April 12, 1960 M. H. GODDEN 2,932,719

ELECTRICAL RESISTANCE MATS

Filed July 14, 1955 2 Sheets-Sheet 1

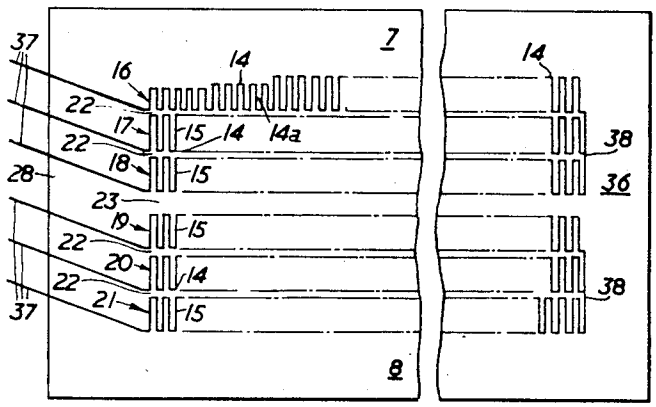


FIG. 1.

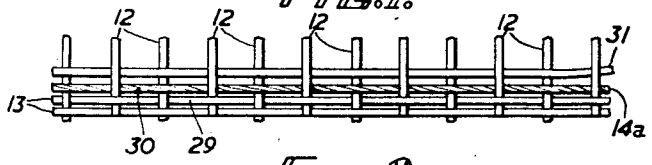


FIG. 2.

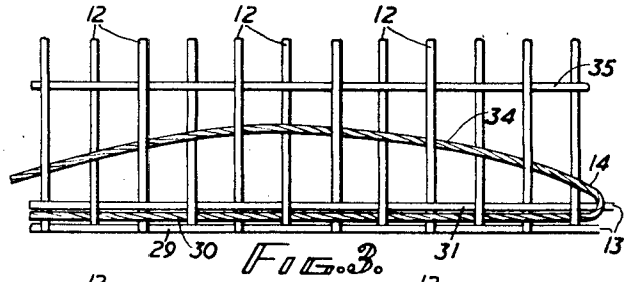


FIG. 3.

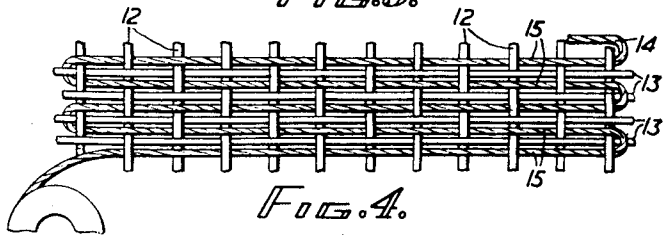


FIG. 4.

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ELECTRICAL RESISTANCE MATS

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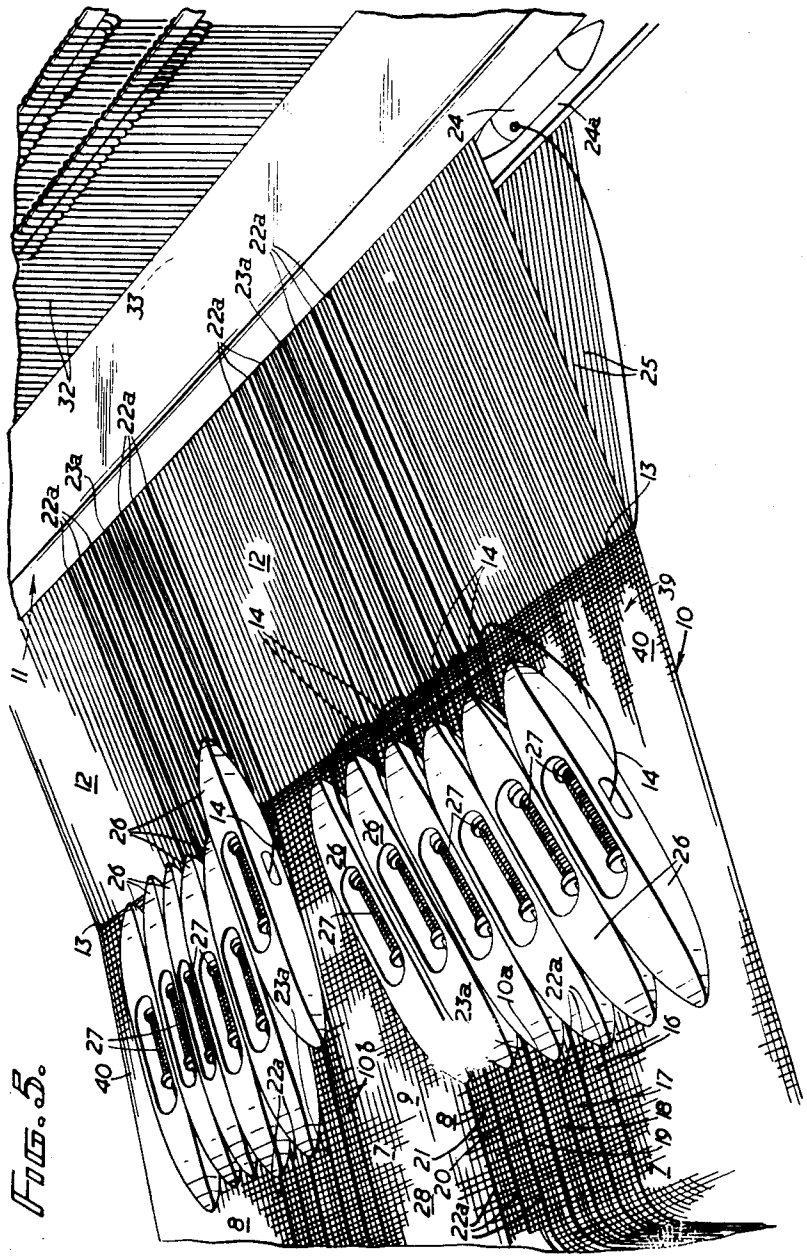


FIG. 2.

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ELECTRICAL RESISTANCE MATS

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11 Claims. (Cl. 219—46)

This invention relates to electrical resistance mats, that is to woven textile fabrics having an electrical resistance element or wire incorporated in their weave. Such fabrics are coming into increasingly common usage as surface-heating layers for attachment to aircraft and other surfaces, as for example the blades of propellers, in connection with the ice protection of such control surfaces, blades or the like.

Particularly when such resistance mats are employed in connection with the ice protection of propeller blades, the resistance element or wire is subjected to repeated vibrational stresses with the result that fatigue of the wire rapidly occurs with eventual failure of the complete ice protection system of the particular blade. One reason for the failure of the element or wire in the known resistance mats, in which the element or wire runs longitudinally from the root towards the tip of the blade, is thought to be the work hardening of the wire which occurs under the flexural vibration of the blade, such work hardening being aggravated by the length of each run of the wire in the longitudinal direction of the blade.

The object of the present invention is to provide a new or improved electrical resistance mat the arrangement of the resistance element or wire of which is such that the element or wire will be considerably less prone to mechanical or electrical failure under vibrational stresses than in the resistance mats known hitherto. In this connection it will be understood that the electrical resistance element or wire is invariably a stranded wire so that mechanical failure of even only one of the strands will have the immediate effect of increasing the resistance of the stranded wire at the point of fracture and consequently cause failure of the wire due to burning of the wire at that point.

A further object is to provide an electrical resistance mat in the form of a textile fabric sheet woven from warp threads and weft threads of electrically insulating material and having electrical resistance elements forming part of its woven structure and laid in as weft during the weaving of the mat in such manner that the picks of resistance weft are electrically insulated from each other and so that the electrically insulating weft threads provide proper spacing and insulation between such picks of resistance weft.

A still further object is to provide an electrical resistance mat having electrical resistance elements woven into the fabric of the mat as a series of weft threads and so that each pick of resistance weft extends across only a portion of the width of the sheet of warp threads of the mat in order to form a plurality of separated parallel "ribbons" extending side by side longitudinally of the mat.

The invention also includes the novel weaving process by which the electrical resistance mat is manufactured.

It will be understood that each ribbon may be separately fed with electrical power or the ribbons may be electrically connected across their ends and supplied with current in parallel.

As used herein the term "textile" is intended to include not only fabrics woven from the usual textile fibres, but also from fibre, such as glass fibre yarn, which has been found to have the required heat resistant and electrical insulating properties necessary for the electrical resistance mats having a bare element as the heating element.

An electrical resistance mat in accordance with the invention and the process by which it is woven will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a broken plan view of the mat,

Figures 2, 3 and 4 illustrate diagrammatically on a greatly enlarged scale, one of the six parallel ribbons of resistance wire weft of the mat shown in Figure 1 during various stages of the weaving process, and

Figure 5 illustrates the central portion of a hand-loom with the partially woven mat in position therein.

Referring to the drawings, the electrical resistance mat **10** shown therein is suitable as a surface heater for application to an aircraft propeller blade for use in the protection of such blade against the consequences of ice accretion in flight. As shown clearly in Figure 1, the mat **10** is of generally elongated rectangular shape, its length being for example two thirds of the length of the propeller blade to which it is to be fitted so that when applied to the root end of the blade it extends somewhat over half way towards the tip. The mat **10** is woven on a hand-loom, sufficient of which is illustrated at **11** in Figure 5 to enable the weaving process to be understood. In order to permit the whole effective width of the loom to be employed, two mats are woven simultaneously side by side, as shown at **10***a* and **10***b*, the two mats being connected during the weaving process by a central web portion **9** which is subsequently cut longitudinally in order to separate the mats. Each of the mats **10***a*, **10***b* is woven from warp threads **12** of glass fibre yarn and, in the main, weft threads **13** of the same material. However, in addition to the glass fibre weft threads **13** a metallic resistance wire **14** is laid in as weft **14***a* during the weaving of the mat in such manner that each of the picks **15** of resistance wire are electrically insulated from each other and so that the intervening glass fibre weft threads provide proper spacing and insulation between such wire picks.

The electrical resistance wire, which is woven in as auxiliary weft thread **14***a*, may be for example a copper nickel alloy wire annealed to render it capable of being woven and is so laid in that the length of each pick **15** of resistance wire is only a fraction of the width of the complete resistance mat **10**. In the example illustrated in Figure 1 there are six separate ribbons **16** to **21** respectively formed of wire weft thread woven parallel and side by side with each other within the central area of the resistance mat **10** between comparatively wide selvedge portions **7**, **8** formed by the glass fibre weft threads disposed one on each side of the central area formed by the ribbons. It will be appreciated that when the two mats **10***a*, **10***b* are being woven side by side, as illustrated in Figure 5, the two adjacent selvedge portions **7**, **8** of the two mats form part of the central web portion **9** which is subsequently divided to form the respective selvedge portions. The ribbons **16** to **21** are separated into two groups of three, each group having a narrow strip **22** of textile fabric, as shown in Figure 1, between the central and two outer ribbons of the group while a wider strip **23** of textile fabric is left between the two groups. Such wider strip **23** forms the part of the mat **10** which runs longitudinally along the leading edge of the propeller blade when the mat is applied thereto, as the task of wrapping the mat round the blade is thereby facilitated.

In practice the two mats **10***a*, **10***b* are woven side by side by unwinding glass fibre warp threads **12** from a

beam, not illustrated, of the hand weaving loom **11** and the glass fibre weft threads **13** which extend across the entire width of the two mats are inserted by means of the usual fly-shuttle **24** of the loom which is driven across the raceboard **24***a* to pass under and over the alternate warp threads forming the shed **25**. The resistance wire weft threads **14***a* forming the ribbons of the electrical resistance element, however, are laid in as part of the weaving process by means of small hand shuttles **26** each having a bobbin **27** which carries a sufficient length of the resistance wire **14** to form one of the ribbons to be woven into the main area of the mats **10***a*, **10***b*. It will be seen, therefore, that the number of hand shuttles employed corresponds to the number of ribbons required in the two mats. It is desirable, for the assistance of the loom operative, to have certain of the warp threads of different colour from the main body of warp threads **12** to enable the operative to tell where to insert and withdraw the respective hand shuttles **26** during the weaving of the web of material. Such differently coloured warp threads, which are shown for the purpose of illustration by thickened lines in Figure 5 at **22***a* and **23***a*, are arranged side by side in groups of the necessary width and at the required spaced intervals to correspond with the aforesaid strips **22**, **23** of textile fabric between the ribbons **16** to **21** to form a guide for the operative.

The sequence of operations during the weaving process, most clearly shown in Figures 2, 3 and 4 which show diagrammatically the formation of one ribbon of resistance wire, is as follows:

The fly-shuttle **24** is first of all caused to make its picks through the shed **25**, back and forth between shed changing in the usual manner, until the commencing electrically insulating end **36** of the mat **10** has been woven. At the point where the six electrical resistance wire ribbons **16** to **21** are to be woven in, after the fly-shuttle **24** has laid its pick of glass fibre weft, **29** in Figure 2, across the shed **25**, the shed is changed and then the six hand shuttles **26**, each carrying resistance wire for one ribbon, are passed in sequence and in the same sense of direction under their respective groups of warp threads **12** and out, all in the same shed, to lay the first pick **30** of resistance wire, shown in shaded lines. Thereupon the fly-shuttle **24** lays a further glass fibre weft **31** in the same shed but in the opposite direction, the shed is changed by movement of the healds **32** and the picks **30** and **31** are beaten up by the reed **33**. The six hand shuttles **26** are then passed in the opposite direction to that of their previous picks under their respective groups of warp threads **12** to lay further picks **34** of resistance wire, as shown in Figure 3, whereafter a pick of glass fibre weft **35** is laid in the same shed by the fly-shuttle, the shed being then changed and the further picks beaten up.

This sequence of operations is repeated until the total length of web with resistance wire ribbon inserts **16** to **21** has been woven, an enlarged view of a short portion of one of such inserts being shown in Figure 4. When that state has been reached the small hand shuttles **26** are left free and the required remaining length of web consisting of the terminating electrically insulating end **38** of the mat **10** is completed by weaving the glass fibre weft threads **13** with the sheet of glass fibre warp threads **12** in the usual manner.

At the commencement and termination of resistance wire weave suitable electrical connections are made between the wire weft threads **14** of the various ribbons **16** to **21** to comply with the electrical requirements of the particular electrical ice protection system. In the mat illustrated in Figure 1 the commencing ends **38** of the groups of ribbons **16** to **18** or **19** to **21** are secured together, as by soldering, whilst the terminating ends **37** of each ribbon are left free and are subsequently covered with rubber or plastic insulating sleeving, not shown.

By forming the elongated electrical resistance mat **10** with the resistance element or wire woven thereinto to form a plurality of separate narrow ribbons **16** to **21** extending in parallel along the length of the mat, each pick **15** of resistance wire weft is very short and consequently each ribbon, due to its concertina-like form, becomes resilient and thereby reduces the fluctuating stresses to which the resistance mat is subjected due to the flexural vibration of the propeller blade under flight conditions, and to which the mat is itself accordingly subjected.

The web **39** is woven of considerably greater width than the required finished width of the two resistance mats **10***a*, **10***b*, the resulting wide selvedges **40**, **40** on the outer sides of the web, which are unnecessary in the finished product, being subsequently trimmed away as well as the central web portion **9**. As clearly shown in Figure 5 such selvedges, together with the remainder of the web **39**, provide a fell of sufficient width to serve as a travelling platform for the small hand shuttles **26** between each pick made by these latter, it being necessary during the weaving process to lay these shuttles in close proximity to the particular group of warp threads **12** which they serve.

Although the resistance wire picks **15** in the mat described are separated from each other by a single weft thread **13** of glass fibre, it will be appreciated that a plurality of glass fibre weft threads may be laid by means of the fly-shuttle **24** between adjacent picks of resistance wire if it is desired to increase the length of the ribbons **16** to **21** without substantially increasing the electrical resistance of each ribbon.

I claim:

1. An electrical resistance mat comprising a textile fabric sheet woven from glass fibre yarn, and a plurality of electrical resistance elements forming part of the woven structure of said mat, each of said resistance elements being woven into the fabric of the mat as a series of weft threads and so that each pick of resistance weft extends across only a portion of the sheet of warp threads of the mat in order to form a plurality of separated parallel "ribbons" extending side by side longitudinally of said sheet of warp threads, each ribbon comprising a single length of resistance element and adjacent picks of such element being laid between the warp threads in opposite directions so that the ribbon extends in concertina-like form longitudinally of the mat.

2. An electrical resistance mat according to claim 1, wherein a weft thread of glass fibre yarn which extends across the whole width of the sheet of warp threads is woven thereinto to separate and electrically insulate each pick of resistance weft from the adjacent pick, and an insulating portion woven with similar weft threads is formed at each end of the mat, the ribbons of resistance element commencing and ending short of each end of the mat.

3. For an aircraft propeller blade, a surface heater comprising an electrical resistance mat according to claim 1, wherein the ribbons of resistance element are separated into two groups each comprising a plurality of ribbons having a narrow strip of textile fabric therebetween while a wider strip of textile fabric is left between the two groups of ribbons to form a part of the mat adapted to run longitudinally along the leading edge of a propeller blade to which the resistance mat is to be applied.

4. An electrical resistance mat comprising a sheet of textile warp threads interwoven with textile weft threads which extend across the whole width of the sheet of warp threads to form a textile fabric sheet and a plurality of electrical resistance elements forming part of the woven structure of said mat, each of said resistance elements being woven into the fabric of the mat as a series of weft threads and so that each pick of resistance weft extends across only a portion of the width of the sheet of warp threads in order to form a plurality of parallel "ribbons" separated by strips of textile fabric and extending side by side longitudinally of said sheet of warp threads, each

ribbon comprising a length of resistance element and adjacent picks of said element being laid between the warp threads in opposite directions so that each ribbon extends in concertina-like form longitudinally of the mat, some of said textile weft threads which extend across the whole width of the sheet of warp threads being interposed between the picks of resistance weft threads.

5. An electrical resistance mat comprising a sheet of textile warp threads interwoven with textile weft threads which extend across the whole width of the sheet of warp threads to form a textile fabric sheet and an electrical resistance element forming part of the woven structure of said mat, said resistance element being woven into the fabric of the mat as the series of weft threads and so that each pick of resistance weft extends across only a portion of the width of the sheet of warp threads in order to form a plurality of parallel "ribbons" separated by strips of textile fabric and extending side by side longitudinally of said sheet of warp threads, each ribbon comprising a length of resistance element and adjacent picks of said element being laid between the warp threads in opposite directions so that each ribbon extends in concertina-like form longitudinally of the mat, some of said textile weft threads which extend across the whole width of the sheet of warp threads being interposed between the picks of resistance weft threads.

6. An electrical resistance mat according to claim 4, wherein at least some of said parallel ribbons of resistance weft are electrically connected to each other at their ends.

7. A process of weaving on a loom having a fly shuttle an electrical resistance mat comprising the steps of weaving textile weft threads across the whole width of a sheet of textile warp threads to form a textile fabric sheet in which textile weft threads extend transversely across the entire sheet of textile warp threads, inserting during the weaving process a plurality of resistance elements each of which is woven as a series of weft threads extending longitudinally of said sheet of warp threads and so that each pick of each series of resistance weft extends across only a portion of the width of the sheet of warp threads in order to form a plurality of parallel ribbons of resistance element separated by strips of textile fabric and extending side by side longitudinally of said sheet of warp threads.

8. A process according to claim 7, wherein the resistance element for each ribbon is carried by a separate shuttle and a pick is made by each of these latter of the

necessary width to form each ribbon in the same shed as a pick of weft thread laid by the fly-shuttle across the entire width of the fabric sheet, whereafter the shed is changed and a further pick in the opposite direction is made by each of the separate shuttles across the respective groups of warp threads together with a further pick laid by the fly-shuttle, this sequence of operation being repeated until the total length of fabric sheet with resistance ribbon inserts has been woven.

9. A process according to claim 8, wherein the loom is a hand loom and before the weaving process is commenced warp threads of different colour from the main body of warp threads are inserted in said main body side by side in groups of the necessary width and at the required spaced intervals to correspond with the strips of textile fabric between the ribbons to form a guide for the operative when making the picks by said separated shuttles.

10. A process according to claim 8, wherein said fabric sheet is woven of considerably greater width than the required finished width of the mat so that wide selvedges of textile material are formed on either side of the mat which extend normal to the picks of resistance weft and from end to end of the mat, such selvedges providing a fell of sufficient width to serve as a travelling platform for said separate shuttles, by which the resistance element is carried, between each pick made by these latter, said separate shuttles being in the form of small hand shuttles.

11. A process according to claim 7, wherein a plurality of resistance mats are woven simultaneously side by side on the same loom to permit the width of the latter to be effectively employed, the mats being connected to each other during the weaving process by a web portion which is subsequently cut longitudinally in order to separate the mats.

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