevated temperature of about 180° C.

3. A method of treating fibrous electrical insulating material in sheet, tape or like form comprising drying the fibrous material, passing the material through a bath of an impregnant predominantly consisting of styrene in order to impregnate the fibrous material, winding the ma-

- terial into the form of a roll while immersed in the styrene or styrene mixture, allowing excess impregnant to drain off, placing the impregnated roll of material in a rotatable container, polymerising the styrene at a temperature below 100° C. but at least substantially as high as 90° C. while rotating the container and subsequently unwinding the impregnated and polymerised fibrous material at an elevated temperature of about 180° C.
- 10 4. A method according to claim 2, wherein the fibrous material is unwound from a roll, is then impregnated and thereafter rewound under reduced pressure.
- 15 5. A method according to claim 2, wherein the outer turns of fibrous material are interleaved with styrene impregnated fabric.
6. A method according to claim 3, characterised in this that the material is unwound from a roll and rewound both under styrene.
- 20 7. A method according to claim 2, wherein the

impregnated material is wound on to a spindle and the roll of material is then inserted into a container so dimensioned that the roll of material fits tightly therein.

8. A method of preparing electrical insulation 5 which comprises building up the insulation in the form of lappings of insulation manufactured according to claim 1 and then drying the built up insulation by heating to about 120° C. preferably combined with vacuum treatment at which tem- 10 perature the insulation may be dried without the adjacent layers adhering together.

9. A method according to claim 2, wherein after the impregnation excess impregnant is removed from the fibrous material by smoothing rolls, and 15 wherein the fibrous material is thereafter wound up into a roll prior to polymerising it in said rotatable container.

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