July 6, 1971 P. V. PALMQUIST ET AL 3,591,400

HEAT-REFLECTIVE FABRICS

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FIG. 1

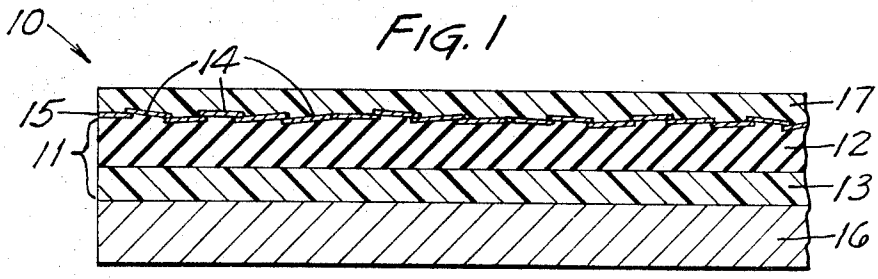
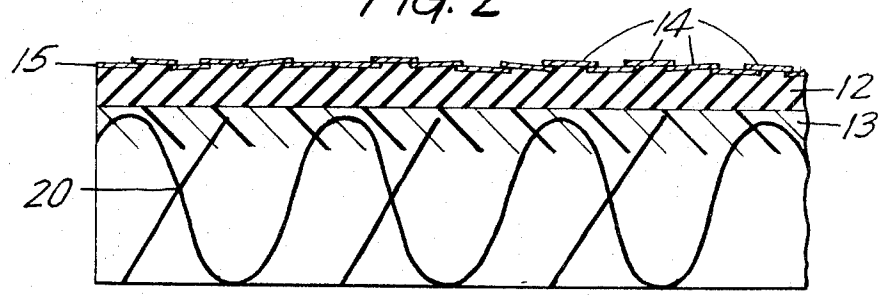



FIG. 2




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# HEAT-REFLECTIVE FABRICS

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U.S. Cl. 117—3.3 5 Claims

## ABSTRACT OF THE DISCLOSURE

A heat-reflective fabric, and transfer sheet material for application to a base fabric to make heat-reflective fabric. A continuous layer of partially overlapping reflective flakes adhered to, and carried on, a layer of elastomeric material covers the outside of the fabric. The transfer material includes a fabric-adhesive layer by which the elastomeric, flake-covered layer is attached to the fabric.

## BACKGROUND OF THE INVENTION

Protective garments used in an area of high heat, such as the vicinity of a furnace in a steel mill, are often made from heavy, tightly woven, cotton or asbestos fabrics externally coated with a varnish that is pigmented with aluminum powder. A primary purpose of the aluminum-pigmented varnish coating is to reflect radiant heat and thereby protect the fabric from the deterioration that is caused by heat; in addition, the reflection by the coating increases the heat protection for the wearer. In fact, however, these conventional coatings exhibit only moderate heat reflectivity since the aluminum particles are separated and covered with the varnish binder, which in contrast to the aluminum particles is quite heat-absorptive and nonreflecting. As a result, these conventional coatings are inadequate for the job; the fabric prematurely deteriorates from the heat, and undesirable heat is conducted through the garment to the wearer.

Another previously existing protective garment is made from fabric externally covered by a thin continuous mirror-like vapor-deposited aluminum film, and this garment is much more heat reflective than the painted garments. But such an aluminum film-covered garment, which is used, for example, by firemen when approaching a very hot fire, has not been durable enough for day-to-day use in an industrial area such as a steel mill. Because of its short useful life, such a garment is uneconomical for heavy-duty industrial jobs.

The result is that for many years there has existed a need for a garment with a surface treatment that has sufficient heat reflectivity to better protect the garment and garment wearer than aluminum-pigmented varnish coatings protect them, but that in addition has long life. Although both of the above products had been in existence for this period of need, and their inadequacies recognized, no one had provided the needed garment.

## SUMMARY OF THE INVENTION

The present invention provides a heat-reflective fabric that includes a base fabric externally covered by a thin continuous layer of partially overlapping reflective flakes supported on, and highly adhered to, a layer of rather firm elastomeric material that is preferably heat cured. In most cases, this heat-reflective fabric is made by application of a transfer sheet material to the base fabric, the transfer sheet material including a thin self-supporting base sheet with the continuous layer of reflective flakes disposed flat against, and firmly adhered to, the outside surface of the base sheet. The base sheet, in a preferred form, includes (1) the flake-binding layer of elastomeric material, and (2) an exterior fabric-adhesive layer of initially thermosoftening and flowable material that penetrates the fabric during application of the transfer material and has good adhesion to the fabric. Preferred transfer sheet materials of the invention also include a removable cover sheet over the layer of reflective flakes to assist in supporting the flakes in place during application of the transfer sheet material to fabric.



Garments made from the fabric of this invention exhibit much better heat reflectivity than painted fabrics exhibit. For example, when a garment made from a typical painted fabric and one made from a fabric of this invention are each exposed in a room temperature environment to a 550° F. heat source spaced five inches from the garments, in ten minutes the temperature inside the painted garment rises 65° F. above room temperature while the temperature inside the garment of this invention rises only 25–30° F. above room temperature. The better protection provided by the continuous overlapping flake layer of a fabric of this invention reduces the deterioration of the base fabric and improves the comfort of a person wearing a garment of the fabric.

It is recognized that the present invention is not the first occasion for the application of an exterior layer of metal flakes to an article. In McBurney et al. U.S. Pat. 2,087,094 and Higgins, U.S. Pat. 2,139,824, issued in 1937 and 1938, the application of continuous layer of oriented partially overlapping metal flakes to rather rigid articles such as sheet steel, paper, cellulose derivative-coated fabrics, and the like is described. Schramm, U.S. Pat. 2,748,019, issued in 1956, describes a method for depositing a layer of metal flakes on fabric, but the flakes in the layer are intentionally adhered only to the spaced threads of the fabric so that the fabric is left air-permeable. In two patents to Rand, U.S. Pats. 2,630,573 and 2,630,620, issued in 1953, a heat-retaining garment is described which includes fabric that has been sprayed with a solution of binder that contains a suspension of metal flakes; as in Schramm, the flake-containing layer is discontinued between the threads of the fabric.

Despite the long availability of the teachings of these patents, however, the need for a durable heat-reflective fabric was not met before this invention. None of the fabrics in these patents would be useful as a durable heat-reflective fabric. McBurney et al. and Higgins attempt to obtain decorative results rather than heat protection; where fabrics are discussed they are not supple, wearable fabrics, and the flakes are adhered to the fabric with a nonelastomeric binder. Presumably the Schramm fabric is intended for heat protection, but the noncontinuous nature of the layer of flakes would significantly impair the desired heat protection, as well as the durability of the layer, Further, assuming the Schramm fabric is wearable, that wearability is due to the noncontinuous nature of the nonelastomeric binder and metal-flake layer. The Rand fabrics are subject to the same deficiencies as the Schramm fabric, and in addition, since the metal flakes are deposited as a suspension in a binder, their heat-reflective properties are reduced as in the painted fabrics described above. It should be noted that to make the Rand fabric wearable, it is suggested that the fabric be distorted to break up the binder layer.

In summary, none of these prior art techniques suggests the use on fabric of a continuous layer of partially overlapping reflective flakes supported on and adhered to the fabric by an elastomeric binder that has high adhesion to the flakes. Further, none of them suggests that such a surface treatment on fabric would be wearable and durable nor that it would provide a high level of heat reflectvity. Insofar as is known, no one in the prior art has provided or suggested such a surface treatment nor

have they suggested that it is the answer to the long-standing need for durable heat-reflective fabrics.

## DRAWINGS

FIG. 1 is a greatly enlarged cross-section through a preferred transfer sheet material of this invention; and

FIG. 2 is a greatly enlarged cross-section through a preferred fabric of this invention.

## DETAILED DESCRIPTION

As previously described, a preferred transfer sheet material of this invention **10**, illustrated in FIG. 1, includes a thin base sheet **11** that includes an elastomeric flake-binding layer **12** and a fabric-adhesive layer **13**. Thin, highly reflective flakes **14**, such as flakes of aluminum, are adhered over the outside surface of the flake-binding layer **12**. The flakes lie substantially flat against the layer **12** and slightly overlap one another so as to provide a continuous metal layer **15**. The base sheet **11** is typically carried on a removable carrier sheet **16**, and the metal layer **15** is covered by a removable cover sheet **17**. In some constructions the flake-binding layer **12** is separated from the fabric-adhesive layer **13** by other material, such as a thin barrier layer.

One typical method for making the transfer sheet material **10** shown in FIG. 1 includes the steps of coating the layer **13** on a release paper that serves as the carrier sheet **16**; coating the layer **12** over the layer **13**; cascading the flakes **14** on the surface of the layer **12**; brushing to remove the excess of flakes and orient the remaining flakes; passing the thus prepared assembly through nip rolls that further orient the flakes; and finally coating a releasable film over the layer **15** of flakes **14**. After several coating operations, the layers may be heated to dry or cure them.

In one typical application of the transfer sheet material to fabric, the carrier sheet **16** is first removed and the outside surface of the layer **13** laid against the fabric. Then with a vacuum drawn underneath the fabric, the sheet material and fabric are heated to 250–300° F. Atmospheric pressure presses the sheet material **10** against the fabric, and the adhesive material of the layer **13** flows into the fabric; substantially all of the adhesive material penetrates into the interstices in the fabric and soaks into the threads of the fabric, as shown for the fabric **20** in FIG. 2.

With the transfer sheet material of this invention in place on the fabric as shown in FIG. 2, the fabric is essentially as supple as it was before application of the sheet material. This suppleness in combination with good retention of the flakes, partially follows from the elastomeric properties of the layer **12**. The layer **12** is cross-hatched in FIG. 1 with lines that symbolize an elastomer, though the elastomeric material of this layer may include synthetic resins. For purposes of this specification, a material is elastomeric if it is elongatable by 100 percent while taking an elongation-set of no more than 50 percent. Preferably, the layer 12 may be elongated 200 percent without taking an elongation-set of more than 10 percent.

Beside having elastomeric properties, the layer **12** should have strong adhesion to the flakes **14**. Peel tests measuring the strength of adhesion between a layer of the flake-binding material coated on a panel of the metal from which the flakes are made have been used herein for defining the forces of adhesion between the elastomeric flake-binding layer and the flakes (the specific test used most often is described later, in Example 1). For good results, the material of the flake-binding layer should resist removal from the panel of metal with a force of at least five pounds per inch of width and preferably with a force of at least ten pounds per inch of width. It will be recognized that this adhesion of the material of the flake-binding layer to the flakes may be contributed by the basic



ingredients of the layer as well as by additives and primer coatings on the flakes.

Another requirement for the material of the flake-binding layer **12** is that it should not significantly soften during use of a garment made from the fabric. If the flake-binding layer softens during use of the garment, the abrasion accompanying that use might seriously disrupt the metal flake layer. Most often, the flake-binding layer will not be heated higher than about 250° F. during use. However, there are occasions when fabrics of the invention are exposed for short periods to heat sources having a temperature up to 3000° F., in which case the material of the flake-binding layer may reach the temperature of 500° F. or higher.

Thus, whether the flake-binding layer is thermoplastic or thermosetting, after application to the fabric it should not soften at 250° F., and preferably not at 500° F. Typically, the material of the flake-binding layer is a cross-linked or heat-cured material and is substantially infusible and insoluble after application to the base fabric. At present the materials known to most adequately meet the above requirements include an epoxy resin, and consist, for example, of an epoxy resin and a curing agent that imparts elastomeric properties to the cured material. If the epoxy resin used exhibits sufficient elastomeric properties itself, the curing agent need not exhibit elastomeric properties.

By contrast to the layer **12**, the fabric-adhesive layer **13** need not exhibit elastomeric properties. It has been found that where the material of the layer **13** penetrates into the base fabric as shown in FIG. 2, the penetrated material is not subjected to as extensive stresses as the layer **12**. The fabric-adhesive layer generally has a thickness less than two mils, so as to avoid the possibility of any significant portion of the layer **13** not penetrating into the fabric; more preferably the thickness of the layer is about one mil or less. To permit penetration, the material of the layer **13** should be at least initially thermosoftenable and initially flowable; preferably the layer **13** is thermoplastic, so that it remains softenable throughout the curing operations performed on the layer **12**.

The cover sheet **17** is a preferred, but not essential, member of the transfer sheet material of the invention. During lamination of the transfer sheet material to fabric, the cover sheet assists in maintaining the flakes in place, if the flake-binding layer softens because of incomplete curing, for example, and also provides a barrier against leakage of any of the binder material.

In less desired but still useful constructions of transfer sheet material of this invention, the base sheet **11** consists of a single layer of elastomeric material. This single layer typically comprises a heat-curable elastomeric material only partially advanced so that it will initially soften when the sheet material is applied to fabric. Unless such a single-layer sheet material is very carefully applied, there is danger that the flakes will separate. Cover sheets are especially desirable in transfer sheet materials in which the base sheet consists of a single layer of material.

Rather than attaching a flake-covered elastomeric layer to a base fabric by application of the described transfer sheet material, the elastomeric layer may be attached by directly coating it on the fabric. Reflective flakes are then cascaded on the wet, coated, continuous layer and the flakes oriented as described above; where, as is typical, the material of the flake-binding layer is heat curable, the fabric is then heated to cure the flake-binding layer. The material in the flake-binding layer must, of course, have good adhesion to the fabric, and this adhesion is sometimes enhanced through use of a coupling agent.

The preferred flakes for use in the heat-reflective fabrics of this invention are aluminum flakes, which are highly reflective, light in weight, and readily available. These flakes are typically quite thin, as about 0.1 to 1 micron, and in normal commercial lots include a distribution of flakes having different flat dimensions (that is, length or

width dimensions of the flake rather than the thickness dimension). For good reflectivity, the smallest flat dimension of at least about 50 percent of the flakes should be more than about 15 microns. While larger flakes give better reflectivity, flakes in which the largest flat dimension is larger than about 1250 microns tend not to become fully adhered to the support sheet and tend to break off during use of a fabric on which they are carried, leaving a gap in the layer **15**. With present flake-binding materials it is accordingly preferred that flakes larger than 1250 microns not be used. While metal flakes are most typically used, metallized flakes of thin glass, which have the disadvantage that they provide a fabric that is somewhat harsh to the touch, and other forms of heat-reflective flakes may be used.

The invention is further illustrated in the following examples:

Example 1

A fabric-adhesive layer, such as the layer **13** in FIG. 1, was coated from a solution of the following ingredients onto silicone-treated release paper adapted to serve as the carrier sheet **16** in FIG. 1:

| | Parts by weight |
|---|---|
| Vinyl chloride-vinyl acetate resin consisting of 87 weight percent vinyl chloride and 13 weight percent vinyl acetate (VYHH vinyl resin) | 27 |
| Dioctyl phthalate | 18 |
| Extra-fine lining aluminum pigment (40XD supplied by Reynolds Aluminum Company) | .54 |
| Toluene | 19 |
| Methyl ethyl ketone | 35 |

A notched bar coater was used to coat the solution, with the bar being set four mils above the release paper, and after coating, the deposited layer was dried for ten minutes in a 200° F. oven.

A flake-binding layer, such as the layer **12** in FIG. 1, was then coated over the first-coated layer using a solution of the following ingredients:

| | Parts by weight |
|---|---|
| Diglycidyl ether of bisphenol A having an epoxide equivalent weight of 190 (Epon 828) | 53.1 |
| Tris(2,4,6 dimethyl amino methyl) phenol catalyst (DMP 30) | 2.7 |
| Poly (tetramethyleneoxide) amine having a number-average molecular weight of about 10,000 and an amine equivalent weight of about 4,610 | 100 |
| N(5-amino ethyl-γ-amino propyltrimethoxy silane) coupling agent (Dow-Corning's Z 6020) | 2.8 |
| Methyl siloxane oil flow agent (Dow-Corning's 200 fluid) | 1.4 |
| 100-mesh aluminum flake, leafing grade (MD 2100 by Alcan Metal Powders, Inc.) | 24 |
| Toluene | 100 |

This solution was coated under a notched bar set five mils above the top of the first layer, and after coating, the resulting layered assembly partially dried five minutes in a 200° F. oven.

(The poly (tetramethyleneoxide) diamine listed above was prepared by the reaction of dicationically active polytetramethyleneoxide with ammonia. The polytetramethyleneoxide aminated was prepared by the polymerization of a commercial reagent grade, peroxide-free tetrahydrofuran monomer, the reaction being initiated by trifluoromethane sulfonic anhydride. This reaction was carried out in a 95-liter glass lined reactor equipped with a stirrer under about 0.7 kilogram per square centimeter of nitrogen pressure. Tetrahydrofuran in the amount of 79.9 kilograms was first stirred and cooled to 15° C. whereupon 1.63 kilograms of trifluoromethane sulfonic anhydride was added. The subsequent reaction took about 28.5 minutes with a maximum reaction temperature of 38° C.

The amination followed and was performed in a 190-liter stirred stainless steel reactor containing 1.95 kilograms of anhydrous ammonia dissolved in 43.35 kilograms of tetrahydrofuran. The polymerized polytetramethyleneoxide was drained from the 95-liter reactor under pressure through a 2.5 centimeter polyethylene tube into the closed amination kettle which was always under about 2.5 kilograms/square centimeter pressure and which was cooled continuously to about 12° C. After the transfer was completed, in from about two to four minutes, the resulting solution was stirred for one-half hour and then the excess ammonia vented to the atmosphere. The excess tetrahydrofuran and residual ammonia were vacuum stripped off, while the temperature was gradually increased to about 40° C., after which the polyether diprimary diamine produced by the reaction was diluted to about 30 percent solids by the addition of toluene.

To remove the catalyst residue, any suitable strongly basic ion exchange resin may be added to the kettle. A satisfactory one is IRA402 sold by the Rohm and Haas Company. Infrared spectra examinations were performed on samples of the kettle contents to test whether the catalyst residue was removed, with the absence of absorption bands at 9.7 and 15.7 microns indicating when purification was complete. Additional ion exchange resin was used until the catalyst was completely removed. The mixture was then filtered and the filtrate vacuum-stripped at temperatures up to 95° C. to bring the product to 100 percent resin.

The resinous product was found to have a number average molecular weight of 10,000, an amine equivalent weight (measured by titration) of 4610, an inherent viscosity in benzene at 25° C. of 0.42, and a viscosity at 65° C. of 49,500 centipoises).

The same 100-mesh leafing aluminum flake described above was next cascaded on the tacky surface of the flake-binding layer and the excess of flake brushed off and the remaining flakes oriented by hand-brushing the surface of the assembly. Next, the assembly was placed in the 200° F. oven and dried ten more minutes. Upon removal from the oven, the assembly was passed through a pair of nip rolls under a pressure of 40 pounds per inch width at the nip to further orient the flakes. The assembly was then given a final cure of ten minutes in a 250° F. oven, after which the flake-covered surface was wiped with a damp cloth to remove any excess flakes.

The adhesion obtained between this flake-binding layer and the layer of flakes on it was tested as follows. A first layer of the above solution of the material of the flake-binding layer was coated on an aluminum panel. A second layer of the solution was then coated on unbleached muslin cloth (Style 3468 of the Puritan Textile Co.) and the coated layer on the cloth pressed while wet against the layer coated on the panel to form a combined layer with the cloth partially embedded in it; this cloth increases the tensile strength of the layer so that it can be peeled back. With the fabric partially embedded in it, the thickness of the combined layer was about five mils. The assembly was then heated for ten minutes at 150° F. to remove solvent, and then heated about 40 minutes at 325° F. while held under a pressure of about 14 pounds per square inch to cure the material in the test layer. The fabric-supported test layer was then peeled from the sheet at a 90° angle and at a rate of one inch per minute. The cloth was torn from the layer when the peel force reached 15 pounds per inch width, and it was concluded that the adhesion of the layer to the panel was greater than 15 pounds per inch width.

A cover sheet, such as the cover sheet **17** in FIG. 1, was coated over the layer of flakes from a solution of the following ingredients:

| | Parts by weight |
|---|---|
| Cellulose acetate resin, 2-second viscosity grade, having an acetyl content of 39.8 percent | 22.5 |
| Diethyl phthalate | 2.5 |
| Acetone | 75.0 |

The notched bar of the coater was set eight mils above the surface of the flakes. The transfer sheet material

was completed by drying the assembly ten minutes in a 200° F. oven.

A length of this transfer sheet material was laminated to a flame-proof cotton twill fabric. The silicone-treated release paper was first stripped from the transfer sheet material and the exposed adhesive surface laid against the fabric. The fabric and transfer sheet material were then placed in a heated vacuum applicator as described in U.S. Pat. 2,620,289 and laminated for 60 minutes at 325° F.; with a vacuum drawn under the fabric, the effective pressure holding the transfer sheet material against the fabric was atmospheric pressure. Following this laminating operation, the cellulose acetate cover sheet was stripped away leaving the fabric with a durable heat-reflective surface.

The resulting heat-reflective fabric was tested for its heat-reflective capabilities by the following test. A 2700° F. radiant heat source for the test consisted of a bank of five parallel coplanar 500-watt infra-red tubular translucent quartz lamps. The lamps were enclosed in a steel box but were closely adjacent and parallel to one side-wall in which there was a 2¼-inch by 5½-inch cutout exposing the lamps. The lamps were spaced 15 mils apart and each had a five-inch lighted length. A piece of white blotting paper was laid against the non-flake cover side of the fabric, and the assembly placed in a test holder that consisted of a metal frame having a central opening. The portion of the flake-covered side of the fabric revealed through the central opening in the frame holder was then exposed to the radiant heat source; the test holder was placed adjacent the cutout such that the revealed portion of the flake-covered surface of the fabric was spaced one inch from the bank of quartz lamps, and the fabric was exposed for 30 seconds. There was no visible damage to the flake-covered surface, a very slight discoloration of the back of the fabric, and no discoloration of the blotter.

A second piece of the heat-reflective fabric prepared above was abraded on a Wyzenbeek abrader which, as described in Federal Test Method CCC–T–191b, includes an oscillating cylinder section over which the test sample is laid. An abrading material is held under tension in a cooperating fixture and pressed against the test sample on the curved surface of the oscillating cylinder section. The abrasive material used was No. 6 hard-textured cotton duck (Type 1 of Federal Specification CCC–C–419) and it was held under a tension of two pounds and pressed against the test sample on the oscillating cylinder section with a force of two pounds. The test sample of heat-reflective fabric of this example was abraded 300 cycles. After abrading, it was exposed to the 2700° F. radiant heat source in the manner described above. Again there was no visible damage to the flake-covered surface, only a very slight discoloration of the back of the fabric, and only a very slight discoloration of the blotting paper.

Several fabrics painted with an aluminum-pigmented varnish were tested in the same manner as the fabric of this example. Both before and after abrading the blotters behind the painted fabrics in these tests were discolored to a very dark brown or black.

## EXAMPLE 2

A solution was prepared from the following ingredients for coating a fabric-adhesive layer onto silicone-treated release paper:

| | Parts by weight |
|---|---|
| Thermoplastic polyester resin formed from terephthalic acid, ethylene glycol, and neopentyl glycol (Vitel PE 207) | 25 |
| Tri(dichloropropyl) phosphate flame retardant (Fyrol FR 2) | 2.5 |
| Methyl ethyl ketone | 75 |

This solution was coated using a four-mil orifice, and then dried ten minutes in a 200° F. oven. When dry, the layer had a thickness of about 0.6 mil.

The flake-binding layer was coated from a solution prepared as follows. First the ingredients below were mixed on a two-roll rubber mill and the resulting mixture dissolved in 244 weight parts of toluene:

| | Parts by weight |
|---|---|
| Chlorosulfonated polyethylene having a molecular weight of about 20,000, a density of 1.26, and a chlorine content of 43 weight percent (Hypalon 30) | 50 |
| Chlorosulfonated polyethylene having a molecular weight of about 20,000, a density of 1.18, and a chlorine content of 34.5 weight percent (Hypalon 40) | 50 |
| Antimony trioxide flame retardant (ONCOR 23 A) | 7.5 |
| Dipentamethylene thiuram tetrasulfide curing agent (Tetrone A) | 1.5 |
| Benzothiazole disulfide accelerator | 0.5 |
| Di-ortho-tolylguanidine accelerator | 0.5 |

The resulting solution was then mixed with a second solution composed of:

| | Parts by weight |
|---|---|
| Diglycidyl ether of bisphenol A having an epoxide equivalent weight of 485 (Epon 1001) | 26.0 |
| Extra-fine lining aluminum pigment (40 XD) | 9.0 |
| Methyl ethyl ketone | 36.0 |

The resulting mixture of solutions was coated onto the previously coated fabric-adhesive layer by a notched bar coater using a five-mil orifice.

Next, 20-mesh aluminum flake, nonleafing grade (MD 9503 made by Alcan Metal Powder, Inc.) was cascaded onto the surface of the flake-binding layer, after which the surface was brushed to remove the excess flakes and orient the remaining flakes. The assembly was then dried ten minutes at 150° F. passed through a pair of nip rolls at 40 pounds pressure per inch width at the nip, and then placed in an oven for ten more minutes at 250° F. to partially cure the flake-binding layer. A cellulose acetate cover sheet was then applied as illustrated in Example 1 to complete the transfer sheet material. At this point, the thickness of the flake-binding layer was about 1 mil. In the peel test described in Example 1, except that the test layer was cured for 60 minutes at 325° F. instead of 40 minutes, the adhesion between the panel and test layer was measured as about 8.5 pounds per inch width.

## EXAMPLE 3

A solution was prepared from the following ingredients and coated on silicone-treated release paper with a notched bar set four mils above the paper:

| | Parts by weight |
|---|---|
| Thermoplastic polyurethane elastomer made from 4,4'-diphenyl methane diisocyanate, adipic acid, and 1,4-butanediol (Estane 5703) | 25.0 |
| O,O-diethyl-n,n-bis (2-hydroxy ethyl) amino methyl phosphate flame retardant (Fyrol 6) | 2.5 |
| Methyl ethyl ketone | 75.0 |

The fabric-adhesive layer was dried for ten minutes in a 200° F. oven.

A flake-binding layer was then coated over the fabric-adhesive layer using the solution of the flake-binding ingredients of Example 2, except that the nine parts of aluminum powder were replaced with 27 parts of copper flakes (designated as No. 250 copper flake by Belmont Snelling & Refining Works Inc., the largest of the flakes being about 200 mesh in size). The notched bar was set five mils above the surface of the fabric-adhesive layer. More of the copper flake was then cascaded onto the surface of the flake binding layer and the surface brushed off. As in Example 2, the assembly was then heated to dry

the flake-binding layer, passed through nip rollers, and heated again to partially cure the flake-binding layer.

The completed transfer sheet material was then laminated to woven asbestos fabric which had a weight of 1.2 pounds per square yard. The silicone-treated release paper was first stripped away and the fabric-adhesive layer placed against the fabric. The transfer sheet material and fabric were passed together between a pair of nip rolls heated to 300° F. with a nip pressure of 250 pounds per inch width. The laminate was then cured in a 250° F. oven for ten hours, and the resulting fabric had a durable heat-reflecting surface. In the test described in Example 1, there was no discoloration of the blotter before the fabric was abraded and only a very slight discoloration after abrading.

## EXAMPLE 4

The transfer sheet material of this example included a single-layer base sheet. This base sheet was prepared by first mixing the following ingredients on a rubber mill:

| | Parts by weight |
|---|---|
| Chlorosulfonated polyethylene (Hypalon 30) | 50 |
| Chlorosulfonated polyethylene (Hypalon 40) | 50 |
| Antimony trioxide flame retardant | 7.5 |
| Dipentamethylene thiuram tetrasulfide curing agent | 1.5 |
| Benzothiazole disulfide accelerator | 0.5 |
| Di-ortho-tolylguanidine accelerator | 0.5 |

After milling, the ingredients were dissolved in toluene and added to the following solution:

| | Parts by weight |
|---|---|
| Diglycidyl ether of bisphenol A having an epoxide equivalent weight of 485 (Epon 1001) | 16.0 |
| Extra-fine lining aluminum pigment (40 XD) | 1.5 |
| Methyl ethyl ketone | 16.0 |

The combined solution was coated on silicone-treated release paper using an orifice of nine mils, after which 100-mesh leafing aluminum flake (MD 2100) was cascaded onto the coated layer. The excess flake was brushed off and the assembly then dried for ten minutes in a 150° F. oven, passed through a pair of nip rolls at a pressure of 40 pounds per inch width, and heated for 20 minutes at 200° F. to partially cure the single layer that serves as a flake binder and fabric adhesive. The adhesion between an aluminum panel and the material of this base sheet, as measured in the peel test of Example 2, was about 8 pounds per inch of width. A cellulose acetate cover sheet was applied in the manner described in Example 1.

The resulting transfer film was applied to fabric as described in Example 1, the base sheet initially softening and then completing its cure. Before and after abrading of the fabric in the test described in Example 1, there was, respectively, none and then only a very slight discoloration of the blotter.

## EXAMPLE 5

A fabric woven from nylon monofilaments was first soaked for five minutes in a one weight percent solution in acetone of N-perfluoroctane sulfonamide of diethylenetriamine, which has the formula,

$$C_8F_{17}SO_2N(H)C_2H_4N(H)C_2H_4NH_2$$

After drying the fabric, the flake-binding solution of Example 1 was coated on the fabric with a notched bar using a five-mil orifice, and then 100-mesh leafing aluminum flake (MD 2100 aluminum powder) was cascaded on the surface of the coating. The surface was then brushed to remove the excess and orient the remaining flakes. The bond was then cured for 30 minutes at 250° F. The resulting fabric had a good reflective, durably attached, surface layer of flakes.

We claim:

1. A heat-reflective transfer sheet material for adhesive application to predetermined fabric to adapt the fabric for incorporation in a durable heat-reflective supple wearable garment, said sheet material comprising a self-supporting base sheet and a continuous layer of thin partially overlapping highly reflective flakes disposed substantially flat against and firmly adhered to one surface of the base sheet, at least 50 percent of the flakes having a flat dimension greater than 15 microns, and the base sheet including a flake-binding layer to which the flakes are adhered comprising a material that is heat-curable to a crosslinked infusible insoluble elastomeric material that is capable of an elongation of at least 200 percent with a set of less than 10 percent, an adhesion to the flakes of at least 5 pounds per inch of width, and does not soften to permit the layer of flakes to be disrupted when heated to a temperature of 500° F.

2. A transfer sheet material of claim 1 in which the flake-binding layer comprises epoxy resin and poly(tetramethyleneoxide) diamine.

3. A transfer sheet material of claim 1 which includes a cover sheet removably adhered over the reflective flakes.

4. A transfer sheet material of claim 1 in which the base sheet further includes a fabric-adhesive layer adhered to the flake-binding layer and comprising an initially thermo-softening and flowable material that has good adhesion to said predetermined fabric.

5. A transfer sheet material comprising a self-supporting base sheet and a continuous layer of thin partially overlapping metal flakes disposed substantially flat against and firmly adhered to one surface of the base sheet, at least 50 percent of the flakes having a flat dimension greater than 15 microns, and the base sheet including a flake-binding layer to which the flakes are adhered comprising a material that includes epoxy resin and poly(tetramethyleneoxide) diamine and is heat-curable to a crosslinked infusible insoluble elastomeric material that is capable of an elongation of at least 200 percent with a set of less than 10 percent, an adhesion to the flakes of at least 5 pounds per inch of width, and does not soften to permit the layer of flakes to be disrupted when heated to a temperature of 500° F.

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