

April 28, 1959

H. A. DELCELLIER ET AL
HEAT RESISTANT WOVEN CLOTH

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2 Sheets-Sheet 1

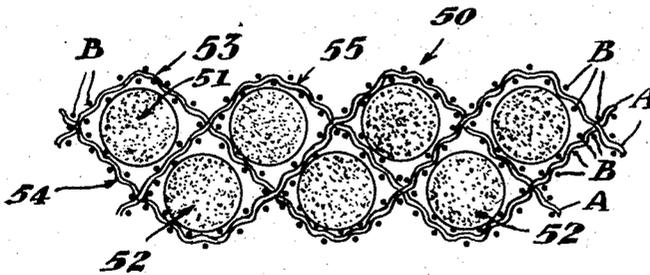


FIG. 1.

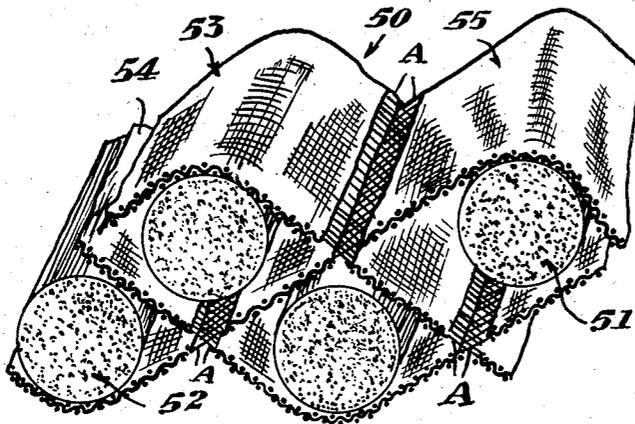


FIG. 2.

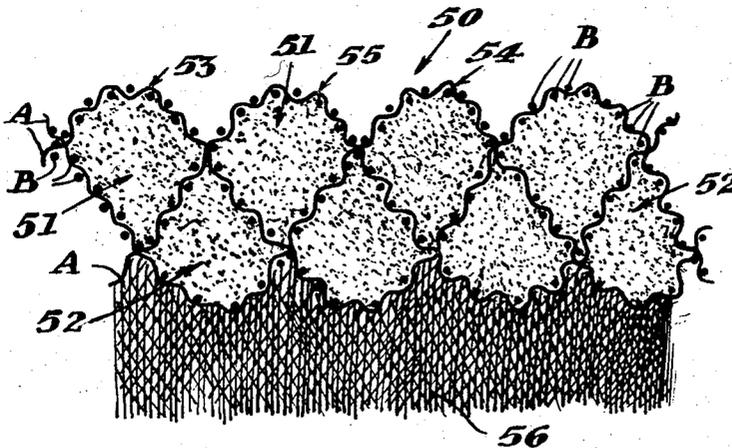


FIG. 3.

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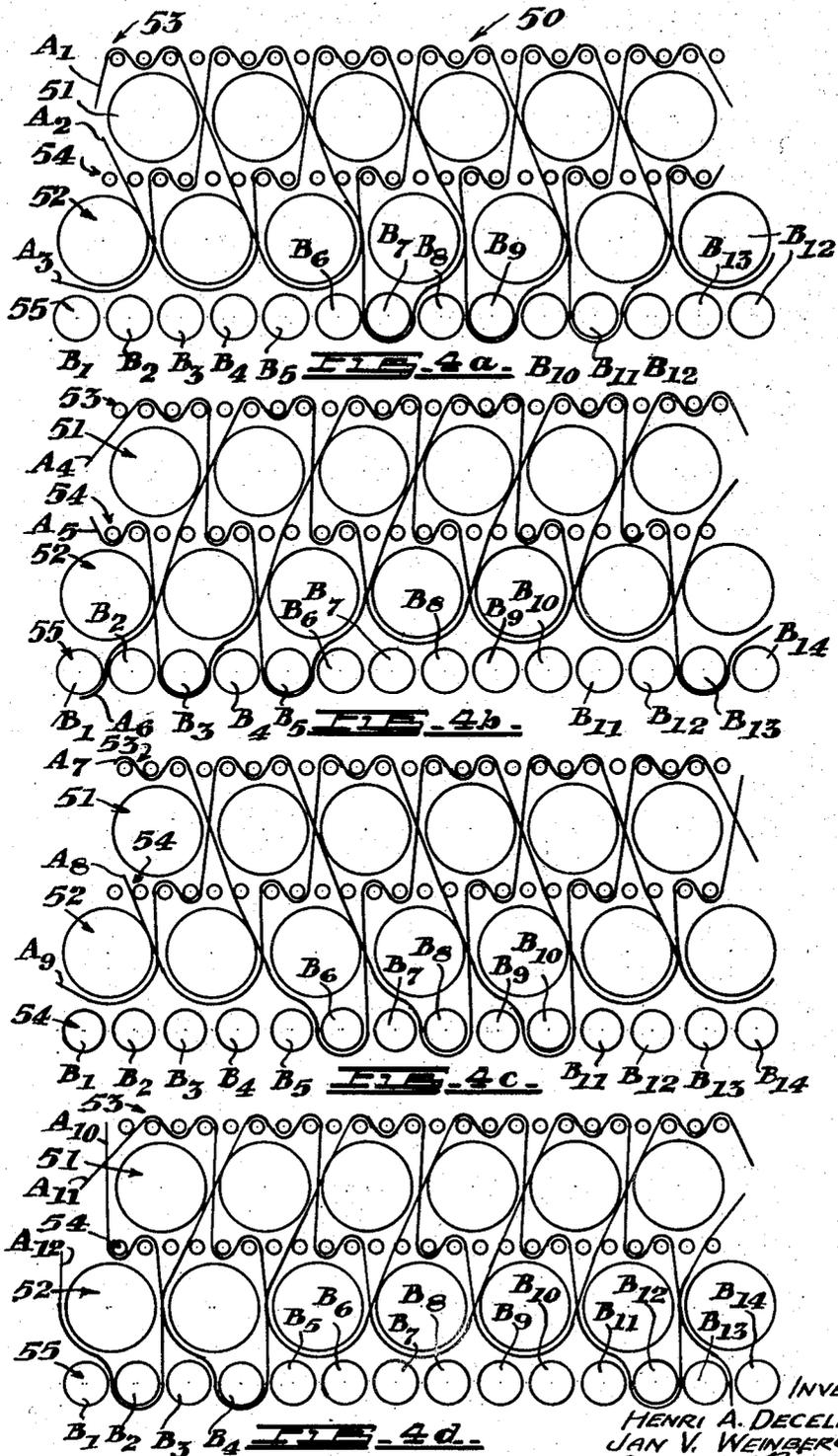
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2,884,018

HEAT RESISTANT WOVEN CLOTH

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Application November 5, 1956, Serial No. 620,460

9 Claims. (Cl. 139—408)

This invention relates to a cloth for use as a protection
against radiant or conducted energy emanating from a
heat source.

There are many requirements for the protection of
personnel against such radiant or conducted energy, and
particularly against flame. They may be liable to ex-
posure to flame for short periods, as in the case of gunners
and others exposed to the heavy back flash of rockets
and the like, or they may be liable to exposure for longer
periods as in the case of fire fighters.

The standard fire fighting suit is made of cotton and
is provided with a rubber lining or interlining to keep
out not only the water with which the fighter is soaked
to cool him, but the steam formed as a result of this
soaking. It was earlier proposed to use suits made of
asbestos which in order to be spun had to be mixed with
cotton or the like. It was found, however, that asbestos
suits so reduce the efficiency of a fire fighter (to about
5%) as to make them totally unsuitable for any case in
which the fire fighter must perform work, e.g., in rescuing
personnel from a crashed aeroplane. The asbestos suit
is very heavy, weighing approximately 80 lbs. as opposed
to about 12 lbs. for a suit according to the present inven-
tion and is so stiff as greatly to restrict the movements
of the wearer of the suit. Asbestos is also subject to the
disadvantages that asbestos has a very low resistance to
friction and is highly conductive. It has, therefore, been
thought necessary to use the fire fighting suit which is
presently standard and is made of cotton with a coating
of rubber on the inside or with an interlining of rubber.
The cotton burns, of course, and it is therefore necessary
for a fire fighter equipped with such cotton suit to refrain
from entering a flaming area and to rely on frequent
wetting.

The principal object of the present invention is to
provide a cloth particularly suitable for a fire fighting
suit which allows the wearer freedom equal to that of
the existing cotton-plus-rubber suit, while providing pro-
tection far in excess of that heretofore thought possible.
A further object of the invention is to provide a cloth
that lends itself to a great number of other applications
in the military and industrial field, such as protection
of personnel operating open hearth furnaces, or hand-
ling of ingots, or troops which can be expected to be
exposed to the flash of nuclear weapons in tactical war-
fare.

Thus, a woven cloth according to the invention com-
prises a plurality of layers of large gauge weftwise ex-
tending fillers bound in place by a plurality of intersec-
ting woven binding fabrics forming at least an outer layer
and an inner layer of binding fabric, the fillers of each
layer being staggered with reference to the fillers of
the next adjacent layer and the woven binding fabrics
being trained around the fillers so that each binding fabric
repeatedly crosses each of the remaining fabrics at a
plurality of points of intersection and extends in zigzag
fashion from one face to the opposite face of the finished
cloth, at least the portions of the binding fabrics forming

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the outer layer being composed substantially, both as to
warp and weft, of materials of a high degree of heat
resistance, and a substantial portion of each of the fillers
of at least the outer layer being formed of a non inflam-
mable material adapted under exposure to extreme heat
to shrink and eventually to disintegrate in large part
from the solid state to the gaseous state.

The material of which the binding fabric is formed is
preferably inorganic matter such as glass fibre or any
mineral fibre suitable for weaving. It is advantageously
combined with more conventional textile fibres by blend-
ing or twisting so as to improve the weaving efficiency
of the more brittle mineral fibre. Excellent results have
been obtained with a twisted yarn composed of glass
fibre and a textile material of low extensibility with a
high flash point, the latter acting as a carrier during the
processing of the material which disintegrates in the
course of exposure to heat without, however, substantially
affecting the intrinsic properties of the remaining binding
fabric. A saponified acetate such as that sold under the
trademark Fortisan has been found to serve this purpose
best.

The fillers of at least the first or outer course, and pref-
erably all of the fillers, are composed of blends of fibres,
and consist of a substantial portion of acrylic fibres. The
copolymer of vinyl chloride and acrylonitrile known as
"Dynel" (trademark) has been found to be the most
suitable basic filler material as indicated below.

According to the preferred form of the invention, the
acrylic fibres are present as fine staple filaments and the
fillers comprise a combination of these fine staple acrylic
filaments, plus animal hair, the latter being arranged to
space the acrylic filaments.

It is desirable that the cloth according to the invention
be formed with a woolly pile on the side which is not to
be exposed, this being formed of very thin animal hair of
low specific weight in order to produce a great unit den-
sity of the pile while maintaining a comparatively high
flash point. A combination or blend of angora hair and
fine wool have been found to be most suitable for this
purpose.

The invention will now be described with reference to
the accompanying drawings in which:

Figure 1 is a diagram illustrating a cloth of the general
construction used according to the invention illustrating
the arrangement of the large gauge weftwise extending
fillers bound in place between a plurality of woven fabrics,

Figure 2 is a perspective view illustrating diagram-
matically the manner in which the warp threads of each
fabric pass between the warp threads of the remaining
fabrics where these cross one another,

Figure 3 is a diagram illustrating the manner in which
the fillers are condensed between the binding fabrics in the
actual cloth, so assuming a more or less triangular shape,
and also illustrating the provision of a woolly pile on the
unexposed face of the cloth, and

Figures 4a, 4b, 4c and 4d are cross sections of a sche-
matic weaving layout suitable for the provision of a woolly
pile as indicated in Figure 3.

The woven cloth according to the invention is of the
general construction described in Canadian Patent 437,565
granted October 29, 1946, to Jan V. Weinberger. The
cloth 50 in the illustrated embodiment comprises five
layers or courses, two layers of fillers 51, 52, and three
woven binding fabrics 53, 54, 55 forming outer, inter-
mediate and inner layers. The fillers 51 of one course
lie adjacent one face of the cloth and are staggered with
reference to the fillers 52 of the companion course which
lie adjacent the opposite face of the cloth. The fillers
51, 52 extend in the weftwise direction of the cloth and
are of much larger gauge than the component warp and
weft strands of the binding fabrics 53, 54, 55. Each of

the binding fabrics 53, 54, 55 is a complete woven fabric comprising warp strands A and weft strands B. These binding fabrics are trained around the fillers 51 and 52 as shown in the drawings so that said fabrics extend in sinuous or zigzag fashion from one face to the opposite face of the finished cloth.

During the weaving operation in which the fillers 51 and 52 are bound in place between the fabrics 53, 54 and 55, the latter are woven so that the warp strands A of each fabric pass between the warp strands A of the remaining fabric at a number of points of intersection where the fabrics cross one another in passing from one face to the opposite face of the cloth as best seen in Figure 2. During the weaving operation the fabrics 53, 54 and 55 are placed under sufficient warp tension so that the fillers 51 and 52, which are initially of circular cross section as shown in Figure 1, are crushed together so that they assume the triangular shape illustrated in Figure 3.

It will be noted that the binding fabrics 53, 54 and 55 are trained around the fillers 51, 52 so that in the finished cloth each filler is substantially completely enveloped by a woven fabric covering which is conjointly formed by filler engaging portions of the binding fabrics. The result is a construction which is basically desirable for the purposes of the present invention. It is a multi-layer cloth which is relatively thick and yet flexible and it presents a corrugated surface, thus reducing the energy intensity to which a given area covered by the cloth is subjected.

According to the invention it has been found possible to provide a modified construction which, in addition to providing high thermal insulation, results in high heat absorption and to some extent serves to extinguish flame. Thus the construction while providing initially only a weftwise extending corrugation of the cloth according to the prior patent, develops under exposure to extreme heat, additional warpwise extending corrugations thereby greatly increasing the degree of dissipation of heat by decrease of the intensity relative to the exposed area. To this end the fillers 51 and 52 are formed of a material which shrinks under the influence of extreme heat. Secondly, the fillers are formed of a material which undergoes an endothermic reaction, passing from solid to gaseous state substantially without the formation of a liquid (which would store latent heat to be dissipated into the inner side of the cloth) and leaving a small residue of tars and ashes.

It has been found that suitable filler materials for this purpose are acrylic fibres such as those commercially sold under the trademarks Orlon, Acrylan, X51 and Dynel. The most suitable is Dynel which passes from the solid to the gaseous state without the formation of a liquid, while Orlon, Acrylan and X51 do leave some liquid and solid residue, as well as tars and ashes. Dynel is a synthetic fibre made by the copolymerisation of 60% vinyl chloride and 40% acrylonitrile. It becomes subject to shrinkage at a temperature of 250° F. in unextended condition unless stabilised at a higher temperature. The dielectric constant is 4.5 at 60 cycles. Orlon and X51 are composed essentially of acrylonitrile. Acrylan is composed of 85% to 90% acrylonitrile and 10% to 15% vinyl acetate or vinyl pyridine.

As the filler of acrylic fibre is consumed it absorbs heat and the gas which is developed dissipates into the atmosphere thereby automatically carrying heat out of the cloth, and moreover displacing oxygen-containing air so as to serve as a flame extinguisher and to prevent the protected matter next to the cloth from bursting into flames although the temperature margin of the flash point has been exceeded. On disintegration of the acrylic fibre, there remain gas or air pockets which contribute substantially to the thermal insulation properties of the cloth. The acrylic fibres have the added advantage for use in the fillers 51 and 52 that as they soften they tend to adhere

to the warp and weft threads of the binding fabrics to seal them at their junction and thus strengthen the fabric.

It is preferred that the acrylic fibres be present in the form of fine staple filaments, whereby the fillers flex readily, and that the filaments are spaced by animal hairs, e.g., wool or acetate or other conventional textile fibre materials, to prevent packing and reduce shrinkage of the acrylic fibre. It has been found in practice that when the temperature to which the fillers are subjected reaches the softening point of the acrylic fibre, the filaments tend to adhere together and pack into a mass interfering with the desired flexibility of the woven cloth. In addition to serving this purpose, the animal fibres serve to control the extent of shrinking weftwise which, though desirable, as indicated above, if controlled, has undesirable effects if excessive. If the heat energy against which protection is sought is focussed on a particular area of cloth, excessive shrinkage of the acrylic fibre in weftwise direction tends to pull the warp threads of the binding fabric apart (away from the focus point) forming a hole therein. Furthermore, excessive shrinkage makes a fire fighter's suit formed of the cloth too small so that it is too tight, and moreover causes the cloth to break at points such as the elbows where the cloth is subjected to strain when work is performed under the simultaneous exposure to heat which tends to soften the material. Accordingly the degree of shrinkage is controlled by providing the animal fibres spacing the acrylic filaments. The woven fabrics 53, 54, 55 or at least the portions of them forming the outer layer are designed to form a mechanical barrier to the heat impact. The material must then be one which does not support combustion. Metals such as copper are suitable as a heat barrier but the greater flexibility and lesser conductivity of glass makes it suitable in spite of its lower resistance to abrasion. In order to improve the weaving properties of glass fibres, it is preferred that it be combined by twisting or otherwise with a conventional textile fibre material to serve as a carrier, one which has been found very suitable being the saponified acetate (Fortisan) referred to above because of its low extensibility and high flash point.

Flame or radiant heat coming in contact with the cloth is thus met first by a non combustible layer of binding fabric which acts as a mechanical barrier, and yet is flexible and relatively light so as not to interfere unduly with work to be performed. Then follows a layer 51 of filler having the properties of high energy absorption in its conversion from solid into the gaseous state and thermal insulation as well as serving to extinguish flame as indicated above. There follows then a third layer of the binding fabric which becomes exposed on destruction of the two outer layers which leave a residue of tars and ashes including small particles of glass. This third layer is of substantially the same composition as the first layer and is followed by a fourth layer of filler 52 corresponding to the second layer, and then a layer of binding fabric. The number of layers may be multiplied as desired, an over-all thickness of some 3/4 mm. to 4 mm. at 1 lb. pressure per square cm., having been found suitable for various purposes. In the preferred embodiment, the thickness is 2 1/2 mm., this including three layers of binding fabric, two layers of filler, and a backing of a woolly pile as hereinafter described.

It is desirable that in the portions of binding fabrics forming the inner layer, the weft thread B be formed of a brushable material bound by the warp threads A in a manner which makes the threads B suitable for brushing to form a woolly pile by which additional air spaces or voids are obtained, further increasing the thermal resistance value of the cloth by increasing its bulk with relatively little increase in weight or stiffness. The woolly pile 56 is illustrated in Figure 3 and a suitable weaving layout for producing it is indicated in Figures 4a to 4d. A suitable material is a very thin animal hair of low specific weight in order to produce a great unit density

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of the pile and a high flash point. A particularly suitable material is a blend of angora hair and fine wool and this is used for the weft threads B of the inner layer of binding fabric. In order that it may be readily brushed up, it is more loosely bound by the warp threads A than is the case in the outer and intermediate layers of binding fabrics.

On comparing Figures 4a, 4b, 4c and 4d, illustrating a twelve harness weave with repeat after the seventy second weft thread, it will be seen that the first, third and fifth weft threads B1, B3 and B5 of the inner (lower) layer are bound by warp threads A4, A5 and A6, but not by any of the others. Weft threads B2, B4 and B12 are bound by warp threads A10, A11 and A12, but not by any of the others. Weft threads B6, B8 and B10 are bound by warp threads A7, A8 and A9, but not by any of the others, and weft threads B7, B9 and B11 are bound by warp threads A1, A2 and A3, but not by any of the others. It will be understood that Figures 4a to 4d are only schematic and do not illustrate the actual relationships of the layers in the cloth, the fillers being compressed between the binding fabrics as noted above and as illustrated in Figure 3.

The result is a woven cloth which, as indicated above, provides protection far in excess of the existing cloth for heat resistant clothing permitting freedom for the wearer to perform work. Because of the multiple layer construction, a suit formed of the cloth according to the invention remains intact while outer layers may gradually be disintegrated. Because of the resistance of the cloth to heat, it is possible to coat it with molten metal without the cloth suffering from the high temperature developed in the process and without the cloth becoming rigid. Thus a suit coated with lead, known to afford a measure of protection against nuclear radiation may be provided, a coating of .026 inch of lead offering full protection against alpha and beta radiation and absorbing approximately 3% gamma radiation. As mentioned above, the cloth itself without the coating of lead or the like, provides protection against ambient temperatures of 1600° F., for 60 seconds without allowing a temperature rise on the inside of the garment in excess of the tolerance of a man clothed in a layer of conventional suiting and shirting material. This constitutes sufficient protection against the infra-red radiation emanating from nuclear flashes of fire balls resulting from napalm bombs, etc. At lower temperatures the period of protection is correspondingly longer. A high degree of protection is thus afforded against burning fuels as used in chemical warfare as well as white phosphorous which is prevented from penetrating into the adjoining layers of clothing.

What we claim as our invention is:

1. A woven cloth comprising a plurality of layers of large gauge weftwise extending fillers bound in place by a plurality of intersecting woven binding fabrics forming at least an outer layer and an inner layer of binding fabric, the fillers of each layer being staggered with reference to the fillers of the next adjacent layer and the woven binding fabrics being trained around the fillers so that each binding fabric repeatedly crosses each of the remaining fabrics at a plurality of points of intersection and extends in zigzag fashion from one face to the opposite face of the finished cloth, at least the portions of the binding fabrics forming the outer layer being composed substantially, both as to warp and weft, of materials of a high degree of heat resistance, said fillers being composed of conventional textile fibres and a substantial portion of a copolymer of 60% vinyl chloride and 40% acrylonitrile, the latter being present as fine staple filaments and the conventional textile fibres being arranged to space said filaments, and the weft threads of the portions of the binding fabric forming the inner layer of binding fabric being composed of a blend of angora hair and fine wool and being bound by the warp threads only intermittently.

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2. A woven cloth comprising a plurality of layers of large gauge weftwise extending fillers bound in place by a plurality of intersecting woven binding fabrics forming at least an outer layer and an inner layer of binding fabric, the fillers of each layer being staggered with reference to the fillers of the next adjacent layer and the woven binding fabrics being trained around the fillers so that each binding fabric repeatedly crosses each of the remaining fabrics at a plurality of points of intersection and extends in zigzag fashion from one face to the opposite face of the finished cloth, each of the binding fabrics being formed both as to warp and weft of a twisted yarn composed of glass fiber and a conventional textile fiber and the fillers of at least the layer adjacent the outer binding fabric consisting substantially of fine staple filaments of a copolymer of 60 percent vinyl chloride and 40 percent acrylonitrile spaced by conventional textile fibers.

3. A woven cloth comprising a plurality of layers of large gauge weftwise extending fillers bound in place by a plurality of intersecting woven binding fabrics forming at least an outer layer and an inner layer of binding fabric, the fillers of each layer being staggered with reference to the fillers of the next adjacent layer and the woven binding fabrics being trained around the fillers so that each binding fabric repeatedly crosses each of the remaining fabrics at a plurality of points of intersection and extends in zigzag fashion from one face to the opposite face of the finished cloth, at least the portions of the binding fabrics forming the outer layer being composed substantially, both as to warp and weft, of materials of a high degree of heat resistance, said fillers of at least the layer adjacent the outer binding fabric being composed of conventional textile fibres and a substantial portion of a copolymer of 60% vinyl chloride and 40% acrylonitrile, the latter being present as fine staple filaments and the conventional textile fibres being arranged to space the said filaments, and the weft threads of the portions of the binding fabric forming the inner layer of binding fabric are composed of a blend of angora hair and fine wool and are bound by the warp threads only intermittently.

4. A woven cloth including in combination a plurality of layers of fillers comprising an outer layer including fibers comprising a polymer of acrylonitrile adapted under exposure to extreme heat to shrink and eventually to disintegrate in large part from the solid state to the gaseous state and a plurality of intersecting woven binder fabrics comprising an inner binder fabric and an outer binder fabric, said binder fabrics extending around said fillers with each binder fabric repeatedly crossing the other binder fabrics at a plurality of points alternately to extend from one face to the other face of the finished cloth, said outer binder fabric comprising yarns including fibers of an inorganic incombustible material having a high degree of heat resistance with respect to the degree of heat resistance of said filler fibers which comprise a polymer of acrylonitrile.

5. A woven cloth including in combination a plurality of layers of fillers comprising an outer layer including fibers comprising a polymer of acrylonitrile adapted under exposure to extreme heat to shrink and eventually to disintegrate in large part from the solid state to the gaseous state and a plurality of intersecting woven binder fabrics comprising an inner binder fabric and an outer binder fabric, said binder fabrics extending around said fillers with each binder fabric repeatedly crossing the other binder fabrics at a plurality of points alternately to extend from one face to the other face of the finished cloth, said outer binder fabric comprising yarns including glass fibres having a high degree of heat resistance with respect to the degree of heat resistance of said filler fibres which comprise a polymer of acrylonitrile.

6. A woven cloth including in combination a plurality

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of layers of fillers each including fibres comprising a polymer of acrylonitrile adapted under exposure to extreme heat to shrink and eventually disintegrate in large part from the solid state to the gaseous state and a plurality of woven binder fabrics each comprising yarns including glass fibres having a high degree of heat resistance with respect to the degree of heat resistance of said filler fibres comprising a polymer of acrylonitrile, said binder fabrics extending around said fillers with each binder fabric repeatedly crossing the other binder fabrics at a plurality of points alternately to extend from one face to the other face of the finished cloth.

7. A woven cloth as in claim 6 in which said fabric yarns include conventional textile fibres.

8. A woven cloth as in claim 6 in which said fabric yarns include saponified acetate fibers.

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9. A woven cloth as in claim 6 in which said fillers comprise conventional textile fibers for spacing said acrylonitrile polymer fibers.

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