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(54) **PENETRATION RESISTANT GARMENT**

STICHFESTE BEKLEIDUNG

VETEMENT RESISTANT A LA PENETRATION

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EP 1 133 246 B1

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Description**Background of the Invention*****Field of the Invention***

[0001] This invention relates to penetration resistant garments and more particularly to lightweight, high-pressure water jet penetration resistant garments.

Related Art

[0002] Industrial tools utilizing high pressure water jets continue to be developed, such as, for example, metal working and cutting tools in which the water jet is fixed and the workpiece is moved relative to the water jet. Other tools, for example, hand-held gun-like water jet lances in which the operator moves the water jet over a stationary workpiece, have also been developed. These lances are used, for example, to remove coatings, such as paint, from metallic surfaces. In both types of tools, high pressure water pumps capable of delivering up to 276 MPa (40,000 psi) supplies the high pressure water to the jet. With increased operating pressures, the overall horsepower of the pumps has also increased, which has resulted in an increase in water flow rates.

[0003] The increase in pressure and flow has increased the risk of serious injury from direct cuts or amputations and infections, especially when using the hand-held water jet lance, for example. Not only does the water jet contain very large energies that will penetrate body tissue very aggressively, the water jet may carry dirt and bacteria into the wound beyond the region of obvious tissue damage.

[0004] U. S. Patent 5,996,115 discloses flexible body armor having bevelled overlapping ceramic tiles adhesively attached to a flexible fragment-trapping blanket. The blanket preferably includes at least forty plies of a ballistic cloth stitched together in a quilt pattern.

[0005] The water jet can be thought of as a needle-like penetrator because the diameter of the jet is small. However, unlike a needle, which is defeated when the tip is bent, a water jet continuously renews the sharp focus of penetration. Conventional cut resistant or bullet proof garments, such as the butcher's apron disclosed in US 3,611,438, or the ballistic body armor disclosed in US 5,996,115 offer little protection from a water jet because the fabrics used in such garments are readily cut and eroded by the jet's small intense contact point such that full penetration may occur. In general, once penetration has started, the erosive effect of the water jet destroys all of the remaining fabric at the contact point. As a result, the use of high performance fabrics having open, flexible weaves make such fabrics poor candidates for use in protective garments for water jet applications.

[0006] Rigid steel or aluminum would offer protection from the erosion of the water jet. However, in addition to the added weight, such materials significantly compro-

mise comfort and freedom of motion and thus are generally not suitable for use in protective garments, especially in industrial environments where such characteristics are necessary.

5 [0007] Given the risk in this industry, a number of attempts at safety garments have been developed. DuPont and others, for example, have developed lined suits using penetration resistant fabrics. An example of such a fabric is disclosed in U.S. Patent Nos. 5,565,264 and
10 5,837,623, which are assigned to the present assignee and to which the reader is referred for further information. The suits made from such fabrics are shaped and formed using conventional techniques. For example, the front of the pant of the suit is cut from a continuous piece of the
15 penetration resistant fabric. Alternatively, the penetration resistant fabric may be added as a liner following the basic shape of the outer layer of the garment.

[0008] To provide a desired level of penetration resistance while retaining some flexibility, multiple layers of penetration resistant fabric are used. However, these
20 added layers significantly add to the cost and weight of the garment. In addition, the suits, which cover the entire body, tend to hold heat and reduce the evaporative cooling of the wearer, which may result in heat stress.

Summary of the Invention

[0009] The invention is defined by the independent claims. The dependent claims are directed towards preferred
25 embodiments.

[0010] One aspect of the present invention is directed to a penetration resistant garment for use, for example, in the water jet industry that may be comfortably worn by a user while offering protection against injury from a penetrating fluid jet. The penetration resistance of a single
30 layer of the penetration resistant fabric for use in a penetration resistant garment, may be significantly increased when a coating is applied to the fabric. However, the coating may result in a significantly stiff fabric, which may be less desirable for use as a continuous piece of fabric in
35 a penetration resistant garment.

[0011] Thus, the penetration resistant garment includes a plurality of light-weight, rigid, discrete penetration resistant sections cooperating with and arranged relative to one another to provide a flexible garment. In another embodiment, the penetration resistant garment includes a plurality of penetration resistant panels cooperating with and arranged relative to one another to provide substantially complete coverage. In yet another aspect
40 of the invention, the panels each have a length. The panels cooperate with and are arranged relative to one another such that a length of the garment is less than a sum of the lengths of the individual panels.

[0012] In still another aspect of the invention, the penetration resistant garment includes a first panel and a second panel joined to the first panel to define a length. The panels are adjustable relative to one another to selectively adjust the length of the panels.
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[0013] In yet another aspect of the invention, the penetration resistant garment includes an undergarment having penetration resistant properties and a cover removably attached to the undergarment.

[0014] In another aspect of the invention, the penetration resistant garment includes a penetrating resistant fabric and a hardening material cooperating with the fabric.

[0015] In yet another aspect of the invention, the penetration resistant garment includes a penetration resistant fabric forming the garment. The garment is adapted to be worn exclusively on the front or the back of the user.

[0016] In still another aspect of the invention, the penetration resistant garment includes a first panel, a second panel and a knee pad coupled between the first and second panels. The knee pad is pivotally connected to the first panel about a first pivot axis and pivotally connected to the second panel about a second pivot axis. The axes are positioned through the knee pad at predetermined locations such that an effective center of rotation of the first panel, the second panel and the knee pad passes through a center of rotation of the knee of a wearer.

[0017] In yet another aspect of the invention, a method of donning at least a section of a penetration resistant garment on a wearer is disclosed. The section includes a knee section having a knee pad, a first panel pivotally connected to the knee pad and a second panel pivotally connected to the knee pad. The section further includes a thigh section adapted to be adjustable relative to the first panel of the knee section. The method includes the steps of first securing the knee section to the wearer, then attaching the thigh section to the first panel of the knee section. In this manner, the garment may be readily sized for different sized wearers.

[0018] In another aspect of the invention, a panel construction use in a penetration resistant garment is disclosed. The panel construction includes a backing and a penetration resistant material covering the backing. The penetration resistant material occupies an area less than a total area of the backing.

[0019] In yet another aspect of the invention, a panel construction for use in a penetration resistant garment is disclosed. The panel construction includes a backing and a penetration resistant material covering the backing. A laminate is disposed over the penetration resistant material.

[0020] In still another aspect of the invention, a kit of parts for use in assembling at least a portion of a penetration resistant garment is disclosed. The kit includes at least one penetration resistant panel. The panel is adapted to cooperate with an arranged relative to an adjacent panel to provide substantially complete coverage.

[0021] In a further aspect of the invention, a panel construction for use in a penetration resistant garment is disclosed. The panel construction includes a backing and at least two layers of penetration resistant material covering the backing.

[0022] Various embodiments of the present invention

provide certain advantages and overcome certain drawbacks of the conventional techniques. Not all embodiments of the invention share the same advantages and those that do may not share them under all circumstances. This being said, the present invention provides numerous advantages including the noted advantage of increased protection with decreased physical and heat stress to the wearer.

[0023] Further features and advantages of the present invention as well as the structure and operation of various embodiments of the present invention are described in detail below with reference to the accompanying drawings.

Brief Description of the Drawings

[0024] The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a perspective view of a penetration resistant garment according to one embodiment of the present invention shown on a wearer;

FIG. 2 is a front view of a torso section of the garment of FIG. 1;

FIG. 3 is a rear view of the torso section of FIG. 2; FIG. 4 is an exploded view of the torso section of FIG. 2;

FIG. 5 is a front view of a chaps section of the garment of FIG. 1;

FIG. 6 is an exploded view of a leg section of the chaps section of FIG. 5;

FIG. 7 is perspective view showing adjustment of the chaps section according to the present invention;

FIG. 8 is a front view of a gaiter section of the garment of FIG. 1;

FIG. 9 is an exploded view of the gaiter section of FIG. 8;

FIG. 10 is a perspective view of the gaiter section of FIG. 8;

FIG. 11 is a perspective view of single panel of the garment according to the present invention;

FIGS. 12a and 12b are cross-sectional views of alternative embodiments of the panel taken along line 12-12 of FIG. 11;

FIG. 13 is front view of a pair of chap covers for use with the garment of FIG. 1; and,

FIGS. 14 and 15 are diagrammatic representations of alternative embodiments of the present invention.

Detailed Description

[0025] A penetration resistant garment that may be comfortably worn by a user while offering protection against injury from a penetrating object, such as a water jet for example, includes a plurality of light-weight, rigid, discrete penetration resistant sections cooperating with each other to provide a flexible garment offering substan-

tially complete coverage extending over an area of desired coverage. The sections or panels may be layered in an overlapping manner to provide the substantially complete coverage for the garment such that a length of the garment is less than a sum of the lengths of the individual sections or panels to aid in protecting the wearer from penetration while keeping the wearer dry and clean. Sufficient overlap is provided to maintain adequate coverage of the wearer when the garment is bent during use as the wearer bends. In one embodiment, the panels are arranged to overlap in a vertical manner from the top of the garment to the bottom to reduce the likelihood that water will run behind the garment onto the wearer.

[0026] Although reference is made to use of the present invention for added protection when using a water jet, the present invention may be used in any environment requiring added protection from penetration of other fluids or objects.

[0027] Figure 1 is a perspective view of the penetration resistant garment 20 according to the present invention shown worn by a wearer 22 using a lance-type water jet device 24. The garment 20 includes a plurality of penetration resistant panels 30, shown as 30a-30k and collectively referred to as panels 30, a torso section 32 (shown in more detail in Figures 2-4), a chaps section 34 (shown in more detail in Figures 5-7), and a gaiter section 36 (shown in more detail in Figures 8-10). Although only three sections are shown and described herein, it is to be appreciated that other sections covering other parts of the wearer's body may be provided using the construction of the present invention. For example, arm sections may be provided, which may be constructed and arranged similar to the thigh section and knee section, thereby allowing bending of the wearer's arm. The shoulder and neck may be protected with separate panels joined to the torso section. In addition, although the garment described herein is adapted for use with a human, the panels may be arranged to conform to the shape of any desired animal that may be used in environments requiring protection.

[0028] According to one aspect of the invention, the panels 30 cooperate with one another in a manner such that the garment 20 remains flexible. In one embodiment, as will be fully described hereinafter, the panels slide relative to one another. In another embodiment, the panels are pivotally connected to one another. In any event, it is to be appreciated that the panels, which individually may be rigid, cooperate in a manner such that the overall garment is flexible and therefore comfortable for the wearer.

[0029] Referring now to Figures 2-4, the torso section 32 includes a chest panel 40 generally shaped according to the chest of a wearer. The torso section 32 also includes a left waist panel 42 and a right waist panel 44, both coupled to the chest panel and both generally shaped to conform to the waist area and hip area of a wearer. Preferably, the waist panels are coupled to the chest panel with the use of pivot pins 46, 48 passing

through respective holes formed in the panels. To provide adjustability in the length of the torso section, a plurality of fastening locations may be provided. For example, a plurality of holes 49 may be provided. The pivot pins may be any suitable fastener. Preferably, the fastener permits pivoting of the two panels and, as will be described hereinafter, allows removing and replacing a panel. In one embodiment, the fasteners are formed by a screw 50 and "T" nut 52 (see Figure 4). Other fastening means envisioned include a snap fastener or a rivet. The waist panels 42 and 44 are attached to the chest panel at outside portions 54 and 56, respectively. As a result, when the torso section is placed on the wearer and wrapped around the waist of the wearer to conform to the upper body, the waist panels are permitted to pivot about the pivot pins to allow increased flexibility of the garment.

[0030] If pivoting between the waist panels and the chest panel is not a requirement, for example, if the user is not required to bend, but adjustability is desired, other suitable fasteners may be used, such as a hook and loop fastener (not shown). As will be discussed with reference to the thigh section, the hook and loop fastener may provide adjustability in the overall length of two adjacent panels while also securing them together. Thus, in this regard, the chest panel 40 may be adjusted relative to the waist panels by positioning and attaching the hook and loop fastener at a desired fastening location.

[0031] The torso section 32 also may include a groin panel 58 coupled between the waist panels and attached to the waist panels at inside portions 59a and 59b, respectively, of the waist panels with pivot pins 60, 62. The groin panel 58 also is attached to the chest panel at an upper location 63 of the groin panel with pivot pins 68, 70. The pivot pins may be any suitable fasteners as described above. In the embodiment described herein, the pivot pins are formed by a screw and a "T" nut. Of course, the groin panel may be adjustable relative to the chest and waist panels in a similar manner as described above with reference to the waist panels.

[0032] As best shown in Figure 3, shoulder straps 72, 74, which may be made of any suitable material such as a woven web, are attached to the chest panel 40 to allow the torso section to be worn like a vest. The straps may criss-cross to provide greater secureness of the torso section to the wearer. However, according to one aspect of the invention, the torso section preferably is loosely fit on the wearer to provide for air flow between the garment and the wearer to allow for adequate cooling of the wearer. In addition, the straps may be adjustable provided that the wearer is able to maintain adequate air flow between his or her body and the garment. Although according to one embodiment the garment may be adapted to be worn exclusively on the front or back of a wearer for added cooling, the back and buttocks may be protected by additional panels as desired. In such an embodiment, the garment portions protecting the back and buttocks also preferably are loosely fit on the wearer.

[0033] To secure the bottom portion of the torso sec-

tion to the wearer, a third strap 76 may be used. In one embodiment, the strap may be secured to the bottom section 78 of the groin panel 58 and attached to the straps 72, 74. This strap also may be adjustable as described above. In addition, the strap may include a snap buckle 80a, 80b to provide ease of placing the torso section on the wearer.

[0034] Referring now to Figures 5-7, the panels are configured to form a chaps section 34. The chaps section includes first 90 and second 92 leg sections. For the sake of convenience, the construction and arrangement of the chaps section will be discussed with reference to one leg section with the understanding that the other leg section is of similar construction and arrangement. Although it is to be appreciated that the leg sections discussed herein are similar, they may be adapted slightly to accommodate the left or right leg or may be constructed and arranged to offer greater protection to one leg or to certain areas of the leg, as may be desired. In addition, although the chaps section described herein provides added protection to the front of the legs only, the back of the legs may be protected with or without front leg protection by additional or alternative panels as desired.

[0035] Each leg section includes a thigh section 94, which, in this example, is constructed from one panel, and a knee section 96. The knee section 96 includes an upper knee panel 98, a lower knee panel 100 and a knee pad 102 coupled between the upper and lower panels. The upper panel is adjustably secured to the thigh panel. One or more straps 104 with associated buckles may be used to secure the chaps section to the leg of the wearer and may be held up with one or more loops 106, which may be used to attach the chaps section to a belt 108. In one embodiment, the straps 104 are adjustable in a manner described above with respect to the torso section 32 and may or may not be formed of elastic webbing. In any event, preferably, the chaps section is loosely held to the legs so as to allow adequate air flow for cooling. An outhaul strap 110 may also be provided to restrict movement or rotation of a leg section toward the inner thigh of the wearer. The strap may include a buckle to adjust the length of the strap to accommodate the height of the user.

[0036] As shown in Figure 1, the torso section is constructed and arranged to sufficiently overlie the chaps section to offer adequate protection and water shedding, even as the wearer bends. In addition, the torso section is permitted to slide relative to the chaps section to provide the wearer with unrestricted movement while bending or turning.

[0037] The knee section 96 includes a first pair of pivot pins 112 pivotally securing the knee pad 102 to the upper knee panel 98 about a first pivot axis and a second pair of pivot pins 114 pivotally securing the knee pad 104 to the lower panel 100 about a second pivot axis. The first and second pairs of pivot pins may be positioned through the knee pad at predetermined locations such that an effective center of rotation of the upper panel, the lower

panel and the knee pad passes through a center of rotation of the knee of a wearer. Of course, as described with reference to the torso section, the pivot pins may be formed of any suitable fastener such as a screw and "T" nut or snap fasteners. Hook and loop fasteners may be used if pivoting is not a requirement.

[0038] As best shown in Figures 6 and 7, the upper knee panel 98 may be adjustably secured to the thigh panel 94 with the use of a hook and loop fastener 120. In this manner, the length of the leg section 92 may be fitted to the wearer by moving the location of the attachment area of the hook and loop fastener. Of course, those skilled in the art will recognize that other fasteners may be used to adjust the length of the leg section. For example, a plurality of mounting holes 122 may be formed in the thigh panel to receive a snap fastener, a rivet, a screw and "T" nut or the like. The preferred amount of adjustment accommodates wearers having an inseam length of 60,96 cm to 91,44 cm (24" to 38"). Accordingly, the amount of overlap is about 10,16 cm to 15,24 cm (4" to 6").

As described above with reference to the torso section, any of the panels forming a leg section may be replaced as desired. The chaps section may be donned by first securing the knee section to the wearer, then attaching the thigh panel to the first panel of the knee section. In this manner, the chaps section may be readily sized for different sized wearers.

[0039] Referring now to Figures 8-10, the garment 20 further includes a gaiter section 36. The gaiter section 36 includes first and second shin panels 130, 131, an ankle panel 132 and a foot panel 134. In one embodiment, the foot panel 134 is adapted to extend up to the steel toe of the shoe of the wearer. The shin panels and the ankle panel are secured together with pivot pins 136 at a position adapted to allow ankle rotation of the gaiter section when worn by a wearer. The two shin panels are shaped with similar arc sections such that upon bending by the wearer, the second shin panel 131 is able to slide, at least partially, under the first shin panel 130 as can be seen in Figure 10. Although two shin panels are shown and described, it is to be appreciated that only one shin panel may be provided. The ankle panel and the foot panel are secured together with similar pivot pins 137 at a second hinge point that coincides with the ball area of the user's foot such that the user may articulate the foot at the toe area as shown in Figure 10. With such a double hinge arrangement, the gaiter section allows the user to bend to a maximum extent.

[0040] The pivot pins 136 may be formed of any suitable fastener as described above, such as a screw and "T" nut shown. One or more straps 138 may be provided to secure the gaiter section. In addition, a heel strap 140, which may be formed of an elastic webbing or band, may be used to secure the heel area of the gaiter section. The heel strap may be fixed to pivot pins 136, as shown in Figure 8, or may be attached at any other suitable location on the gaiter section, such as the shin panel 130, as

shown in Figure 10. Preferably, the chaps section 34 is adapted to cover the shin panel 130 to provide a garment having continuous coverage.

[0041] With the cooperation of one panel to one or more adjacent panels, the garment may provide substantially complete coverage over a desired area of protection of the user. Thus, the panels are arranged in any suitable manner such that a full coverage of a selected area is possible while a single panel may cover less than the desired area.

[0042] According to another aspect of the invention, the garment may be provided in a kit of parts containing at least some of the individual panels, fasteners, and straps to allow a user to assemble and wear the garment once it has been partially or completely assembled. Also, replacement parts may be provided in one or more kits. The kits may also be provided with selected components such that a user may arrange a specific assembly suitable for a specific need.

[0043] In one embodiment, the panels have curved corners for added comfort and the panels themselves may be curved to conform to the particular body part for which the panel protects. In addition, the sides on some panels are curved and complement the shape of adjacent panels. For example, the waist panels are formed with a concave side 148 (see Figure 2) on a side of the panel facing the lower and outer thigh of the wearer's leg so as to complement the bend formed on the chaps that offers protection to the inner and outer leg. The concave side of the waist panels and the bend formed on the chaps may also facilitate sliding of the waist panels over the chaps without binding. Also, the groin panel is formed as an elongated panel having curved edges to provide protection when the wearer's knees are straight and when they are bent without causing binding or otherwise constraining the wearer.

[0044] As shown in Figures 11 and 12, each panel may include a backing 150, with the penetration resistant material 152 covering the backing. The penetration resistant material occupies an area less than a total area of the backing. The penetration resistant material may cover the backing such that an edge 154 of the backing remains exposed. The backing may be formed of a closed cell low moisture polyethylene foam material or a polyester material. The backing provides added comfort to the wearer and the exposed edge reduces discomfort if the panels wedge into a body part, such as, for example, the thigh, of the wearer. A liner 156 formed of a soft fabric may be used to cover the foam. Preferably, the liner is made of polypropylene or polyester filament fabrics, however, any fabric that is easy to clean and provides low or no water retention may be used.

[0045] The penetration resistant material 152 of the present invention may be formed of an ultra-tight woven fabric material made of high tenacity yarns, such as that developed by the inventors of the present invention and disclosed in U.S. Patent Nos. 5,565,264 and 5,837,623. Other suitable fabrics made of high strength fibers of

greater than 8 grams per denier and less than 10% elongation at break may be used. Examples of such fibers includes: para-arimid fibers including, for example, Kevlar[®], manufactured by Du Pont, Charlotte, NC; Twarmon[®], manufactured by AXZO Nobel Industrial Fibers, Inc., Scottsboro, AL; Technoroa[®], manufactured by Teijin, Osaka, Japan; Trevir[®] manufactured by Kosa, Charlotte, NC; ultra high molecular polyethylene fibers including, for example, Spectra[®], manufactured by AlliedSignal Inc., Atlanta, GA; Dynema[®], manufactured by DSM "The Polymer Corp.", Reading, PA; Certran[®], which may be manufactured by Hoescht Celanese, Salisbury, NC; Vectran[®] fibers, manufactured by Hoescht Celanese, Salisbury, NC; carbon fiber; or glass fibers.

[0046] To increase the penetration resistance of the material 152, the material cooperates with a hardening material. For example, the hardening material may be coated on the penetration resistant fabric or may be saturated therein. In addition, the hardening material includes a filler of a crystalline material adhered thereto. The epoxy and filler provide resistance to the erosive effect of the water jet. Examples of such an epoxy include epoxy resins, cross-linked polyester resins and also polyether resins. Examples of such a crystalline material includes ceramic, garnet, metal, silicon carbide, aluminum oxide and diamond. The crystalline material may be in a fine grain powder form and may have a mesh size of at least 150 or finer, for example, 600.

[0047] Preferably, the penetration resistant fabric has a very tight woven construction. Saturation and/or coatings and/or laminations and/or calendaring may be used to further bind the filaments of the fabric together. However, any material that is added to the woven fabric should have excellent adhesion to the fiber. For example, the use of an epoxy when using a para-arimid provides adequate adhesion.

[0048] In another embodiment, also shown in Figure 12a, which is a cross-sectional view of Figure 11 taken along line 12-12, a laminate 158 may be disposed over the penetration resistant material to allow ease of water shedding and cleaning. The laminate may be formed of a low friction material, such as polypropylene, and may have a thickness of about 50,8 μm (2 mils). In another embodiment, the laminate may be formed as a woven material that is hot glued and stitched to the penetration resistant fabric. Preferably, this laminate fabric provides high durability and abrasion resistance. In one embodiment, the fabric used in the laminate may include synthetic yarns, which may be made up of individual filaments or multiple filaments. Each filament may have a denier of not less than 50.

[0049] In another embodiment, as shown in Figure 12b, which is a cross-sectional view of an alternative embodiment of Figure 11 taken along line 12-12, the panel may be constructed of multiple layers of penetration resistant fabric 152. In addition, to further increase the penetration resistance of the garment, a spacer material 180 may be placed between two or more layers of the pene-

tration resistant material 152. In this regard, the spacer material may alternate between single layers of the penetration resistant material 152 or between multiple layers of the penetration resistant material 152. The spacer material 180 preferably deflects and distorts the water jet hitting the garment as the water jet penetrates the outer layer. In one embodiment, the spacer material separates the layers by a distance of about 0,381 mm (.015") to about 0,635 mm (.025").

[0050] The spacer may be formed of a fabric composed of synthetic yarns. The yarns may be made up of individual filaments or multiple filaments. Each filament may have a denier of not less than 50. Alternatively, the spacer 180 may be formed of a fibrous felt or foam having, in part, synthetic yarns. In another alternative, the spacer may be formed of both a synthetic yam (made of individual or multiple filaments having a denier not less than 50) and the fibrous felt or foam and may be formed in a layered construction.

[0051] According to another aspect of the invention, the garment may include a cover adapted to cover all or a portion of the side of the garment facing away from the wearer. Referring now to Figure 13, removable covers 160, 162 are shown adapted to cover each leg section of the chaps section 34. The covers may include slits 164 to receive the straps attached to the panels. Thus, the wearer may weave the straps through the slits, thereby securing the cover to the panel. Of course, other suitable attaching means may be employed. For example, snaps, adhesives, or hook and loop fasteners may be used.

[0052] Due to the water and waste associated with water jet operations, operators of water jet lances generally wear commercial rain suits having rubber boots, plastic or rubber coated pants and hooded jacket. This rain gear becomes contaminated by sticky waste, which requires the disposal of the rain gear after a brief period of use. In addition, because of the high physical exertion associated with water jetting, full coverage protective gear and rain suits are not desirable as they tend to prevent evaporation and retain body heat.

[0053] Preferably, the covers are made of a material that economically allows the covers to be disposable, yet offer water resistance, thereby protecting the garment from dirt and grime, which may tend to reduce the useful life of the garment. An example of such a material is spun bonded olefin, which has a low cost, high tear resistance, high water resistance and high slip surface properties. In addition, little water falls on the back of the wearer's legs. Thus, preferably, the covers are adapted to cover only the front portion of the wearer, thereby maintaining a low cost and providing adequate cooling for the wearer.

[0054] According to another aspect of the invention, the garment may include a base material adapted for wearing by a user. Such a base material may be formed as pants or a shirt which the user wears or which is strapped onto the wearer. According to this aspect of the invention, which is shown in Figure 14 as a leg section, the panels 30 are secured to the outer surface of the

base material 170 using any suitable fastening means, such as a hook and loop fastener or snaps. The panels are secured to the base material in an overlapping manner, as described above, but, in this embodiment, cooperate with the base material such that the base material may flex at an intersection between adjacent panels. Thus, in this embodiment, attaching the panels to one another may not be necessary. In a similar embodiment, which is shown in Figure 15, the base material 170 may include at least one pocket 172. The panels 30 are placed in the pocket 172 in an overlapping manner, although, as shown in Figure 15, one panel is being placed into the pocket while others are already inserted therein. In this example, the base material formed with a pocket provides not only the required flex for the panels, but also acts as the disposable cover.

[0055] While the best mode for carrying out the invention has been described in detail, those skilled in the art to which this invention relates will recognize various alternative embodiments including those mentioned above as defined by the following claims.

Claims

1. A penetration resistant garment (20) suitable for resisting penetration of a fluid jet having a pressure of up to 275.79 MPa (40,000 psi), comprising:
 - a plurality of penetration resistant panels (30) cooperating with and arranged relative to one another to provide substantially complete coverage extending over an area of desired coverage, the panels being layered in a vertically overlapping manner, thereby to reduce the likelihood that water will run behind the garment onto the wearer, wherein each said panel comprises a penetration resistant fabric (152) coated or saturated with a hardening material, comprising a crystalline material adhered to said hardening material, said hardening material cooperating with said penetration resistant fabric, and said crystalline material being selected from ceramic, garnet, metal, silicon carbide, aluminum oxide and diamond.
2. A garment according to claim 1 wherein said panels are layered in an overlapping manner.
3. A garment according to claim 1 wherein said continuous layer defines a length, with at least some of said panels cooperating with each other such that said length of said continuous layer may be adjusted.
4. A garment according to claim 1 wherein any of said panels forming said garment is replaceable.

5. A garment according to claim 1 further comprising at least one strap (72) for a wearer to don said garment.
6. A garment according to claim 1 wherein said garment is adapted to be worn exclusively on one of a front or back of a wearer.
7. A garment according to Claim 1 wherein each said panel comprises a backing (150) and a penetration resistant fabric covering said backing, with said penetration resistant fabric occupying an area less than a total area of said backing.
8. A garment according to claim 13 wherein said backing includes an edge (154), with said penetration resistant fabric covering said backing such that said edge of said backing remains exposed.
9. A garment according to claim 1 wherein each said panel comprises a backing, a penetration resistant fabric covering said backing, and a laminate (158) disposed over said penetration resistant fabric.
10. A garment according to claim 1 further comprising a cover (160) removably covering at least one of said panels.
11. A garment according to claim 1 wherein at least some of said panels are configured to form a torso section (32), with said torso section comprising a chest panel (40), a left waist panel (42) attached to said chest panel, a right waist panel (44) attached to said chest panel (581) and a groin panel attached to said chest panel and said waist panels.
12. A garment according to claim 1 wherein at least some of said panels are configured to form a chaps section (34), with said chaps section comprising first and second leg sections (90, 92), with each said leg section comprising a thigh panel (94) and a knee section (96), said knee section comprising an upper knee panel (98), a lower knee panel (100) and a knee pad (102) coupled between said upper and lower panels, with said upper panel being adjustably secured to said thigh panel.
13. A garment according to claim 12 wherein said thigh panel is adapted to receive an outhaul strap (110).
14. A garment according to claim 12 wherein said knee pad is pinned to said upper panel with a first pair of pivot pins and pinned to said lower panel with a second pair of pivot pins, said first and second pairs of pivot pins being positioned through said knee pad at predetermined locations such that an effective center of rotation of said upper panel, said lower panel and said knee pad passes through a center of rotation of the knee of a wearer.
15. A garment according to claim 1 wherein at least some of said panels are configured to form a gaiter section (36), with said gaiter section comprising at least one shin panel (130), an ankle panel (132) and a foot panel (134), with said shin, ankle and foot panels being pinned together at one or more locations to allow at least one of ankle rotation and toe articulation of said gaiter section when worn by a wearer.
16. A kit of parts for use in assembling at least a portion of a penetration resistant garment suitable for resisting penetration of a fluid jet having a pressure of up to 275.79 MPa (40,000 psi), with said kit comprising:
at least one penetration resistant panel, with said panel being adapted to cooperate with and arranged relative to adjacent panels to provide substantially complete coverage extending over an area of desired coverage, the panels being layered in a vertically overlapping manner, thereby to reduce the likelihood that water will run behind the garment onto the wearer, and wherein said panel comprises a penetration resistant fabric (152) coated or saturated with a hardening material, comprising a crystalline material adhered to said hardening material, and said crystalline material being selected from ceramic, garnet, metal, silicon carbide, aluminum oxide and diamond.
17. A kit of parts according to claim 16 further comprising a plurality of pivot pins, wherein at least some of said panels is adapted to be joined together with at least one of said pivot pins.
18. A kit of parts according to claim 16 wherein at least two of said panels comprises a hook and loop fastener, respectively.
19. A kit of parts according to claim 16 further comprising a base material (170) adapted for wearing by a user, with said panels adapted to be secured to said base material.
20. A kit of parts according to claim 19 wherein said base material comprises at least one pocket (172), with said panels adapted to be disposed within said at least one pocket.
21. A kit of parts according to claim 16 wherein at least one of said panels comprises at least one strap adapted for donning said panel to a wearer.
22. A kit of parts according to claim 16 wherein each said panel comprises a backing and a penetration resistant material covering said backing, with said

penetration resistant material occupying an area less than a total area of said backing.

23. A kit of parts according to claim 22 wherein said backing includes an edge, with said penetration resistant material covering said backing such that said edge of said backing remains exposed.
24. A kit of parts according to claim 16 wherein each said panel comprises a backing, a penetration resistant material covering said backing, and a laminate disposed over said penetration resistant material.
25. A kit of parts according to claim 16 further comprising a cover adapted to removably cover at least one of said panels.
26. A kit of parts according to claim 16 wherein each said panel comprises a penetration resistant material and a hardening material cooperating with said penetration resistant material.
27. A kit of parts according to claim 16 wherein each said panel further comprises a crystalline material adhered to said hardening material.
28. A kit of parts according to claim 27 wherein said crystalline material is selected from the group consisting of ceramic, garnet, metal, silicon carbide, aluminium oxide and diamond.

Patentansprüche

1. Eindringungshemmendes Kleidungsstück (20), das dafür geeignet ist einem Eindringen eines Fluidstrahls, der einen Druck von bis zu 275,79 MPa (40.000 psi) aufweist, zu widerstehen, umfassend:
 - eine Vielzahl von eindringungshemmenden Paneelen (30), die miteinander zusammenwirken und relativ zueinander angeordnet sind, um eine im Wesentlichen vollständige Abdeckung bereitzustellen, die sich über einen Bereich einer gewünschten Abdeckung erstreckt, wobei die Paneele in einer vertikal überlappenden Weise geschichtet sind, wodurch die Wahrscheinlichkeit, dass Wasser hinter das Kleidungsstück auf den Träger laufen wird, verringert wird, bei dem jedes Paneel eine eindringungshemmende Struktur (152) umfasst, die mit einem Härtematerial bedeckt oder getränkt ist, die ein kristallines Material umfasst, das an dem Härtematerial anhaftet, wobei das Härtematerial mit der eindringungshemmenden Struktur zusammenwirkt, und das kristalline Material aus Keramik, Granat, Metall, Siliziumkarbid, Aluminium-

oxid und Diamant ausgewählt ist.

2. Kleidungsstück nach Anspruch 1, bei dem die Paneele auf eine überlappende Weise geschichtet sind.
3. Kleidungsstück nach Anspruch 1, bei dem die kontinuierliche Schicht eine Länge definiert, wobei wenigstens einige der Paneele so miteinander zusammenwirken, dass die Länge der kontinuierlichen Schicht eingestellt werden kann.
4. Kleidungsstück nach Anspruch 1, bei dem jedes der Paneele, welches das Kleidungsstück ausbildet, austauschbar ist.
5. Kleidungsstück nach Anspruch 1, ferner umfassend wenigstens einen Gurt (72), damit ein Träger das Kleidungsstück anlegen kann.
6. Kleidungsstück nach Anspruch 1, bei dem das Kleidungsstück angepasst ist, um ausschließlich entweder an einer Vorderseite oder einer Hinterseite des Trägers getragen zu werden.
7. Kleidungsstück nach Anspruch 1, bei dem jedes Paneel eine Verstärkung (150) und eine eindringungshemmende Struktur umfasst, welche die Verstärkung abdeckt, wobei die eindringungshemmende Struktur eine Fläche belegt, die kleiner als die Gesamtfläche der Verstärkung ist.
8. Kleidungsstück nach Anspruch 13, bei dem die Verstärkung eine Kante (154) enthält, wobei die eindringungshemmende Struktur die Verstärkung so abdeckt, dass die Kante der Verstärkung freigelegt bleibt.
9. Kleidungsstück nach Anspruch 1, bei dem jedes Paneel eine Verstärkung, eine eindringungshemmende Struktur, welche die Verstärkung abdeckt, und eine Schicht (158) umfasst, die über der eindringungshemmenden Struktur angeordnet ist.
10. Kleidungsstück nach Anspruch 1, ferner umfassend eine Abdeckung (160), die wenigstens eines der Paneele entfernbar abdeckt.
11. Kleidungsstück nach Anspruch 1, bei dem wenigstens einige der Paneele aufgebaut sind, um einen Rumpfabschnitt (32) auszubilden, wobei der Rumpfabschnitt ein Brustpaneel (40), ein linkes Bauchpaneel (42), das an dem Brustpaneel angebracht ist, ein rechtes Bauchpaneel (44), das an dem Brustpaneel (581) angebracht ist, und ein Leistenpaneel umfasst, das an dem Brustpaneel und den Bauchpaneelen angebracht ist.

12. Kleidungsstück nach Anspruch 1, bei dem wenigstens einige der Paneele aufgebaut sind, um einen Hosenabschnitt (34) auszubilden, wobei der Hosenabschnitt erste und zweite Beinabschnitte (90, 92) umfasst, wobei jeder Beinabschnitt ein Oberschenkelpaneel (94) und einen Knieabschnitt (96) umfasst, wobei der Knieabschnitt ein oberes Kniepaneel (98), ein unteres Kniepaneel (100) und ein Kniepad (102) umfasst, das zwischen den oberen und unteren Paneelen verbunden ist, wobei das obere Paneel an dem Oberschenkelpaneel einstellbar befestigt ist. 5
13. Kleidungsstück nach Anspruch 12, bei dem das Oberschenkelpaneel angepasst ist, um ein Unterliekspanner-Riemen (110) zu empfangen. 10
14. Kleidungsstück nach Anspruch 12, bei dem das Kniepad an das obere Paneel mit einem ersten Paar von Gelenkstiften angelenkt ist, und an das untere Paneel mit einem zweiten Paar von Gelenkstiften angelenkt ist, wobei die ersten und zweiten Paare von Gelenkstiften durch das Kniepad an vorbestimmten Orten so positioniert sind, dass ein effektives Drehzentrum des oberen Paneels, des unteren Paneels und des Kniepads durch ein Drehzentrum des Knies des Trägers verläuft. 15
15. Kleidungsstück nach Anspruch 1, bei dem wenigstens einige der Paneele aufgebaut sind, um einen Faltenbalgabschnitt (36) auszubilden, wobei der Faltenbalgabschnitt wenigstens ein Schienenbeinpaneel (130), ein Knöchelpaneel (132) und ein Fußpaneel (134) umfasst, wobei die Schienenbein-, Knöchel- und Fußpaneele an einem oder mehreren Orten aneinandergelenkt sind, um, wenn von einem Träger getragen, wenigstens entweder eine Knöcheldrehung oder Fußdrehung des Faltenbalgabschnitts zu erlauben. 20
16. Bausatz von Teilen zur Verwendung zum Zusammenfügen wenigstens eines Abschnitts eines eindringungshemmenden Kleidungsstücks, das geeignet ist einem Eindringen eines Fluidstrahls, der einen Druck von bis zu 275,79 MPa (40.000 psi) aufweist, zu widerstehen, wobei der Bausatz umfasst: 25
- wenigstens ein eindringungshemmendes Paneel, wobei das Paneel angepasst ist, um mit einem benachbarten Paneel zusammenzuwirken und relativ zu diesem angeordnet zu sein, um im Wesentlichen eine vollständige Abdeckung bereitzustellen, die sich über einen Bereich einer gewünschten Abdeckung erstreckt, wobei die Paneele in einer vertikalen überlappenden Weise geschichtet sind, wodurch die Wahrscheinlichkeit, dass Wasser hinter das Kleidungsstück auf den Träger läuft, verringert wird, 30
- und bei dem das Paneel eine eindringungshemmende Struktur (152) umfasst, die mit einem Härtematerial bedeckt oder getränkt ist, die ein kristallines Material umfasst, das an dem Härtematerial anhaftet, und wobei das kristalline Material aus Keramik, Granat, Metall, Siliziumkarbid, Aluminiumoxid und Diamant ausgewählt ist. 35
17. Bausatz nach Anspruch 16, ferner umfassend eine Vielzahl von Gelenkstiften, bei dem wenigstens einige der Paneele angepasst sind, um miteinander über wenigstens einen der Gelenkstifte verbunden zu werden. 40
18. Bausatz nach Anspruch 16, bei dem wenigstens zwei der Paneele jeweils einen Klettverschluss umfassen. 45
19. Bausatz nach Anspruch 16, ferner umfassend ein Basismaterial (170), das für ein Tragen von einem Benutzer angepasst ist, wobei die Paneele angepasst sind, um an dem Basismaterial befestigt zu werden. 50
20. Bausatz nach Anspruch 19, bei dem das Basismaterial wenigstens eine Tasche (172) umfasst, wobei die Paneele angepasst sind, um in wenigstens einer Tasche angeordnet zu sein. 55
21. Bausatz nach Anspruch 16, bei dem wenigstens eines der Paneele wenigstens ein Riemen umfasst, der angepasst ist, damit der Träger das Paneel anlegen kann.
22. Bausatz nach Anspruch 16, bei dem jedes Paneel eine Rückseite und ein eindringungshemmendes Material umfasst, das die Rückseite abdeckt, wobei das eindringungshemmende Material eine Fläche belegt, die kleiner als die Gesamtfläche der Rückseite ist.
23. Bausatz nach Anspruch 22, bei dem die Rückseite eine Kante enthält, wobei das eindringungshemmende Material die Rückseite so abdeckt, dass die Kante der Rückseite freigelegt bleibt.
24. Bausatz nach Anspruch 16, bei dem jedes Paneel eine Rückseite, ein eindringungshemmendes Material, das die Rückseite abdeckt, und eine Schicht umfasst, die über dem eindringungshemmenden Material angeordnet ist.
25. Bausatz nach Anspruch 16, ferner umfassend eine Abdeckung, die angepasst ist, um wenigstens eines der Paneele entfernt abdecken zu können.

26. Bausatz nach Anspruch 16, bei dem jedes Paneel ein eindringungshemmendes Material und ein Härtematerial umfasst, das mit dem eindringungshemmenden Material zusammenwirkt.
27. Bausatz nach Anspruch 16, bei dem jedes Paneel ferner ein kristallines Material umfasst, das an dem Härtematerial anhaftet.
28. Bausatz nach Anspruch 27, bei dem das kristalline Material aus der Gruppe, die aus Keramik, Granat, Metall, Siliziumkarbid, Aluminiumoxid und Diamant besteht, ausgewählt ist.

Revendications

1. Vêtement (20) résistant à la pénétration, apte à résister à la pénétration d'un jet de fluide dont la pression peut atteindre 275,79 MPa (40 000 psi), et qui comprend :

plusieurs panneaux résistant à la pénétration (30) fonctionnant ensemble et agencés les uns par rapport aux autres de manière à fournir une couverture essentiellement complète sur une zone de couverture souhaitée, les panneaux étant stratifiés de manière à se recouvrir verticalement pour ainsi réduire la probabilité que l'eau passe sur le porteur après avoir traversé le vêtement, chaque panneau comprenant un tissu résistant à la pénétration (152) recouvert ou saturé d'un matériau de durcissement, comprenant un matériau cristallin qui adhère audit matériau de durcissement, ledit matériau de durcissement coopérant avec ledit tissu résistant à la pénétration et ledit matériau cristallin étant sélectionné dans l'ensemble constitué des céramiques, du grenat, des métaux, du carbure de silicium, de l'oxyde d'aluminium et du diamant.

2. Vêtement selon la revendication 1, dans lequel lesdits panneaux sont stratifiés en superposition.
3. Vêtement selon la revendication 1, dans lequel ladite couche continue définit une longueur, au moins certains des panneaux coopérant les uns avec les autres de manière à ce que ladite longueur de ladite couche continue puisse être ajustée.
4. Vêtement selon la revendication 1, dans lequel chacun desdits panneaux formant ledit vêtement est remplaçable.
5. Vêtement selon la revendication 1, comprenant de plus au moins une sangle (72) qui permet à un porteur de porter ledit vêtement.

6. Vêtement selon la revendication 1, dans lequel ledit vêtement est adapté pour être porté exclusivement à l'avant ou à l'arrière d'un porteur.

- 5 7. Vêtement selon la revendication 1, dans lequel chacun desdits panneaux comprend un support (150) et un tissu résistant à la pénétration qui couvre ledit support, ledit tissu résistant à la pénétration occupant une surface inférieure à la surface totale dudit support.

- 10 8. Vêtement selon la revendication 13, dans lequel ledit support comprend un bord (154), ledit tissu résistant à la pénétration recouvrant ledit support de manière à ce que ledit bord dudit support reste exposé.

- 15 9. Vêtement selon la revendication 1, dans lequel chacun desdits panneaux comprend un support, un tissu résistant à la pénétration qui recouvre ledit support et un stratifié (158) placé sur ledit tissu résistant à la pénétration.

- 20 10. Vêtement selon la revendication 1, comprenant de plus une couverture (160) recouvrant de façon libérable au moins une partie desdits panneaux.

- 25 11. Vêtement selon la revendication 1, dans lequel au moins certains desdits panneaux sont configurés pour former une partie de torse (32), ladite partie de torse comprenant un panneau (40) de poitrine, un panneau (42) de hanche gauche attaché audit panneau de poitrine, un panneau (44) de hanche droite attaché audit panneau (581) de poitrine et un panneau d'aine attaché audit panneau de poitrine et auxdits panneaux de hanche.

- 30 12. Vêtement selon la revendication 1, dans lequel au moins certains des panneaux sont configurés pour former une partie (34) de jambière, ladite partie de jambière comprenant une première partie (90) de jambe et une deuxième partie (92) de jambe, chaque partie de jambe comprenant un panneau (94) de cuisse et une partie (96) de genou, ladite partie de genou comprenant un panneau (98) supérieur de genou, un panneau (100) inférieur de genou et un coussinet (102) de genou accouplés entre ledit panneau supérieur et ledit panneau inférieur, ledit panneau supérieur étant fixé de façon ajustable audit panneau de cuisse.

- 35 13. Vêtement selon la revendication 12, dans lequel ledit panneau de cuisse est adapté pour recevoir une sangle de suspension (110).

- 40 45 50 55 14. Vêtement selon la revendication 12, dans lequel ledit coussinet de genou est articulé sur ledit panneau supérieur par une première paire de pivots et articulé sur ledit panneau inférieur par une deuxième paire

- de pivots, ladite première paire de pivots et ladite deuxième paire de pivots étant placées dans ledit coussinet de genou en des emplacements prédéterminés de manière à ce que le centre de rotation effectif dudit panneau supérieur, dudit panneau inférieur et dudit coussinet de genou passe par un centre de rotation du genou du porteur.
- 15.** Vêtement selon la revendication 1, dans lequel au moins certains desdits panneaux sont configurés de manière à former une partie (36) de guêtre, ladite partie de guêtre comprenant au moins un panneau (130) de tibia, un panneau (132) de cheville et un panneau (134) de pied, ledit panneau de tibia, ledit panneau de cheville et ledit panneau de pied étant articulés ensemble en un ou plusieurs emplacements pour permettre au moins une rotation de la cheville et une articulation d'orteils de ladite partie de guêtre lorsqu'elle est portée par un porteur.
- 16.** Ensemble de pièces destiné à être utilisé dans l'assemblage d'au moins une partie du vêtement résistant à la pénétration capable de résister à la pénétration par un jet fluide dont la pression peut atteindre 275,79 MPa (40 000 Psi), ledit ensemble comprenant :
- au moins un panneau résistant à la pénétration, ledit panneau étant adapté pour coopérer avec les panneaux adjacents et étant agencé par rapport à eux pour fournir une couverture essentiellement complète qui s'étend sur une zone de couverture souhaitée, les panneaux étant stratifiés en superposition verticale pour ainsi réduire la probabilité que l'eau passe sur le porteur après avoir traversé le vêtement,
- et dans lequel ledit panneau comprend un tissu résistant à la pénétration (152) recouvert ou saturé d'un matériau de durcissement, qui comprend un matériau cristallin qui adhère audit matériau de durcissement, ledit matériau cristallin étant sélectionné parmi l'ensemble constitué des céramiques, du grenat, des métaux, du carbure de silicium, de l'oxyde d'aluminium et du diamant.
- 17.** Ensemble de pièces selon la revendication 16, comprenant de plus plusieurs pivots, au moins certains desdits panneaux étant adaptés pour être reliés ensemble par au moins un desdits pivots.
- 18.** Ensemble de pièces selon la revendication 16, dans lequel au moins deux desdits panneaux comprennent respectivement une attache en crochet et une attache en boucle.
- 19.** Ensemble de pièces selon la revendication 16, comprenant de plus un matériau (170) de base adapté
- pour être porté par un utilisateur, lesdits panneaux étant adaptés pour être fixés audit matériau de base.
- 20.** Ensemble de pièces selon la revendication 19, dans lequel ledit matériau de base comprend au moins une poche (172), lesdits panneaux étant adaptés pour être placés dans ladite ou lesdites poches.
- 21.** Ensemble de pièces selon la revendication 16, dans lequel au moins un desdits panneaux comprend au moins une sangle adaptée pour qu'un porteur puisse porter ledit panneau.
- 22.** Ensemble de pièces selon la revendication 16, dans lequel chacun desdits panneaux comprend un support et un matériau résistant à la pénétration qui couvre ledit support, ledit matériau résistant à la pénétration occupant une superficie inférieure à la superficie totale dudit support.
- 23.** Ensemble de pièces selon la revendication 22, dans lequel ledit support comprend un bord, ledit matériau résistant à la pénétration couvrant ledit support de manière à ce que ledit bord dudit support reste exposé.
- 24.** Ensemble de pièces selon la revendication 16, dans lequel chacun desdits panneaux comprend un support, un matériau résistant à la pénétration recouvrant ledit support et un stratifié placé sur ledit matériau résistant à la pénétration.
- 25.** Ensemble de pièces selon la revendication 16, comprenant de plus une couverture adaptée pour couvrir de façon libérable au moins un desdits panneaux.
- 26.** Ensemble de pièces selon la revendication 16, dans lequel chacun desdits panneaux comprend un matériau résistant à la pénétration et un matériau de durcissement qui coopère avec ledit matériau résistant à la pénétration.
- 27.** Ensemble de pièces selon la revendication 16, dans lequel chacun desdits panneaux comprend de plus un matériau cristallin qui adhère audit matériau de durcissement.
- 28.** Ensemble de pièces selon la revendication 27, dans lequel ledit matériau cristallin est sélectionné parmi l'ensemble constitué des céramiques, du grenat, des métaux, du carbure de silicium, de l'oxyde d'aluminium et du diamant.

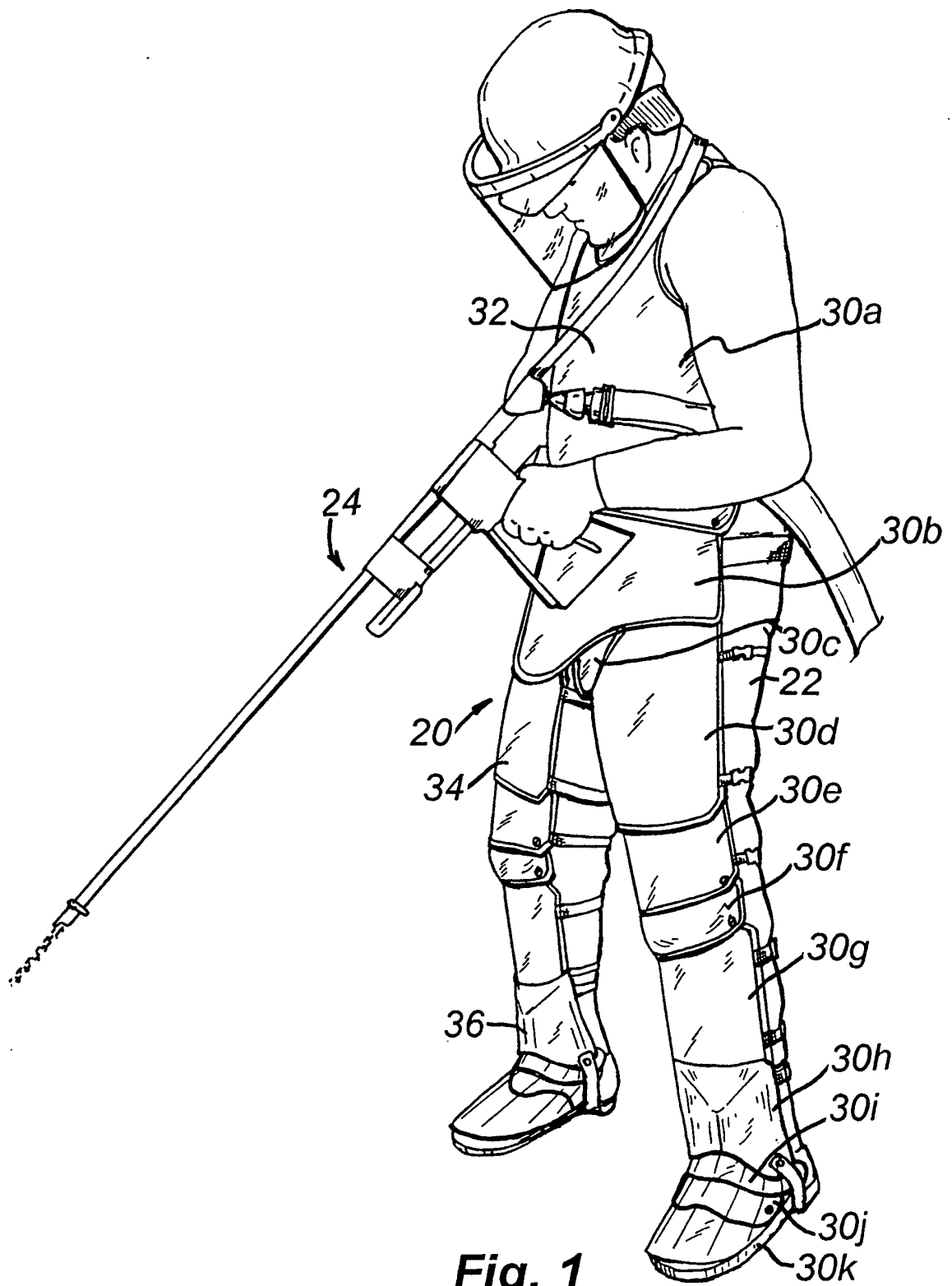


Fig. 1

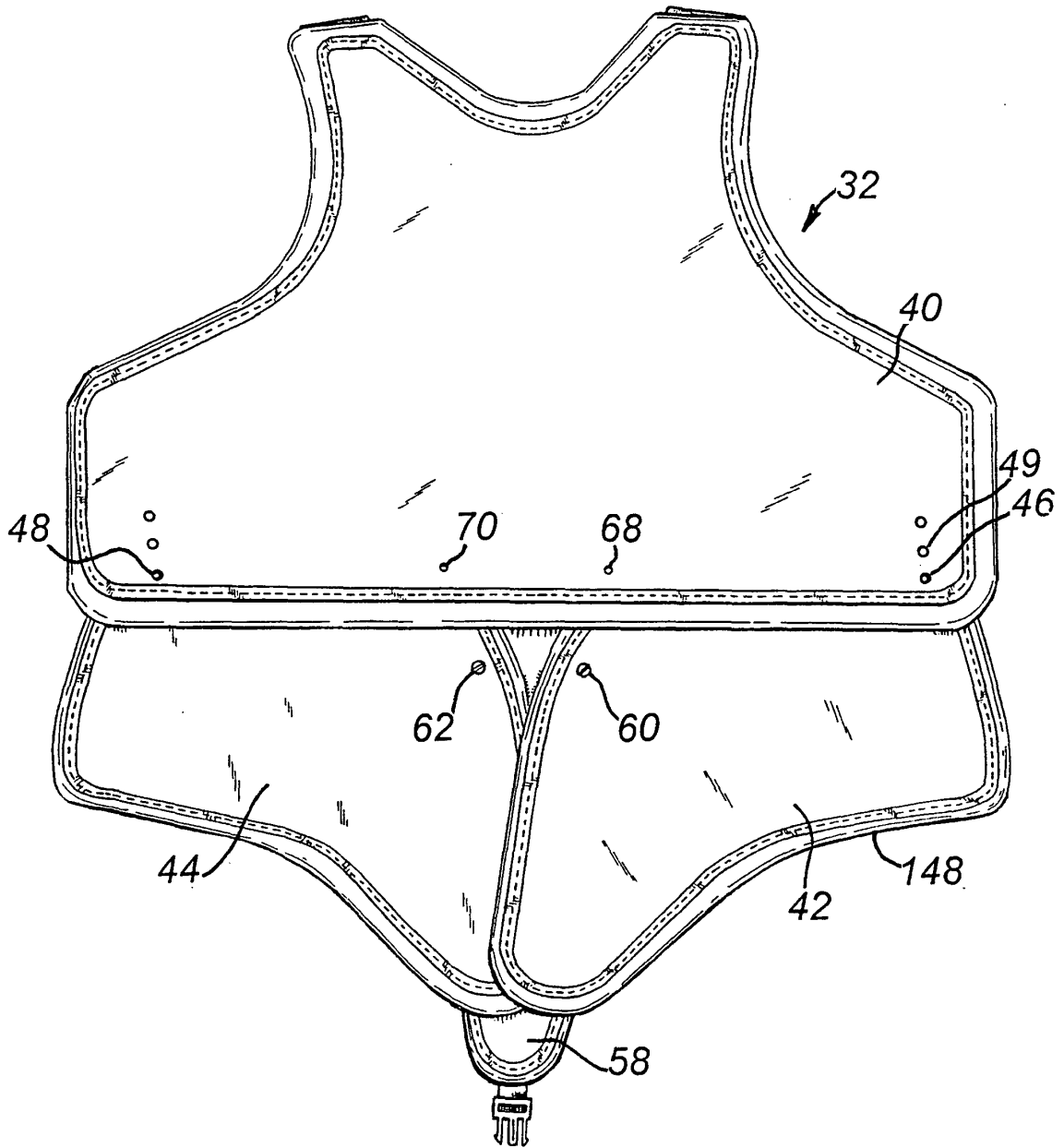


Fig. 2

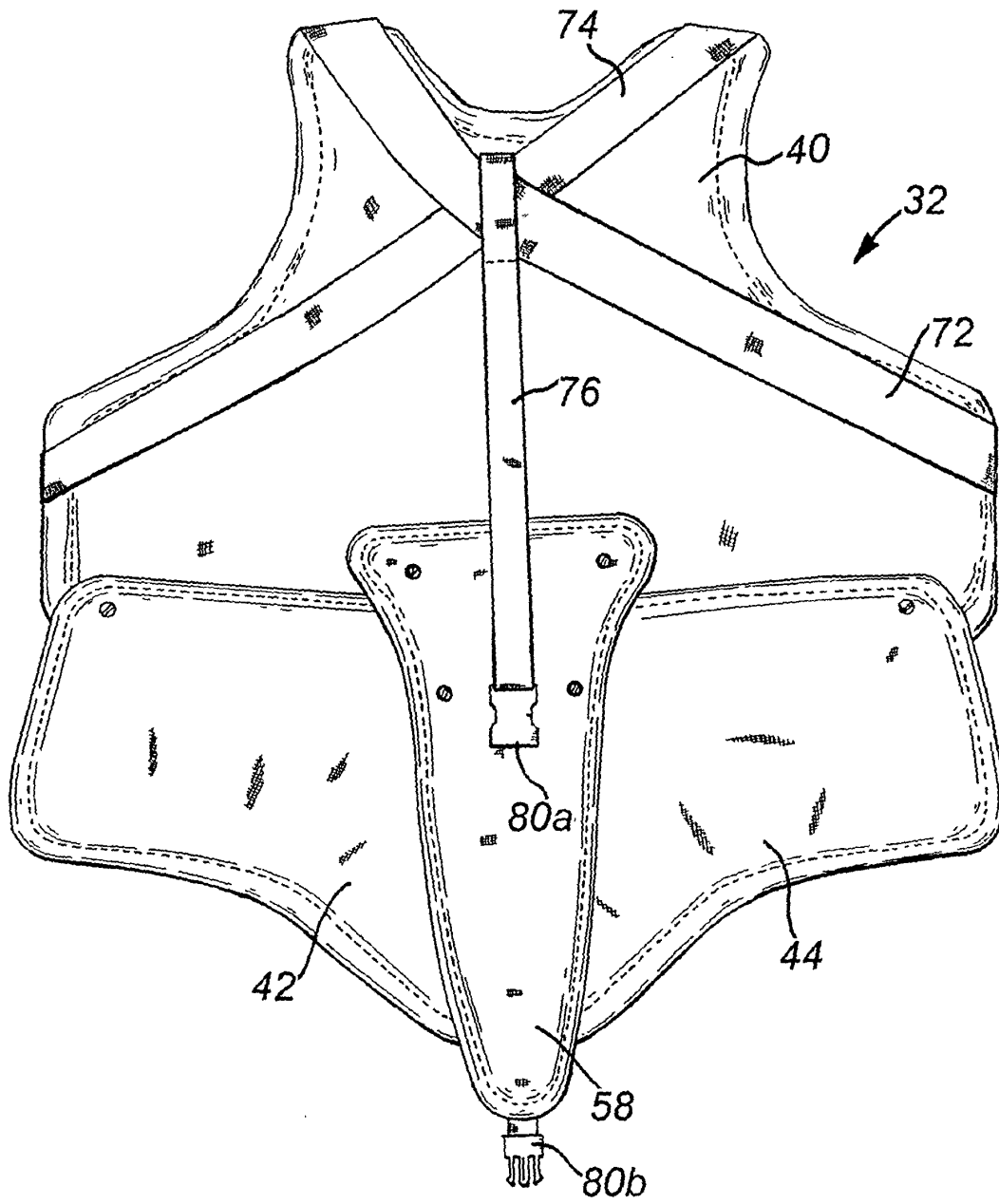


Fig. 3

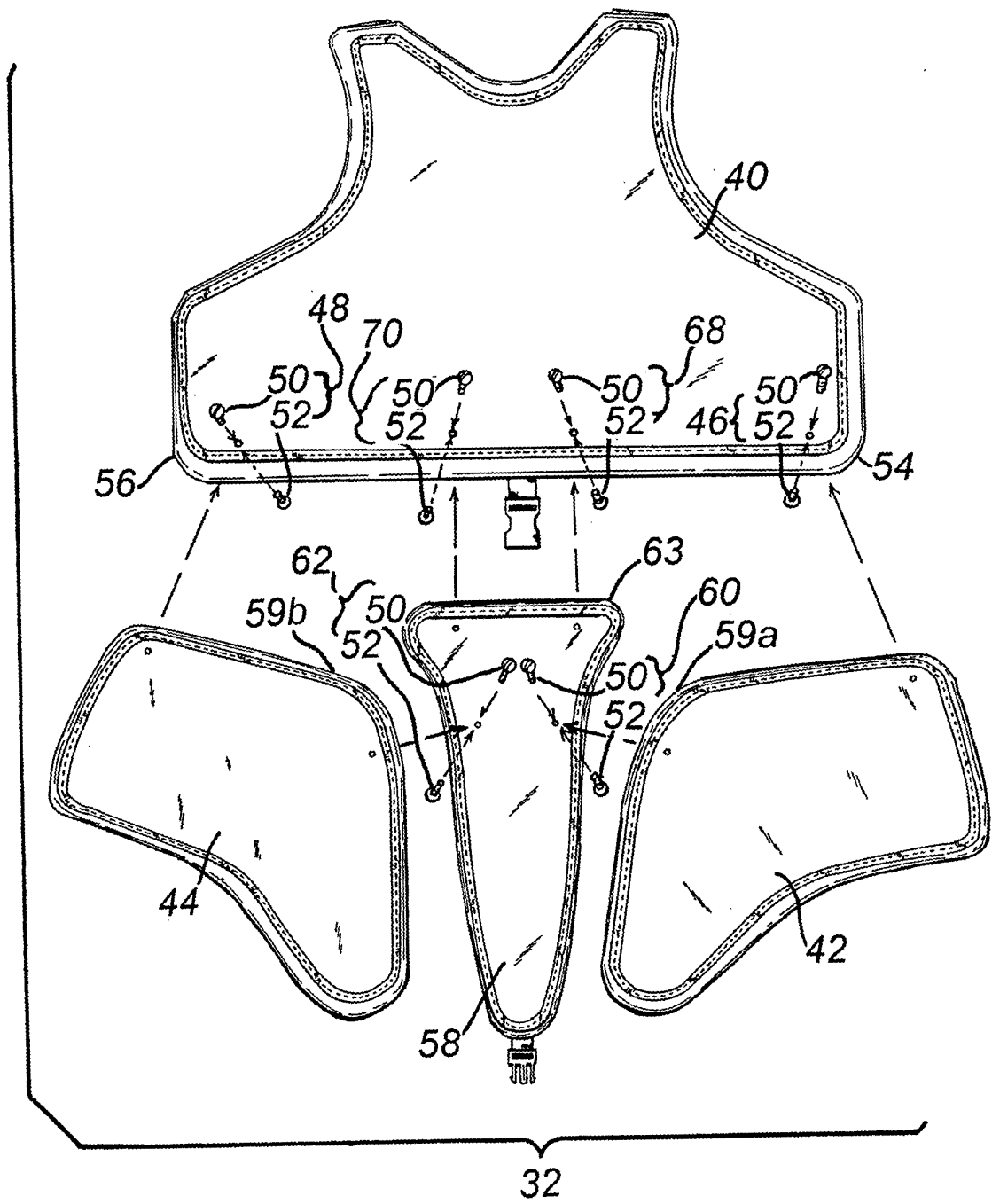


Fig. 4

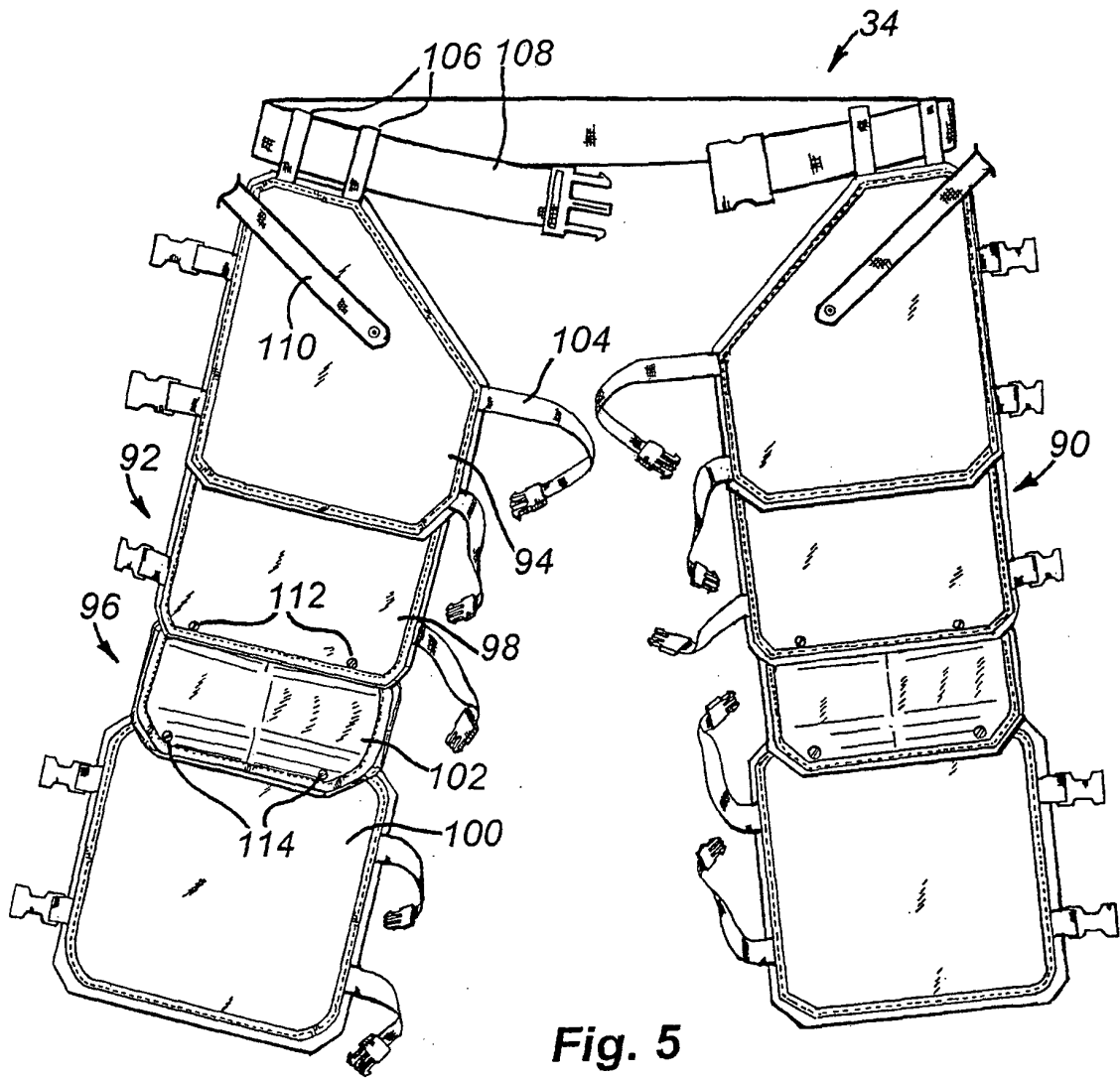


Fig. 5

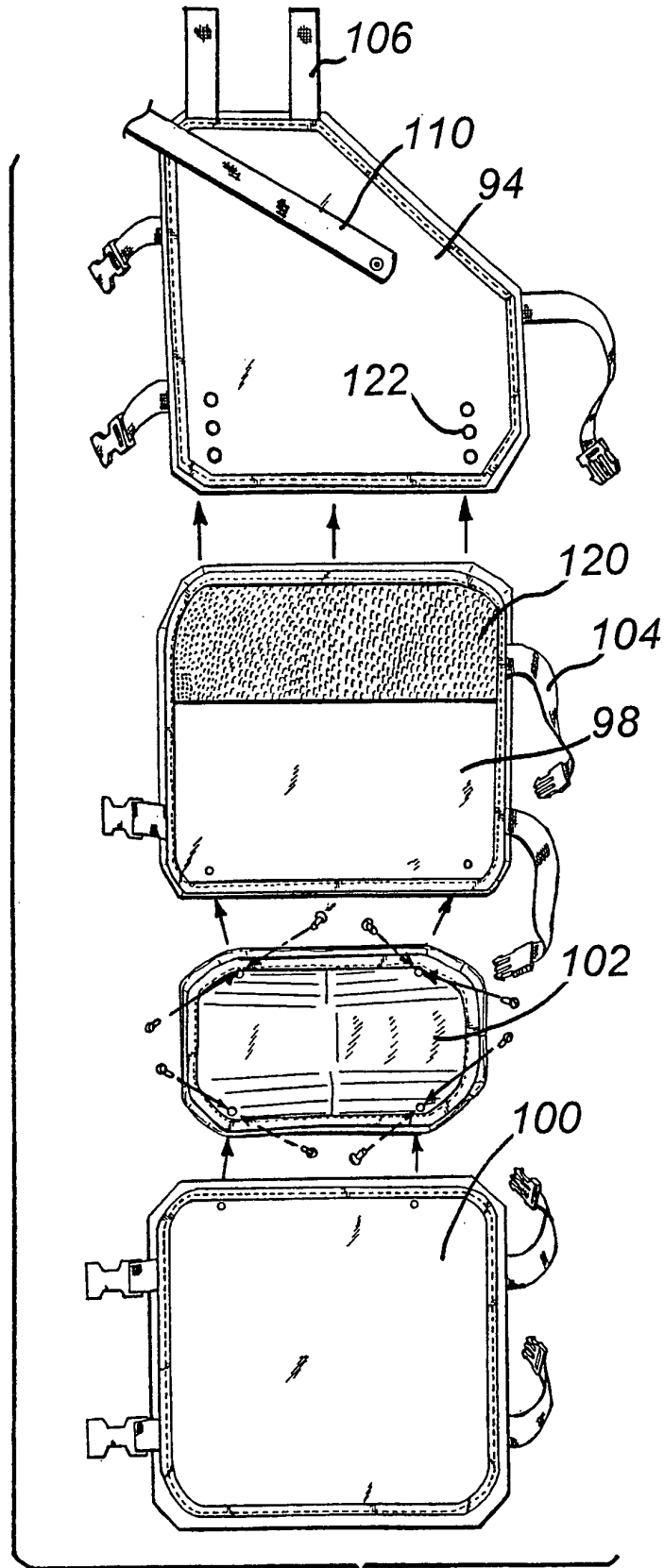


Fig. 6

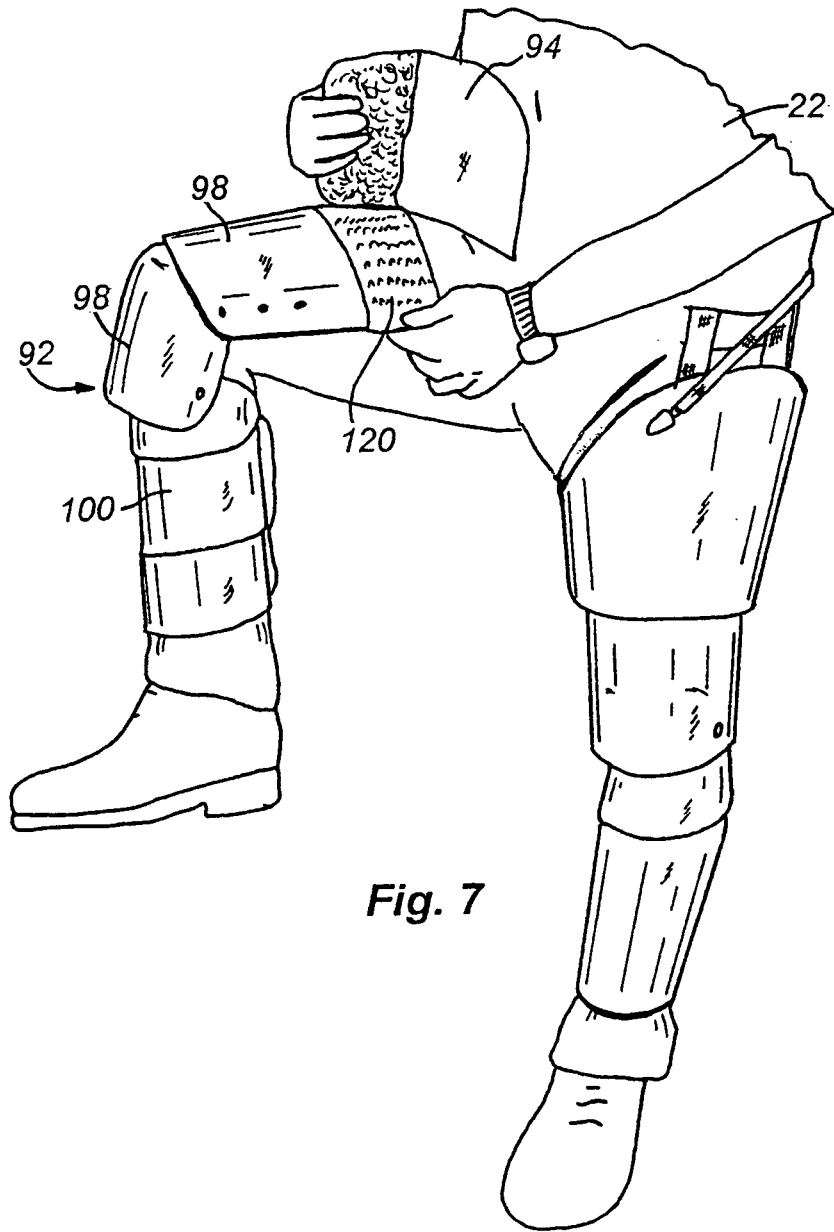


Fig. 7

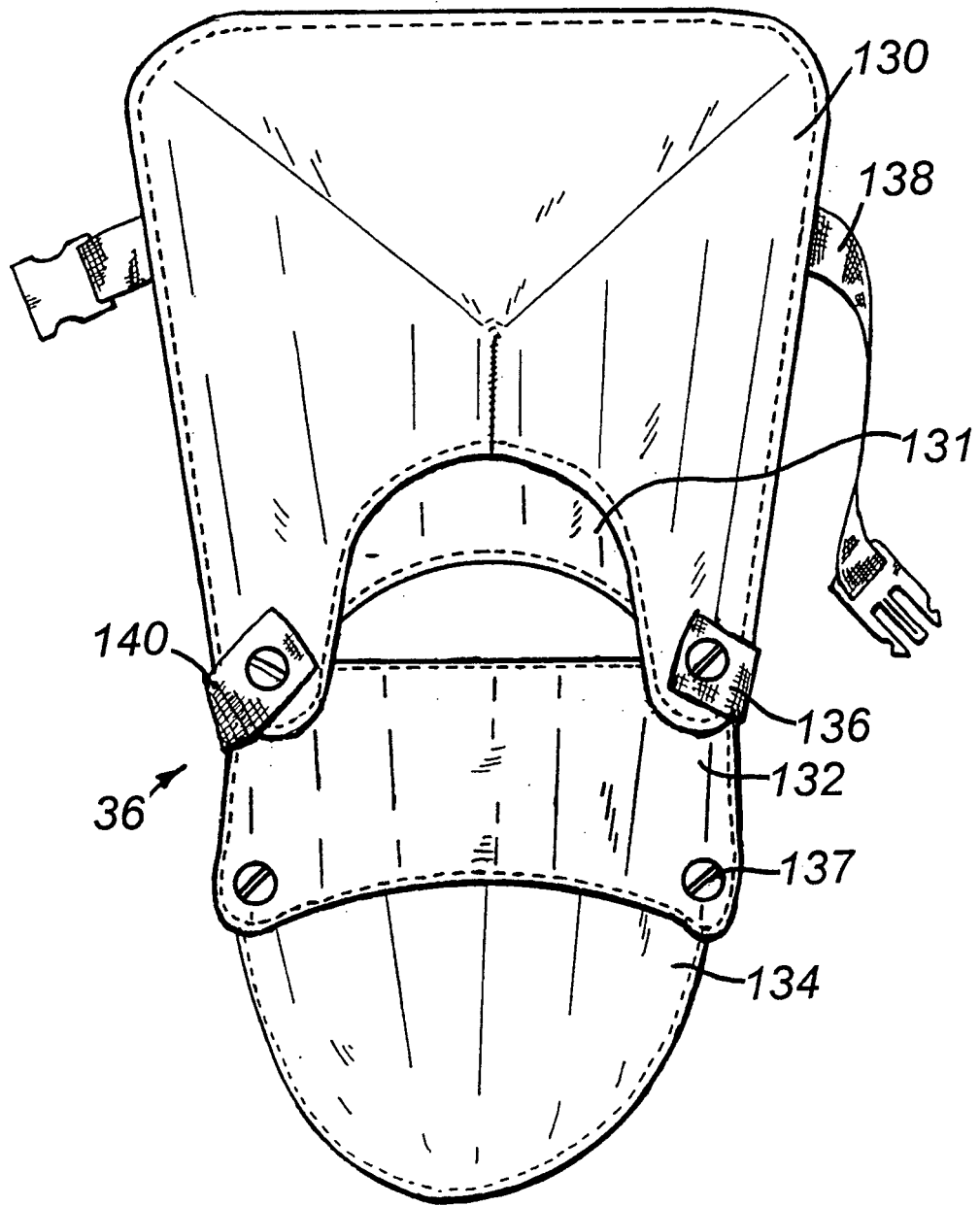


Fig. 8

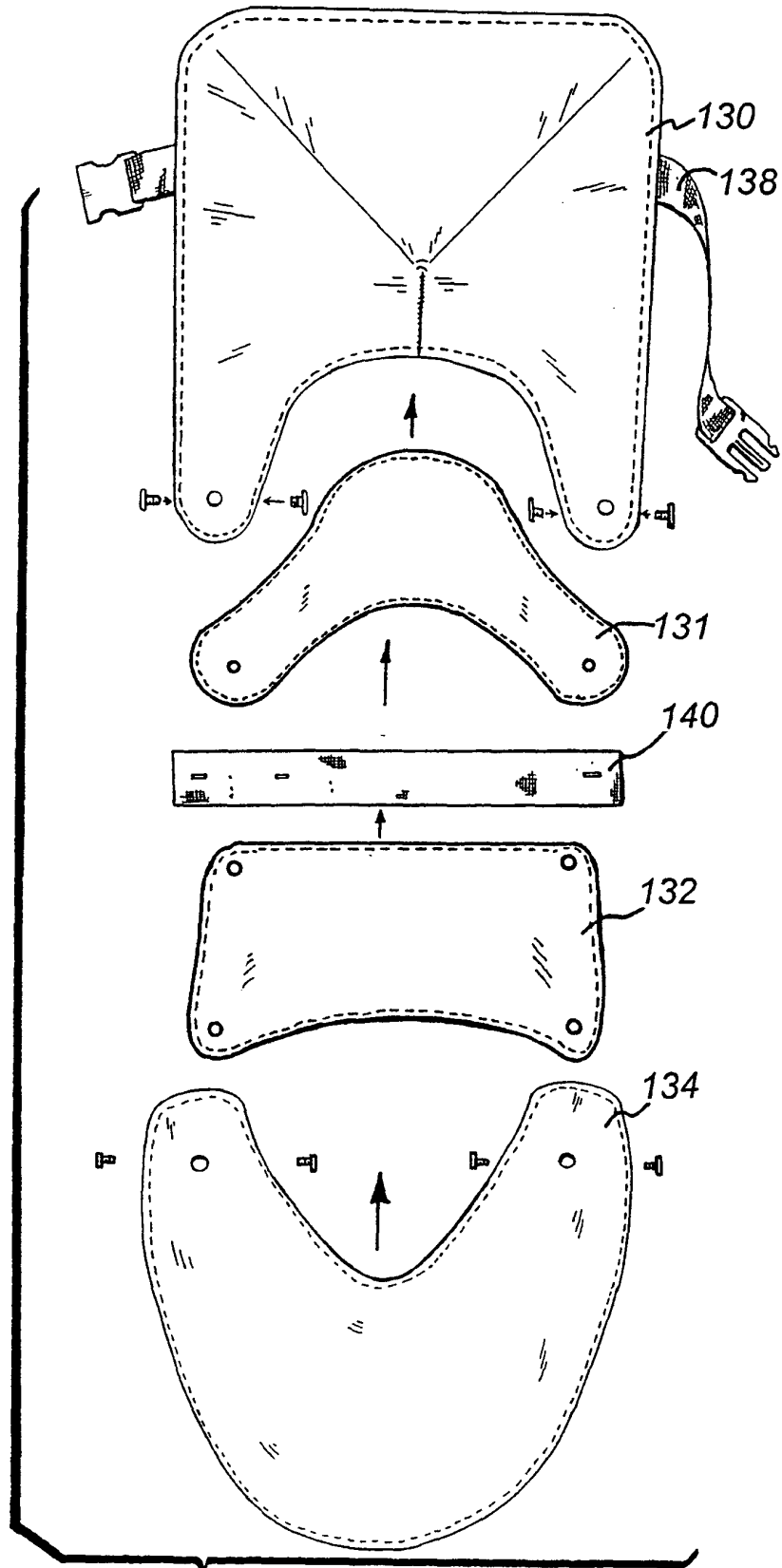


Fig. 9

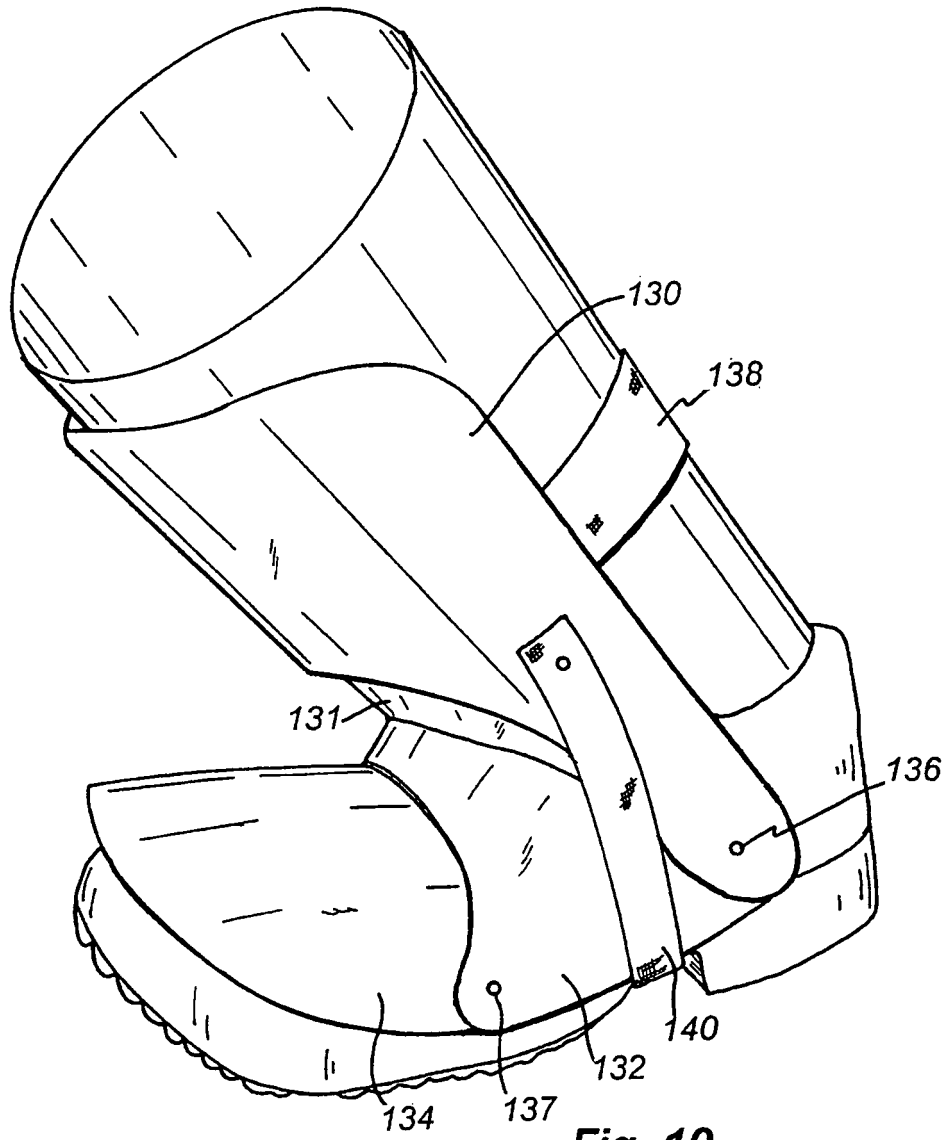


Fig. 10

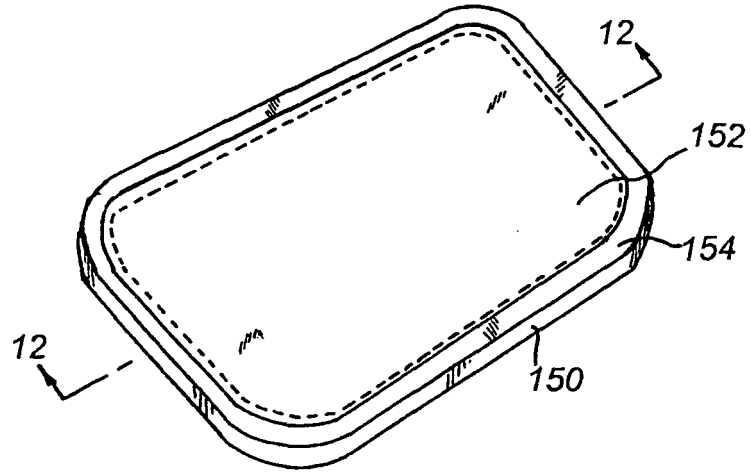


Fig. 11

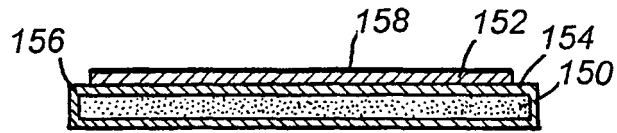


Fig. 12a

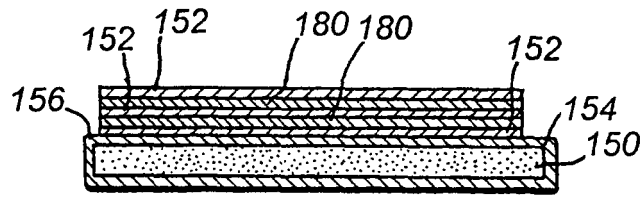


Fig. 12b

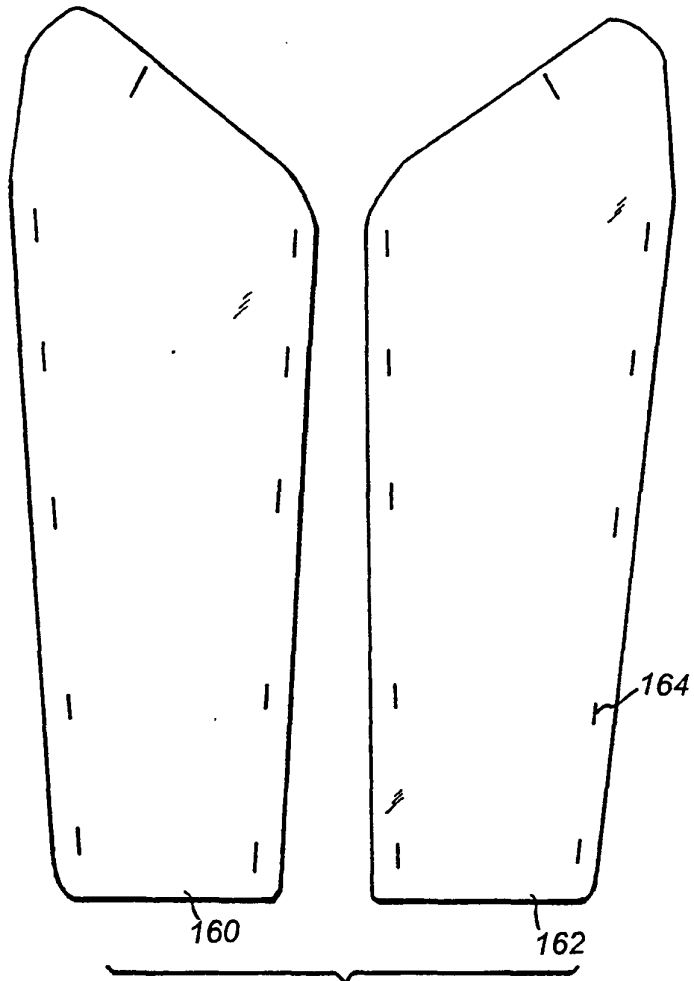


Fig. 13

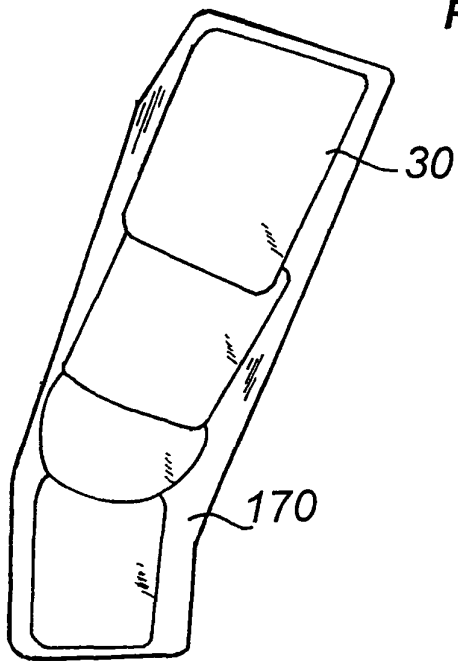


Fig. 14

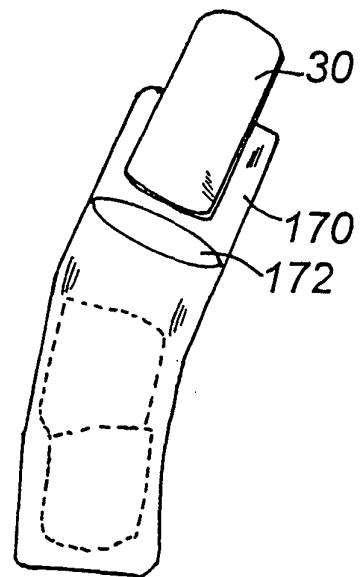


Fig. 15

REFERENCES CITED IN THE DESCRIPTION

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