Jan. 12, 1965 M. R. REYNOLDS 3,164,840

RADIATION PROTECTIVE GARMENT

Filed Feb. 27, 1961 2 Sheets-Sheet 1

FIG. 1

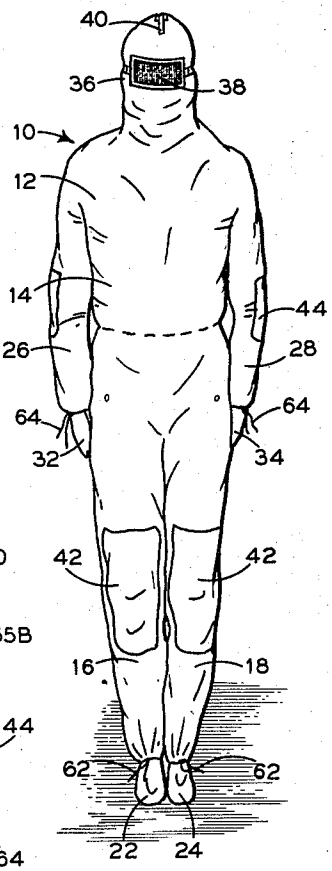


FIG. 3

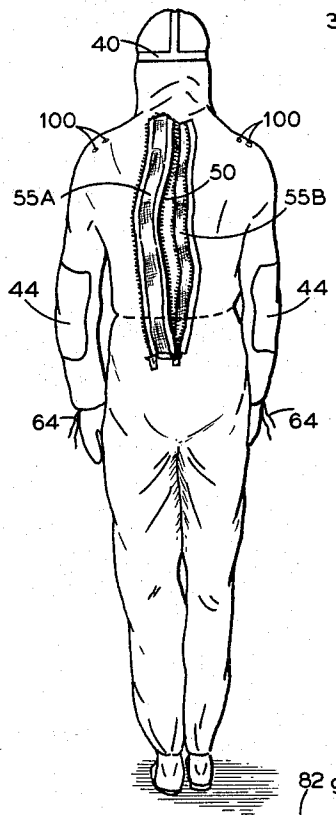


FIG. 2

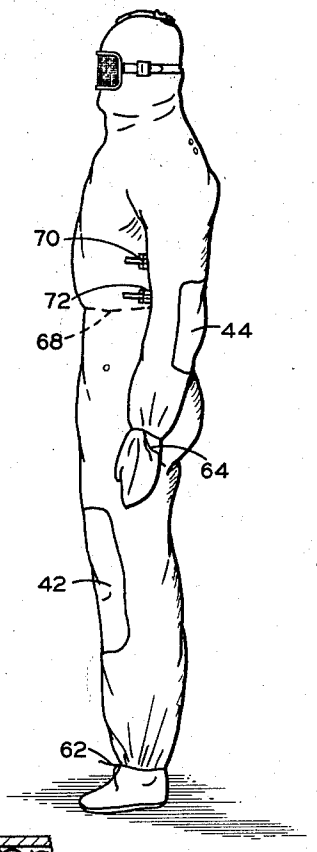
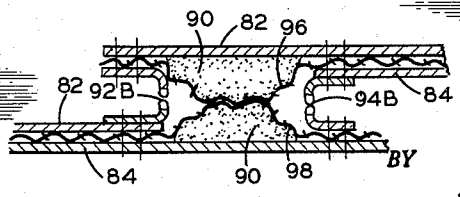


FIG. 6B



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RADIATION PROTECTIVE GARMENT

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FIG. 4

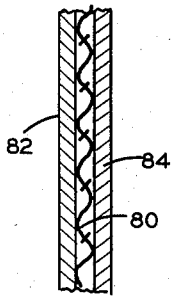


FIG. 5

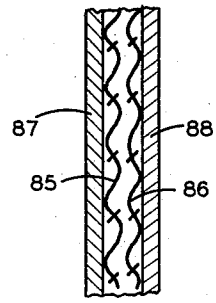


FIG. 6

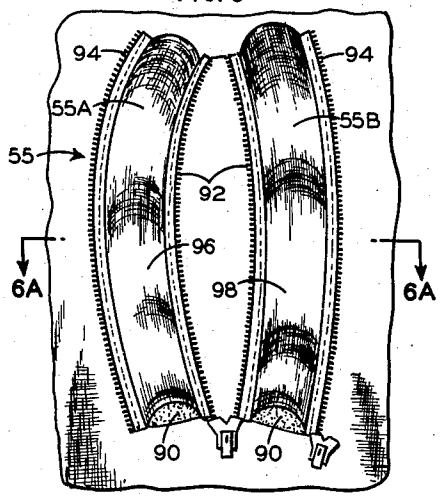


FIG. 7

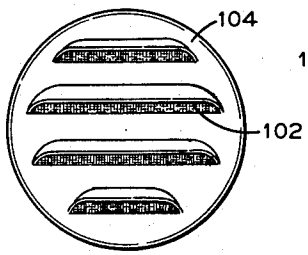


FIG. 7A

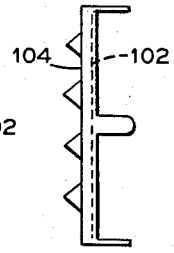


FIG. 8

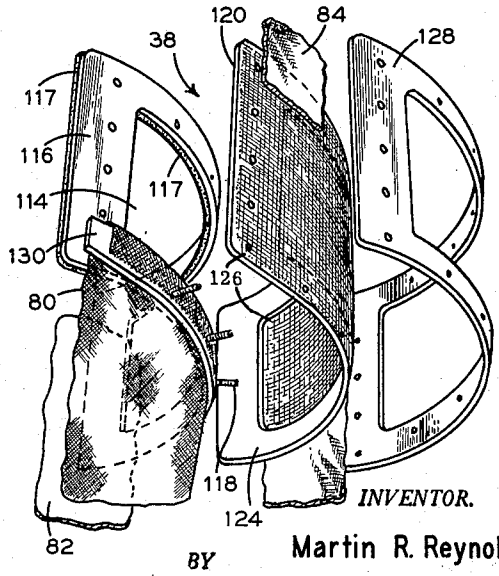
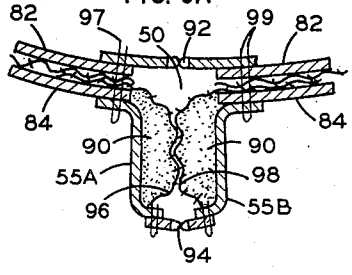


FIG. 6A



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RADIATION PROTECTIVE GARMENT

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4 Claims. (Cl. 2—2)

This invention relates to a protective garment to be worn by a person working in a region immersed in, or irradiated by, an electromagnetic field of very high frequency. For convenience, such a suit will be referred to as an R-F suit, that is, a radio-frequency suit.

It is known that a radio-frequency electromagnetic field will affect the human body. That is to be expected from electromagnetic theory, since an ambient electromagnetic field will establish a potential gradient in the human body with a consequent current flow through the body, depending upon the relative impedance of the various paths available to such current.

In the case of operators working in a region that is so irradiated by such a high-frequency electromagnetic field, various harmful effects have been observed. Even though such electromagnetic fields are not focused and concentrated, some of the effects are such as would be expected only from a concentrated or focused field. The possibility of some effects of the microwave field upon a human body may be realized upon considering that various dimensions of the human body are several wave lengths long at very high frequencies, and the human body may therefore be considered to act as non-infinite electric line. Thus, depending upon the direction of the gradient of the electromagnetic field passing through the human body, reflections may be set up in the body depending upon the nature of the termination provided by the exit side of the human body with relation to the transmitted wave represented by the electromagnetic energy passing through the body.

From this point of view, the standing waves thus produced will naturally also create heat in the body and raise the body temperature. If this were the only result, it is possible that the presence of the electromagnetic field surrounding a worker would not be too serious and could be tolerated, merely by providing adequate cooling in the environment.

However, there is some evidence that internal stresses are established within the body, and that the rise in temperature is merely a symptomatic indication. It is quite likely that some of the conditions that have been observed are related to internal stresses in the body, which may be caused by a type of vibration occurring at various points in the body, as at anti-nodes or termination of line sections. Such vibrations may create a condition similar to "whipping" which is the snapping action at the end of a whip, as recognized, for example, in the whipping action of a flag that is blowing in the wind.

All of the harmful biological effects that have been observed indicate that the human body requires protection from such a field, and, therefore, any worker in such an electromagnetic field must be protected.

The primary object of this invention is to provide a protective garment to be worn by an operator working in a region that is bathed in, or irradiated by an electromagnetic field of very high frequency.

Another object of this invention is to provide such a garment that will provide a completely closed electrically conductive shell around the body of a wearer, so that no electromagnetic energy from the ambient field can reach the body of the operator within the shell to cause any possible biological detrimental effects.

Another object of the invention is to provide such a protective garment that shall enclose the entire body of the operator and have a peep hole area or window that will enable the operator to look out, while the window area will be suitably shielded to prevent the passage therethrough of any energy from the ambient electromagnetic field into the garment.

Another object of the invention is to provide a garment of the foregoing character, which shall have a single opening through which an operator may enter the garment or exit from the garment, in order that a minimum amount of space need be required for the closure but still insure that the metallic conducting shell around the body is completely closed at all points, including the closure, when worn.

Generally the garment or suit is formed from a fabric material having a metallic layer that is essentially continuous and is disposed to define a closed electric conducting shell when the suit is applied and worn and suitably closed. The entire human body is covered.

The fabric material in one modification is laminated with the conducting layer protectively disposed between two sandwiching layers of wear-resistant cloth. The conducting layer may be a screen of fine wire mesh. Different parts of the suit are sewed together in such manner as to ensure good electrical contact between adjacent sections of mesh. The glove portions that cover the hands may be provided with particularly fine metallic wires or threads to permit necessary flexibility.

In a second modification, the fabric may be uni-layer, or multi-layer with one layer treated with a surfacing of metallic film. For example, a surface-metallized nylon, or similar fabric base, may be employed.

To limit the possibility of open spaces in the suit, a single opening is preferably provided, through which a wearer may enter the suit. Such opening is arranged to be closed in a suitable safe way, as by a zipper, to ensure metallic contact of the metal layer across the opening.

The closure is a feature of major importance in this suit, since the closure, when closed, must establish and maintain the continuity of the conductive shell throughout all working movements by a wearer, without hampering any such movements.

The closure may take various forms, but generally embodies a construction which places two panel areas of the wire mesh or conductive cloth, from both sides of the closure, into direct surface engagement, and then holds the two panels so engaged by two zippers that join related edges of the panels to prevent relative movement between the two panels.

To provide vision to the clothed worker, a window is formed in the garment in front of the eyes and a shield is suitably supported by head straps. The shield is of light weight metal frame with a metallic screen view piece that is conductively joined to the metallic shell in the fabric. Since the metallic screen is out of the focal plane of anything being viewed by the wearer, the screen causes very little visual interference.

Thus, a total enclosed metallic shell or shield is maintained around the body of the worker, as he performs the manual operations of his duties.

The various features of construction of the garment, in accordance with this invention, may be better appreciated from the following, more detailed description, with reference to the accompanying drawings, in which,

FIG. 1 is a front elevational view of the garment as it appears when worn by an operator;

FIG. 2 is a side elevational view of the garment in FIG. 1;

FIG. 3 is a rear elevational view of the garment of FIG. 1, and serves to show the opening thru which an operator may enter, or exit from, the garment;

FIG. 4 is an edge view of a section of the material, showing the laminated structure, where metallic mesh is used as one layer;

FIG. 5 is a view similar to FIG. 4, in which two layers of metallic nylon cloth are used as internal layers of the laminated material;

FIG. 6 is an elevational front view of a closure, showing the mesh layers that are to be held in contact by the two zippers;

FIG. 6A is a sectional view of the closure of FIG. 6, taken along lines A—A in FIG. 6;

FIG. 6B is a sectional view of a modified form of the closure;

FIGS. 7 and 7A are respectively front elevational and side views of a ventilation louver of metal mesh sewed as a patch into a selected area of the garment; and

FIG. 8 is an exploded view of the vizor or eye shield, showing the mesh mask permitting vision but preventing field energy passage.

As shown in FIGS. 1 to 3, the protective garment, to be referred to herein as an R–F suit **10**, is shown consisting of a closed coverall type of garment to completely enclose the body of a human, including the trunk, arms, hands, legs, feet and head. The garment thus comprises a body portion **14**, two leg portions **16** and **18** with foot covering portions **22** and **24**, two arm covering sleeves **26** and **28** with continuous glove or mitten portions **32** and **34**, and a head covering or hood **36** provided with a front visor **38** and suitable head straps **40** for supporting the visor **38** in position in front of the eye region of the wearer.

In order to provide extra strength to regions that are likely to be subjected to wear due to extra bending, the suit is provided at the knees and elbows with reinforcing patches **42** and **44**. Because the garment involves a structural element that must provide a completely closed electroconductive shell, the garment is preferably provided with a single opening **50**, thru which an operator may enter, and exit from, the garment, so that the closures for the garment are reduced to a minimum number, preferably one. In this manner the proper operation of the garment may be safeguarded by reducing the number of closures to just one closure, which cannot be overlooked during the operation of donning the garment for use.

Such single opening **50** at the back of the garment, as shown in FIG. 3, is made merely of sufficient length to enable an operator to get into the garment, with the aid of an assistant, after which opening **50** is closed by any suitable means, being indicated herein as two zippers, for convenience.

In order to permit easy entry of the human body into the garment, the garment should have a certain amount of looseness or oversize in various parts of the garment, so the arms, feet and legs may be inserted with maximum ease and minimum friction. Similarly the head portion of the garment **36** is relatively loose, with the visor and head straps not in operating position until after the operator's head has been inserted into the hood portion **36**. After the garment has been entered by the operator, the garment may be tightened around the ankles, as by suitable draw strings **62**, and around the wrists by suitable draw strings **64**, and around the waist by two sets of such strings, one set of internal draw strings **68** and a set of external side straps **70** and **72** that will serve to hold the body of the garment snugly against the body of the operator, in order thereby to prevent relative movement of the internal parts of the garment that would be likely to impose disturbing displacement forces on parts of the garment.

The material of which the suit or garment is formed is preferably of laminated construction, with one lamination or layer consisting of a fabric woven from insulating filaments, such as cotton, wool or any of the man-made fibers, such as nylon. A second lamination consists of a layer of material which is electrically conductive. Such conductive layer may consist of material of various forms, such as, for example, metallic woven fabric consisting of woven cloth with metallic threads of metallized or silver-coated nylon, in the warp and woof, so that the metallic threads are in contact at all cross-over points, or the conductive layer may be a mesh of thin metallic wire to form a continuous metallic screen throughout the body of the garment or R–F suit, and co-extensive with the entire surface area of the garment. When an outer layer of nylon cloth is used, it may be rubberized to be antistatic.

In either case, whether the mesh is formed of metal wire or of metallized nylon filaments, the conductive layer of the laminated structure may be formed as a double layer for greater flexibility. By using a double layer, the mesh openings may be made slightly larger with consequent greater flexibility, and the double layer provides sufficient overlap to establish an equivalent smaller mesh opening, with resultant greater reflectivity to oncoming electromagnetic waves.

As indicated FIG. 4, in the schematic sectional view of a portion of the body of the suit, one form of the suit material is indicated in which a layer or lamination of metal mesh **80** is disposed between two layers of cloth **82** and **84**. The metal mesh layer or lamination is thus sandwiched between these two cloth layers, as by means of tailor cement or by sewing the three layers together with a suitable insulating thread. Various parts of the garment may be suitably formed in pattern form, and joined by sewing along continuous edges or by cementing. In this manner the pattern sections of the metal mesh may be provided with sufficient overlapping areas to insure continuity of the metallic shell formed by the mesh throughout the entire garment. In any parts of the garment where extreme flexibility may be necessary, as in the hands and fingers, the layer of metallized cloth, such as nylon woven from metallized filaments may be utilized for the metallic conducting layer between the sandwiching layers of cloth. As shown in FIG. 5, two layers of silver metallized nylon mesh **85** and **86** are sandwiched between two layers of cloth **87** and **88**.

The opening of entry **50** is provided with a closure **55**.

The closure **55** is reinforced, as schematically indicated in FIGS. 6 and 6A. A pad or strip **90** of foam rubber or cellular neoprene is secured to each closure piece **55A** and **55B** of the garment, preferably in such locations as to press the metallic mesh layers close together to establish and maintain the continuity of the shell. Two zippers **92** and **94** hold the two pads pressed together and locked against casual displacement. The two metallic mesh areas **96** and **98** over the rubber pads **90** are exposed so pressure of the pads together will engage and hold the two mesh areas **96** and **98** in contact while the zippers are closed.

In the closure construction of FIGS. 6 and 6A, the two closure pieces or panels **55A** and **55B** are suitably attached or stitched to the edges of the garment material along the opening **50** as indicated by the stitching lines **97** and **99**. The inner zipper **92** is also attached to the edges of the material along the opening, to hold the edges of the material together against movement or separation, and to take the main stress on that part of the suit resulting from working movements of the wearer. The mating strips of outer zipper **94** are suitably attached to the outer edges of panels **55A** and **55B**, so closure of the outer zipper **94** will press the mesh panels **96** and **98** into engagement

and hold them engaged to maintain electrical continuity of the mesh across the opening **50**.

The two zippers **92** and **94** hold the two mesh panels **96** and **98** against relative movement and abrasive wear.

A second modification of the closure is shown in FIG. 6B. In this modification, the foam strip **90** is disposed between the metal mesh and one layer of the insulative cloth, in one case between the conductive mesh and cloth layer **82**, and in the other case between the conductive mesh and the cloth layer **84**. The two zippers **92B** and **94B** are attached as shown and function as in the first modification. Zipper **92B** holds the two edges of the material **82** together against displacement, and zipper **94B** then serves to press and to hold the wire mesh panels **96** and **98** in contact, to maintain electrical continuity across the opening.

In FIGS. 6A and 6B for both modifications, for clarity, the zippers are not shown fully closed, and the mesh panels not yet touching. Closure of the zippers will press the wire mesh panels into engagement.

To permit ventilation and cooling, the garment or R-F suit **10** is provided with ventilation louvers **100**, as in FIGS. 7 and 7A, at a lower level on the legs of the suit, and at an upper level, such as shoulder level, where combined chimney effect and movement of the arms of the wearer will tend to move the air out through the upper level louvers and thus cause intake of ambient air at lower level louvers. The louvers may be formed by forming a hole in the fabric and sewing a disk **102** of metal mesh with a louvered cover **104** in place to fill the holes, thereby providing passage for air but blocking electromagnetic wave energy.

To provide visibility to a worker in the R-F suit, while preventing entrance of field energy into the suit, the shielded vizor **38** is employed. The hood of the R-F suit is provided with an opening or window **114** which is surrounded by a metallic border or frame **116** of relatively thin aluminum curved to correspond to the general curvature of the front of a human head adjacent the front of the eyes. The metallic frame **116** is suitably sewed to the fabric material for support and is electrically connected to the metallic mesh or fabric. An inner frame of rubber pads **117** on the metallic window frame **116** protects the wearer's face against injury from the metal frame.

The metal window frame **116** is provided with positioning and anchoring bolts **118** to receive an external mesh mask or cover shield **120** consisting of a curved metallic frame **124** and a front layer **126** of mesh covering the opening in the frame **124** and secured to the frame by soldering or welding for good electrical contact. An outer pressure frame **128** fits over the bolts **118** and takes the pressure of tightening units on the bolts **118** to press the mesh mask frame **124** against the window frame **116**.

To provide for an electrically closed shell at the vizor even though the curved frames **116** and **124** may not nest regularly, the inner window frame **116** is covered with a rubber strip frame **130**, fitted over, and held in place by, the bolts **118**, with the mesh layers of the fabric folded over on top of the outer surface of the rubber frame **130** and also held in place by the bolts **118**. In assembly, the mesh mask frame **124** fits onto the bolts **118**, and then the outer pressure frame **128** is similarly fitted onto the bolts **118**, and suitable locking nuts or thumb nuts screwed onto the bolts to hold the several elements of the vizor tightly. The head straps **40** provide additional support for the vizor structure and hold it in desired position against casual movement or displacement.

As indicated by the exploded view in FIG. 8, the inner layer of cloth **82** extends to the edge of inner frame **116**, and the outer layer of cloth **84** may extend over the border of mesh frame **124**. The inner frame **116** is thus itself supported on the cloth and mesh laminated suit material, and, in turn, it supports the other frame elements **124** and **128** of the vizor. The head straps **40** then serve the double purpose of tightening the hood, and providing additional support for the vizor and holding the vizor in proper position.

The window mesh layer **126** is sufficiently close woven to bar the transfer of any field energy, and to serve as an efficient reflector, to protect the wearer of the garment. At the same time, since the mesh is far removed from the focal plane of the field of view of the wearer, the mesh does not interfere with the vision of the wearer.

The extremities of the garment at the hand and foot coverings may be additionally provided with separate covering gloves and overshoes to protect those parts of the garment against extra wear.

The hood **36** is shown herein as an integral part of the garment, but it could be made as a separate part, so long as the metallic lamination in the hood is properly conductively joined to the corresponding metallic lamination of the body of the garment.

Patches **42** and **44** may be cloth or cloth covered metallic laminations.

This invention thus provides a protective garment, for a worker in a region irradiated by a high frequency field, with a continuous conducting shell to act as a reflector to energy of the field, and with sufficient flexibility to permit unimpeded manual operations, with a protected window to permit vision through the window while blocking and reflecting radiant energy, and with air transmitting areas for permitting free air pasage for removing body heat while blocking entrance of the radiant energy of the field.

While only a few embodiments of the invention have been described in detail, it should be apparent that many modifications and changes may readily be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A protective work garment electrically shielded against radio frequency, comprising a fabric enclosure to fit over and enclose a human form, and having an opening to serve as a window in the region to be in front of the eyes of a wearer, such fabric having at least one layer of electrically conductive flexible metal extending throughout the area of the body of the enclosure to the region of the window, and a protective closure for said window, said closure embodying at least one layer of foraminous electrically conductive material to permit vision therethrough but to prevent transmission of field energy, and means for electrically coupling the conductive material of the closure to the flexible conductive material layer in the body of the fabric, to establish a closed conductive shell.

2. A shielded protective garment, as in claim 1, in which portions of the electrically conductive layer of the body fabric extend outwardly to overlap the edges of the window and to be accessible for direct engagement on the outside of the garment, and in which the protective closure embodies a metallic frame to enframe the window and to press said associated conductive material of the closure into electrical engagement with the overlapping portions of the layer of conductive material of the body fabric.

3. A shielded protective garment, as in claim 2, in which the coupling means includes a head-strap to hold the closure tightly in electrical engagement with the portions of the body fabric, or to release the closure to uncover the window in the garment, when manipulated for that purpose.

4. A protective garment of the type described, comprising a fabric enclosure shaped to fit over a human form and embodying a layer of electrically conductive material to constitute a continuous electrically conductive shell having an opening to serve as a window in the region of the garment to be in front of the eyes of a wearer, and a protective closure for said window to complete the continuity of the conducting shell, and to permit vision through the closure but to prevent transmission of electric field energy therethrough, said closure comprising a stationary metallic frame supported in selected position on the fabric material, to surround the window, said frame being electrically connected to the layer of conductive material, and a removable cover for said fixed frame, said cover embodying a lightweight metallic frame shaped to seat congruently on the stationary frame, and a layer of

thin wire gauze covering the enclosed area of the cover frame and electrically bonded to said cover frame, to provide a window that is transparent to vision but opaque to electromagnetic field energy.

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