United States Patent [19]

Norris et al.

[11] **3,873,998**

[45] **Apr. 1, 1975**

[54] **BODY ARMOR SYSTEM**

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[73] Assignee: **The United States of America as represented by the Secretary of the Army**, Washington, D.C.

[22] Filed: **Mar. 26, 1974**

[21] Appl. No.: **454,897**

[52] **U.S. Cl.** **2/2.5**

[51] **Int. Cl.** **F41h 1/02**

[58] **Field of Search** 2/2.5

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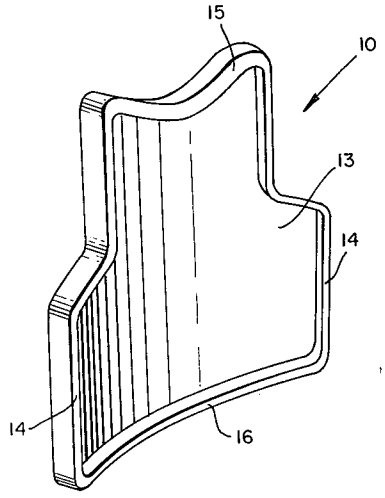
Primary Examiner—Alfred R. Guest

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[57] **ABSTRACT**

A coordinated missile- and fragmentation- protective body armor system comprising a ceramic type armor plate component that is provided with a spall shield made of a plurality of layers of ballistic fabric and a spacer container for the ceramic armor plate made of a foamed plastic. The spacer container, though of little value for stopping primary missiles, is very effective in combination with the spall shield in preventing the escape from the body armor system of spall from the ceramic armor plate.

7 Claims, 8 Drawing Figures



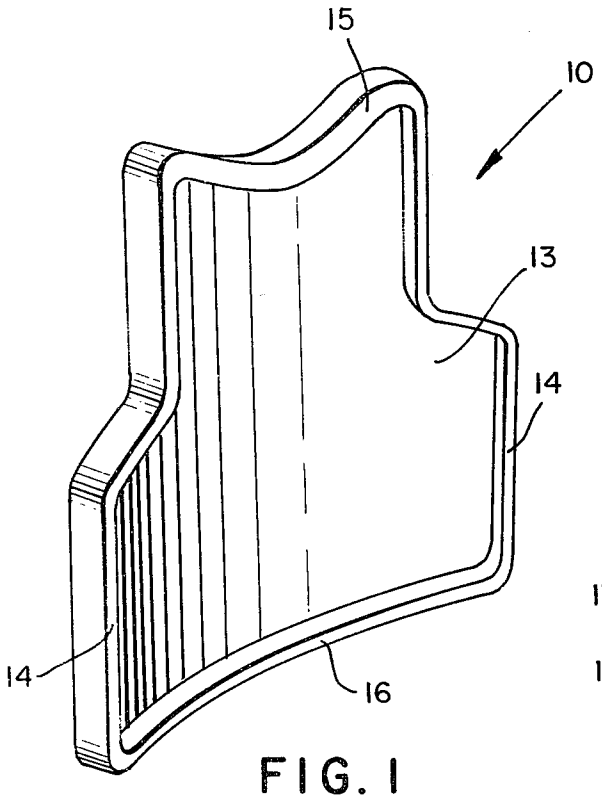


FIG. 1

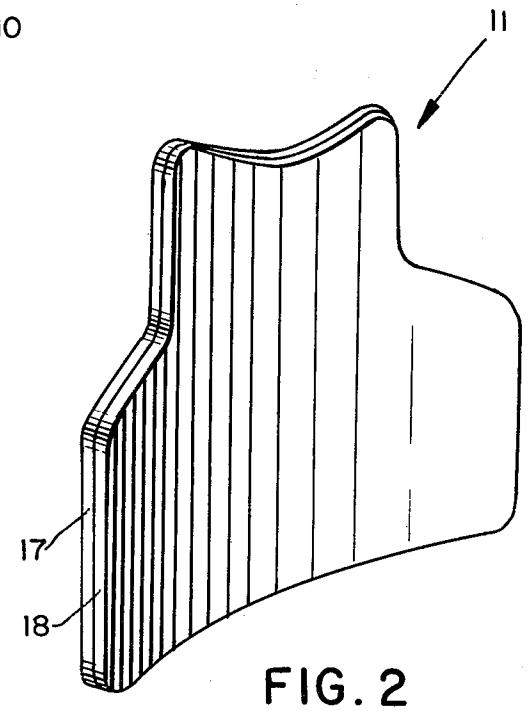


FIG. 2

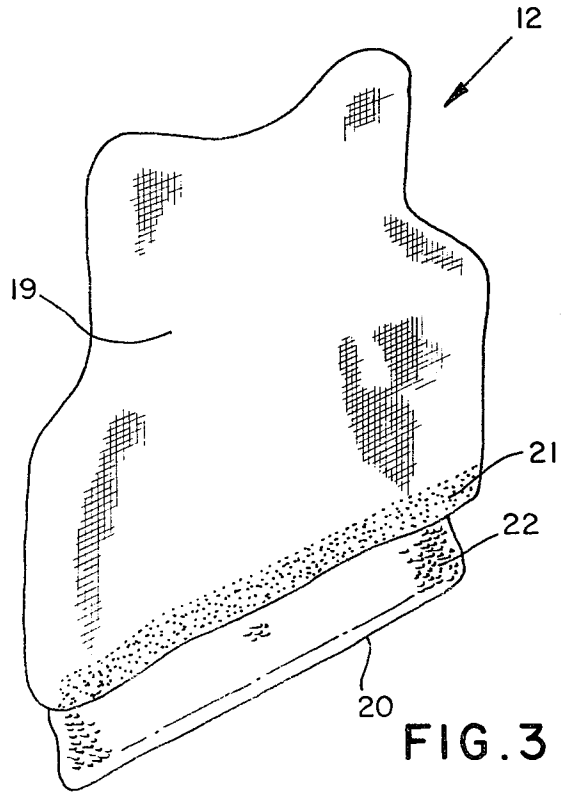


FIG. 3

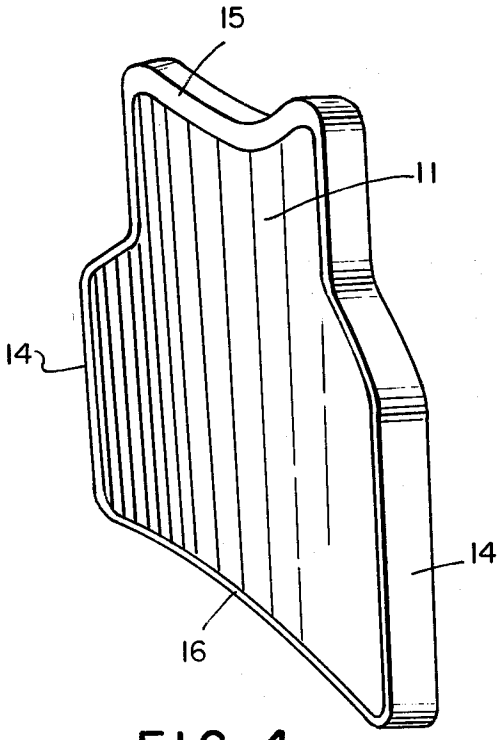
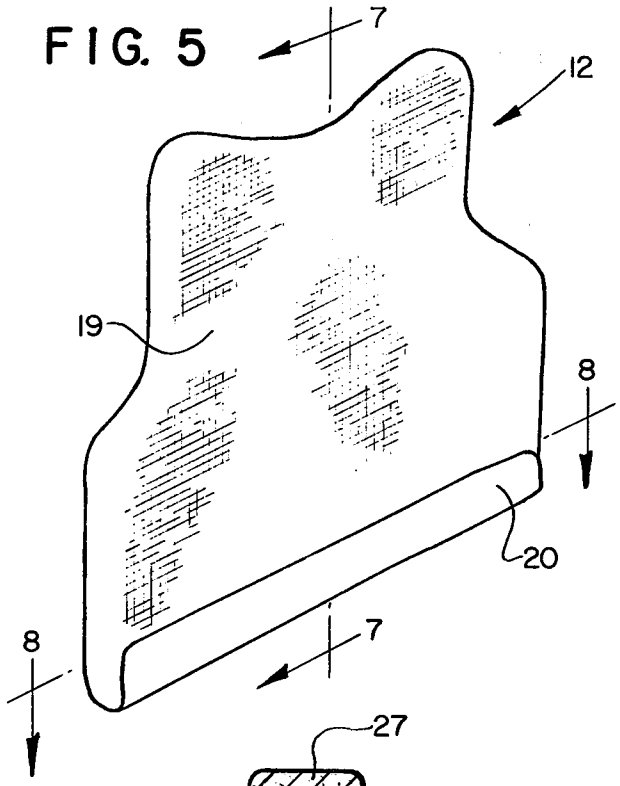


FIG. 4

FIG. 5



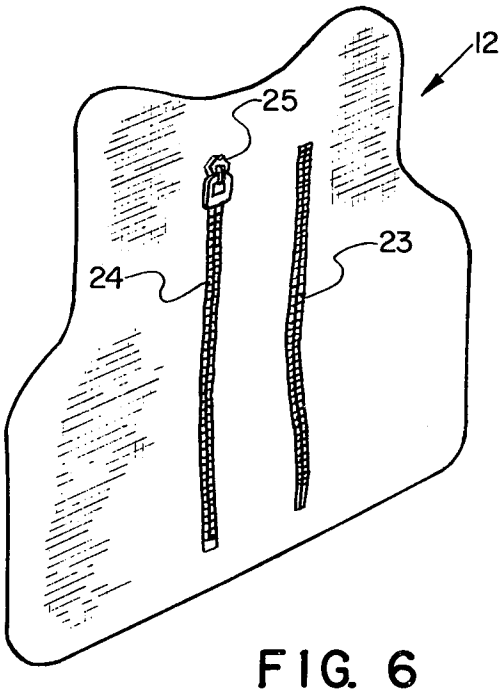


FIG. 6

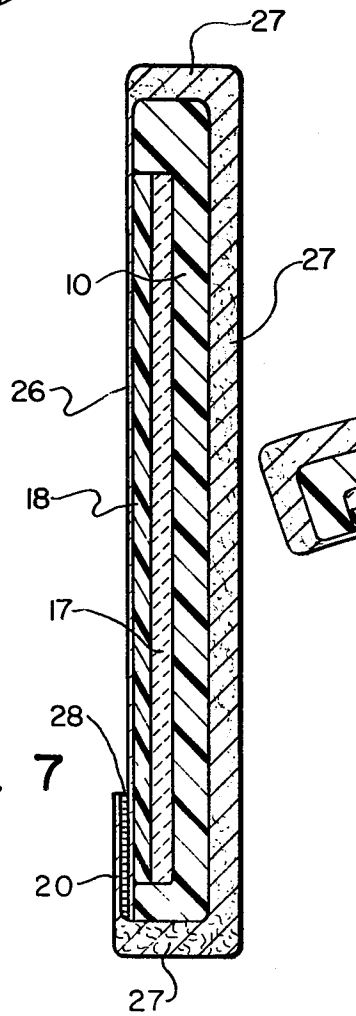


FIG. 7

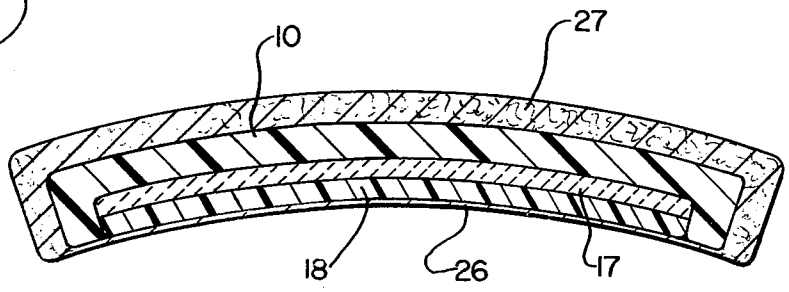


FIG. 8

BODY ARMOR SYSTEM

The invention described herein may be manufactured, used, and licensed by or for the Government for governmental purposes without the payment to us of any royalty thereon.

BACKGROUND OF THE INVENTION

This invention relates to a coordinated missile- and fragmentation-protective body armor system wherein lightweight means are provided for markedly reducing or preventing the escape of spall from a ceramic type armor plate component of the body armor and thereby greatly reducing the probability of injury to others in the vicinity of the wearer of the body armor when it is impacted by high velocity projectiles, shell fragments, or other particles.

In recent years body armor comprising ceramic armor plates to protect the torso of the wearer against serious or fatal injury to the vital organs has been developed to the point that good protection is obtained against low caliber missiles, such as missiles of up to .30 caliber, and effective protection is obtained against shell fragments and the like. However, this type of armor plate is prone to fragment, i.e., to produce spall, when struck by a high velocity missile or fragment. The spall thus produced as a spray of secondary particles of varying sizes and shapes may have very high velocities imparted to the particles by absorption of energy from the primary projectile or fragment. Such spall, if permitted to escape from the proximity of the ceramic armor plate and the fabric carrier therefor, is capable of causing severe injury to eyes or other portions of the bodies of other nearby persons.

It is therefore, an object of the invention to provide a body armor system which is not only effective in protecting the wearer thereof, particularly in the region of the torso, against low caliber missiles, i.e., missiles of up to about .30 caliber, and against shell fragments, shrapnel and the like, but also effectively prevents the escape of spall from the system, particularly the spall produced from a ceramic armor plate element of the armor system. Another object of the invention is to provide a body armor system comprising a ceramic armor plate and having means for preventing injury to the neck, chin or face of the wearer of the body armor system in the event that the ceramic armor plate impacts those portions of the body of the wearer if the wearer is involved in a crash or other incident in which his body comes to an abrupt halt or is subjected to sudden deceleration. A further object of the invention is to provide a body/armor system comprising a ceramic armor plate and having means for preventing or minimizing breakage or cracking of the ceramic armor plate in case the body armor system is dropped upon a hard surface.

Other objects and advantages of the invention will be apparent from the following description of one embodiment of the invention, and the novel features will be particularly pointed out hereinafter in connection with the appended claims.

SUMMARY

The objects of the invention are accomplished by providing a coordinated body armor system which comprises a ceramic/fiber glass composite armor plate, a fabric carrier therefor comprising a plurality of plies of ballistic fabric and a foamed plastic spall protective spacer container for the armor plate. The foamed plastic spall protective spacer container spaces the armor plate from the plies of ballistic fabric in the fabric carrier a distance which has been found to greatly assist in and augment the slowing down of the spall from the point of impact of a missile or fragment on the ceramic armor plate. Additionally, the foamed plastic spacer container is provided with shock absorbent side edges which overlap the edges of the armor plate and thus provide edge protection for the armor plate against breakage or cracking if it is dropped. The shock absorbent side edges also provide protection against injury to the neck or chin or face of the wearer by the upper edge of the armor plate in case the latter shifts upwardly at a velocity which would otherwise injure the neck, chin or face of the wearer, or in case the head of the wearer is suddenly caused to pivot in the direction of the armor plate. The fabric carrier for the armor plate is provided on an outer surface thereof with means for attaching the fabric carrier to the jacket of the wearer so that the body armor system may be supported in fromt of the torso of the wearer.

Thus the components of the body armor system of the invention are coordinated to perform a variety of highly useful and desirable functions in protecting the wearer thereof as well as persons in close proximity to the wearer and in being protected from inadvertent damage in the handling of the same.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a perspective view of the foamed plastic spall protective spacer container viewed from the rear thereof, the spacer container having a curvature approximating the curvature of the front of the torso of a wearer of body armor, the rear of the spacer container, when being worn, being oriented toward the front of the torso of the wearer.

FIG. **2** is a perspective view of a ceramic/fiber glass composite armor plate.

FIG. **3** is a perspective view of a fabric carrier for the ceramic/ fiber glass composite armor plate.

FIG. **4** is a perspective view of the foamed plastic spall protective spacer container of FIG. **1** with the ceramic/fiber glass composite armor plate of FIG. **2** inserted therein preparatory to the insertion of the spacer container containing the ceramic/fiber glass composite armor plate in the fabric carrier of FIG. **3.**

FIG. **5** is a perspective view from the rear of the assembled armor system after insertion of the spacer container containing the ceramic/fiber glass composite armor plate in the fabric carrier and closure of the fabric carrier.

FIG. **6** is a perspective view from the front of the assembled armor system of FIG. **5.**

FIG. **7** is a vertical cross-section of the assembled armor system of FIG. **5** taken along a plane through the line **7—7** of FIG. **5.**

FIG. **8** is a horizontal cross-section of the assembled armor system of FIG. **5** taken along a plane through the line **8—8** of FIG. **5.**

DETAILED DESCRIPTION OF THE INVENTION

Body armor developed in recent years for use by members of the Armed Forces for protection of their torsos and vital organs against low caliber missiles and shell fragments comprises a ceramic/fiber glass com-

posite armor plate, such as the armor system described in U.S. Pat. No. 3,557,384. In such body armor the facing or outward component is a onepiece aluminum oxide, silicon carbide, or boron carbide ceramic structure bonded by an adhesive to a resin-bonded ballistic fabric laminate back plate which is preferably a fiber glass fabric laminate. The fiber glass fabric laminate is a resin-impregnated, multi-layer, fiber glass ballistic fabric with the resin content being in the range of 20% to 30% by weight. The maximum areal density of this type of armor plate is less than 9 lbs. per square foot and preferably less than 7 lbs. per square foot. Because of the weight of this armor material, the body area being protected must be reduced to the absolute minimum. Therefore, the armor plates are designed to cover the more vulnerable portions of the torso. The body armor may be worn inside of a jacket or other outer garment which may or may not be constructed of or comprise ballistic materials or spall protective materials.

The present invention provides a spacer container made of a light-weight material, such as foamed plastic, which has the capability of slowing down the spall produced when high velocity projectiles or shell fragments strike the ceramic outward surface of the armor plate, thus enabling a plurality of layers of a ballistic fabric, e.g., ballistic nylon woven fabric, incorporated in a carrier for the body armor outside of the spacer container to further reduce the velocity of the spall and in most instances completely prevent escape of the spall from the carrier. Thus a coordinated missile- and fragmentation- protective body armor system which is of relatively light weight yet quite effective against low caliber, high velocity missiles as well as spall produced thereby is obtained. The spacer container also serves other purposes which will be more particularly described hereinafter.

The spacer container **10** illustrated in FIG. **1** is molded in one piece out of foamable plastic such as polyethylene, polystyrene, or other polymeric materials which are capable of being foamed in place in a mold, or may be machined from a block of foamed plastic. It is formed with a recess **13** or hollow opening corresponding very closely to the size, outline shape, and curvature of armor plate **11** shown in FIG. **2** so that the latter can be fitted snugly in recess **13,** as shown in FIG. **4,** with the rear face of the armor plate flush with the top of the flanged edge **14** of the spacer container. Thus the armor plate is recessed within the spacer container so that a thickness of from about ½ inch to about ¾ inch of the foamed plastic of the spacer container overlies the ceramic armor plate **17** of armor plate **11.** It has been found to be preferable for the portion of the spacer container overlying the ceramic armor plate to be about ½ inch thick. The top edge **15** of the spacer container flanged portion is about one inch thick from top to bottom and is approximately twice the thickness of the flanged edge **14** measured from one side edge to the other and twice the thickness of the extension thereof along the bottom edge of the spacer container in the form of flanged edge **16** so that there will be appreciable cushioning of the neck and chin or other portions of the face or head of the wearer of the body armor in the event that the wearer is involved in a crash or is abruptly decelerated while in motion. Under such circumstances the armor plate **11,** which is rather heavy, would tend to continue in motion and, in the absence of the relatively thick top edge **15** of the spacer container, would impact with great force against the neck or chin of the wearer or possibly against other portions of the face or head. Thus the spacer container made of a crushable foamed plastic serves to protect the wearer against serious injury by the armor plate.

As previously stated, armor plate **11** fits a recess **13** of spacer container **10,** as shown in FIG. **4.** The spacer container, together with the armor plate, is placed inside of fabric carrier **12,** which has a body portion **19** and a closure flap **20.** Along the bottom edge of the back of the body portion **19** the fabric carrier has a strip of plastic loops **21** which cooperate with a strip of plastic hooks **22** attached to the inner surface of closure flap **20** to close the opening along the bottom edge of the fabric carrier through which the armor plate is inserted into the fabric carrier. The armor plate is inserted in fabric carrier **12** so that the concavity of the composite structure will be up as seen in the drawing and will be oriented toward the torso of the wearer of the body armor when being worn. Thus the ceramic armor plate **17** will be oriented away from the torso of the wearer.

As shown in FIG. **6,** the front of the fabric carrier **12** has zipper stringers **23** and **24** attached thereto for the purpose of attaching the assembled armor system to the inside surface of a combat jacket or other type of garment with which the body armor is worn to protect the torso of a wearer. The jacket (not shown) has a pair of suitably spaced zipper stringers (not shown) which cooperate with zipper stringers **23** and **24** with the combined action of slider **25** on stringer **24** and a similar slider on the stringer of the jacket which cooperates with stringer **23.** Thus the assembled armor system, being supported by two spaced apart zippers joining the fabric carrier to the jacket is maintained in reasonably stable position in front of the torso of the wearer, protecting the same against low caliber missiles and shell fragments.

As seen in FIGS. **7** and **8,** the assembled armor system comprises a spall shield **27** made of plies of ballistic fabric, ceramic armor plate **17,** fiber glass laminate backup layer **18,** foamed plastic spacer container **10,** and fabric carrier **12.** The innermost layer **26,** i.e., the layer which is worn closest to the torso of the wearer, is a single thickness of ballistic fabric, preferably nylon ballistic cloth such as that described in military specification MIL-C-12369D (GL) entitled "Cloth, Ballistic, Nylon." This layer of ballistic cloth is also the outermost layer of spall shield **27,** which is a nine-layer composite of nylon ballistic cloth of the type described in the above-referenced military specification. The spall shield **27** extends over the top, sides, front, and bottom of fabric carrier **12,** thus providing spall protection across the top, sides, front, and bottom of armor plate **11.** The outermost layer of spall shield **27,** which is a continuation of innermost layer **26** of fabric carrier **12** extends upwardly from the bottom of the fabric carrier to form closure flap **20.** The nine layers of nylon ballistic cloth are stitched together along their peripheries, but remain as separate, unattached fabrics over most of their surfaces so that they are more or less free to move and adjust to the impact of a particle and thus to perform well as a spall shield. The plastic hooks **22** and plastic loops **21** mate to form hook and pile fastener **28** which maintains the fabric carrier closed.

Next to the innermost layer **26** progressing outwardly therefrom and from the torso of the wearer is the fiber

glass laminate backup layer **18**, which backs up the ceramic armor plate **17** and is bonded thereto. After the ceramic armor plate comes the spacer container **10** made of foamed, plastic, which because of its thickness spaces the ceramic armor plate about ½ to ¾ inch from the spall shield **27** and thus contributes materially to the prevention of the escape of spall from the ceramic armor plate when the latter is impacted by a missile or shell fragment.

The spacer container has relatively low stopping power for primary missiles, but is quite effective against the spall from the ceramic armor plate since the cooperation thereof with the spall shield practically prevents all escape of spall from the ceramic armor plate. The ceramic armor plate serves as the main stopping agent for the primary missiles, though the spall shield slows the primary missiles down considerably before they impact the ceramic armor plate. Spacing of the spall shield from the ceramic armor plate influences spall resistance because spall travels in a conical pattern radiating from the point of impact with the ceramic armor plate. Thus, spacing causes the spall to impact the spall shield over a broader area, producing less concentration of force per unit area. Consequently, the spall shield can better sustain the forces of the spall. In addition, spacing requires the typical spall particle traveling at oblique angles to traverse a greater distance than the thickness of the spacing and to dissipate more energy before impacting the spall shield overlying the spacing.

The fiber glass laminate backup layer **18** serves to augment the stopping power of the ceramic armor plate and to complete the defeat of the primary missiles if any penetrate the ceramic armor plate.

The overall result is a coordinated missile- and fragmentation- protective body armor system which is relatively light in weight yet very effective in defeating primary missiles of low caliber and in preventing the escape of spall from a ceramic armor plate component of the body armor system which serves as the main protective medium against the primary missiles.

We have found it to be preferable that the foamed plastic of the spacer container have a density of from about 1 pound per cubic foot to about 10 pounds per cubic foot. Foamed polyethylene of approximately 9 pounds per cubic foot, for example "Ethafoam," fabricated by United Packaging Corp., Georgetown, Mass., has been found to be particularly effective for all three of the purposes served by the spacer container, i.e., assisting in the prevention of the escape of spall derived from the ceramic armor plate, protecting the neck, chin, and other portions of the face and head of the wearer of the body armor from serious injury upon impact against the ceramic armor plate, and protecting the ceramic armor plate against cracking or shattering due to dropping thereof onto a non-resilient surface or bumping of the armor by sharp, non-resilient objects. Furthermore, the resiliency of the polyethylene foam spacer container permits repetitive use, whereas some foamed plastics, such as polystyrene, have very good shock absorbing capacities even at quite low densities, but are permanently crushed and, therefore, not effective for repetitive use.

It is preferred that the nylon ballistic cloth of the spall shield and the fabric carrier be a plain weave fabric of about 7.5 ounces per square yard. However, other nylon ballistic fabrics, particularly those of from about 6 to about 9 ounces per square yard may be employed with good results as spall shield material.

The coordinated missile- and fragmentation- protective body armor system of the invention is very effective in an areal density of about 0.83 pounds per square foot in protecting the torso of the wearer against low caliber missiles and in preventing the escape of spall from the system. It has been found that about 1.0 pound per square foot areal density is about the upper limit for a useful body armor system. The system of the present invention falls well below this limit while accomplishing excellent spall suppression.

The invention has been described in terms of a particular type of coordinated missile- and fragmentation-protective body armor system. A particularly important element of this system is the foamed plastic spall protective spacer container for the ceramic armor plate. The spacer container may be constructed of a rather large number of different foamed plastic materials. These materials need to be crushable, but neither too easily crushable nor too difficult to crush, since in the coordinated armor system they need to be able to prevent injury to the neck or chin or other portions of the face or head of the wearer by absorbing energy through crushing in case the armor plate impacts portions of the head or neck; and they also need to be able to prevent damage to the armor plate in case it is dropped or struck by a sharp, non-resiliant object. Hence, the spacer container material must have the proper crushability characteristics in order to be shock-absorbent for the two purposes mentioned. Furthermore, the density and thickness of the spacer container material must be such as to cause spall from the ceramic armor plate to be slowed down by the combination of the spacer container and the ballistic fabric spall shield used in combination with the armor plate sufficiently to prevent escape of the spall and the possible inflicting of injury to persons in close proximity to the wearer of the armor system. The corrdinated system of the present invention accomplishes all of these objectives while having a tolerable weight when fabricated so as to cover and protect the more vital areas of the torso of a wearer of the body armor system.

It will be understood that various changes in the details, materials, and arrangements of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art, within the principle and scope of the invention as expressed in the appended claims.

We claim:

1. A coordinated protective body armor system to provide protection against low caliber missiles which will also minimize escape of spall from within said system, cushion the brittle elements of the system against breakage, and provide cushioning protection to protect the head and neck of the wearer from injury upon impact against the armor system comprising a ceramic/fiber glass composite armor plate which comprises a ceramic face plate bonded to laminate back plate of resin-bonded plies of a glass fiber fabric, a foamed plastic spall protective container for said ceramic/ fiber glass composite armor plate which is disposed so as to completely cover said ceramic/fiber glass composite armor plate, and a carrier for said ceramic/fiber glass composite armor plate and said foamed plastic spall protective container comprising a spall shield which overlies said foamed plastic spall protective container and said cera-

mic/fiber glass composite armor plate and which comprises a plurality of plies of a woven ballistic fabric.

2. A coordinated protective body armor system according to claim **1,** wherein said foamed plastic spall protective container is formed of polymeric foam having a density of from about 1 to about 10 pounds per cubic foot.

3. A coordinated protective body armor system according to claim **2,** wherein said foamed plastic spall protective container is formed of polyethylene foam having a density of about 9 pounds per cubic foot.

4. A coordinated protective body armor system according to claim **1,** wherein said foamed plastic spall protective container in the portion thereof which completely covers said ceramic/fiber glass composite armor plate is from about ½ inch to about ¾ inch thick.

5. A coordinated protective body armor system according to claim **1,** wherein said woven ballistic fabric is a plain weave nylon fabric weighing from about 6 to about 9 ounces per square yard.

6. A coordinated protective body armor system according to claim **1,** wherein said spall shield comprises nine plies of ballistic nylon fabric weighing about 7.5 ounces per square yard.

7. A coordinated protective body armor system according to claim **1,** wherein said fabric carrier comprises means for detachably suspending said fabric carrier in proximity to the front of the torso of said wearer.

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