POLICE WEAPONS CENTER

POLICE BODY ARMOR

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During January, 1971, 23 commercially available body armor units reporting the products of 12 manufacturers were ballistically tested at the Naval Research Laboratory, Washington, D.C.; this was done under the direction of the Law Enforcement Standards Laboratory which the National Bureau of Standards is operating under a grant from the National Institute of Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration, United States Department of Justice. The results of these tests are reported in the section starting on page 22.

POLICE BODY ARMOR

INTRODUCTION

For over 3,000 years, military forces used armor as a protection against missiles and hand-held weapons, but with the advent of the longbow and the introduction of gun powder, armor was no longer effective and ceased to be used, except for ceremonial purposes. Not until World War I was there a rebirth of interest in personal armor to defend the individual against shell fragments and projectiles. During World War II, body armor was further developed to protect personnel, especially air crews, against bomb and shell fragments. However, none of the types of military armor developed offered any substantial protection against hand weapons.

Until recently, police forces have had only a sporadic need for body armor, usually in connection with attempts to dislodge barricaded criminals. The recent increase in violent civil disorders and assaults on police officers has generated a new interest in protective armor, including a critical review of the characteristics of on-hand armor as well as the merits of newer units being vigorously marketed to the law enforcement community.

There are four basic situations in which police might utilize body armor: (1) the barricaded criminal or psychotic, (2) riot control situations, (3) protection of certain prominent and highly vulnerable individuals, and (4) bomb squad operations. The latter application is not discussed in this report since it involves a highly specialized type of operation sufficiently important to warrant separate and more detailed consideration.

While operations involving barricaded criminals, riot control, and VIP protection each present different protective requirements, there are basically three questions which must be considered in the selection of body armor for any police operation:

- What protection should the armor give?
- What loss of mobility and efficiency will be caused by the wearing of armor?
- What is the cost of armor in relation to the protection provided?

Protection

How much protection should the armor give? Obviously, the size of the weapon fired against the armored man determines the thickness and weight of the armor. Ideally, armor should be able to stop a 20 mm cannon shell and weigh no more than a few ounces. However, the state of the art precludes development of such armor, and some compromise must be reached that reflects the capability of the armorer.

Armor is essentially a means of providing protection for police personnel against a given threat. Figure 1 summarizes the threats presented by a selected group of firearms. The damage inflicted by a particular bullet when it strikes an individual or object depends on factors such as bullet weight, velocity, and design configuration. All other things being equal, the muzzle impact energy of a bullet, which is a function of its weight and velocity, is one of the most important factors to be considered in the selection of protective armor. As a general rule, the level of protective armor necessary to stop the bullet must increase as impact energy increases.

For the purpose of comparison, the data in figure 1 are arranged in order of increasing muzzle energy. Bullets fired from handguns are generally much lower in energy than are bullets of comparable size and weight fired from rifles. It follows then that the level of armor to defeat handgun bullets is less than that required to defeat rifle bullets.

Type of Bullet	Muzzle Typical Velocity, feet per second	Bullet Weight, grains	Muzzle Impact Energy, foot-pounds
.32 S & W Long	705	98	115
.22 Long Rifle	1,335	40	158
.38 Special	855	158	255
9 mm Parabellum	1,140	115	332
.45 ACP	860	230	370
.38 Super Auto	1,280	130	475
.357 Magnum	1,550	158	845
.30 Carbine	1,980	110	955
.44 Rem. Magnum	1,470	240	1,150
.223 (5.56 mm) Rem.	3,300	55	1,330
.243 Winchester	3,070	100	2.090
.300 Savage	2,370	180	2,240
7 mm Mauser	2,490	175	2,410
8 mm Mauser	2,570	170	2,490
12 Gauge (Rifled slug)	1,600	438	2,490
7.62 mm NATO	2,860	150	2,730
.30 Cal M2	2,970	150	2,930

Figure 1
CHARACTERISTICS OF TYPICAL SMALL ARMS AMMUNITION

In the selection of armor, the challenge is essentially one of matching various existing armor systems to the weapon caliber or calibers which constitute the anticipated threat. An important point to remember, however, is that the matching of armor and threat has practical limits. The number of types of armor which can be stocked by police departments is sharply limited by cost considerations. To provide multiple armor units for each man to meet any eventuality is unrealistic. If the expected principal threat is a caliber .38 handgun, a lighter armor would be selected than if the threat were from caliber .30 fire. The armor designed to stop caliber .30 rifle bullets might also stop caliber .38 handgun slugs, but the equipment would be heavier and more cumbersome. Any advantage that might be gained by using the heavier-than-necessary armor protection would be offset by a reduction in mobility and comfort for the wearer, as well as a marked increase in fatigue.

The police departments of several large cities of the United States were surveyed as to the distribution, by type and caliber, of firearms seized as a result of confiscation following criminal action, suicide, or voluntary surrender. The distribution of this sample of guns processed by the police probably provides a general indication of the types of firearms available for use against police, and, consequently, is some reflection of the nature of the principle threat posed to police personnel.

The results of this survey, summarized in figure 2, demonstrate, among other points, that caliber .22 and caliber .38 handguns are by far the most common firearms, representing almost 55 percent of the total number of weapons reported, as illustrated in figure 3. The popularity of these two calibers can be explained by the low cost and easy availability of both the arms and the ammunition.

Police Department	RIFLES										SHOTGUNS										SMG		Total Shoulder	
	.22	%	30.30	%	30.06	%	Misc	%	Total	%	12 ga	%	16 ga	%	20 ga	%	.410	%	Total	%	Total	%	No	%
New York	NOT REPORTED								429	7.04	NOT REPORTED								284	4.66	8	0.13	721	11.64
Memphis	7	3.13	1	0.45	2	0.89	0	0	10	4.47	15	6.70	0	0	6	2.68	1	0.45	22	9.83	0	0	32	14.30
Seattle	60	8.45	42	5.92	12	1.69	19	1.27	133	26.08	40	5.63	6	0.85	5	0.70	36	5.07	87	17.06	0	0	220	43.14
Buffalo	0	0	0	0	9	3.36	0	0	9	3.36	31	11.57	8	2.99	7	2.61	5	1.87	51	19.03	0	0	60	22.39
Phoenix	48	7.74	10	1.61	12	1.94	37	5.96	107	17.26	43	6.94	11	1.77	10	1.61	12	1.94	76	12.26	1	0.16	184	29.68
Columbus	24	6.17	3	0.77	1	0.26	0	0	28	7.20	37	9.51	14	3.60	7	1.80	5	1.29	63	16.20	1	0.26	92	23.65
Dallas	91	5.14	12	0.68	2	0.11	32	1.88	137	7.74	130	7.35	22	1.24	37	2.09	36	2.04	225	12.72	0	0	362	20.46
Kansas City	34	6.16	4	0.72	2	0.36	6	1.09	46	8.19	29	5.25	8	1.45	10	1.81	8	1.45	55	9.79	0	0	101	17.98
Philadelphia	NOT REPORTED								561	13.23	NOT REPORTED								521	12.29	0	0	1082	25.52
St. Louis	118	8.13	0	0	0	0	46	3.17	164	11.30	119	8.20	25	1.72	11	0.76	39	2.69	194	13.37	0	0	358	24.67
Washington, D.C.	41	4.04	9	0.89	0	0	6	0.59	56	5.56	60	5.91	5	0.49	18	1.77	10	0.98	93	9.24	0	0	149	14.80
San Diego	0	0	2	0.6	7	2.2	14	4.3	23	7.21	18	5.6	6	1.9	6	1.9	5	1.6	35	10.98	0	0	58	18.19
Total	423		83		47		160		1,703		522		105		117		157		1,706		10		3,419	

HAND GUNS																							Total Weapons
.22	%	.25	%	.32	%	.38	%	.357	%	.380	%	.44	%	.45	%	9mm	%	Misc	%	Total	%		
1,859	30	663	10.70	985	15.90	1,721	27.76	16	0.26	0	0	9	0.15	101	1.63	113	1.82	5	0.08	5,472	88.36	6,193
85	37.95	13	5.81	25	11.16	54	24.11	2	0.89	2	0.89	2	0.89	5	2.23	4	1.79	0	0	192	85.70	224
72	14.31	17	2.39	19	2.68	108	21.18	20	2.82	24	3.38	0	0	12	1.69	18	2.54	0	0	290	56.86	510
108	40.30	20	7.46	28	10.45	45	16.79	3	1.12	0	0	0	0	4	1.49	0	0	0	0	208	77.61	268
217	34.94	25	4.03	36	5.81	107	17.26	15	2.42	2	0.32	5	0.81	15	2.42	5	0.81	10	1.61	437	70.48	621
131	33.68	35	8.99	52	13.37	59	15.17	6	1.54	0	0	1	0.26	5	1.29	8	2.06	0	0	297	76.35	389
623	35.23	145	8.19	175	9.89	377	21.31	8	0.45	33	1.87	2	0.11	37	2.09	1	0.06	6	0.34	1,407	79.54	1,769
121	21.92	51	9.24	88	15.94	173	31.84	3	0.54	3	0.54	2	0.36	16	2.90	0	0	4	0.73	461	82.02	562
NOT REPORTED												NOT REPORTED								3158	74.48	4,240
328	22.61	121	8.34	195	13.44	360	24.81	0	0	13	0.90	6	0.41	32	2.21	30	2.07	8	0.55	1,093	75.33	1,451
306	30.19	94	9.25	170	16.74	224	22.05	8	0.79	3	0.30	1	0.10	27	2.67	22	2.17	3	0.30	858	85.20	1,007
126	39.5	30	9.4	26	8.2	45	14.1	7	2.2	7	2.2	2	0.6	11	3.4	6	1.9	1	0.3	261	81.81	319
3,976		1,214		1,799		3,273		88		87		30		265		207		37		14,134		17,553

Figure 2
CONFISCATED WEAPONS

Police Department	Caliber .22	Caliber .38	Total	Total Weapons Reported	Percentage
New York	1,859	1,721	3,580	6,193	57.80
Memphis	85	54	139	224	62.05
Seattle	72	108	180	510	35.29
Buffalo	108	45	153	268	57.08
Phoenix	217	107	324	620	52.25
Columbus	131	59	190	389	48.84
Dallas	623	377	1,000	1,769	56.52
Kansas City	121	173	294	562	52.31
St. Louis	325	360	688	1,451	47.41
Washington, D.C.	306	244	550	1,007	54.62
San Diego	126	45	171	319	53.60
Total	**3,976**	**3,293**	**7,269**	**13,312**	**54.60**

Figure 3
CALIBER .22 AND CALIBER .38 HANDGUNS AS PERCENTAGE OF TOTAL WEAPONS REPORTED

The proportion of shoulder weapons in the sample taken varied from 11.64 percent (New York) to 43.14 percent (Seattle) of all weapons, with no national pattern apparent. For example, Philadelphia, only 90 miles from New York, reported 25.52 percent shoulder weapons as contrasted with New York's 11.64 percent. Of the 1,703 rifles reported, the caliber .22 represented 60.17 percent of the total and was the most popular caliber, probably because of the low cost of the weapon as compared with other available rifles.

It would appear from this survey that, among handguns, the caliber .22 and the caliber .38 pose the most common threat. Among shoulder weapons, the caliber .22 is again the most common threat.

Generally speaking, armor is used when it is known or suspected that police will draw fire; and in most cases, the use of armor will provide the wearer with the degree of protection for which the armor is rated.

However, it should be noted that armor will cause mushrooming or, in the case of ceramic armor, disintegration of the impacting round. Should the round subsequently penetrate the armor, the resulting wound will be irregular in nature and the bullet will probably inflict greater injury than it would if no armor were worn. This is especially likely to occur if the armor is hit by a higher caliber round than it is designed to stop. In some cases, especially where glass reinforced plastic armor is worn, the introduction into the wound of bits of fiber glass, which is not visible under X-ray, can be a cause of serious infection.

Mobility and Efficiency

The weight of protective armor is roughly proportional to the degree of protection it gives, and varies from 3.69 pounds for an armored vest which is rated to protect against caliber .38 special ammunition, to over 30 pounds for a protective vest which is rated to defeat caliber .30 armor piercing rounds. Obviously, to conduct rapid maneuvers for extended periods carrying an added weight of 30 pounds will be more fatiguing than carrying 3.69 pounds.

While almost any use of body armor will result in some loss of mobility and reduced efficiency, the greatest fatigue results from the prolonged wearing of armor under hot, humid weather conditions. Tests conducted at Camp Lejeune, North Carolina, by the U.S. Navy found that the impermeability of body armor, rather than its weight, was the most important factor in causing heat exhaustion under hot, humid conditions, Even in cases which did not go to complete heat exhaustion, there was a marked reduction in the effectiveness in personnel wearing body armor because of insufficient evaporation of body perspiration.

R.F. Goldman of the U.S. Army Research Institute of Environmental Medicine, writes in an article for *Military Medicine* that:

> Man's resting heat production, about 70 kilocalories (Kcal) per hour, is increased five- or tenfold during exercise. He compensates for this additional heat production largely through the production and evaporation of sweat. Thus, during work, although his deep body temperature rises slightly, it is kept at physiologically safe levels by sweat evaporating and thus cooling both the skin and the blood supplied to it from the deep body centers. Unevaporated sweat is worse than useless, since it not only produces no cooling but results in increased loss of body water.[1]

It was found by the U.S. Navy that:

> In unacclimatized men, both rectal and skin temperatures rise faster and higher in men wearing body armor than in those not wearing it. Only 39 percent of men wearing body armor, as opposed to 77 percent of men not wearing body armor, were able to complete a 90-minute march under conditions of load and climate approximating those found in Southeast Asia.[2]

However, in other tests by the U.S. Navy, it was determined that fatigue resulting from the wearing of body armor did not adversely affect marksmanship.[3] In any event, it would appear that the detrimental effects of body armor mobility and efficiency are based on temperature, humidity, and the amount of motion required of the wearer, rather than on the weight of the armor alone.

The tests cited above showed that young, fit men withstand the effects of wearing body armor in hot, humid climates better than older men. This can pose a problem for some police departments, since the older man, with the greater possibility of his carrying excess fat and a greater probability of physical defects, is more likely to be in a leadership position. This points up to the necessity of providing frequent rest breaks, a readily available supply of water, and salt tablets for all police engaged in any prolonged armored action under hot, humid conditions, such as might occur in summer civil disorder operations.

Needless to say, police body armor should be designed in such a way that the firing of hand or shoulder weapons is not inhibited. While military armor units for combat troops are designed to

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[1] R.F. Goldman, "Physiological Cost of Body Armor," *Military Medicine,* Vol. 134, No. 3, March 1969, p. 3.

[2] W.E. Yarger, L.H. Cronau, Jr., and R.F. Goldman, "Body Armor in a Hot Humid Environment," Part 1: Studies in Unacclimatized Men. *Naval Medical Field Research Laboratory Report,* Vol. 18, No. 16, September, 1968, p. iii.

[3] R.S. Leopoid and L.G. Derrick, "The Influence of Wearing Body Armor of Different Designs, Materials and Weights on the Marksmanship of the Marine," *Naval Medical Field Research Laboratory Report,* Vol. 12, March, 1962.

permit the use of firearms, a number of units designed for police use severely limit or preclude the firing of shoulder weapons. For law enforcement applications, the body armor unit should permit the accurate use of shotguns or rifles from at least each of the standard firing positions.

A consideration related to mobility and efficiency involves the speed with which an armor unit can be employed. In some cases officers may be required to get into body armor while inside or crouched behind vehicles and conceivably while under fire. When comparing body armor options, consideration should be given to the time required for trained and untrained personnel to get protective units into position.

Costs of Body Armor

Like the weight of body armor, the cost is also roughly proportional to the degree of protection provided. Heavier armor which protects against caliber .30 armor piercing rounds costs up to $500 per complete set, while a complete set of lighter armor which defeats caliber .38 special ammunition can be obtained for approximately $65. Police departments must consider the cost of armor against the real and intangible costs of losing a trained officer as well as against the loss of efficiency which may ensue from wearing excessively heavy armor.

From the cost/effectiveness standpoint, it would appear desirable for a police department to procure a minimal number of sets of heavy armor for use in extracting barricaded criminals or countersniper operations. For general riot duty, a lighter, less expensive type of armor should be obtained.

BODY ARMOR MATERIALS

There are five types of materials currently considered appropriate for use in the manufacture of body armor:

- Ballistic nylon or other cloth, felted or nonfelted.
- Glass reinforced plastic, either compressed (Doron) or in the form of woven rovings.
- Metals such as steel, titanium, and aluminum.
- Ceramics, such as boron carbide or aluminum oxide.
- Polycarbonate resin.

Ballistic Nylon

The original body armor developed during World War II was composed of eight layers of heavy nylon cloth, which partially protected the wearer against flak fragments from antiaircraft shells. In Korea, the U.S. Army provided infantrymen with the M1952 vest composed of twelve layers of ballistic nylon, which afforded protection against shell fragments and, hopefully, ricocheting small arms bullets. The U.S. Marine Corps later developed their M1955 jacket which combined thirteen layers of ballistic nylon with inserts of glass reinforced plastic.

In general, ballistic nylon alone, although useful as protection against fragments from shells and grenades, is less effective in protecting men against small arms fire.

Glass Reinforced Plastic

Glass reinforced plastic is usually called "Fiberglas," although the term is a registered trade name for one specific brand of glass reinforced plastic. Therefore, the use of the generic term, abbreviated

to GRP, is preferable. GRP exists in two forms which are useful in making body armor: woven rovings and compressed. In manufacturing woven rovings, sheets of woven glass fibers are hand laid upon a form using an adhesive resin between layers. A squeegee is used to compress the material and prevent the formation of air bubbles between the layers. The complete unit is then vacuum-bagged and baked in an autoclave at high heat until dry.

Doron is a GRP which is compressed under high heat and heavy pressure to form a denser material than that which can be produced by the woven roving method. When used in body armor, both GRP materials have a tendency to delaminate in the area around the point of bullet impact and may subsequently provide reduced protection in that area.

Metals

There are four metallic, lightweight armor materials and all except dual hardness steel are homogeneous materials:

- Aluminum Alloy
- Titanium Alloy
- Homogeneous Steel
- Dual Hardness Steel

Unlike ceramic armor, the metallic armors are considered structural materials. As such, they are most suitable for vehicle application where extra weight can be handled without undue penalty. In the manufacture of armor, aluminum and titanium alloys are readily formed and welded by conventional methods, while steel armors, such as homogeneous steel armor and dual hardness armor, are more difficult to form and weld.

Presently, dual hardness armor is considered the best metallic armor available. This material is a composite steel armor consisting of two kinds of steel metallurgically bonded together. The steel on the front face, or attack side, is harder but less tough than the equally thick steel on the back face. One steel combination finding considerable application at the present time is a dual hardness steel armor designated DPSA-2 (Dual Property Steel Armor). All metallic armor is considered to have multihit capability.[4]

Ceramics

The most common ceramics used in body armor are boron carbide, aluminum oxide (alumina), and silicon carbide. These materials are stronger and lighter than most metals and would be ideal, except that none developed to date can provide multihit protection since they are excessively brittle. Usually, the hard face or attack side consists of a very hard ceramic material that has been either molded in one piece to fit the contour of the part of the body that is to be protected or has been made up as small flat plates that are carried in pockets in the armor vest. The back face, or back-up material, is normally fabricated of glass reinforced plastic (GRP) which is bonded to the ceramic by an adhesive. It should be pointed out that in order for the ceramic to function properly, it must be completely bonded to the back-up material which is less tough and brittle than the ceramic face. This is analogous to the nonshattering safety glass composite used in all modern automobiles.

[4] Multihit capability is defined as the ability of a piece of armor to withstand a second hit of the same caliber bullet traveling at the same velocity as the original bullet within two inches of the original impact.

Law enforcement agencies that are stocking or planning to acquire ceramic armor should be aware that such units are substantially weakened by being dropped or roughly handled. As supplied to the U.S. Army, ceramic armor bears the notation imprinted in letters one inch high "DO NOT DROP," and instructions are issued to logistic personnel that if dropped from any height, the armor is to be returned to the manufacturer for detailed examination to insure serviceability. This precaution is taken since dropping or otherwise damaging ceramic armor can destroy its ability to withstand first round hits.

Until such time as ceramic armor manufacturers provide police armor with "DO NOT DROP" warnings similar to those affixed to identical military models, new ceramic armor should be inspected and so marked at the time of its receipt by the law enforcement agency. In addition, ceramic armor should be utilized only be specially trained officers who have been given adequate instruction on its fragile nature. Before wearing ceramic armor, officers should inspect each segment, feeling for fractures. While it is not feasible for police officers to remove the spall shield and inspect the armor in detail, the manual palpation will often reveal major fractures of the armor. Any evidence of a break or other irregularity should cause the immediate replacement of that segment, or at least should alert the policeman to the fact that he may not be fully protected by his armor.

To further reduce the risk of damage, ceramic armor should be kept in central storage and withdrawn only when necessary. Under no circumstances should it be stored in the trunk or other parts of a squad car. Personnel withdrawing and returning ceramic armor to central storage should be held responsible for reporting any possible damage to the armor. Unless the departmental armorer is trained to detect structural damage, ceramic armor can be a risky investment for the average police agency.

Polycarbonate Resin

This material, a synthetic resin developed by General Electric Company under the trade name "Lexan," is a rigid, transparent material which is suitable for glazing and construction work, and can be produced in sections suitable for body armor. Like all polymers, it has no true melting point, but under strain the material will dissolve at about 308° F and can be poured.

Lexan is a relatively soft material and scratches easily. For this reason, it is to be treated with caution in fabricating helmet face shields or other sections where vision is of primary importance. For body armor, the susceptibility to abrasion is of less importance.

CONSTRUCTION OF BODY ARMOR

There are two basic designs represented by body armor currently in use: rigid armor and variable armor.

Rigid Armor

Armor composed of sections molded to fit a certain part of the body is called rigid armor. For example, one piece is usually molded to cover the front portion of the chest and extends part way around the sides of the upper body, while a second section is designed to cover the upper back region and extends around the sides to meet (or overlap) the front section. This design eliminates the joints present when using small individual plates of armor. Most commercially available armor is of the rigid type, constructed of glass reinforced plastic, metals, or ceramics.

Rigid ceramic armor vests are now being made for the armed forces in limited quantities and two units, the Carborundum KT and the AVCO PA500, are available for police purchase. However, this type of armor is expensive and difficult to manufacture, and problems of quality control are still present. The weight of rigid armor pieces depends on the area to be protected, but is approximately as follows:

Chest protection	10.0 pounds
Back protection	12.5 pounds
Groin protection	4.2 pounds
Coccyx protection	5.9 pounds
	32.6 pounds

This weight is for a man of average size, 67 1/2 to 70 inches tall. The total weight range of rigid ceramic armor for small to large men for full protection would be from about 29 to 35 pounds. This particular armor is rated to protect against all bullets up to and including the caliber .30 armor piercing round at muzzle velocity.

Variable Armor

This concept, on which the U.S. Army has devoted much time and money, includes the use of pockets in a nylon vest or jacket, into which overlapping armor segments or plates can be inserted. The armor plates may be ceramic-faced composites, metal, or glass reinforced plastic. The basic vest itself is made of closely woven nylon fibers and, in the medium size, has a total weight of about 5 pounds without armor plates.

As the level of threat increases, armor segments are inserted into the vest to upgrade it. Therefore, to meet the highest level of small arms threat anticipated, a point-blank caliber .30 armor piercing bullet for example, the vest with ceramic-faced plates inserted in front and back pockets would weigh from 24 to 27 pounds. In this manner, various levels of protection can be obtained from a vest than may weigh from 5 to 27 pounds.

In some cases, metallic armor plates made from titanium alloy or Hadfield manganese steel could be inserted into variable armor pockets instead of ceramic plates. However, for the same protection, the weight of a vest with metal plates would be heavier than one with ceramic segments and, therefore, metal segments would be used by law enforcement personnel only for limited purposes. An important advantage of the variable armor concept is that damaged plates can be readily replaced, and this is especially important in the case of ceramic-faced plates which have no multihit capability.

The variable armor concept would appear to offer some major advantages for police uses. For example, lightweight units for civil disorder protection against thrown objects could be upgraded in special situations to provide protection against small arms fire.

POLICE BODY ARMOR

This section will describe a number of body armor units currently marketed, or under development, by commercial sources in the United States. Figure 17, at the end of this section, summarizes selected characteristics of the armor units to be covered and provides a convenient format for comparing specific products.

While military body armor is not included in this report, certain military body armor may be declared surplus to the needs of the service and sold at very low prices by the Defense Supply Agency under the provision of Section 2576, Title 10, USC (Public Law 90-500). When considering the use of surplus armor, however, it should be noted that most military armor units are designed to protect against shell fragments rather than bullets. This results from the fact that in World War II and Korea approximately 80 percent of the casualties were produced by fragments from artillery and mortar shells and grenades. Consequently, it should *not* be assumed in the absence of comprehensive tests that military armor is suited to police applications.

Some armored vests are composed entirely of the protective armor material, while others utilize pockets in a cloth carrying garment into which the armor material is placed. In this latter group, the extent of the carrying garment may be much greater than the armored portion providing maximum rated protection. Since it is important to know the area of the body given full protection, the figures illustrating armor units in this section show in black the area giving the maximum protection claimed for that garment. The fabric, and nonprotective areas of the garment, are shown in grey. It should be noted, however, that for some units multiple layers of nylon used in areas of reduced protection can provide defense up to .38 special rounds.

For each armor unit the manufacturer or supplier makes certain claims regarding the protection afforded the wearer. In the following section, these claims are referred to as the "rated" protection. As part of a comprehensive study of body armor standards being conducted for the National Institute of Law Enforcement and Criminal Justice (LEAA) by the National Bureau of Standards, preliminary firing tests against armor were recently conducted. The results of these tests are included in the discussion of each unit of armor. A description of these tests is included in a subsequent section entitled Ballistic Testing of Body Armor.

AGRAMONTE Lancer Armored Vest

The Lancer Armored Vest is manufactured by Ed Agramonte Incorporated, Yonkers, New York, and is rated by the maker to protect against caliber .357 magnum rounds. The vest, shown in figure 4, is made entirely from ballistic nylon approximately 30 layers thick and weighs 11.6 pounds without the groin protector. The cost of this vest is $89 plus $15 for the groin piece, and it provides its maximum protection to 407 square inches in front and 484 square inches in back. It also provides full protection over the shoulders, although the sides are not covered.

The Lancer Vest did not provide protection against caliber .357 magnum lead and soft point rounds. Two out of two rounds fired penetrated. However, the vest did stop thirteen out of thirteen rounds fired from a caliber .38 special, using both lead and metal point ammunition. It also stopped five of five rounds .22 long rifle, high velocity ammunition fired from a rifle.

AVCO Vest PA 100

AVCO Special Materials Company, Lowell, Massachusetts, manufactures two types of body armor, a regular line (PA 100) and a high protective line (PA 500). The regular type, made of 11 layers of glass reinforced plastic, is available in a short vest, shown in figure 5, which is designed to be worn under clothing or in a long vest which affords groin protection. The short vest weighs only 3.25 pounds, and is rated to withstand caliber .357 magnum rounds. A back protection portion will shortly be introduced to the market. The regular AVCO vest affords its maximum protection to 267 square inches of the front of the body. The cost for the short vest is $75.

Ballistic testing of the PA 100 armor conducted by the Naval Research Laboratory showed that the armor stopped two out of two hits with caliber .22 long rifle high velocity ammunition fired

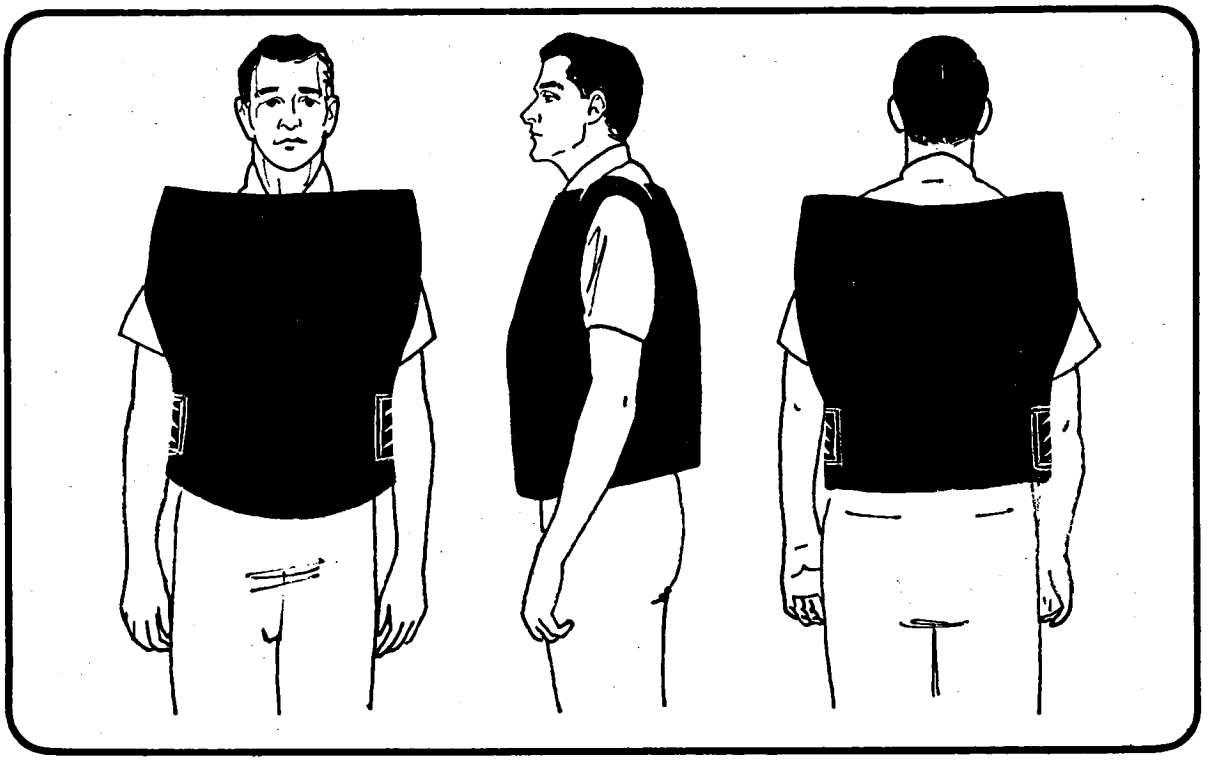

Figure 4
LANCER VEST

Figure 5
AVCO REGULAR ARMOR, MODEL PA 100

from a pistol, and a total of eleven out of eleven hits with caliber .38 special lead and metal point rounds. Using caliber .357 magnum lead rounds, the first of ten shots penetrated and the remainder were stopped. In a retest, the front section stopped three out of three caliber .357 magnum lead rounds.

All GRP armor produced by AVCO prior to November 1, 1970, is reported by the manufacturer to be subject to initial hit penetration which is caused by direct overlaying of the first three layers of glass rovings, and consequent exposure of resin only in the first lamina of the armor. All armor produced since November 1, 1970, is reportedly examined to assure that this fault is not present. The date of production should be ascertained from the manufacturer or supplier.

AVCO Vest PA 500

The AVCO high protective line of vests, illustrated in figure 6, is made of the same glass reinforced plastic as the regular vest but is faced with ceramic (alumina) and weighs 36.25 pounds. It is rated to withstand caliber .30 armor piercing rounds at velocities in the region of 3,000 feet per second. Like all ceramic armors, this unit has no multihit capacity. The vest gives maximum protection over approximately 318 square inches in the front and 217 square inches in the back. It is available in small, medium, and large sizes and costs (with groin protector) $340 per set.

When the PA 500 armor was ballistically tested, it was found that the front section stopped three out of three caliber .30 armor piercing direct hits, but the back section failed to stop three rounds of the same ammunition. The manufacturer claimed that the failure of the back section was due to

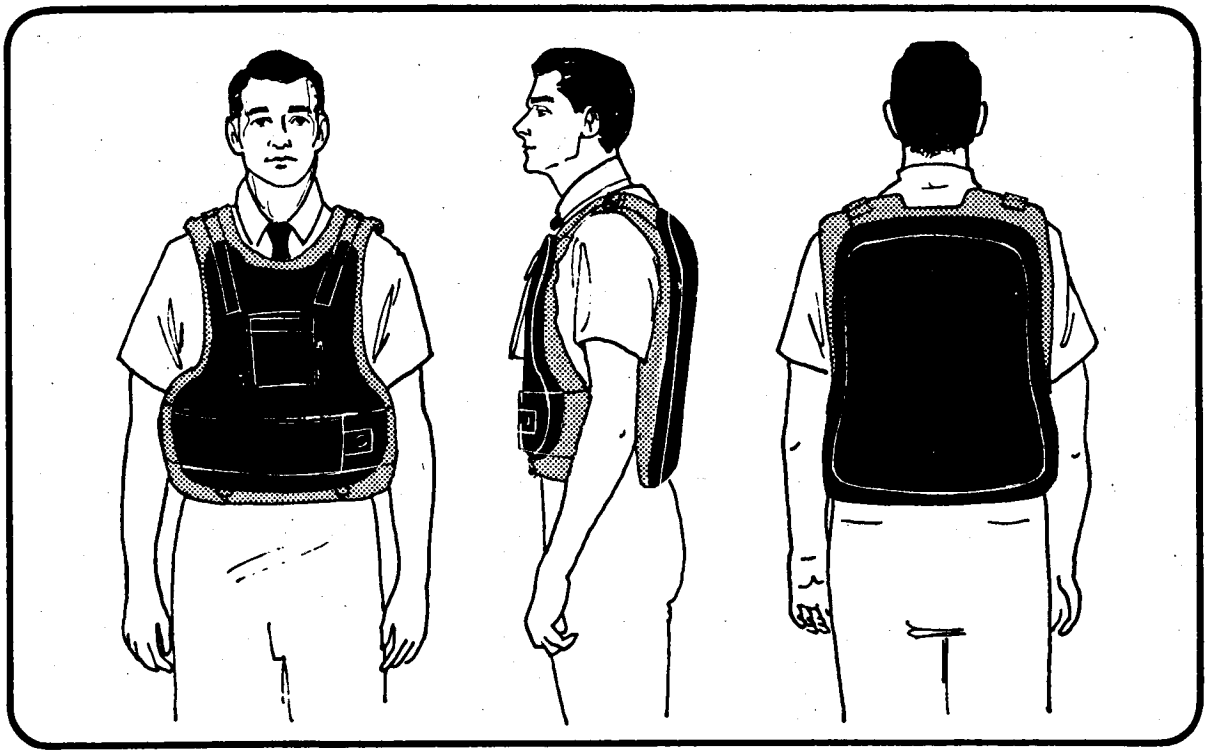

Figure 6
AVCO HIGH PROTECTIVE VEST, MODEL PA 500

the armor having been cracked by rough handling and a retest was scheduled. Upon retesting at the manufacturer's range, a rear section of PA 500 armor, selected at random from the production line successfully withstood the impact of three out of three rounds of caliber .30 armor piercing ammunition.

CARBORUNDUM KT-1 Vest

The Carborundum Company, Niagara Falls, New York, manufactures a line of ceramic body armor which is rated to protect against caliber .30 armor piercing ammunition. This armor, which protects the chest, back, and groin, is made of Doron panels bonded to hard ceramic (silicon carbide). These composite plates are inserted into pockets in a nylon carrier that distribute the weight efficiently on the shoulders of the wearer. The KT-1 vest provides maximum protection to 277.5 square inches in front and 206.8 square inches in back and weighs 35.3 pounds.

The Carborundum KT-1 vest, illustrated in figure 7, is available in regular, large, and extra-large sizes. The entire assembly, including front, back, groin, and coccyx sections plus a carrying case, markets for approximately $500.

When ballistically tested, this ceramic vest failed to stop a caliber .30 armor piercing round in the groin section. The front section stopped three out of four caliber .30 armor piercing rounds and the coccyx section stopped a caliber .30 armor piercing round. The back section stopped only two out of four rounds of caliber .30 armor piercing ammunition fired, the failures occurring on rounds 3 and 4, which is an example of the recognized lack of multihit capability of ceramic armor.

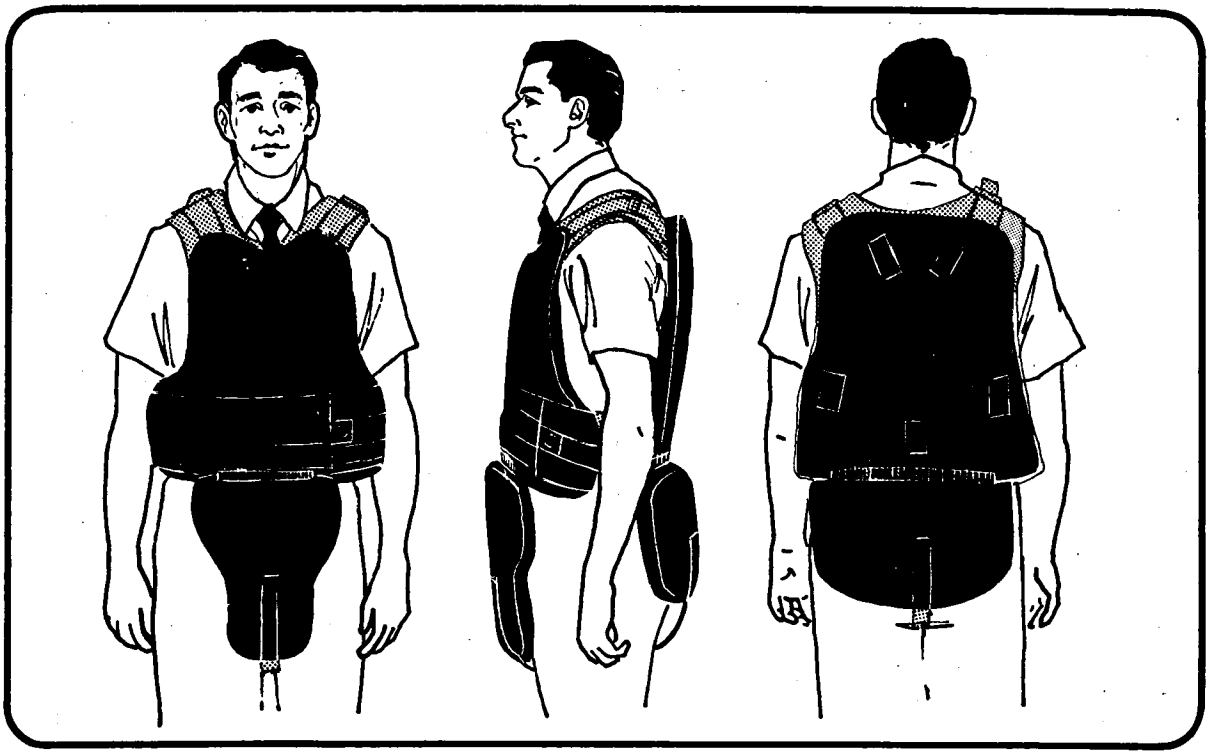

Figure 7
KT-1 ARMOR

DAVIS Vest, Model 6003-3

Davis Aircraft Products Company, Northport, Long Island, New York, manufactures a rather extensive line of armored vests. Their model 6003-3, shown in figure 8, is rated effective against caliber .357 magnum, caliber .44 magnum, and 9 mm parabellum bullets, as well as deer slugs, and 00 and No. 4 buckshot from 12-gauge shotguns. It protects the front, back, and groin area and weighs, exclusive of the groin section, 13 pounds, which is rather light for a steel-plate vest protecting 182.5 square inches of the front and 181.5 square inches of the back of the body. The vest, composed of Hadfield steel plate and 12 layers of ballistic nylon, costs $135.

The ballistics test of this protective outfit showed that the vest stopped seventeen hits out of seventeen rounds fired using caliber .357 magnum lead, metal point and soft point bullets. It also stopped two out of two rounds of caliber .44 magnum lead ammunition.

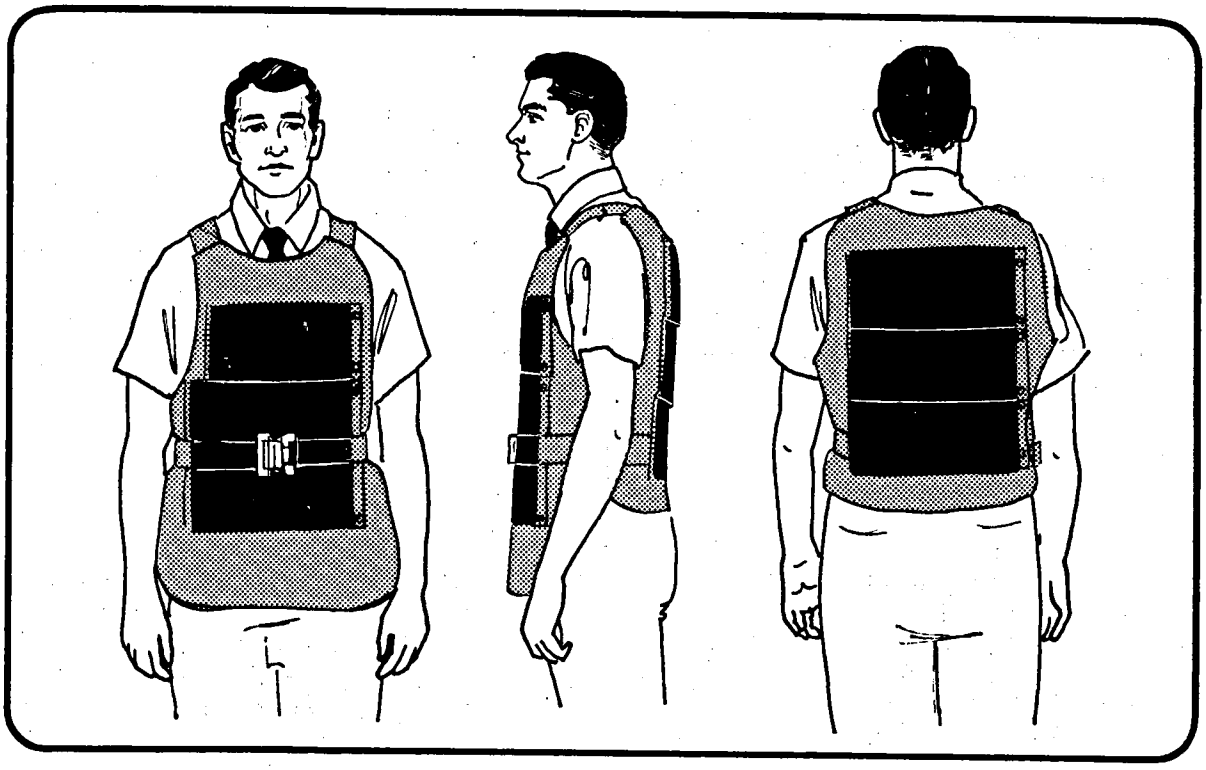

Figure 8
DAVIS VEST, MODEL 6003-3

DAVIS Vest, Model 6003-1

The model 6003-1 vest, which is composed of 12 layers of ballistic nylon, weighs, exclusive of the groin section, 8 pounds, and is rated to stop caliber .38 special rounds. In design it is identical to the model 6003-3 illustrated in figure 8, but does not have the steel plates found in the 6003-3 armor. The model 6003-1 provides its maximum protection to 385 square inches in front and 333 square inches in the rear and markets for $100 per set.

In tests, the model 6003-1 stopped ten of ten rounds of caliber .38 special lead, and one of three rounds of caliber .38 special metal point ammunition.

DAVIS Vest, Model 6003-5

The 6003-5 model, which is also identical in appearance to the 6003-3, is composed of three layers of steel and 12 layers of ballistic nylon. It markets for $140 with an additional $20 for the groin piece and is rated to stop caliber .30 carbine rounds, as well as caliber .357 magnum and caliber .44 magnum rounds. It provides maximum protection to 130 square inches in front and 130 square inches in the rear. The front and back sections together weigh 23 pounds and the groin section weighs an additional 4.5 pounds.

In tests, the model 6003-5 stopped two of two rounds of caliber .357 lead and metal point ammunition, and two of two rounds of caliber .44 magnum lead rounds. It also stopped six of six rounds of caliber .30 carbine metal point rounds, but only six of nine rounds of caliber .30 carbine soft point ammunition fired.

DAVIS Vest, Model 6010-2

The Model 6010-2 also is designed for wear under outer clothing and is constructed of 12 layers of ballistic nylon without steel plates. The 6010-2 has, in addition, an outer covering of black "Shok cloth" which in effect increases the protection to 14 layers of ballistic material. Model 6010-2 gives its maximum protection to 395 square inches in front and 355 square inches in the rear and weighs 6.25 pounds, exclusive of the 1.75-pound groin section. It markets for $100 per set plus $12.50 for the groin piece. This vest is rated to withstand the impact of caliber .38 special rounds.

The model 6010-2 stopped ten of ten rounds of caliber .38 special lead ammunition, but only one of four rounds of caliber .38 special metal point ammunition.

DAVIS Vest, Model 6007-4

The model 6007-4, designed to be worn under outer clothing, is constructed of one layer of steel and 12 layers of ballistic nylon. It weighs 11.5 pounds, exclusive of the three-pound groin piece, and provides maximum protection to 130 square inches in front and 130 square inches in the rear. Model 6007-4 markets for $120 per set plus $15 for the groin section. It is rated by the manufacturer to stop a caliber .357 magnum lead, soft point or metal piercing round.

In tests, the model 6007-4 stopped caliber .357 magnum lead, metal point, and soft point bullets in thirteen of thirteen rounds fired, but stopped only one of four of the caliber .44 magnum rounds fired.

DEFENSOR Vest, Model V1-A

An armored vest similar to the Davis vest is available through Defensor Protective Equipment, Incorporated, Media, Pennsylvania. This vest, model V1-A, is illustrated in figure 9 and weighs 3.9 pounds. It is made of overlapping Doron armor plates which are covered by 12 layers of nylon material with reinforced webbing. It is designed to protect vital frontal body areas from thrown objects, bricks, bottles, and knives, as well as from bullets traveling up to 855 feet per second, such as the caliber .38 special. The vest provides maximum protection over 261 square inches in front only and costs $68 with groin protection.

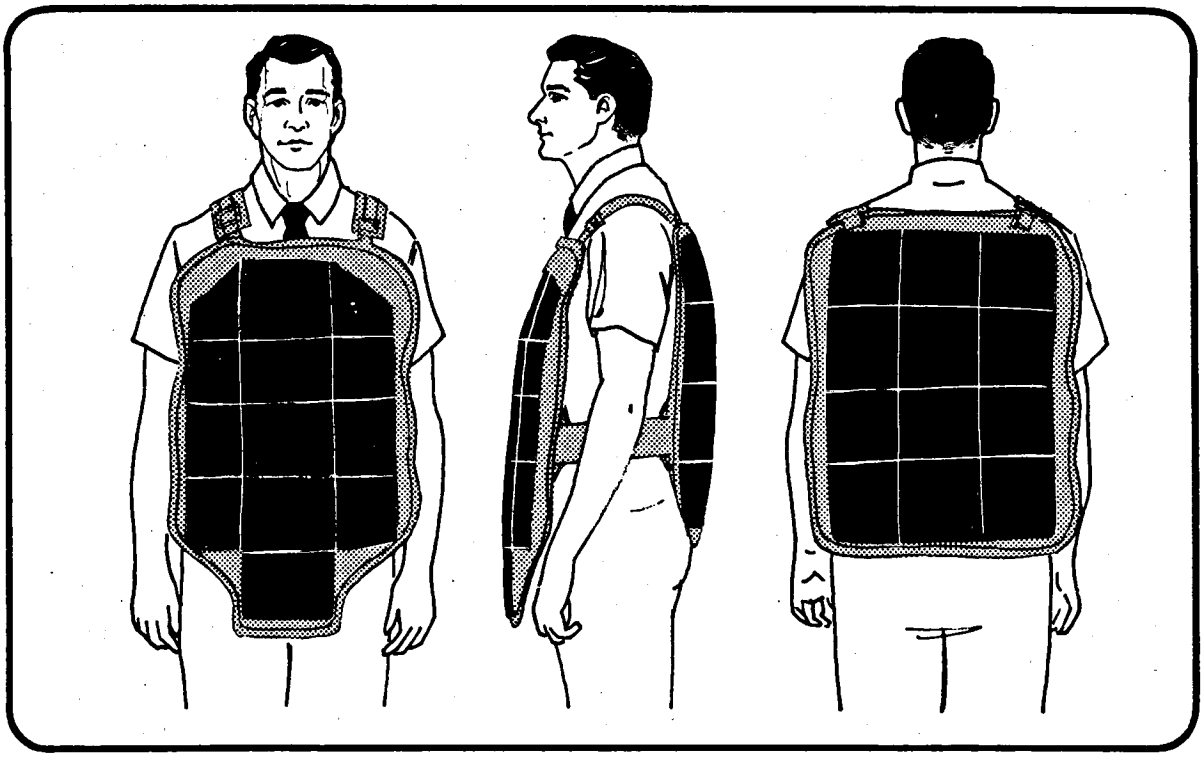

Figure 9
DEFENSOR VEST, MODEL V1-A

The Defensor vest, model V1-A, stopped ten of ten rounds fired from caliber .38 special pistol using metal point rounds. However, two out of two rounds of 12-gauge 00 buckshot penetrated, with one of the impacts blowing the Doron plates through the back of the vest. It also failed to stop two of two .357 magnum rounds.

DEFENSOR Vest, Model V2-A

The Defensor V2-A is identical to the V1-A unit, except for an additional Doron layer that increases the rated protection to handgun bullets up to and including the 9 mm parabellum and the standard caliber .357 magnum load with a 158 grain lead bullet. It weighs 12 pounds and provides 261 square inches of protection in front and 288 square inches of protection in the rear and costs $125 per set. In tests, the model V2-A stopped fifteen of sixteen rounds of caliber .357 magnum lead, metal point, and soft point ammunition. It failed to stop a caliber .30 metal point round.

FEDERAL-SPOONER Vest, Model P

The Federal-Spooner-System of armored vests, which is available from Federal Laboratories, Incorporated, Saltsburg, Pennsylvania, is designed to defeat the threat of handgun bullets up through caliber .357 magnum ammunition. The model P full vest, illustrated in figure 10, weighs approximately 16.5 pounds and provides protection to the torso and groin from the front, side, and rear. It provides maximum protection to 266.5 square inches in front and 318 square inches in the rear and costs

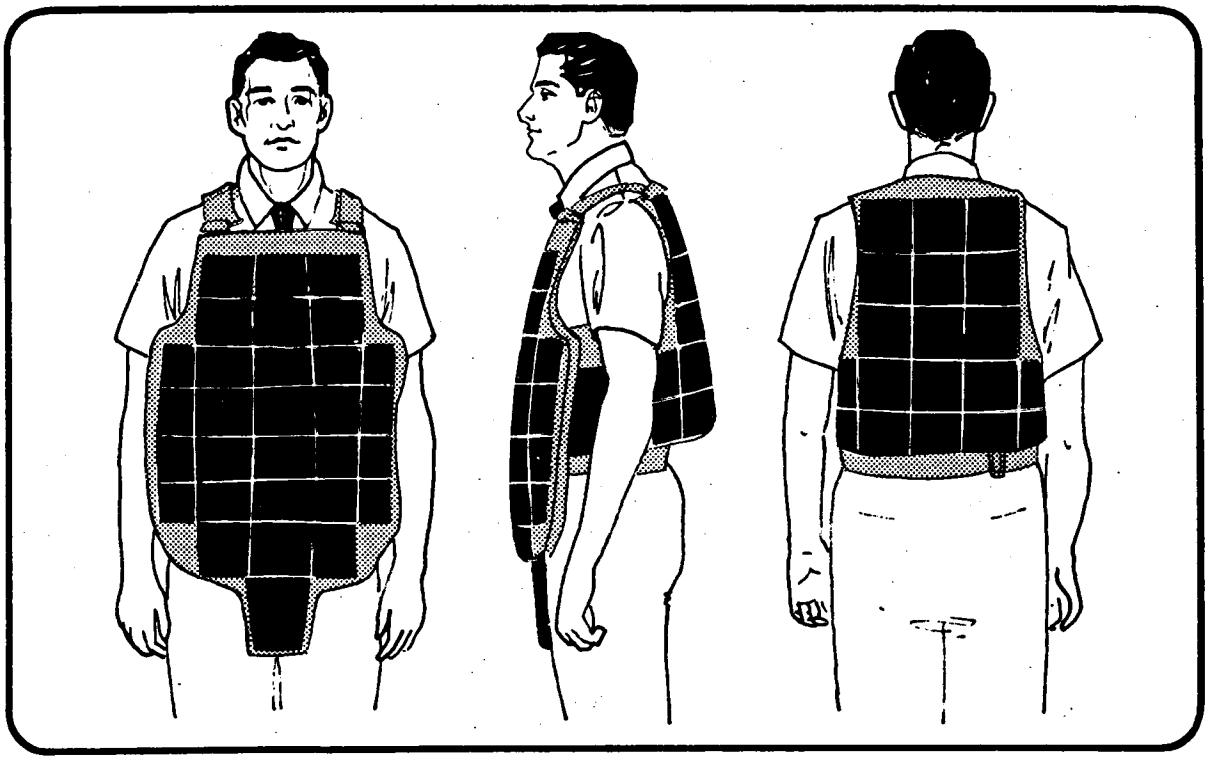

Figure 10
FEDERAL-SPOONER VEST, MODEL P

the rear and costs $150 for the complete set. This vest is constructed of two overlapping steel armor plates sewn into pockets which are made of three layers of ballistic nylon. The model P vest is flexible and is rated to withstand handgun bullets with a velocity up to 1,430 feet per second, about the equivalent of a caliber .357 magnum at 25 yards.

In tests, the model P armor stopped twenty-eight out of twenty-nine rounds fired from a caliber .357 magnum pistol using lead, metal point, and soft point ammunition, but failed to stop caliber .30 carbine metal point rounds or a 12-gauge rifled slug.

FEDERAL-SPOONER Vest, Model C (708)

The model C is composed of a layer of steel sewn into a carrying vest made of three layers of ballistic nylon and is rated to provide protection against a caliber .38 special round. The model weighs 12.6 pounds and provides maximum protection to 266.5 square inches in front and 318 square inches in back. It markets for $125. A groin section is available on special order.

Model C stopped eleven of eleven rounds of caliber .38 special lead and metal point ammunition, but failed to stop a caliber .357 magnum metal point round.

FEDERAL-SPOONER Vest, Model C (708F)

The model C (708F), which is the front section of model C, is designed to be worn under clothing and weighs only five pounds. Like model C, it is rated to defeat caliber .38 special rounds. It sells for $63 and provides protection to 266.5 square inches in front only.

Model C (708F) stopped ten of ten rounds of caliber .38 special lead and metal point ammunition, but failed to stop a round of caliber .357 magnum metal point ammunition.

GOEC Barrier Vest, Models 120 & 217

The General Ordnance Equipment Corporation (a subsidary of Smith and Wesson), Pittsburgh, Pennsylvania, markets body armor which is sold under the trade name "Barrier Vest." There are three models available: model 217, model 120, and model 434 C.

The model 217, shown in figure 11, is made of molded steel bonded to ten layers of ballistic nylon in the front section, and the back section is composed of one layer of molded steel bonded to seven layers of ballistic nylon, for a total weight of 9.25 pounds. There is also a groin section of the same composition which weighs 2.3 pounds and costs $15. The vest costs $120 and provides maximum protection to 125 square inches in front and 125 square inches in back. The model 217 is rated to withstand caliber .357 magnum ammunition.

Model 120 is identical in design to model 217, except the back section does not contain the steel plate and consists of ten layers of ballistic nylon only. The front and back sections weigh 8.5 pounds and cost $105. The groin section contains the steel plate, weighs 2.3 pounds, and costs $15. The front section provides maximum protection of 125 square inches and is rated by the manufacturer to withstand caliber .357 magnum rounds.

The front section of model 217 stopped fourteen of fourteen rounds fired from a caliber .357 magnum, using lead, metal point, and soft point ammunition. The back section of model 217 stopped twelve of twelve rounds caliber .357 lead, metal point, and soft point ammunition.

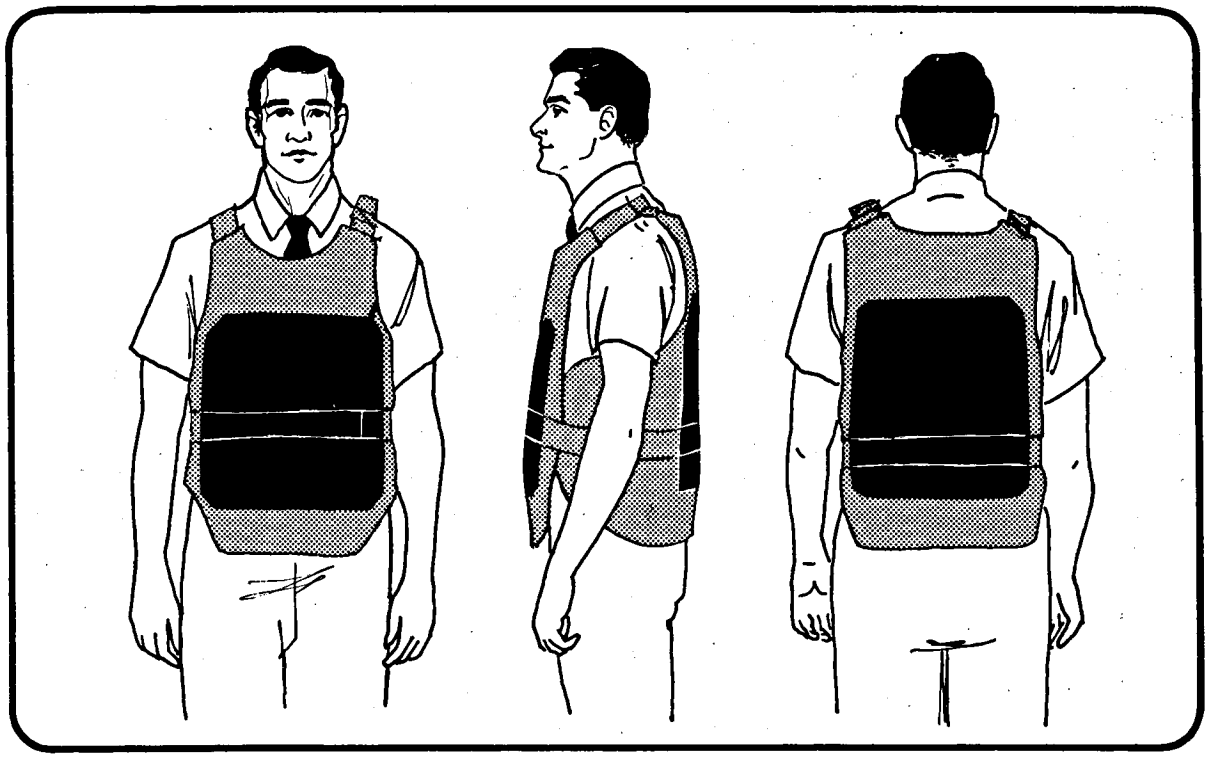

Figure 11
GOEC BARRIER VEST, MODEL 217

The front section of model 120 stopped thirteen of thirteen rounds of caliber .357 magnum lead, soft point, and metal point ammunition. Two of two rounds caliber .357 magnum lead ammunition were stopped by the groin section of model 120.

GOEC Barrier Vest, Model 434C

GOEC's model 434C, illustrated in figure 12, is composed of three layers of steel bonded to 10 layers of ballistic nylon in all three sections, front, rear and groin, and weighs 20 pounds. It sells for $160 including groin protector and provides maximum protection to 125 square inches in front and 125 square inches in back. The model 434C armor is rated to withstand caliber .357 magnum and caliber .30 carbine ammunition.

In addition to defeating five out of five caliber .357 magnum lead, metal point and soft point rounds, the model 434C also provided protection against three of three rounds of caliber .30 carbine metal point ammunition, and three of four caliber .30 carbine soft point rounds fired.

IMPERIAL Supershield (Prototype)

This very recent development of the Imperial Protector Company of Compton, California, is manufactured of polycarbonate resin. It is transparent and is designed to be worn routinely under the uniform. The Supershield, shown in figure 13, may be fabricated in ¼-inch thickness, or in two laminated ¼-inch sheets to give an overall thickness of half an inch. It is also available in

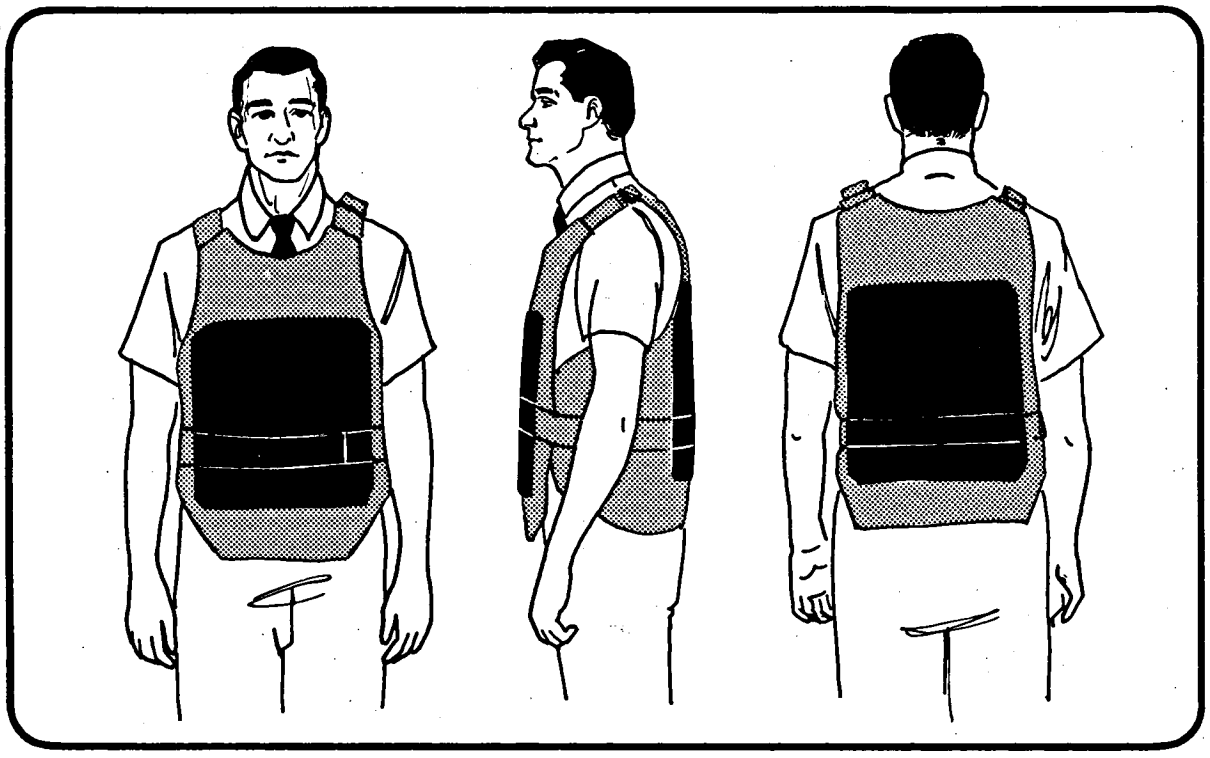

Figure 12
GOEC BARRIER VEST, MODEL 434C

$^3/_8$-inch-thick sections. The front section of the ½-inch-thick shield weighs seven pounds. A back section is now under design. In the ½-inch configuration, the Supershield is rated to withstand the caliber .44 special, the caliber .38 special, and the caliber .45 a.c.p. and to provide protection against the caliber .22 long rifle. However, even the $^3/_8$-inch section will not provide protection against the magnum or high velocity rifle loads. The Supershield front section provides protection to 226 square inches of the body, and weighs four pounds. The manufacturer estimates that this armor will market for under $50.

As claimed by the manufacturer, the $^3/_8$-inch Supershield stopped eleven out of eleven lead and metal point rounds fired from a caliber .38 special, and three out of three rounds of caliber .22 long rifle, high velocity ammunition fired from a pistol. It failed to stop either a caliber .357 magnum or two caliber .22 long rifle high velocity round fired from a rifle.

ROLLS ROYCE-Colt Security Vest

Colt Industries, Hartford, Connecticut, recently obtained the U.S. distributing license from the manufacturers, Rolls Royce (Composite Materials) of England, for this armor called the Security Vest. Figure 14 illustrates this garment which consists of a chest protector, a back protector, and an optional pelvis protector and costs $200. Each portion is made of 10 laminated sections of GRP backed by ¼ inch of foam rubber. The total weight is 11.31 pounds and the garment provides maximum protection to 230.5 square inches in front and 141 square inches in back. The Security Vest is rated to stop 7.62 Mauser, 9 mm, 7.62 mm AK47 and caliber .357 magnum rounds.

Figure 13
SUPERSHIELD

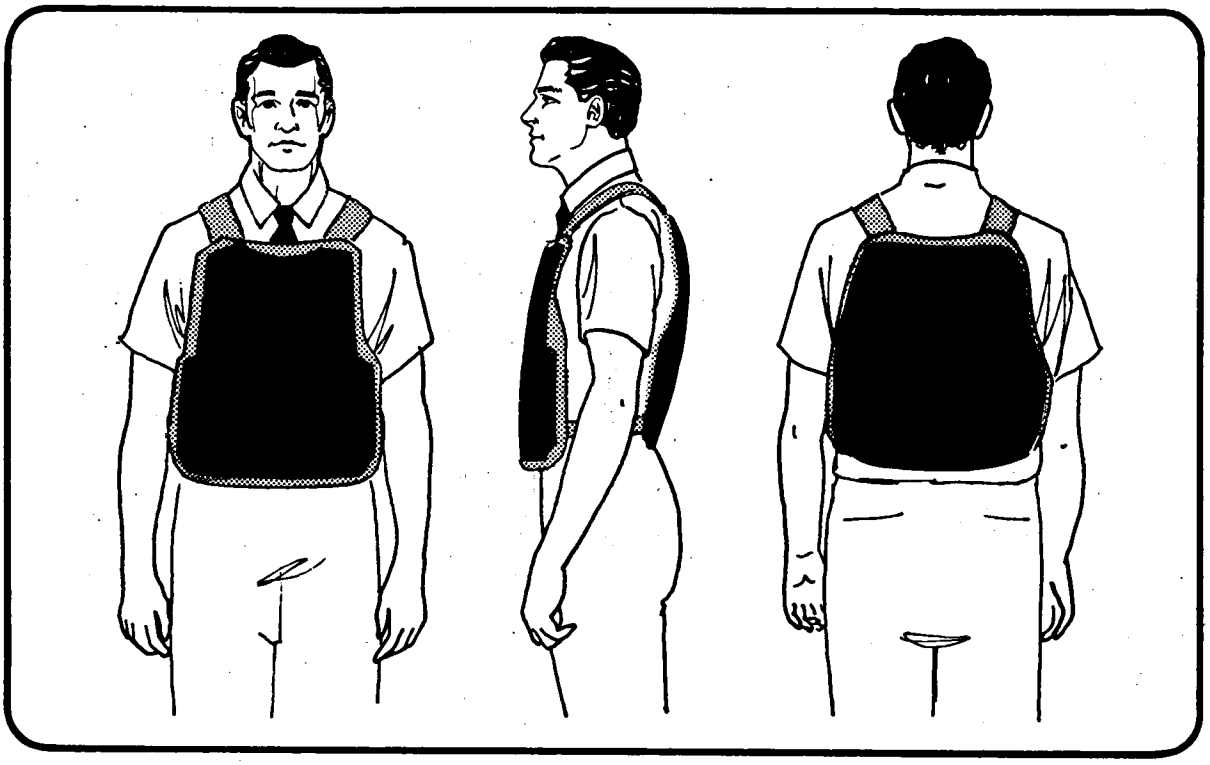

Figure 14
ROLLS ROYCE SECURITY VEST

A heavier, ceramic composite version called the Combat Vest has the same dimensions but, naturally, is heavier and thicker. It is rated to stop caliber .30 high velocity rifle bullets.

In tests, the Security Vest stopped thirteen out of thirteen rounds of lead, metal point, and soft point ammunition fired from a caliber .357 magnum pistol and also stopped three of four rounds from a caliber .44 magnum using lead ammunition. It failed to stop either a caliber .30 metal point round or a rifled slug from a 12-gauge shotgun.

SKYLINE Armored Vest, Model SK 426328 (Prototype)

This rigid glass reinforced plastic vest is made in three parts to protect the chest, back, and groin and is available in three sizes, small, medium, and large. The material is 3/8 inch thick and has a nominal weight of 8 to 15 pounds for the front and back sections. The armored sections are carried in nylon pockets. The Skyline Vest is rated to withstand a caliber .357 magnum 158-grain bullet at 20 feet from the muzzle as well as the caliber .44 magnum Norma round.

This armor satisfactorily stopped a caliber .357 magnum lead round and also stopped ten out of ten rounds of caliber .44 magnum ammunition using lead rounds. It also stopped a rifled slug from a 12-gauge shotgun.

TABOR-Colt Vest

The Tabor vest is made by the P.M. Tabor Company of Laguna Beach, California, and consists of three pieces designed to protect the front, back, and groin areas. This vest is shown in figure 15, and

Figure 15
TABOR VEST

each section is made of molded glass reinforced plastic, approximately ¼ inch thick, backed by foam rubber. The manufacturer states that the Tabor vest will withstand the caliber .38 special, the caliber .45 a.c.p. and the caliber .22 long rifle. The complete unit (front, back, and groin) weighs 16 pounds and markets for $176. The Tabor vest protects approximately 301.5 square inches in front and 400 square inches in the back. The P.M. Tabor line of equipment is now marketed through the Colt Firearms Company of Hartford, Connecticut.

The Tabor vest on ballistic testing stopped ten out of ten rounds fired from a caliber .38 special pistol using metal point ammunition and also stopped three out of three rounds of caliber .22 long rifle high velocity ammunition fired from a rifle. It failed to stop a caliber .357 magnum metal point round.

TRANSCON Armored Vest, Model 401 V

The Transcon Manufacturing Company of Los Angeles, California, markets two armored vests: models 201V and 401V. Model 201V weighs 7.5 pounds with front and back plates and provides maximum protection over 310 square inches in front, and 281 square inches in back. It is rated by the manufacturer to defeat caliber .45 a.c.p. and caliber .38 special rounds. The cost is $49 for front and back protection; a groin protector is available for $20 additional.

The model 401V weighs 14.2 pounds for the front and back portions of the assembly and provides protection over 310 square inches in front and 281 square inches in back. Figure 16 illustrates the model 401V. According to the manufacturer, it will withstand the 9 mm parabellum,

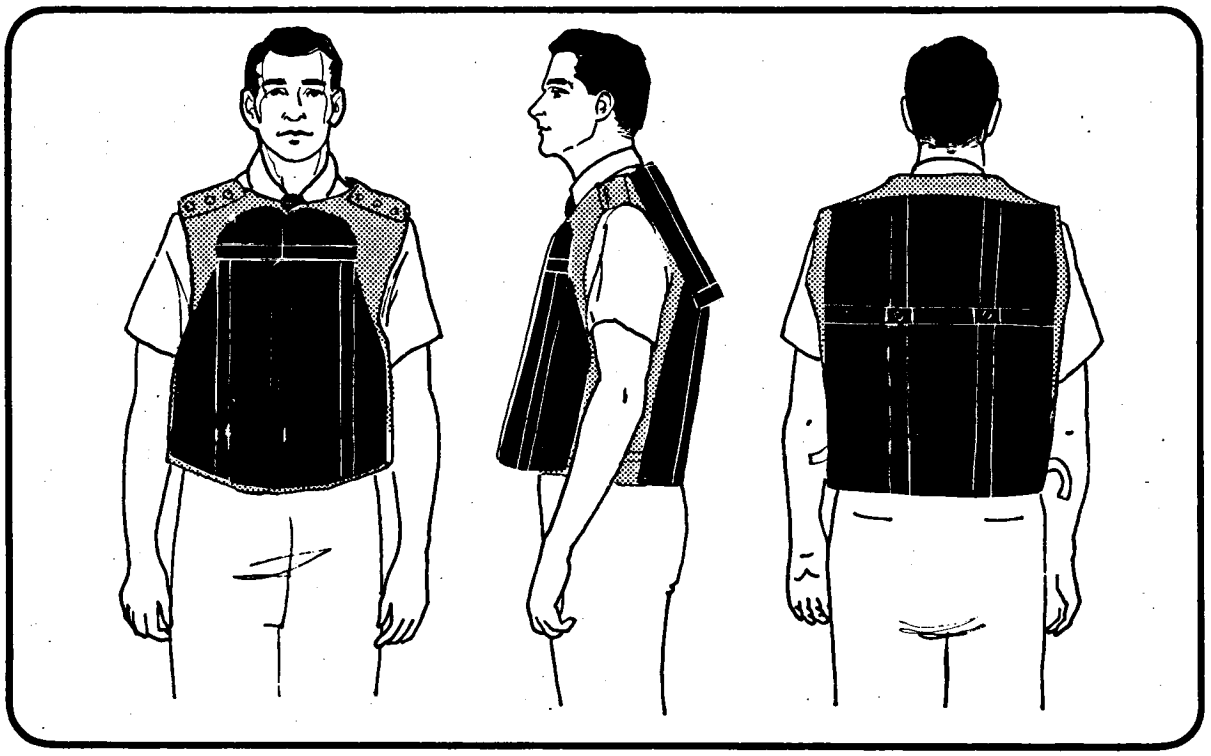

Figure 16
TRANSCON VEST, MODEL 401V

the caliber .357 magnum, and caliber .22 long rifle ammunition. The cost is $69 for the front and back protection and a groin protector is available for an additional $30.

Both models are made of Doron plates carried in pockets in the nylon carrier vest. Metal hinge plates cover the areas where armor plates butt together. The model 401V armor stopped twelve out of thirteen rounds of caliber .357 magnum using lead, metal point and soft point ammunition, but did not stop a caliber .30 carbine round. When fired at with 00 buckshot from a 12-gauge shotgun it stopped the shot, but the back of the vest was torn and the Doron plates fell out. The model 201V was not tested.

BALLISTIC TESTING OF BODY ARMOR

During January, 1971, 23 commercially available body armor units reporting the products of 12 manufacturers were ballistically tested at the Naval Research Laboratory, Washington, D.C.; this was done under the direction of the Law Enforcement Standards Laboratory which the National Bureau of Standards is operating under a grant from the National Institute of Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration, United States Department of Justice. The previously described armor units were among those tested.

The various makes of armor were divided into three main groups:

Group A	–	Rated to resist caliber .38 special
Group B	–	Rated to resist caliber .357 magnum
Group C	–	Rated to resist caliber .30 AP

MANUFACTURER	MODEL	AREA ARMORED FRONT (Square Inches)	AREA ARMORED BACK (Square Inches)	WEIGHT (Pounds)	COST	CONSTRUCTION	PROTECTION CLAIMED	PROTECTION TEST RESULTS	EMPLOYMENT TIME (Seconds) FIRST TRY	EMPLOYMENT TIME (Seconds) SECOND TRY	EMPLOYMENT TIME (Seconds) VEHICLE	BALLISTIC DEFORMATION (Inches) WIDTH x DEPTH ROUND	BALLISTIC DEFORMATION (Inches) WIDTH x DEPTH MINIMUM	BALLISTIC DEFORMATION (Inches) WIDTH x DEPTH MAXIMUM
AGRAMONTE	Lancer	407	484	Front and back–11.6 Groin–1.25- (varies 1.5 with size)	Front and back–$89 Groin–$15	Front, back, and groin–30 layers of ballistic nylon	.357 magnum	Front section failed to stop 2 of 2 rounds .357 magnum L, SP and stopped 13 of 13 .38 special L, MP and 5 of 5 rounds LRHV(R)	8.8	9.0	15.8	.38	0	2 1/4x7/8
AVCO	PA 100	267		Front–3.25 Groin–special order only	Front–$75 Groin–special order only	Front–11 layers GRP Groin–11 layers GRP	.357 magnum	Front section stopped 9 of 10 rounds .357 magnum L and 11 of 11 rounds .38 special L, MP. (First round of .357 magnum penetrated.) In retest, stopped 3 of 3 rounds .357 magnum L.	85.4	15.4	22.0	.357	1x1/4	1x1/4
AVCO	PA 500	318	217	Front and back–36.2 Groin–7	Front and back–$340 Groin–$70	Front, back, and groin–multiple layers GRP plus ceramic.	.30 AP(R)	Front section stopped 3 of 3 rounds .30 APM2(R). Back section stopped 0 of 3 rounds .30 APM2(R).	109.6	24.8	23.4	Not determined		
CABORUNDUM	KT-1	277.5	206.8	Front–16 (med.) Back–19.3 (med.) Groin–6.5 Coccyx–6	Front–$185 Back–$200 Groin–$35 Set plus case–$445 Coccyx–$75	Front and back–Doron (GRP) and ceramic.	.30 AP(R)	Front section stopped 3 of 4 rounds .30 APM2(R). Back section stopped 2 of 4 rounds .30 APM2(R) with rounds 3 and 4 penetrating. Groin section stopped 0 of 1 round .30 APM2(R). Coccyx section stopped 1 of 1 round .30 APM2(R).	77.0	39.2	25.8	Not determined		
DAVIS	6003-1	385 (cloth only)	333 (cloth only)	Front and back–8.6 Groin–1.25	Front and back–$100 Groin–$12.50	Front, back, and groin–12 layers of ballistic nylon.	.38 special	Front section stopped 10 of 10 rounds .38 special L, but only 1 of 3 rounds .38 special MP.	Same design as Model 6003-3			.38	1x1/4	2x3/4
DAVIS	6003-3	182.5	181.5	Front and back–13 Groin–2.25	Front and back–$120 Groin–$15	Front, back, and groin–1 layer steel plus 12 layers ballistic nylon.	.357 magnum	Front section stopped 17 of 17 rounds .357 magnum and 2 of 2 rounds .44 magnum.	11.2	17.2	23.4	.357	0	3x1
DAVIS	6003-5	130	130	Front and back–23 Groin–4.5	Front and back–$140 Groin–$20	Front, back, and groin–12 layers ballistic nylon plus 3 layers of steel.	.357 magnum	Front section stopped 2 of 2 rounds .357 magnum, 2 of 2 rounds .44 magnum, 6 of 6 rounds .30 carbine, MP, and a 12-gauge rifled slug.	Same design as Model 6003-3			.30 carbine	2x1/4	2x1
DAVIS	6007-4	130	130	Front and back–11.5 Groin–3	Front and back–$120 Groin–$15	Front, back, and groin–12 layers ballistic nylon plus 1 layer of steel.	.357 magnum	Front section stopped 16 of 16 rounds .357 magnum L, MP, SP, but only 1 or 4 rounds .44 magnum L.	Same design as Model 6003-3			.357	3/4x1/4	2x1/2
DAVIS	6010-2	395 (cloth only)	355 (cloth only)	Front and back–6.25 Groin–1.75	Front and back–$100 Groin–$12.50	Front, back, and groin–12 layers ballistic nylon plus outer covering of "Shok cloth."	.38 special	Front section stopped 10 of 10 rounds .38 special L and 1 of 4 rounds .38 special MP.	Same design as Model 6003-3			.38	2x3/8	2x3/4
DEFENSOR	V1-A	261	0	Front and groin–3.9	Front and groin–$68	Front and groin–12 layers of ballistic nylon plus 1 Doron (GRP) plate.	.38 special	Front section stopped 10 of 10 rounds .38 special MP, but 0 of 2 rounds .357 magnum.	20.4	46.6	29.8	.38	3x1/4	3x1/4
DEFENSOR	V2-A	261	288	Front, back, and groin–12	Front, back, and groin–$125	Front and back–12 layers of ballistic nylon plus 2 Doron (GRP) plates.	.357 magnum	Front section stopped 15 of 16 rounds .357 magnum L, MP, SP, but failed to stop 1 round .30 carbine MP.	16.4	11.2	37.2	.357	0	2x1/2

Figure 17
BODY ARMOR SUMMARY CHART

MANU-FACTURER	MODEL	AREA ARMORED FRONT (Square Inches)	AREA ARMORED BACK (Square Inches)	WEIGHT (Pounds)	COST	CONSTRUCTION	PROTECTION CLAIMED	PROTECTION TEST RESULTS	EMPLOYMENT TIME (Seconds) FIRST TRY	EMPLOYMENT TIME (Seconds) SECOND TRY	EMPLOYMENT TIME (Seconds) VEHICLE	BALLISTIC DEFORMATION (Inches) WIDTH x DEPTH ROUND	BALLISTIC DEFORMATION (Inches) WIDTH x DEPTH MINIMUM	BALLISTIC DEFORMATION (Inches) WIDTH x DEPTH MAXIMUM
FEDERAL-SPOONER	P	266.5	318	Front, back, and groin–16.5	Front, back, and groin–$150	Front and back–2 overlapping steel plates in nylon pockets plus 3 layers of ballistic nylon.	.357 magnum	Front section stopped 28 of 29 .357 magnum L, MP, SP. Failed to stop a .30 carbine MP round and a 12-gauge rifled slug.	15.6	24.0	44.6	.357	0	1 1/2x1/2
FEDERAL-SPOONER	C (708)	266.5	318	Front and back–12.6 Groin–Special order only	Front and back–$125 Groin–Special order only	Front and back–1 layer of steel plate in nylon pockets plus 3 layers ballistic nylon.	.38 special	Front section stopped 11 of 11 rounds .38 special L, Mp. Failed to stop a .357 magnum MP round.	21.6	16.6	50.4	.38	less than 1/4	less than 1/4
FEDERAL-SPOONER	C (708F)	266.5		Front–5	Front–$63	Front–1 layer of steel plate in nylon pockets.	.38 special	Front section stopped 10 of 10 rounds .38 special L, MP. Failed to stop a .357 magnum MP.	12.6	12.0	20.0	.38	0	0
GOEC	217	125	125	Front and back–9.25 Groin–2.3	Front and back–$120 Groin–$15	Front and groin–1 layer of steel plus 10 layers of ballistic nylon. Back–1 layer of steel plus 7 layers of ballistic nylon.	.357 magnum	Front section stopped 10 of 10 rounds .357 magnum L, MP, SP. Back section stopped 12 of 12 rounds .357 magnum L, MP, SP.	11.2	22.6	23.2	.357	1/2x1/4	2 1/8x1
GOEC	120	125	0 (cloth only)	Front and back–8.5 Groin–2.3	Front and back–$105 Groin–$15	Front and groin–1 layer of steel plus 10 layers of ballistic nylon. Back–10 layers of ballistic nylon only.	.357 magnum (Front only)	Front section stopped 13 of 13 rounds .357 magnum L, MP, SP. Groin section stopped 2 of 2 rounds .357 magnum L.	20.4	24.8	61.4	.357	1 1/4x3/8	3x7/8
GOEC	434C	125	125	Front and back–16 Groin–4	Front and back–$140 Groin–$20	Front, back, and groin–3 layers of steel plus 10 layers ballistic nylon.	.30 carbine (R) .357 magnum	Front section stopped 3 of 3 rounds .30 carbine MP, but only 3 of 4 rounds .30 carbine SP. Also stopped 5 of 5 rounds .357 magnum L, MP, SP.	43.4	23.0	31.2	.30 carbine	1 3/4x1/2	2 1/4x1
IMPERIAL	Supershield	226	0	Front–4	Prototype	Polycarbonate resin.	.38 special	Front section stopped 11 of 11 .38 special L, MP and 3 of 3 rounds .22 LRHV(P). Failed to stop a .357 magnum roundand 2 .22 LRHV(R).	6.2	35.4	56.4	.38	less than 1/4	less than 1/4
ROLLS ROYCE- Colt	Security	230.5	141	Front and back–8.88 Groin–2.43	Front, back, and groin–$200	Front, back, and groin–10 layers of compressed GRP.	.357 magnum	Front section stopped 13 of 13 rounds .357 magnum L, MP, SP, and 3 of 4 rounds .44 magnum L. Failed to stop a .30 carbine MP round and a 12-gauge rifled slug.	12	12	9.2	.357	0	o
SKYLINE	SK 426328	236		Front and groin–7.3	Prototype	GRP and nylon carrier.	.44 magnum	Front section stopped 10 of 10 rounds .44 magnum L, 1 round .357 magnum and a 12-gauge rifled slug.	Carrier not supplied			.44	4x3/4	4x3/4
TABOR-Colt	Tabor	301.5	400	Front and back–15 Groin–1	Front and groin–$88 Back–$88	GRP	.38 special	Front section stopped 10 of 10 rounds .38 special MP and 3 of 3 rounds .22 LRHV(R). Failed to stop 1 round .357 magnum MP.	20.8	16.6	34.8	.38	0	0
TRANSCON	401 V	310	281	Front and back–14.2 Groin–3	Front and back–$69 Groin–$30	Front, back, and groin–2 Doron (GRP) plates and ballistic nylon.	.357 magnum	Front section stopped 12 of 13 rounds .357 magnum L, MP, SP, but failed to stop 1 round .30 carbine MP.	10	20	41.4	.357	2x3/4	2 1/4x1 1/2

Abbreviations: AP = Armor piercing; MP = Metal point; SP = Soft point; L = Lead; R = Rifle; P = Pistol; GRP = Glass reinforced plastic; LRHV = Long rifle, high velocity

Figure 17 (Continued)
BODY ARMOR SUMMARY CHART

Group A included the following brands and models of armor:

Brand		Model
DAVIS	–	6003-1
DAVIS	–	6010-2
DEFENSOR	–	V1-A
FEDERAL-SPOONER	–	C (708)
FEDERAL-SPOONER	–	C (708 F)
GOEC	–	120 (Back)
IMPERIAL	–	Supershield
TABOR-Colt	–	Tabor Vest

Group B included the following brands and models of armor:

Brand		Model
AGRAMONTE	–	Lancer
AVCO	–	PA 100
DAVIS	–	6003-3
DAVIS	–	6007-4
DAVIS	–	6003-5
DEFENSOR	–	V2-A
FEDERAL-SPOONER	–	P
GOEC	–	217
GOEC	–	120 (Front)
GOEC	–	434C
ROLLS ROYCE-Colt	–	Security
SKYLINE	–	SK 426328
TRANSCON	–	401 V

Group C included the following brands and models of armor:

Brand		Model
AVCO	–	PA 500
CARBORUNDUM	–	KT-1

Test Procedure

Each piece of armor tested was placed on a target rack and held in place, normal to the trajectory of the bullet, by C-clamps. A 3-by 6-by 6-inch block of modeling clay, at room temperature, was placed behind the armor and in immediate contact with it. The purpose of the modeling clay was to record the ballistic deformation of the armor in the event the impacting round deformed but did not penetrate the armor. The target array was backed up with a metal deflecting screen designed to stop rounds which penetrated both the armor and the modeling clay.

The weapon was placed in a stand, where it was held firmly in place and fired by means of a lanyard from an adjoining corridor. The test equipment is illustrated in figure 18.

Velocity of Bullets

For the firing of the armor tests cited in this report, chronographs were used for velocity determination. Two velocity screens separated by a distance of two feet were used to start and stop a 1.6-megahertz time interval counter. In most instances, two interval counters were used to provide a check on counter response. The velocity screens consisted of a silver line network on

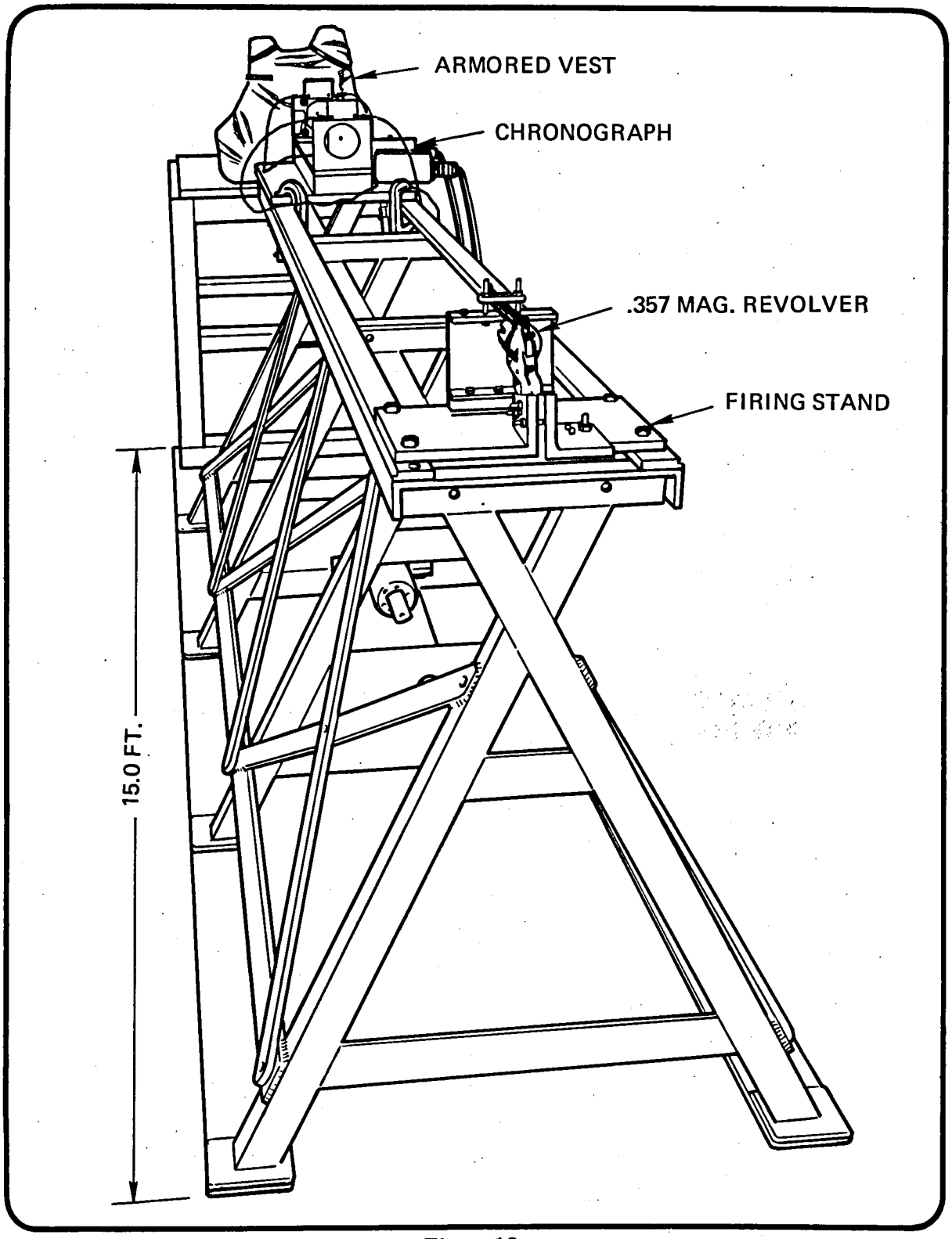

Figure 18
TESTING STAND

approximately .004-inch-thick paper. The projectile passing through a screen breaks a circuit which generates a pulse that starts or stops the interval counter. The circuit between the velocity screens and the interval counter includes matched lines from start and stop screens.

Velocities recorded during tests were the measured velocities and represent the average velocity between the two velocity screens. Such velocities are normally referred to as instrument velocities. The velocity at impact with the target is lower than the instrument velocity by the amount of air drag over the distance from the midpoint between the screens to the target, which was approximately four feet for these tests.

Penetration Data

The results of the ballistic testing (penetration) are summarized in figures 19, 20 and 21. The following ammunition abbreviations are used in all three figures:

LRHV	–	Long rifle, high velocity
L	–	Lead
MP	–	Metal point
SP	–	Soft point
AP	–	Armor piercing
L(P)	–	Lead, fired from pistol
L(R)	–	Lead, fired from rifle
RS	–	Rifled shotgun slug
Spec	–	Special
Mag	–	Magnum
Carb	–	Carbine

It would appear that the following is the order of penetration power of the ammunition used in the test series. Further tests to confirm this order should be conducted.

Cal. .22 LR (P) < Cal. .38 < Cal. .22 LR (R) < #4 shot < #00 buckshot < Cal. 357 magnum < 12-gauge rifled slug < Cal. .44 magnum < Cal. .30 carbine SP < Cal. .30 armor piercing (R)

Ballistic Deformation

In addition to the fact that a given round may or may not penetrate a piece of armor, it is important to learn whether the impact of a bullet will cause the armor to deform to such an extent, whether permanently or transitorily, as to cause injury to the wearer. In the tests reported herein, it was found that the ballistic deformation ranged from ¼ inch to 1½ inch, depending on the armor, the caliber of the weapon, and the type of round fired. Should some armor be worn without providing an offset in the form of clothing worn under the armor, an impact, depending on its location, could cause an injury ranging in seriousness from a heavy bruise to a fractured rib or worse. In addition, the effects of hydraulic shock must be taken into account, although quantitative experiments in this field have not been conducted.

To combat the effects of deformation, the U.S. Army has designed a "tension web" which causes rigid armor to stand away from immediate contact with the body, thereby providing the offset mentioned above. In addition, the tension web allows air to circulate behind the armor, thereby reducing the amount of unevaporated sweat and permitting longer wearing of armor under hot, humid conditions.

Brand	Model	Ballistic Material	Bullet Cal.	Type	Number of Hits	Number of Stops
DAVIS	6003-1	Nylon 12 layer	.22 LRHV	L(R)	3	1
			.38 Spec	L	10	10
			.38 Spec	MP	3	1
			12 Gauge	00 Buck	9 Pellets	6
DAVIS	6010-2	Nylon 12 layer	.22 LRHV	L(R)	2	2
			.38 Spec	L	10	10
			.38 Spec	MP	4	1
			12 Gauge	00 Buck	9 Pellets	6
			12 Gauge	#4	1	1
DEFENSOR	V1-A	1 Doron (GRP)	.38 Spec	MP	10	10
			.357 Mag	L	2	0
			12 Gauge	00 Buck	2	0
			12 Gauge	#4	1	1
FEDERAL-SPOONER	C	Steel	.22 LRHV	L(R)	5	5
			.38 Spec	L, MP	11	11
			.357 Mag	MP	1	0
			12 Gauge	00 Buck	1	0
FEDERAL-SPOONER	708F	Steel	.38 Spec	L, MP	10	10
			.357 Mag	MP	1	0
GOEC	120 (Back)	10 Nylon	.22 LRHV	L(R)	5	2
			12 Gauge	00 Buck	1	0
			12 Gauge	#4	1	1
IMPERIAL	Supershield	Poly-carbonate	.22 LRHV	L(P)	3	3
			.22 LRHV	L(R)	2	0
			.38 Spec	L, MP	11	11
			.357 Mag	MP	1	0
TABOR-Colt		GRP	.22 LRHV	L(R)	3	3
			.38 Spec	MP	10	10
			.357 Mag	MP	1	0
			12 Gauge	00 Buck	9 Pellets	8

Figure 19
BALLISTIC RESISTANCE OF ARMORED VESTS RATED TO RESIST .38 SPECIAL

Brand	Model	Ballistic Material	Bullet Cal.	Type	Number of Hits	Number of Stops
AGRAMONTE	Lancer	Nylon	.22 LRHV	L(P)	3	3
			.22 LRHV	L(R)	5	5
			.38 Spec	L, MP	13	13
			.357 Mag	L, SP	2	0
			.41 Mag	SP	1	0
			12 Gauge	00 Buck	9 Pellets	8
AVCO	PA 100	GRP (11 layer)	.22 LRHV	L(P)	2	2
			.38 Spec	L, MP	11	11
			.357 Mag	L	10 First Shot Penetrated	9
			.357 Mag	L	3	3
DAVIS	6003-3	1 Steel+ 12 Nylon	.357 Mag	L, MP, SP	17	17
			.41 Mag	SP	1	1
			.44 Mag	L	2	2
			.30 Carb	MP	1	0
DAVIS	6007-4	1 Steel+ 12 Nylon	.357 Mag	L, MP, SP	16	16
			.44 Mag	L	4	1
DAVIS	6003-5	3 Steel+ 12 Nylon	.357 Mag	L, MP	2	2
			.44 Mag	L	2	2
			.30 Carb	MP	6	6
			.30 Carb	SP	9	6
			12 Gauge	RS	1	1
DEFENSOR	V2-A	2 Doron (GRP)	.357 Mag	L, MP, SP	16	15
			.30 Carb	MP	1	0
			12 Gauge	00 Buck	1	1
FEDERAL-SPOONER	P	Steel	.357 Mag	L, MP, SP	29	28
			.44 Mag	L	7	6
			.30 Carb	MP	1	0
			12 Gauge	RS	1	0

Figure 20
BALLISTIC RESISTANCE OF ARMORED VESTS RATED TO RESIST .357 MAGNUM

Brand	Model	Ballistic Material	Bullet Cal.	Bullet Type	Number of Hits	Number of Stops
GOEC	217 Front	1 Steel+ 10 Nylon	.357 Mag	L, MP SP	10	10
			.30 Carb	MP	1	0
			12 Gauge	RS	1	0
	Back	1 Steel+ 7 Nylon	.357 Mag	L, MP, SP	12	12
GOEC	120 Front	1 Steel+ 10 Nylon	.357 Mag	L, MP, SP	13	13
			12 Gauge	RS	1	0
	Groin	1 Steel+ 10 Nylon	.357 Mag	L	2	2
GOEC	434C	3 Steel+ 10 Nylon	.357 Mag	L, MP, SP	5	5
			.41 Mag	L, SP	2	2
			.44 Mag	L	2	2
			12 Gauge	RS	1	1
			.30 Carb	MP	3	3
			.30 Carb	SP	4	3
ROLLS ROYCE-Colt	Security	GRP	.357 Mag	L, MP, SP	13	13
			.44 Mag	L	4	3
			.30 Carb	MP	1	0
			12 Gauge	RS	1	0
SKYLINE	SK 426328	GRP	.357 Mag	L	1	1
			.44 Mag	L	10	10
			12 Gauge	RS	1	1
TRANSCON	401V	2 Doron (GRP)	.357 Mag	L	10	9
			.357 Mag	MP, SP	3	3
			.30 Carb	MP	1	0
			12 Gauge	00 Buck	1	1

Figure 20 (Continued)
BALLISTIC RESISTANCE OF ARMORED VESTS RATED TO RESIST .357 MAGNUM

Brand	Model	Ballistic Material	Bullet Cal.	Type	Number of Hits	Number of Stops
AVCO	PA 500	$Al_2 O_3$+	.30(R)	APM2	3 Front	3
		GRP	.30(R)	APM2	3 Back	0*
CARBORUNDUM	KT-1	Doron (GRP) & Ceramic	.30(R)	APM2	1 Groin	0
			.30(R)	APM2	4 Front (#4 Failed)	3
			.30(R)	APM2	1 Coccyx	1
			.30(R)	APM2	4 Back (#3 & 4 Failed)	2

Figure 21
BALLISTIC RESISTANCE OF ARMORED VESTS RATED TO RESIST .30 AP

*Special note on Ceramic Armor Testing. Two makes of ceramic armor were employed in the tests reported herein, AVCO PA 500 and Carborundum KT-1 Armor. Both brands proved less than satisfactory on initial testing, AVCO PA 500 failing in the back section, where none of three caliber .30 armor piercing rounds were stopped and Carborundum KT-1 Armor in the groin section where an initial caliber .30 armor piercing round penetrated.

In the instance of AVCO PA 500 Armor, a claim was made by the manufacturer, after examination of the armor subsequent to firing, that the armor had been dropped, or otherwise mishandled prior to the test, so that first round impermability was not maintained; consequently, the manufacturer asked for a retest of PA 500 armor at his plant at Lowell, Massachusetts. Armor was randomly selected from the AVCO production line and subjected to caliber .30 firing on the AVCO range. The retest proved satisfactory, with the PA 500 unit stopping three of three caliber .30 armor piercing rounds fired at 2850 feet per second.

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