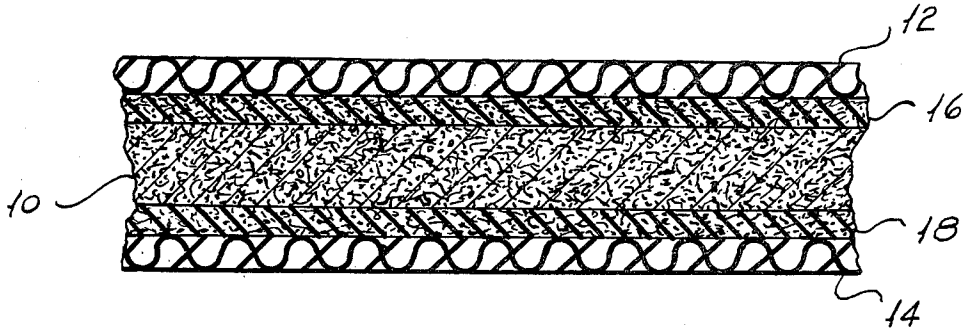
March 8, 1966 J. V. WEINBERGER 3,239,669

FLEXIBLE SHIELD FOR IONIZING RADIATIONS

Filed Nov. 25, 1960

Fig 1



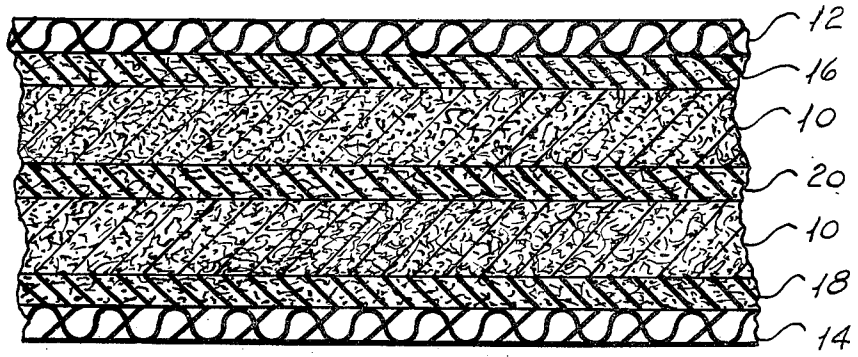


Fig 2

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United States Patent Office

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FLEXIBLE SHIELD FOR IONIZING RADIATIONS

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Filed Nov. 25, 1960, Ser. No. 71,795
7 Claims. (Cl. 250—108)

My invention relates to a flexible shield for ionizing radiations and, more particularly, to an improved flexible medium for providing protection from the emanations of radioactive substances, X-rays and the like. Owing to the fact that ionizing radiations are becoming more and more prevalent in industry as well as in medicine and owing to the fact that such emanations may do serious injury to human beings if subjected to over-doses of the same, it is becoming increasingly important to find materials which will shield against ionizing radiations, which materials may be flexible so they may be shaped to parts of the body and used for gloves, helmets, aprons, leggings, clothing and the like.

Such ionizing radiations vary depending on the energy level of the radiation and include alpha particles, protons, neutrons, positrons, beta rays and gamma rays.

Lead, owing to its high molecular weight, is an excellent shielding material. Unfortunately, however, where a shield has to be contoured to fit a patient's body as in cases where it is desired to subject a particular area of the body to ionizing radiations it is difficult to form a sheet of lead to the required shape and it is infeasible to have a number of shields for different sizes of persons for whom shields are required. It is also extremely desirable to shield the bodies of persons who are occupationally exposed to radiation as, for example, X-ray technicians, medical men employed around X-ray machines, maintenance crews for reactors, technicians who deal with radioactive isotopes and the like.

In the copending application of Jan V. Weinberger and August G. Luisada, Serial Number 14,725, filed March 14, 1960, now U.S. Patent No. 3,065,351, there is disclosed a flexible shield for ionizing radiations which employs a flexible carrier provided with a coating of an amalgam of lead and mercury.

While such shield is effective mercury is expensive and the flexibility is of limited degree.

I have now discovered it is possible to form a shield for ionizing radiations by means of an improved material which is inherently flexible and moldable in and of itself. It may be secured to a fabric or sandwiched between layers of fabric to provide a flexible material which may be readily fashioned into clothing and flexible shields for ionizing radiations.

One object of my invention is to provide an improved flexible shield for ionizing radiations.

Another object of my invention is to provide a material for use in forming shields for ionizing radiations having various complex contours and shapes.

Other and further objects of my invention will appear from the following description.

In general my invention contemplates the formation of a dough having an extremely high lead content together with a minor amount of a silicone rubber and a lesser amount of a fiber flock.

In the accompanying drawings which form part of the instant specification and are to be read in conjunction therewith and in which like reference numbers are used to indicate like parts in the various views,

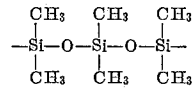
FIGURE 1 is a sectional view of an assembly showing one embodiment of my invention;

FIGURE 2 is a sectional view of a multilaminate assembly showing another form of my invention.

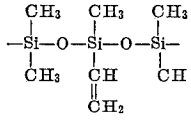
More particularly I start with lead powder. Advantageously, such lead powder may be such that the preponderance of it will pass through a number 200 mesh sieve. Such powder may have a minimum lead content in excess of 99.9% by weight of lead together with traces of silver, copper, arsenic, antimony, tin, zinc, iron and bismuth. Lead powder is well known to the art and is produced by atomization.

Most shielding materials of the prior art are bulky owing to the fact that the art has been unable to exceed a lead content in the vicinity of 40% by weight with relation to the carrier. In my material I am enabled to produce a lead content as high as 98.5% by weight by the use of only 1% by weight of silicone rubber and ½ of 1% by weight of fiber flock. The large quantity of lead per weight with respect to the small quantity of binder produces a high degree of shielding and yet my material is sufficiently flexible to be adhered to or otherwise secured to fabric to enable the production of flexible clothing.

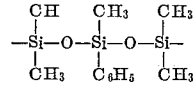
The silicones are semi-inorganic polymers and produce dense, rubber-like material. The most common type of silicone rubber is polydimethylsiloxane. It has the general structure shown by the following fragment of the chain.



In a second type of silicone rubber a small percentage of the methyl groups have been replaced by vinyl groups. A fragment of the chain has the following appearance.



In a third type of silicone rubber a small percentage of phenyl groups are substituted for the methyl groups. A fragmentary showing of the chain is as follows.



It is understood, of course, that the molecular weight of silicone rubber ranges from approximately 300,000 to about 1,000,000.

Any of these silicone rubbers may be employed in carrying out my invention. I have found that a vinyl type improves vulcanization properties.

For flock I may use any fibrous material such as wool, cotton, rayon or any of the synthetic extruded fibers such as polyethylene, nylon or the like. Advantageously, fiber flock produced from wool can be used. Fibers of coarse wool easily separate from each other and wool has the highest natural moisture regain being in the order of 15% to 18% as compared with 8% for cotton and ½ of 1% to 4% for fibers of the thermo-plastic family. The hygroscopic characteristic of wool facilitates the curing of silicone rubbers.

I have also found that I cannot readily amalgamate conventional rubber with lead to form a homogeneous compound. It is only by the use of silicone rubbers that I have been able to achieve a homogeneous amalgamation of the lead and the rubber. Apparently silicone rubber has the property of removing the lead oxide layer on the lead powder and enables a remarkable homogeneous compound to be made.

In carrying out my invention I form a dough by mixing lead powder described above in the amount of 98.5%

by weight with 1% by weight of silicone rubber of type 2 above and ½ of 1% of fiber flock comprising largely wool fibers. The mixture was deposited on a sheet of vinylidene chloride copolymer. It was then thinned by adding toluene in an amount of 5% by weight of the mixture. The mixture was then molded with a blade coated with tetrafluoroethylene copolymer (Teflon). This was necessary owing to the fact that the material adheres very strongly to metals. In making large quantities of the material mixers lined with Teflon must be employed.

During the mixing the curing agent known to the art for silicone rubber, namely benzoyl peroxide, is added. After the material has been thoroughly mixed I form a sheet by rolling the material with a rolling pin covered with Teflon in a manner of rolling out a sheet of dough in baking, the rolling, of course, being carried out against the vinylidene chloride copolymer sheet. The rolling is continued to produce a sheet of the dough having a thickness of about 1½ millimeters. In making large quantities of the material the sheets would be rolled by calendar rolls coated with Teflon. The interroll distance will determinate the thickness of the sheet of mixture.

The curing may be carried out in two stages. In the first stage the cure is advanced where the rolled sheet has dimensional stability under its own weight. This can be readily accomplished by subjecting the sheet to a temperature of about 260° F. for a period of between 5 to 10 minutes. It is understood, of course, that the sheets can be contoured to any desired shape by molds and cured in the molds for 5 to 10 minutes to give the piece dimensional stability. The molded piece is then transferred to a well ventilated oven and baked several hours at about 480° F. This dries off the breakdown fragments from the peroxide and the light gum fractions. The cure also establishes additional cross lengths.

It is understood, of course, that if desired room temperature curing silicones can be used. These are achieved by adding accelerators such as dithiocarbamates, carbon disulfide or zinc mercaptobenzothiazole.

It is understood, of course, that the formation of curable silicones are well known to the art and per se do not form part of my invention. My invention resides in the discovery that a large amount of lead can be held by a comparatively minor amount of silicone rubber together with a lesser amount of flock formed of fibers.

In another example of my invention I proceeded as indicated above except that I used xenol as a solvent. Most of the solvent it will be found will evaporate during the mixing of the dough. The basic material thus formed is then assembled with the fabric. It may be adhered to a fabric by any suitable material. I have found that advantageously I may mix 90% of silicone rubber with 10% of fiber flock such as wool, cotton or the like and use a silicone rubber material of the room temperature curing type. This material is known to the art and contains the necessary catalysts and accelerators for curing at room temperature. The silicone rubber is shipped and stored in air tight containers and usually contains moderators to prevent vulcanization in storage as is well-known in the art. The flock is mixed with this silicone rubber and the resulting mixture forms the adhesive by which a textile may be adhered to in this the basic cured sheet of lead silicone rubber.

Referring now to FIGURE 1, the layer **10** comprises a coated sheet containing 98.5% by weight of lead, .5% by weight of fiber flock and 1.0% by weight of silicone rubber. It is formed and cured as pointed out above. The layer **10** which contains the lead and forms the barrier for stopping the ionizing radiations is protected by an upper layer of fabric **12** and a lower layer of fabric **14**. These layers of fabric are adhered to the barrier layer **10** by layers of adhesive **16** and **18**. It is understood, of course, that any appropriate adhesive can be used such as rubber cement, neoprene cement or the like. Advantageously, I have found that I can employ a mixture comprising 90% of silicone rubber and 10% of fiber flock. This silicone rubber and fiber flock not only secures the fabric to the barrier layer **10** but also provides better tensile strength and resistance against cracking and stress.

The adhesive layers **16** and **18** can be cured by heating or can be of the room temperature curing type described above.

The fabric layers **12** and **14** may be of any appropriate fabric. Advantageously I may employ the heat resistant cloth shown in U.S. Patent 2,884,018 dated April 28, 1959, and granted on application of H. A. Delcellier and Jan V. Weinberger.

If the fabric is made of the heat resistant type it will be apparent that my flexible shielding material can be made into garments or molded into shapes conforming to curvature of the body and thus provide protective clothing guarding against nuclear flash resulting from atomic explosions.

If one of the fabric layers **12** or **14** be made of the heat resistant cloth shown in the Delcellier et al. patent the adhesive layers **16** and **18** must be of the room temperature curing type owing to the fact that the curing temperature may deleteriously affect the material of which the heat resistant fabric is formed. Stated otherwise, a component of the heat resistant fabric sublimates at elevated temperatures to enable the heat resistant mechanism to occur. It is understood, of course, that this mechanism must not be permitted to occur by the elevated temperature of curing.

Referring now to FIGURE 2, it will be seen that I have provided a plurality of barrier layers **10** each of which is formed of the lead powder cohered by silicone rubber. The upper layer **12** of the fabric is similar to the layer **12** in FIGURE 1 and the lower layer of fabric **14** is similar to the layer **12** in FIGURE 1. It is understood, of course, that one of the layers **12** or **14** or both may, if desired, be made of heat resistant fabric as pointed out above. The adjacent barrier layers **10** are adhered by an intermediate adhesive layer **20** which advantageously may be made of 90% silicone rubber and 10% of fiber flock. The adhesive layer **16** and the adhesive layer **18** in FIGURE 2 are similar to the corresponding adhesive layers **16** and **18** of FIGURE 1. The barrier layers **10**, as pointed out above, may advantageously be in the vicinity of between 1 millimeter and 1½ millimeters in thickness though it is to be understood, of course, that any desired thickness may be employed. I have found that the employment of a multiplicity of thinner layers makes a more flexible though more bulky material.

If a permanently curved form is desired a single thicker layer will be employed and molded to the desired form and cured in the molded shape.

The finished material shown in both FIGURES 1 and 2 may be calendered to uniformed thickness and then formed into the desired protective clothing.

It might be thought that the use of finely divided lead particles such as powdered lead bonded into a homogeneous material by silicone rubber might not be efficacious in stopping ionizing radiations owing to the interstices between the lead particles. In order to determine whether or not the construction which imparted flexibility sacrificed shielding power I made a sample of my invention as shown in the embodiment of FIGURE 1 in which the barrier layer **10** had a thickness of 1.5 millimeters. The areal density of the material was 1.25 grams per square centimeter. I subjected a Kodak industrial X-ray film type KK to 100 kv. unfiltered X-rays under broad beam conditions for 10 seconds exposure at 0.64 R./seconds which X-ray film was shielded with the sample of my material. I found that there was transmitted through my material .22%±0.01% of X-rays. I determined the lead equivalence by replacing the sample of my material in the X-ray beam with various thicknesses of lead and found that the lead equivalence was 1.06 millimeters of lead ±0.02%.

I conducted the same test with 250 kv. unfiltered X-rays and obtained a transmission through the sample of 4.1%±0.2%. This was equivalent to 1.11 millimeters of lead ±0.02%.

The results of the test prove that exceptionally high X-ray absorption is achieved and that the fine subdivision of the lead particles together with the minor amount of silicone rubber which need be employed permits a sufficiently close packing so that excellent X-ray absorption is obtained while achieving the desired flexibility.

It will be seen that I have accomplished the objects of my invention. I have provided a flexible shield for ionizing radiations which may be readily formed into protective clothing.

I have provided a material which may be readily molded into any desired shape so that it may be employed to shield the bodies of persons who are occupationally exposed to radiation and to protect curved parts of the body when it is desired to subject certain other areas to ionizing radiations in connection with medical therapy.

My material can be made abrasive resistant and readily combined with heat resistant fabric.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of my claims. It is further obvious that various changes may be made in details within the scope of my claims without departing from the spirit of my invention. It is, therefore, to be understood that my invention is not to be limited to the specific details shown and described.

Having thus described my invention, what I claim is:

1. A flexible material for arresting ionizing radiations including in combination a layer comprising a major amount of powdered lead and a minor amount of silicone rubber forming a cohesive mass and a lesser amount of fiber flock disposed throughout said layer.

2. A flexible material for absorbing ionizing radiations including in combination a layer comprising about 98.5% finely divided lead and 1.0% silicone rubber forming a cohesive mass and 0.5% of fiber flock dispersed throughout said layer.

3. A flexible barrier for ionizing radiations including in combination a barrier layer comprising a major amount of powdered lead cohered with a minor amount of silicone rubber and fiber flock dispersed throughout said barrier layer and sandwiched between two layers of fabric by means of an adhesive.

4. A flexible shield for ionizing radiations including in combination a barrier layer of powdered lead cohered with a minor amount of silicone rubber and fiber flock dispersed throughout said barrier layer sandwiched between a pair of fabric layers by means of an adhesive comprising about 90% of silicone rubber and 10% of fiber flock.

5. A flexible shield as in claim 4 in which one of said fabric layers is a heat resistant cloth.

6. A flexible shield for ionizing radiations including in combination a formed barrier layer comprising a major amount of powdered lead and a minor amount of silicone rubber and a lesser amount of fiber flock dispersed throughout said barrier layer, said barrier layer being sandwiched between two fabric layers by means of an adhesive, said assembly being cured to the desired formed shape.

7. A flexible shield for ionizing radiations including a plurality of barrier layers each comprising lead powder cohered with a minor amount of silicone rubber and a lesser amount of flock dispersed throughout said barrier layer, means for adhering said barrier layers to each other, outer fabric layers and means for adhering said outer fabric layers to said assembled barrier layers.

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RALPH G. NILSON, *Primary Examiner.*