DATA PACKAGE FOR
THE INDUSTRY/USER SYMPOSIUM
ON LIGHTWEIGHT BODY ARMOR

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Law Enforcement Development Group
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V-87890 - Industry/User Symposium on Lightweight Body Armor

The National Institute of Law Enforcement and Criminal Justice through the Advanced Technology Division is sponsoring a Lightweight Body Armor Development symposium. This chart presents an outline of the information to be presented.

In 1972 a discussion between personnel of the Land Warfare Laboratory and the Institute led to the consideration of a new tire cord material as a possible basis for an improved ballistic material. Preliminary tests of the material indicated that it had the desired characteristics, e. g., lightweight, high strength, low elasticity, high impact resistance, and flame resistance. Comparative tests were made with currently available materials and Kevlar demonstrated superior ballistic non-penetration characteristics. At this time a team of government and industry was formed to pursue the development of lightweight, inconspicuous, continuous wear, and limited threat protection garments.

This symposium will make available to industry and the user the data and information derived from the development and test activity. This constitutes a formal part of the technology transfer process from the government to industry.

V-87890

Industry/User Symposium on Lightweight Body Armor

	CONTENT
• INTRODUCTION	PURPOSE OF PRESENTATION, LEAA ROLE
• PROGRAM GOALS	KEY OBJECTIVES, PROBLEM STATEMENT, ISSUES
• OPERATIONAL REQUIREMENTS	ASSAULT DATA, THREAT SURVEY
• TECHNICAL EVALUATIONS	MATERIALS, PHENOMENOLOGY, BLUNT TRAUMA LOADING
• PROTOTYPE GARMENTS	GARMENT DESIGNS, TEST RESULTS
• FIELD EVALUATION PLANNING	TEST OBJECTIVES, PRODUCTION CONTRACTS
• FUTURE EFFORTS	FURTHER INVESTIGATIONS, TEST STANDARDS
• QUESTIONS AND DISCUSSION	

V-87898 R1 - Lightweight Body Armor Program Objectives

The Lightweight Body Armor program objectives are based on the requirement to reduce handgun-induced fatalities to law enforcement personnel. Since 1960 the number of serious injuries and fatalities from guns or knives has been increasing at a high rate (approximately 15% per year); therefore, a need exists for a ballistic-resistant garment that can provide protection and be worn in comfort.

The development program is directed toward demonstrating and verifying the technology base for the use of lightweight materials in this application. This entails the development and testing of the basic materials and their physical characteristics, the demonstration through medical testing that the blunt trauma effect is nonlethal and acceptable, the demonstration through the fabrication and test of prototype garments that the material can be incorporated into protective garments, and the transfer of the developed technology to the manufacturers and users.

Lightweight Body Armor Program Objectives

- DEVELOP LIGHTWEIGHT, INCONSPICUOUS GARMENTS FOR COMMON HANDGUN PROTECTION WHICH COULD BE WORN ON ROUTINE DUTY BASED UPON:
  - INCREASING PUBLIC FIGURE AND LAW ENFORCEMENT ASSAULT RATES
  - LIMITED THREAT RATIONALE (protect against statistically significant threat)
  - NEW MATERIALS AVAILABILITY
- DEMONSTRATE GARMENT PROTECTION AND USER ACCEPTANCE
- PROVIDE TECHNOLOGY RESULTS TO INDUSTRY AND USERS

GARMENT DESIGN CHARACTERISTICS

- INCONSPICUOUS, CONTINUOUS WEAR
- FULL MOBILITY
- PROTECT AGAINST 80-90% OF ALL HANDGUNS
- NO BALLISTIC PENETRATION
- NO INCAPACITATION

V-87900 R1 - Program Participants

The National Institute of Law Enforcement and Criminal Justice Lightweight Body Armor Program has been supported by a broad spectrum of government agencies and industry. The Advanced Technology Division within the Institute has responsibility and authority for program control and direction.

The majority of the detailed material, ballistic, and medical testing and garment development activities have been conducted by Edgewood Arsenal and Natick Laboratories; the Land Warfare Laboratories were responsible for Army program management.

The participation of the National Bureau of Standards is summarized on the chart and will be discussed in detail later.

The Aerospace Corporation provided technical support, program integration, and subcontracting support to the Institute. This entails a limited amount of ballistic, environmental, and laboratory testing, system modeling, and the planning and implementation of the field test programs.

MITRE was originally responsible for operational analysis and developed the body armor operational requirements in conjunction with the National Bureau of Standards.

Industry has supported the program in developing the yarn, weaving the material, and designing and fabricating the garments.

Various law enforcement agencies have contributed to the program both in making recommendations concerning garment types and styles, and in evaluating prototype garments under operational conditions.

Program Participants

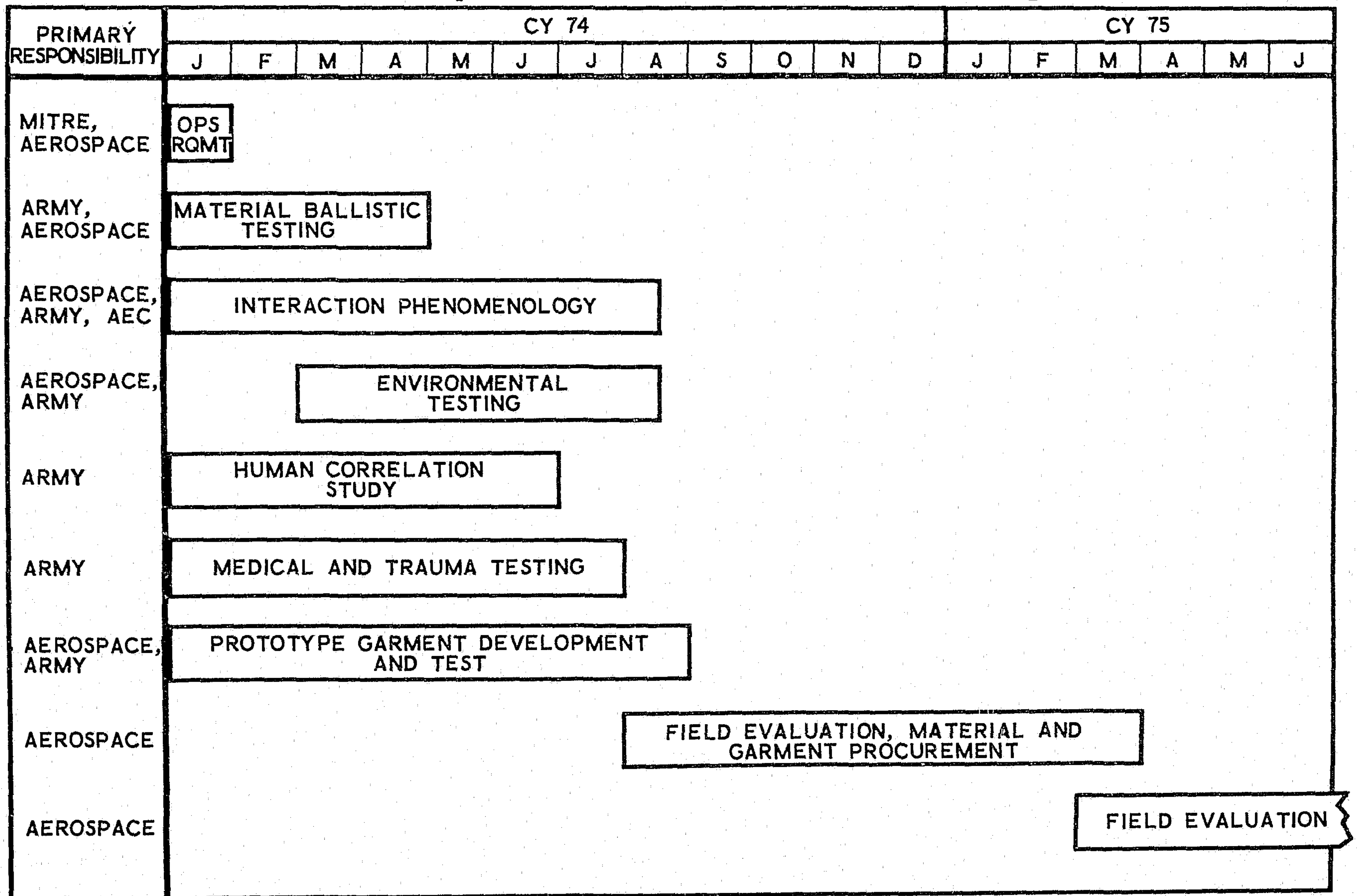
- LEAA (National Institute of Law Enforcement and Criminal Justice)
  - PROGRAM FUNDING, INITIATION, GUIDANCE
- OTHER GOVERNMENT AGENCIES
  - ARMY (Edgewood Arsenal and Natick Labs) MATERIALS TESTING, MEDICAL TESTING, GARMENT DEVELOPMENT
- NATIONAL BUREAU OF STANDARDS - FUTURE TRAUMA GUIDELINES AND TEST STANDARDS
  - AEC LABORATORIES - BALLISTIC TESTING
- THE AEROSPACE CORPORATION
  - PROGRAM INTEGRATION, DEVELOPMENT SUBCONTRACTS, LABORATORY TESTING, FIELD EVALUATION
- MITRE
  - PRELIMINARY OPERATIONAL ANALYSIS
- INDUSTRY
  - MATERIAL, CLOTH, AND PROTOTYPE GARMENT DESIGNS
- LAW ENFORCEMENT GROUPS (various departments)
  - GARMENT DESIGN INPUTS, PROTOTYPE TESTING

V-87899 R1 - Development and Test Phasing

The phasing is shown for the major activities in developing and testing lightweight body armor. The major effort in the program, which has been under way for approximately 2 years, has been directed toward optimizing the material, weave, and number of plies required to ballistically defeat the limited threat. In addition, testing has been completed to assess the effect of the blunt trauma phenomena behind the impact point.

The Army Laboratories and The Aerospace Corporation have developed different types and styles of prototype garments. These have been evaluated both within the program structure and by law enforcement agencies in the Pilot Wearability Program.

Development and Test Phasing



V-84476 R2 - Potential Program Objectives

At the initiation of a program a set of goals is established to be attained over a given period of time. During the period of equipment development every effort is made to attain these goals through development and testing. Because of limitations imposed by time, number of hardware elements available, test facilities, etc., certain objectives are unattainable. It is then necessary to plan and execute a field evaluation test program to demonstrate those program objectives that could not be shown in development testing.

Those program objectives that are unobtainable during development are shown, and a number of potential test objectives are listed which would satisfy these overall objectives. The problem is to investigate each of these test objectives in terms of program impact and to perform the tradeoff between the desire to demonstrate the test objective and the cost and schedule impact associated with it.

Potential Program Objectives

UNATTAINABLE DURING DEVELOPMENT

- BLUNT TRAUMA EFFECT ON THE HUMAN BODY
- ACCEPTABILITY OF INCONSPICUOUS BODY ARMOR CONCEPT TO LAW ENFORCEMENT AGENCIES AND PERSONNEL
- WEARABILITY OF THE GARMENTS UNDER A VARIETY OF WEATHER AND OPERATIONAL CONDITIONS
- REACTION OF PUBLIC AND CRIMINAL ELEMENTS TO PROTECTIVE GARMENTS
- ABILITY TO COST EFFECTIVELY PRODUCE QUALITY GARMENTS IN LARGE NUMBERS

POTENTIAL TEST OBJECTIVES

- DETERMINE BIOLOGICAL CORRELATION ON KEY ORGANS BETWEEN BALLISTIC ANIMAL TESTS AND ASSAULTED OFFICERS
- DEMONSTRATE THE PREDICTED PROTECTIVE FEATURE BY STATISTICALLY PREDICTED ASSAULT ON LAW ENFORCEMENT PERSONNEL
- OBTAIN DATA FROM A NUMBER OF AGENCIES ON ATTITUDES AND LEGAL PRECEDENCE WITH RESPECT TO GARMENTS
- DETERMINE DEPARTMENT ATTITUDE TOWARD CONTINUOUS WEAR PROTECTIVE GARMENTS WITH RESPECT TO CRIMINAL AND PUBLIC REACTION
- OBTAIN DATA ON THE DEGREE OF INCONSPICUOUS APPEARANCE OF THE GARMENTS UNDER ACTUAL USE CONDITIONS
- OBTAIN DATA ON THE PSYCHOLOGICAL RESPONSES SUCH AS INCREASED AGGRESSIVENESS OF POLICE OFFICERS WHILE WEARING BODY ARMOR
- EVALUATE THE COMFORT OF THE PROTECTIVE GARMENTS IN SUMMER AND WINTER CONDITIONS
- DETERMINE THE HINDRANCE LIMITATIONS OF GARMENTS UNDER OPERATIONAL CONDITIONS
- OBTAIN DATA ON THE WEAR DEGRADATION OF GARMENTS WITH BALLISTIC MATERIAL INCORPORATED
- OBTAIN DATA ON CHANGES IN POLICE ASSAULT TACTICS
- OBTAIN INTERVIEW DATA ON THE REACTION OF A CROSS SECTION OF THE PUBLIC AND CIVIC OFFICIALS TO IMPROVED PROTECTIVE ARMOR
- VERIFY THE ABILITY OF FABRIC WEAVERS TO MASS PRODUCE FABRIC TO RIGID QUALITY CONTROL SPECIFICATIONS
- OBTAIN DATA ON THE ABILITY OF A VARIETY OF UNIFORM/ARMOR FABRICATORS TO MASS PRODUCE QUALITY GARMENTS

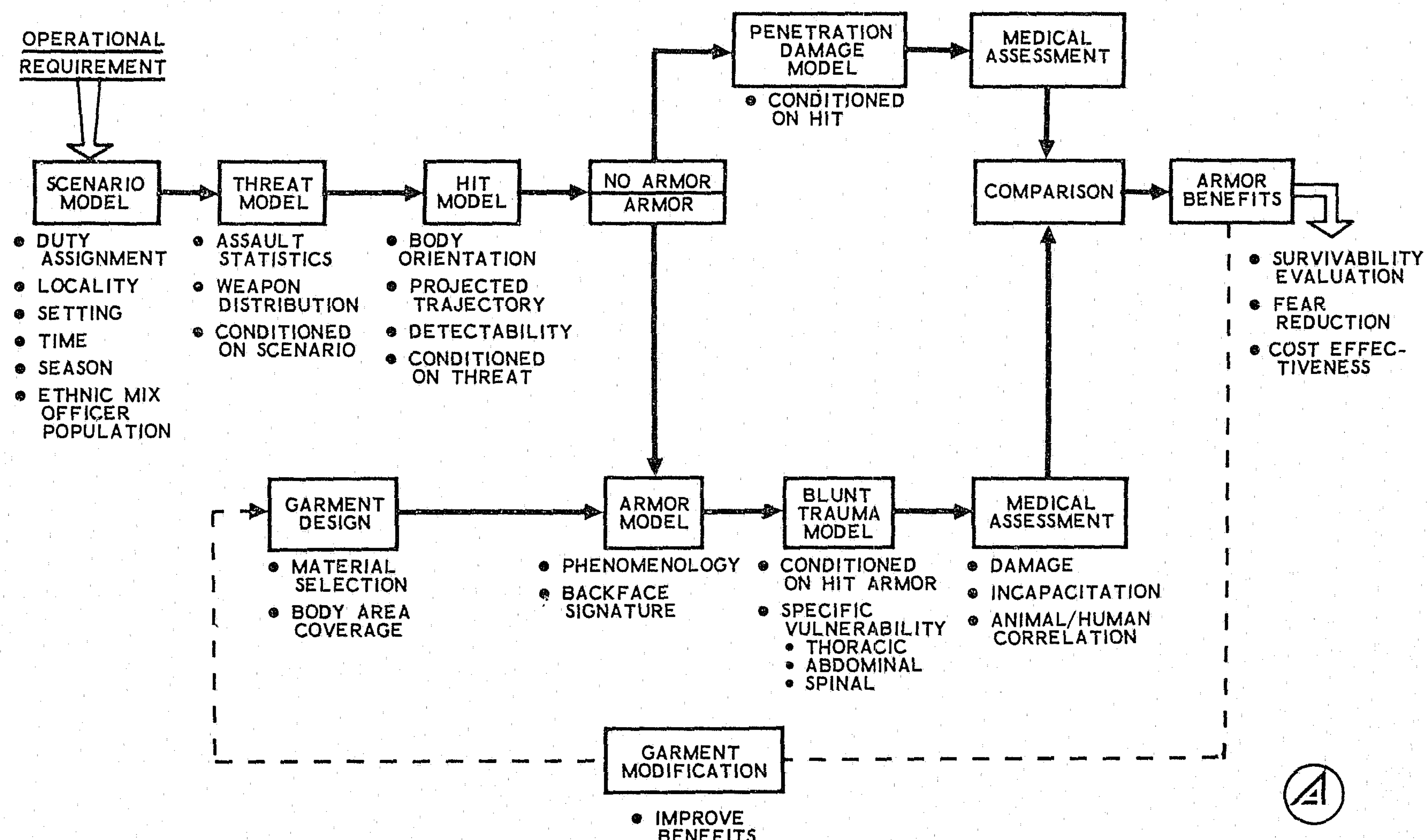
V-85295 - Operational System Model

The operational model shown is a system model in that the entire sequence of events is connected in a cause and effect way proceeding logically from an officer's operational requirement to possible benefits arising from an assessment of his medical condition as a result of an attack. It is a probabilistic model in that the outcome of each module (e.g., threat model, hit model, blunt trauma model) is conditioned on, or dependent upon, the situation existing at the input to that module.

The end result of this model is a comparison of the injuries suffered by an individual not wearing armor with those received while wearing armor. Criteria for a meaningful comparison include survivability, dollars saved in retraining and medical expense, and reduction in the level of fear attending dangerous assignments.

Some of the modules are well defined and quantified; however, others remain to be more fully developed. Much of this development will be aided by the results of operational field testing and evaluation.

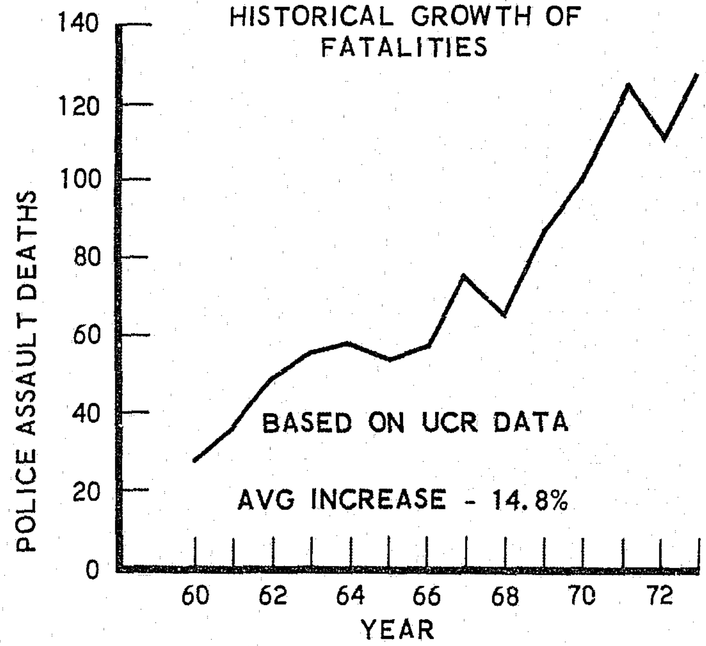
Operational System Model

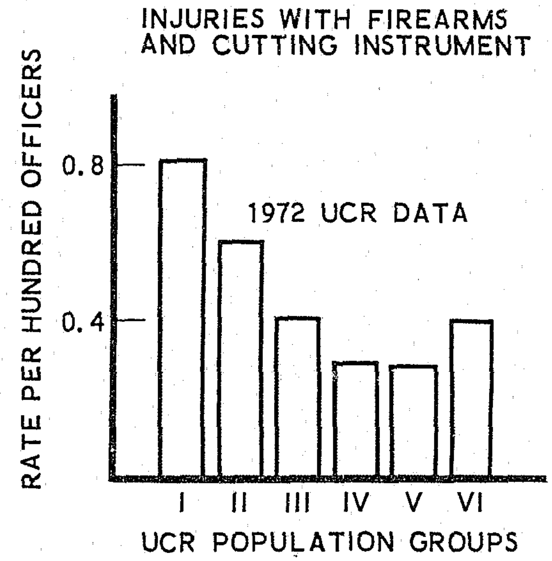


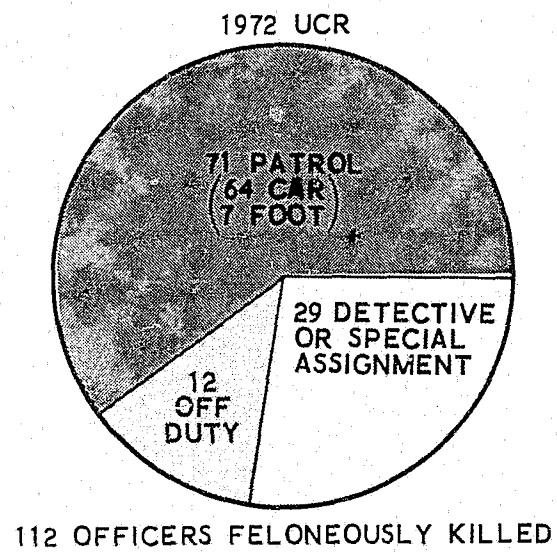
V-83505 R3 - Police Assault Data

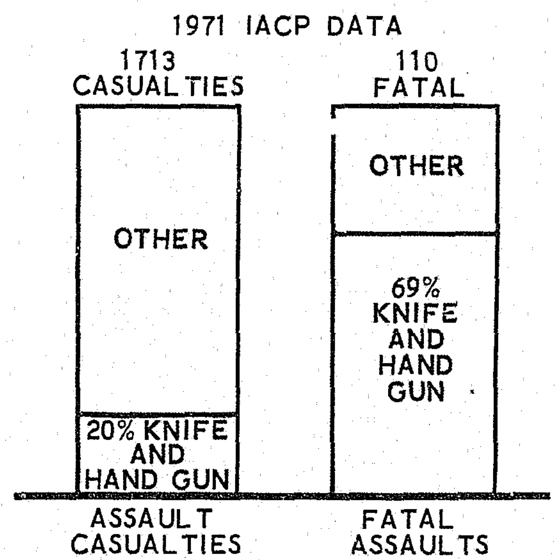
This summary of national police data highlights the criticality of assaults on law enforcement personnel and provides a reference for the requirements for protective garments. Since it is not feasible to obtain detailed statistics from every metropolitan area, the major data sources upon which equipment needs are based are the FBI Uniform Crime Reports (UCR) and information provided by the International Association of Chiefs of Police (IACP). These data show officer fatalities are increasing at an alarming rate, the highest assault rates occur in the larger cities, the uniformed patrol officers have the most fatalities (the detectives or special assignment officers probably have the highest rate), and that knives or handguns are used in the highest percentage of fatal assaults. If the causes of fatal assaults can not be reduced, then continuous wear protection would be highly desirable.

Police Assault Data



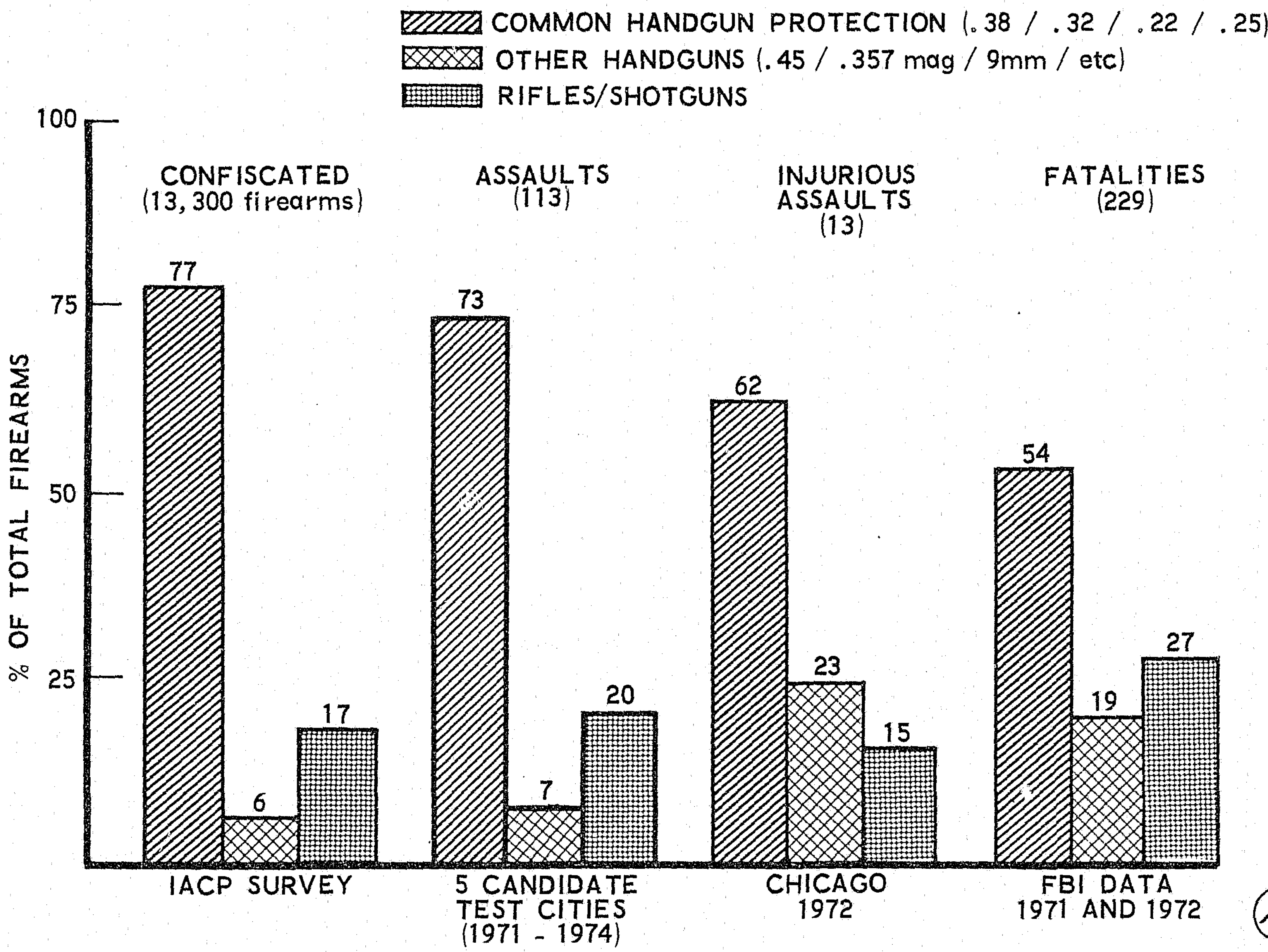






Since current technology would not permit development of a lightweight, inconspicuous, continuous wear garment that would protect against all threats, the problem was to determine a reasonable level of protection. It was recognized that an absolute determination of the threat was impossible; therefore, several independent approaches were made to determine the type of weapons available or used against law enforcement personnel. The results are shown for the different approaches. The weapons were separated into three groups (e.g., common handguns, high-energy handguns, and rifles/shotguns), and the common handguns predominated the statistics for all four categories measured. As expected, the fatalities from the high-energy handguns and shotguns/rifles represented a higher percentage of the total than in the other two assault categories. Since the common handgun group caused more than one-half the fatalities, it was adopted as the design goal for the garments. This resulted in a garment designed to provide protection against this limited threat.

Summary of Firearm Threat Data



V-88063 - Additional Assault Data

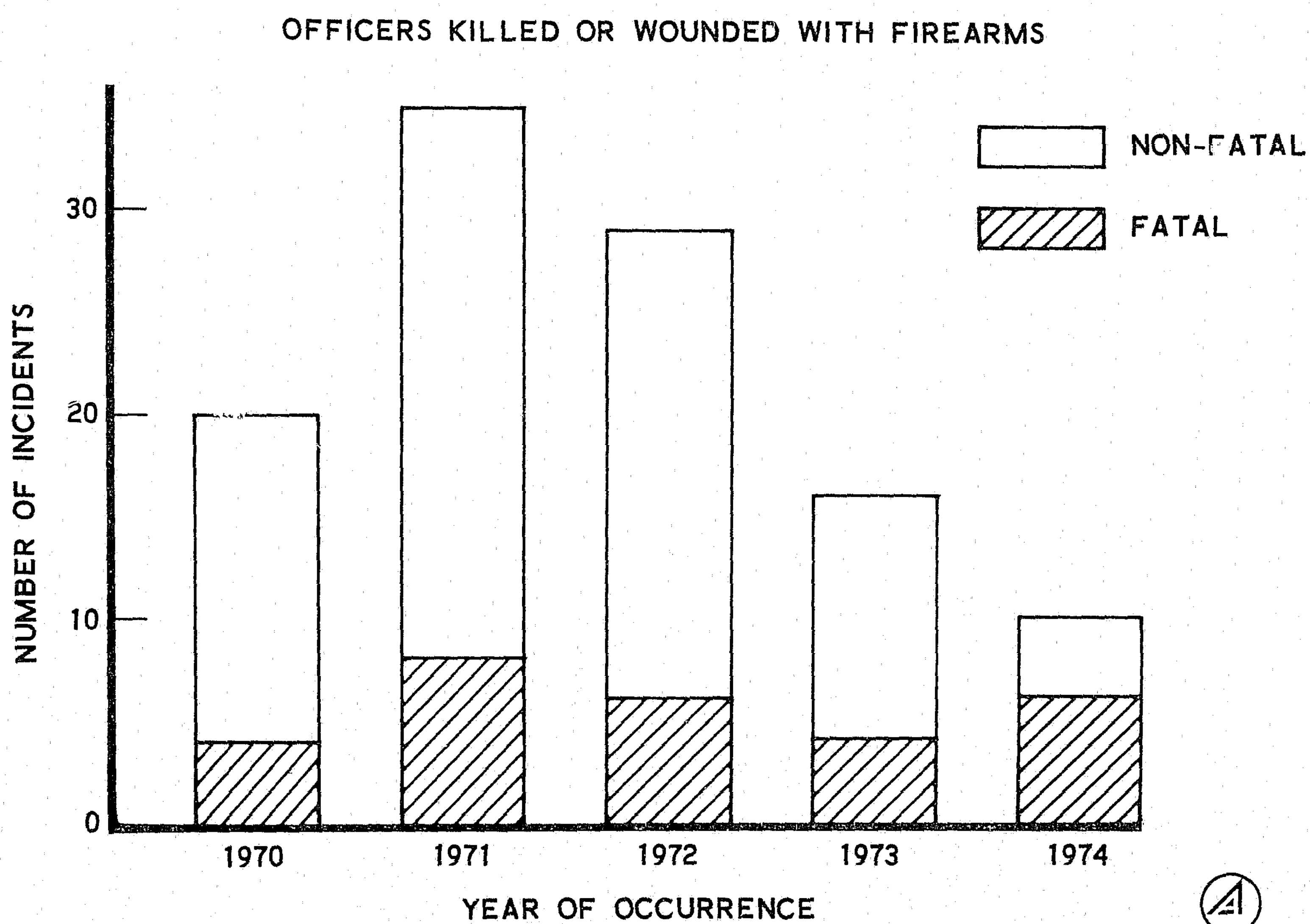
In planning the field evaluation test program, cities throughout the country were visited and data were requested on assaults on police officers. The main purpose of the data was to assist in the city selection process for the field evaluation program and detailed test planning; however, in some cases these data could be compared with those previously obtained. The information on the facing chart was obtained from one of the cities visited. It indicates that over 80% of the officers killed or wounded were assaulted with handguns.

Although the data on officer assaults from individual cities vary considerably, on the average more than 60% were with handguns with an energy of a .38 caliber or less. However, one southwest city reported that 21 of 45 assaults were with shotguns/rifles.

Recent data have reinforced the position that common handguns are used in the majority of officer assaults.

Additional Assault Data

V-88063



V-88064 R1 - Confiscated Weapons Data

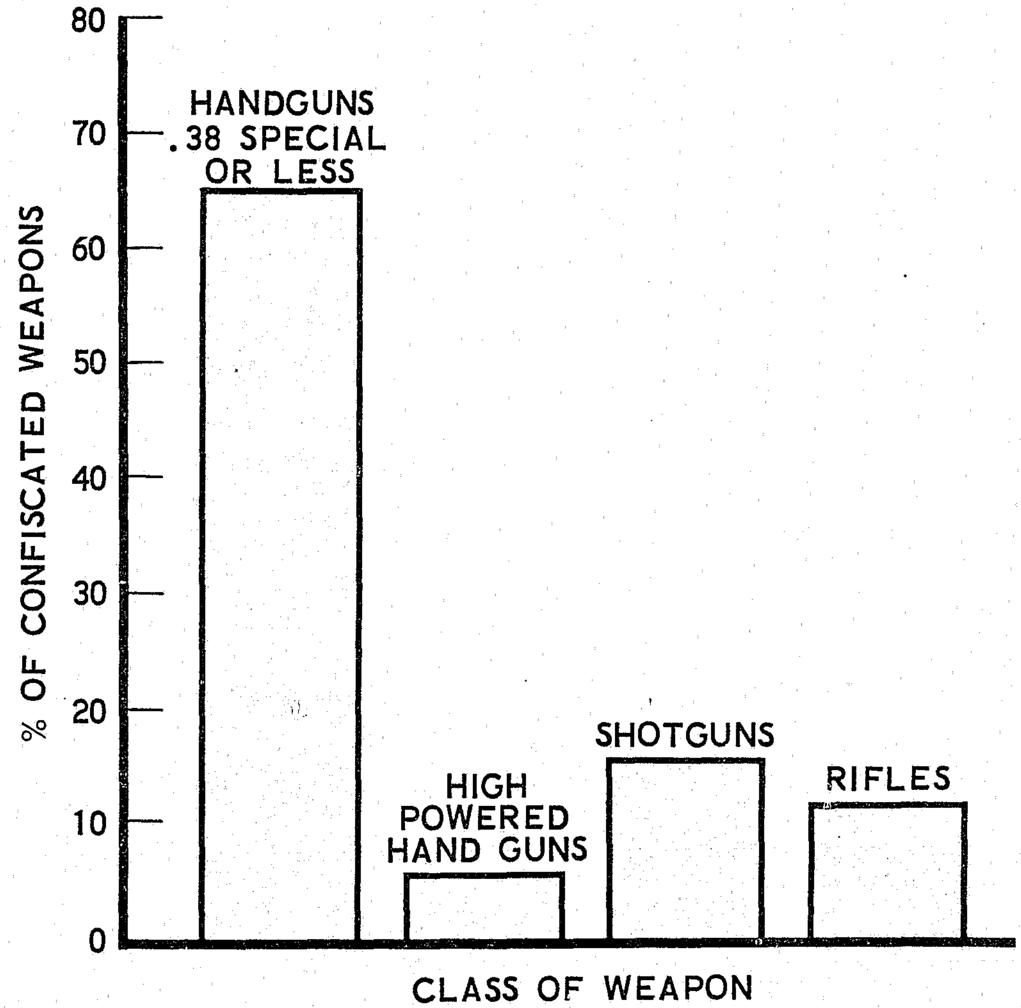
While a previous chart summarized firearm threat data, this one presents a summary of almost 3000 weapons confiscated in a city during one year (1973). These data tend to substantiate the information available for the 1971-1972 period. Of the weapons confiscated, 1966 were handguns, and 1812 of these (or 92%) were in the common handgun group.

Although the specific numbers and percentages vary among cities, the general trend has been consistent for all data reviewed. Some bias will be evident in these types of data in that carrying handguns is unlawful in many cities and states; hence, more handguns would be confiscated than long arms.

Confiscated Weapons Data

1973 - 2769 WEAPONS

• COMMON HANDGUNS		
.22 cal		528
.25 cal		218
.32 cal		317
.380 cal		31
.7.65 mm		24
6.35 mm		9
.38 cal		685
	TOTAL	1812
• OTHER HANDGUNS		
.357 mag		43
.45 cal		42
9 mm		50
.44 cal		12
.41 cal		7
	TOTAL	154
• SHOTGUNS		
ALL GUAGES		455
• RIFLES		
LOW POWER (.22 and .30 Carbine)		271
HIGHPOWER		74
• MISCELLANEOUS		3

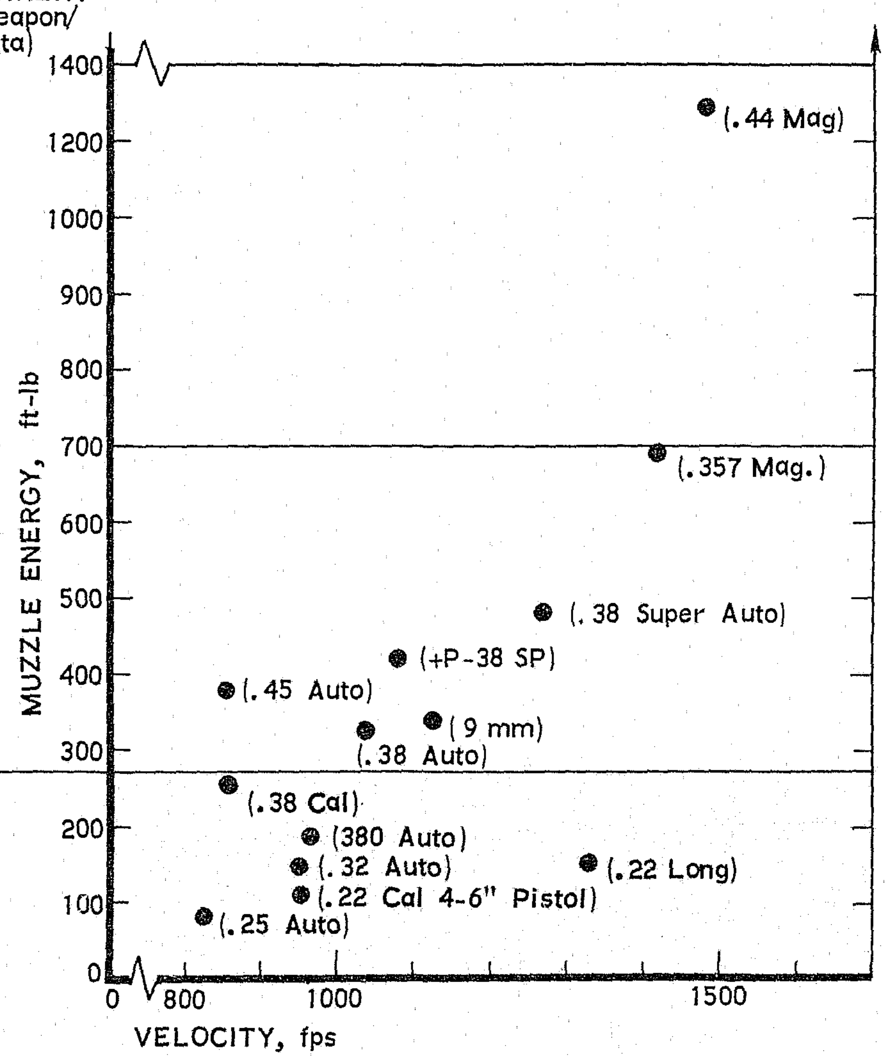


V-60257 R2 - Ballistic Energy Distributions

This chart shows that the common handguns, which constitute the greatest estimated threat, have low muzzle energy. The garments are designed to provide protection against the threat of this group of weapons.

Ballistic Energy Distributions

GENERAL WEAPON TYPE (NBS Standard Groupings)	ESTIMATED THREAT (Confiscated Weapon/ Assault Data)
.30-06 AP .41 Mag .44 Mag .30 Carbine .12 Gauge RS	5 - 20%
.357 Mag 9 mm Luger .45 Colt 12 Gauge 00 BK	5 - 20%
.22 Cal 4"-6" Pistol .22 Long Rifle .38 Special .25 Colt .32 Colt	70 - 90%



V-61579 R2 - Technical Parameters

This chart shows the four major parameters which must be considered in evaluating the effectiveness of protective armor. Of principal concern is the interaction among these elements as they relate to the absorption of the kinetic energy and momentum of the threat projectile.

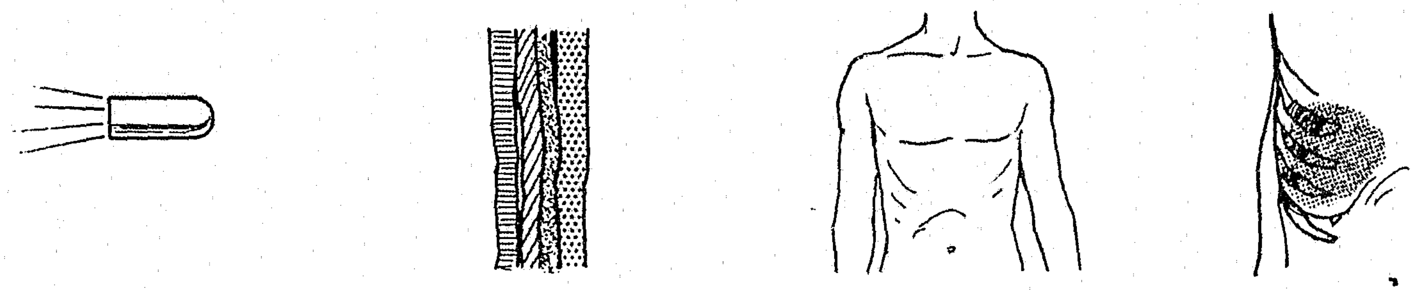
The dissipation of the kinetic energy of a bullet in its interaction with an armored object is the result of three phenomena: (1) projectile deformation, (2) interaction with and deformation of the armor materials, and (3) interaction and deformation of the backing material. In addition, some momentum transfer occurs between the projectile and the target.

In hard armor the energy dissipation is predominantly in projectile deformation, elastic deformation of the armor, and momentum transfer. In soft body armor the projectile is arrested by the material in the form of a relatively large elastic deformation. This deformation is transmitted to the body which in turn absorbs energy by deformation. If the elastic rate limit of the skin is exceeded, a contusion will be evident on the skin's surface; if the deformation is rapid and deep enough, a contusion may result on internal organs. This damage behind the armor at the point of impact is termed "blunt trauma."

In soft body armor, the blunt trauma effect is of most concern; therefore, understanding the blunt trauma effect is a key program element. This is true for the lightweight body armor under development as well as currently available vests.

Technical Parameters

THREAT | PROTECTION | EXTERNAL | INTERNAL



BALLISTIC LOADING → NON-PENETRATING DYNAMICS → BODY LOADING → BLUNT TRAUMA

BALLISTIC LOADING
- MASS
- SHAPE
- MATERIAL
- VELOCITY

NON-PENETRATING DYNAMICS
- MATERIAL (mechanical properties)
- WEIGHT (areal density)
- WEAVE (thread count, denier)
- LAY-UP (No. of plies, orientation)

BODY LOADING
- DECELERATION TIME
- DEFORMATION (depth, volume)

BLUNT TRAUMA
- MEDICAL ANALYSIS

ANALYTICAL/EMPIRICAL (Ballistic Loading, Non-Penetrating Dynamics)

EMPIRICAL (Body Loading, Blunt Trauma)

V-87891 R1 - Real World Issues

This chart shows the results of discussions with concerned groups in the use and manufacture of body armor. A number of issues that impact the acceptance of the lightweight body armor protection concept are not readily quantifiable or amenable to rigorous analysis; in such cases only time and evaluation will provide the answers. For example, some departments had strong objections to any publicity associated with body armor or test programs, others were neutral, and one offered to arrange a press interview.

All law enforcement agencies would like the perfect armor (e.g., complete protection against all threats and zero weight). Since this is unobtainable, the agency must make a determination of the protection desired versus the penalty to achieve that protection. The lightweight body armor requirements established by the common handgun threat represent the lower limit of protection which should be provided while the requirements to protect against the .44 magnum or .30 caliber rifle represent the upper limit.

The effect of body armor on police behavior has been discussed, but it has not been evaluated. Plans are under way to make a preliminary survey and to gather data during the test program.

Similarly the citizen barriers and full-time wear issues will require an evaluation in actual operating conditions at a number of sites before they can be resolved.

Real World Issues

V-87891 R1

- DISCUSSIONS WITH POLICE DEPARTMENTS AND INDUSTRY REPRESENTATIVES HAVE INDICATED A NUMBER OF ISSUES INVOLVED IN LIGHTWEIGHT BODY ARMOR WEAR

ISSUE	COMMENT
DEGREE OF PUBLICITY	WIDESPREAD PUBLICITY COULD LEAD CRIMINALS TO HIGHER THREAT WEAPONS OR "HEAD HUNTING"
LIMITED THREAT PROTECTION	SINCE NO ARMOR IS FULLY PROTECTIVE, DETERMINATION MUST BE MADE OF "WHERE ONE GETS OFF THE TRAIN" ON THREAT SPECIFICATION
SUPERMAN SYNDROME	WIDESPREAD POLICE ARMOR USAGE COULD LEAD TO FALSE SENSE OF SECURITY AND/OR MORE AGGRESSIVE ATTITUDE ON PART OF POLICE
CITIZEN BARRIERS	WIDESPREAD ARMOR USAGE COULD BE VIEWED AS PSYCHOLOGICAL BARRIER BETWEEN AVERAGE CITIZEN AND POLICE
VOLUNTARY/INVOLUNTARY FULL-TIME WEAR	ARMOR PROCUREMENTS FOR ENTIRE DEPARTMENTS RAISE FUNDING AND RESPONSIBILITY QUESTIONS
AVAILABILITY TO CRIMINALS	CONTINUING SURVEILLANCE REQUIRED TO PRECLUDE CRIMINALS FROM BEING ABLE TO BUY ARMOR ON THE OPEN MARKET

The U.S. Army Textile Research Section, Fiber and Fabric R&D Branch, Natick Laboratories, Massachusetts, provided technical direction in selecting the ballistic materials for use in protective garment development, and in conducting a survey of protective armor and material manufacturers. From these investigative efforts, the eleven materials shown were selected for testing. The material selection criteria were:

- Weight-to-strength ratio: lightweight but strong enough to prevent penetration of the bullet.
- Flexible or nonrigid: fabric-type material that would allow wearer freedom of movement.
- Inexpensive: adaptable in the future for law enforcement applications and procurement.
- Good ballistic qualities: able to absorb bullet energy in defeating it.
- Tailoring: tailored so as to provide good fit and styling in order to reduce armor appearance.

Tests performed on a wide range of materials (e.g., nylon, rayon, boron, graphite, and Kevlar) showed that Kevlar 29 was superior.

Protective Material Evaluations

MATERIAL	MANUFACTURER	SELECTION CRITERIA WEIGHT TO STRENGTH PENETRATION CHARACTERISTICS	FLEXIBILITY (non rigid)	COST	BLUNT TRAUMA	TAILORING
NYLON	DUPONT	P	G	G	G	G
RAYON	DUPONT	P	G	G	P	G
DACRON	DUPONT	P	G	G	P	G
KEVLAR 29	DUPONT	G	G	F	G	G
KEVLAR 49	DUPONT	F	G	G	F	G
THORNEL GRAPHITE YARN	UNION CARBIDE	P	P	P	P	P
PANEX GRAPHITE YARN	UNION CARBIDE STACKPOLE INC	P	P	P	P	P
MARLEX X-P	PHILLIP 66	G	P	P	G	P
X-55 FIBER	MONSANTO	P	F	F	P	F
NYLON FELT	DUPONT	P	P	P	P	P
X-500 FELT	MONSANTO	P	P	P	P	P

G = GOOD F = FAIR P = POOR

V-88062 R1 - Kevlar Data

This information was furnished by Mr. H. John Morton, DuPont Technical Service Representative, Textile Fibers Development. These data show that there is an on-going market and a variety of applications for Kevlar. A subsequent chart will identify more of the current uses for Kevlar.

Kevlar Data

- KEVLAR IS IN THE NEW FAMILY OF AROMATIC POLYAMIDES
  - KEVLAR RADIAL TIRE CORDS FOR PASSENGER CARS AND HIGHWAY PATROL
  - KEVLAR 49 REINFORCED PLASTICS (woven by DuPont)
  - KEVLAR 29 BALLISTIC FABRIC, PARACHUTES, INFLATABLE BOATS, SAFETY CLOTHING, SAILS (yarn only supplied by DuPont)
- SIX-MILLION POUND PER YEAR PLANT PRESENTLY OPERATING
- FIFTY-MILLION POUND PER YEAR PLANT NOW UNDER CONSTRUCTION IN RICHMOND, VIRGINIA

V-87990 - Physical Properties of Kevlar 29 Yarn

The important characteristics of Kevlar 29 yarns are shown. This yarn combines very high tensile strength and low elasticity with light weight and excellent toughness. It is available as a continuous filament yarn in a range of deniers and types that can be specifically matched to various industrial requirements. The Kevlar 29 yarn is being used in a variety of high-performance application areas. Kevlar 29 yarn woven in a specific fabric design has excellent ballistic-resistant capabilities.

V-87990

Physical Properties Kevlar 29 Yarn

PARAMETER	PROPERTY	COMMENT
DENSITY	1.45 g/cc	40% LESS THAN GLASS OR BORON
TENSILE STRENGTH	400,000 psi	SUBSTANTIALLY ABOVE CONVENTIONAL ORGANIC FIBERS, GREATER THAN STEEL
MODULUS	19×10^6 psi	TWICE THAT OF GLASS FIBERS
CHEMICAL RESISTANCE	GOOD	RESISTANT TO SOLVENTS, FUELS AND LUBRICANTS; CAN NOT BE DYED
TEMPERATURE RESISTANCE AND FLAMMABILITY	EXCELLENT	NO DEGRADATION IN SHORT TERM EXPOSURES TO 500°F, SELF EXTINGUISHING
TEXTILE PROCESSIBILITY	EXCELLENT	READILY WOVEN ON CONVENTIONAL LOOMS

V-88061 - Kevlar 29 Deniers Tested

The various Kevlar 29 deniers and weaves that were evaluated for ballistic resistance are shown. Although the ballistic resistance of some deniers is superior to others, costs and fabrication difficulties did not warrant further testing. The fabrication of a variety of weaves indicated that ballistic resistance could be improved; however, the type of fabrication would present garment manufacturing problems and would also increase costs.

Based on the evaluation, it was decided that the 400-2 (36 × 36) denier fabric would provide adequate protection against the lower threat projectile and would be acceptable for fabricating a lightweight, inconspicuous garment. Preliminary data indicate that the 1000-1 (31 × 31) is equivalent to the 400-2 at less cost; therefore, the 1000-1 denier will be evaluated further in the very near future.

Kevlar 29 Deniers Tested

DENIER/WEAVE (thread count)	BALLISTIC TEST	GENERAL PENETRATION RESULTS*
200 (60 x 58)	.38 cal (158 gr.) .22 cal (40 gr.)	N.P. - 7 PLIES N.P. - 7 PLIES
200 (110 x 90)	.38 cal .22 cal	N.P. - 5 PLIES C.P. - 5 PLIES
1500 (24 x 23) STYLE 71	.38 cal .22 cal	N.P. - 5 PLIES C.P. - 6 PLIES
400-1 (65 x 40) PLAIN WEAVE	.38 cal .22 cal	N.P. - 7 PLIES C.P. - 5 PLIES
400-1 (65 x 65) BASKET WEAVE	.38 cal .22 cal	N.P. - 7 PLIES C.P. - 6 PLIES
1000 - (31 x 31)	.38 cal .22 cal	N.P. - 7 PLIES C.P. - 5 PLIES
400-2 (32 x 32)	.38 cal .22 cal	N.P. - 7 PLIES C.P. - 5 PLIES
400-2 (36 x 36)	.38 cal (158 gr.) .22 cal (40 gr.) 9 mm (124 gr.) 357 mag (159 gr.) .38 cal SUPER VELOCITY (115 gr.) .32 cal (71 gr.) 380 cal (95 gr.)	N.P. - 7 PLIES C.P. - 5 PLIES C.P. - 15 PLIES C.P. - 10 PLIES N.P. - 7 PLIES N.P. - 7 PLIES N.P. - 7 PLIES
COMPOSITES OF KEVLAR		
5 PLIES 400-2 AND 3 PLIES 200	.22 cal	N.P. AT VELOCITY OF 1050 fps
4 PLIES 200 AND 4 PLIES 400-2	.22 cal	N.P. AT VELOCITY OF 1000 fps
3 PLIES 200 AND 4 PLIES 400-2	.22 cal	N.P. AT VELOCITY OF 990 fps
2 PLIES 200 AND 5 PLIES 400-2	.22 cal	N.P. AT VELOCITY OF 1020 fps
2 PLIES 200 AND 4 PLIES 400-2	.22 cal	C.P. AT VELOCITY OF 1000 fps

* N.P. NO PENETRATION
C.P. COMPLETE PENETRATION

V-88187 - Bullet Projectile and Ballistic Fabric Interaction

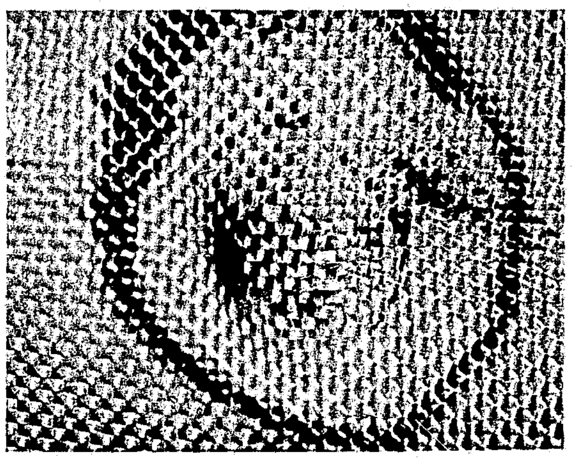
One method of determining the effectiveness of ballistic protective materials is to measure the degree of bullet deformation after impacting against the protective material. The material properties that most effect the bullet deformation characteristics are: denier, tightness of weave (thread count), and cross sectional area of the fibers.

The top two pictures show the comparison of the .38 caliber bullet deformed cross sectional area when impacting a Kevlar 29, 200 denier and 400 denier test specimen. The bullet impacting the lighter (200 denier) and tighter woven fabric has a larger cross sectional area.

The bottom left picture illustrates that when the .22 caliber bullet impacts against the 400 denier fabric, it penetrates by separating the fibers (without breaking them) and is only partially deformed. When impacting the 200 denier fabric, the .22 caliber bullet did not penetrate and deforms similar to the .38 caliber bullet.

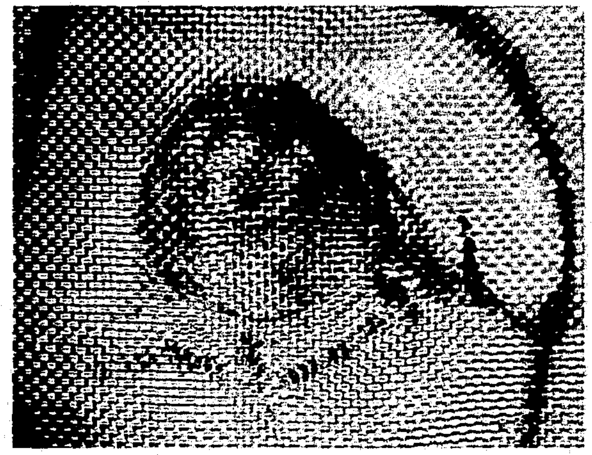
Bullet Projectile and Ballistic Fabric Interaction

400 DENIER FABRIC

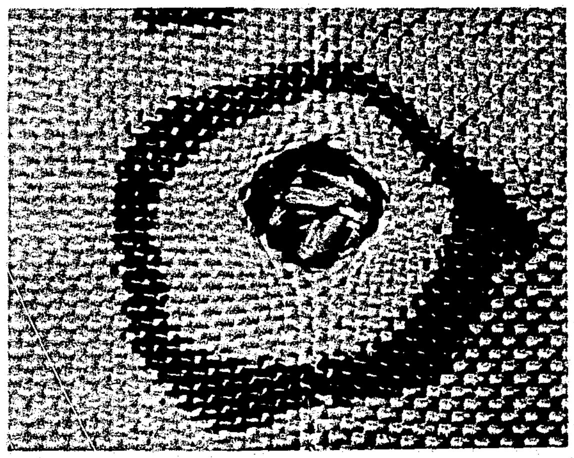


IMPACTED BY .38 CALIBER
158 GRAIN, ~800 fps

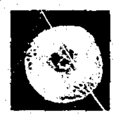
200 DENIER FABRIC

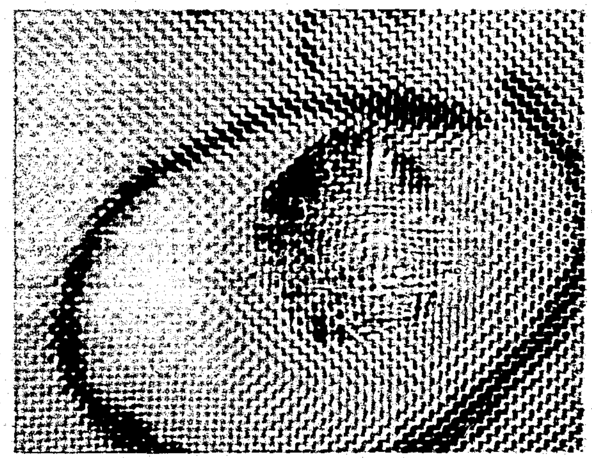


IMPACTED BY .38 CALIBER
158 GRAIN, ~800 fps



IMPACTED BY .22 CALIBER
40 GRAIN, ~1000 fps





IMPACTED BY .22 CALIBER
40 GRAIN, ~1000 fps

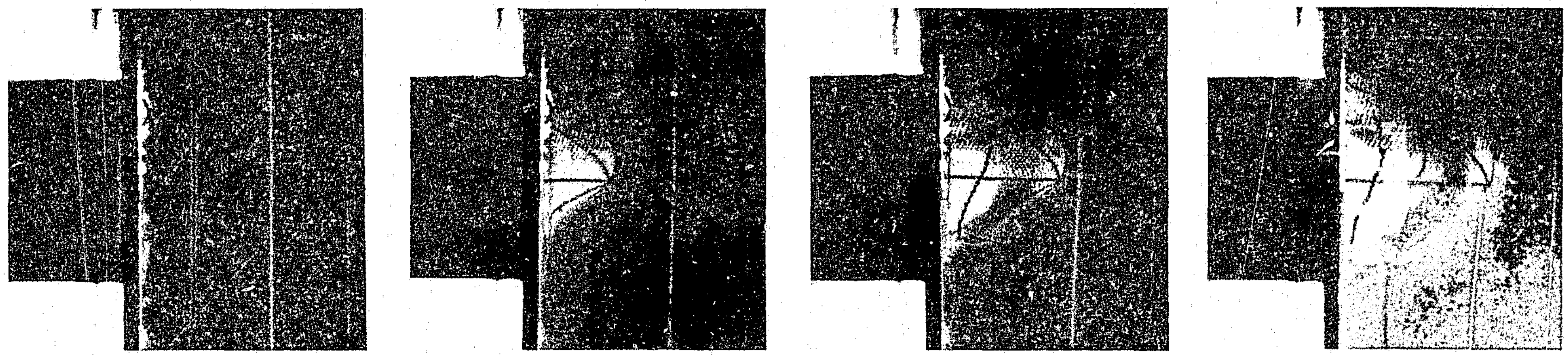
V-87986 R1 - Representative Ballistic Test Results

A series of tests were performed by the Edgewood Arsenal Biophysics Laboratory and Lawrence Livermore Laboratories to determine data trends of the backface signature parameters, e. g., volume of deformation, depth of penetration, deformation time, as functions of incident ballistic parameters and materials characteristics. A test matrix was developed, and tests were performed covering a range of weapon projectile energies, material plies and deniers, and armor standoff distances from backing. Both laboratories used similar methodology in the development of these tests.

As illustrated, an increase in the number of material plies reduced the penetration depth and deformation volume. Results also show that increasing the projectile striking velocity increases the backface signature parameters, except in the case of small caliber projectiles which tend to slip through the weave and defeat the armor. The material backface signature appears to be dependent upon changes in striking kinetic energy, material mass, and material denier. The curve for the standoff test condition shows that when the protective material is in contact with the backing material, the depression factor (a factor similar to the backface signature parameter) is less than when the test specimen is held one-half inch away from the backing material. The shape of the curve between one-half inch and zero is uncertain, and additional tests will be performed to determine this relationship.

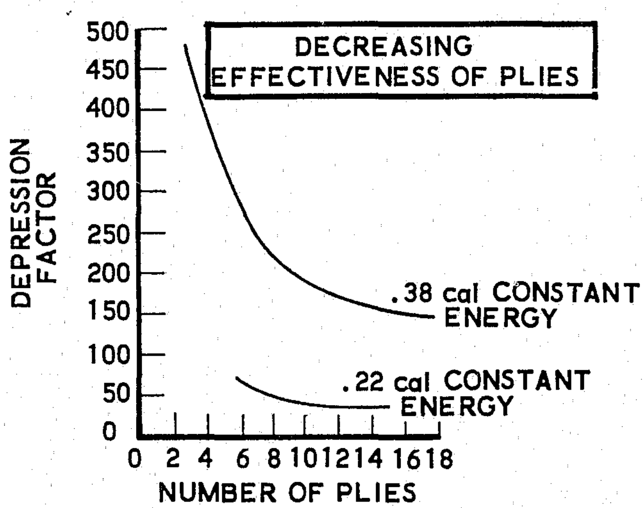
Representative Ballistic Test Results

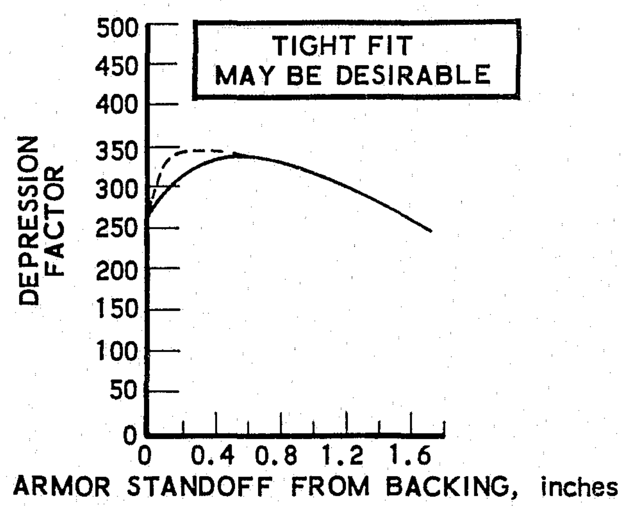
- TYPICAL BACKFACE MEASUREMENT TECHNIQUE (.38 cal bullet/Kevlar/gelatin)



t = -20 microsec | t = 200 microsec | t = 500 microsec | t = 1000 microsec

- PARAMETERS EVALUATED (Edgewood and Livermore Labs)
  - NUMBER OF PLIES
  - STANDOFF DISTANCE
  - BULLET MASS, VELOCITY, DIAMETER
  - BULLET ENERGY, MOMENTUM
- RESULTS (Depression factor proportional to radius and depth squared)





V-87959 R1 - Laboratory Analysis of Interaction Parameters

A number of laboratory experiments have been designed to determine the characteristics of the Kevlar material and its response to a variety of loading conditions. Specifically, characteristics are determined by uniaxial and biaxial static loading using the Instron test equipment, momentum loading using Charpy impact testing, and dynamic loading by ballistic tests on an instrumented range.

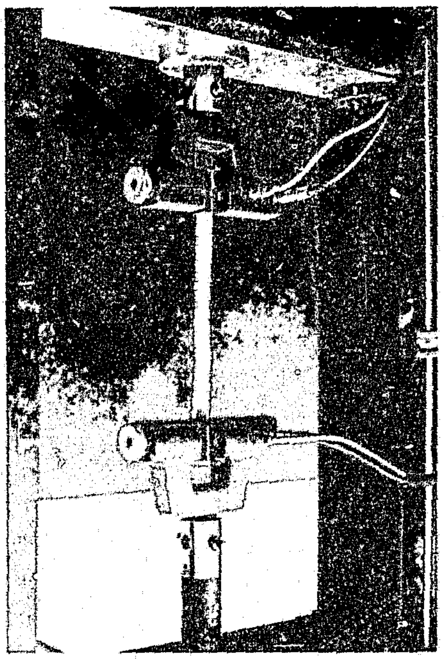
The uniaxial tension tests were performed on an Instron table model testing machine equipped with modified grips to ensure consistent results and fabric failure in the areas of the specimen away from the clamps. The force/deformation measurements provided stress-strain relationships from the various samples. The primary application of these data is the measurement of structural characteristics of the material after exposure to different environments or conditions.

The biaxial loading technique, which more closely approaches the loading distribution during the bullet impact, was also used to study fabric behavior. The load was applied by means of an indentor, shaped as a bullet, mounted on the cross head of the Instron testing machine, and it was applied to the center of an edge-restrained sample. Through this technique, it is possible to study the relative effects of varying the number of plies and the effects of backing material on fabric deformation and penetration under load.

A Charpy impact test machine has been modified to study the dynamic loading (momentum exchange only) of the ballistic material and ballistic material/backing to obtain data and a better understanding of the phenomenology of the interaction and deformation of the material and backing.

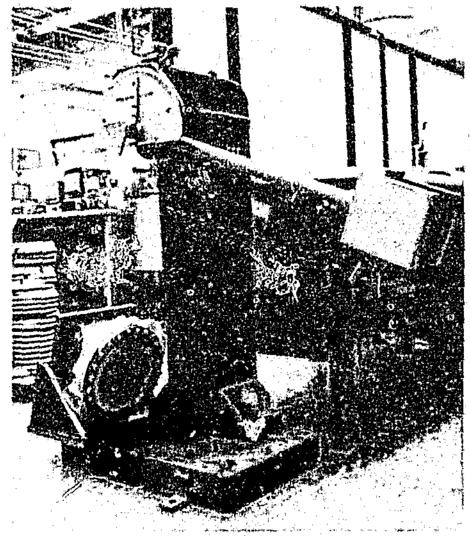
Although the majority of the ballistic testing is accomplished at the Army Laboratories, Aerospace uses the instrumented facilities at Sierra Engineering and their own laboratories to conduct quick assessment-type tests against new weave materials or materials that have undergone environmental or wear tests during the development effort. This provides the capability to quickly evaluate new or innovative ideas in an overall sense without the more detailed, formal, and costly testing required for full evaluation. Promising concepts are presented to the Army Laboratories for full evaluation when warranted.

Laboratory Analysis of Interaction Parameters

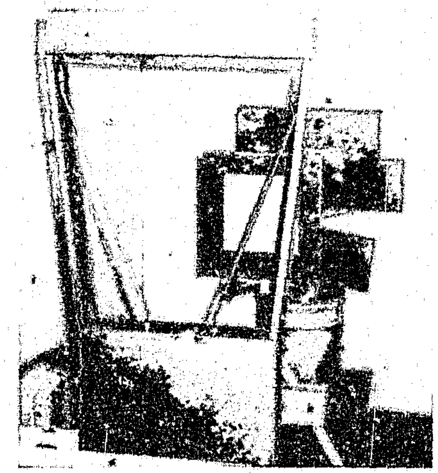


INSTRON

INDENTOR



CHARPY



BALLISTIC

- STATIC, UNIAXIAL
  - MECHANICAL BASELINE
  - STRESS-STRAIN BEHAVIOR AND ULT. TENSILE STRENGTH ON FABRIC STRIPS AND SINGLE YARNS
  - EVALUATES INCREMENTAL LOSSES

- STATIC, BIAXIAL
  - GEOMETRIC SIMULATION
  - BIAXIAL RESPONSE OF FABRIC TO BULLET SHAPE LOADING
  - QUANTITATIVE ANALYSIS OF FABRIC DIFFERENCES

- DYNAMIC, BIAXIAL
  - FORCE-TIME HISTORY
  - DYNAMIC BIAXIAL RESPONSE OF MATERIAL
  - QUANTITATIVE ANALYSIS OF MOMENTUM
  - PARTITIONING OF ENERGY (air, gelatin, clay backings)

- DYNAMIC, BIAXIAL
  - DYNAMIC BASELINE
  - CONTROLLED BALLISTIC RANGE
  - GELATIN AND CLAY BACKING

V-87988 - Key Laboratory Findings

A series of laboratory experiments were designed to investigate the ballistic interaction phenomena and the performance of the materials under various environmental conditions. This chart summarizes the key findings and conclusions from the laboratory experiments.

Key Laboratory Findings

- MOST CLEANING SOLVENTS, SOAPS, DETERGENTS CAUSE SIGNIFICANT DEGRADATION TO PENETRATION CHARACTERISTICS
  - WASH IN WOOLITE OR IVORY SOAP, AIR DRY
  - DRY CLEAN WITH PERCETHLYLENE SOLVENT
- BALLISTIC PROTECTION DEGRADED BY PHYSICAL WETNESS (surface effect, not loss of strength)
  - NO APPARENT EFFECTS WHEN EXPOSED TO 100% HUMIDITY
  - ZEPEL "D" DECREASES MOISTURE ABSORPTION
- PENETRATION PERFORMANCE IMPROVES WITH UNIFORM AND TIGHTER WEAVE AND FINER DENIER
  - BASELINE MATERIAL WEAVE SPECIFICATION DEFINED
- IMPROVED WEAVING METHOD
  - TENSION BALANCE NEEDED TO THE WARP AND FILL DIRECTIONS
  - MAJORITY OF BULLET ENERGY IS ABSORBED BY FILL FIBERS DUE TO CURRENT WEAVING PROCESS
- BACKING MATERIAL A CRITICAL PARAMETER FOR BOTH PENETRATION AND BLUNT TRAUMA
  - DIFFERENCES BETWEEN ELASTIC BACKINGS (air, gelatin) AND INELASTIC BACKINGS (clay)
  - HUMAN SIMULATION BACKING MATERIAL STILL NEEDED

V-87956 - Kevlar Environmental Results

The previous chart summarized the overall laboratory findings. This chart presents the specifics of the environmental testing in which the susceptibility of the baseline protective material to a wide range of conditions was investigated. As noted, the method of washing and drying can cause a permanent degradation of fabric strength. Also, it was discovered that if the material were immersed in water and tested ballistically the non-penetration characteristics were seriously degraded.

The following two charts discuss the test conditions and test results of both mechanical and ballistic testing on material washed and dried in different ways and with different detergents. Specific recommendations are made to minimize this degradation.

The degradation resulting from water immersion has not been completely evaluated. The most direct solution to retard degradation is to protect the ballistic material with a waterproof cover or to waterproof the material itself.

V-87956

Kevlar Environmental Results

ENVIRONMENT	EXPOSURE	TEST METHOD*	RESULTS/RECOMMENDATIONS
• CLEANING-WASHING AND DRYING	WASHING AND DRYING UNDER NORMAL CONDITIONS	MECHANICAL/BALLISTIC	DETERGENTS AND BLEACH DEGRADE FABRIC SEVERELY USE COLD WATER WOOLITE AND AIR DRY CYCLE
• CLEANING-DRY CLEANING	COMMERCIAL CLEANING PROCEDURE	MECHANICAL/BALLISTIC	ONLY PERCETHYLENE SOLVENT DID NOT DEGRADE FABRIC (double knits)
• SALT SPRAY	3% SALT SOLUTION 48 HOURS (simulate perspiration)	MECHANICAL/BALLISTIC	NO DEGRADATION TO FABRIC
• SUNLIGHT	34 HOURS	BALLISTIC	NO DEGRADATION TO FABRIC
• OZONE AND OZONE/ULTRAVIOLET	72 HOURS AT EXTREME CONDITIONS	MECHANICAL/BALLISTIC	NO DEGRADATION TO FABRIC
• HUMIDITY	100% RELATIVE HUMIDITY AT ROOM TEMP. FOR 48 HOURS	BALLISTIC	MINOR CAVITY DEGRADATION
• WATER IMMERSION	TOTAL IMMERSION ~10 MINUTES	BALLISTIC	SIGNIFICANT DEGRADATION, WATERPROOFING MAY BE REQUIRED

*MECHANICAL TEST
INSTRON TENSILE
CHARPY IMPACT

BALLISTIC TEST
.38 CAL. BULLET
.22 CAL. BULLET

V-88060 R1 - Environmental Test Results - Washing & Drying

In addition to all the physical and mechanical data generated, it was necessary to perform environmental tests on the woven fabric. Since the program is intended to produce ballistic-resistant garments, The Aerospace Corporation designed washing and drying procedures to determine what effect multiple cleaning cycles would have on a finished garment. When the material is washed using certain cleaning procedures, the mechanical strength and the ballistic resistance are significantly degraded. The chart shows good correlation between mechanical degradation and ballistic resistance (e.g., where mechanical degradation is severe, changes in ballistic resistance are also severe). Further studies indicated that less severe degradation (mechanically) is evidenced when the garment is laundered in cold water using Woolite and normal household washing procedures.

Environmental Test Results - Washing & Drying

MECHANICAL TEST SUMMARY

EXPOSURE	TENSILE % DEGRADATION*
HOT WATER + TIDE (Fill)	18.8
HOT WATER + IVORY (Fill)	18.9
COLD WATER + ALL (Fill)	25.1
COLD WATER + WOOLITE (Fill)	18.8
HOT WATER + TIDE (Warp)	8.4
HOT WATER + IVORY (Warp)	7.7
COLD WATER + ALL (Warp)	12.8
COLD WATER + WOOLITE (Warp)	7.65

*Average of 20 sample each

$$\% \text{ degradation} = \frac{\text{unwashed specimen} - \text{washed specimen}}{\text{unwashed specimen}}$$

BALLISTIC TEST SUMMARY

EXPOSURE	.22 CALIBER VELOCITY	40 gr.	TEST SPECIMEN: - SEVEN PLYS OF 400-2 *PENETRATION
HOT WATER (Tide and Clorox)	1000		C.P. THRU BACKING
HOT WATER (Tide and Clorox)	936		C.P. STOPPED IN 7TH PLY
HOT WATER (Tide and Clorox)	961		P.P.
COLD WATER + ALL	1000		P.P.
COLD WATER + ALL	920		C.P. STOPPED IN 7TH PLY
COLD WATER + ALL	1008		C.P. STOPPED IN 7TH PLY
HOT WATER + TIDE	1013		P.P.
HOT WATER + TIDE	965		P.P.
HOT WATER + TIDE	948		P.P.

+ C.P. COMPLETE PENETRATION
P.P. PARTIAL PENETRATION

CONTINUED

1 OF 2

In addition to the mechanical tests of the material after exposure to wash cycles, ballistic impact tests were run. These photographs summarize the test results.

The top set of cavity casts show the comparative effects of deformation due to various phases of washing. As the material is washed, the depth of penetration increases indicating a loss in strength of the 200 denier material. The longer cylindrical sections indicate a breakdown in the outer plies with a more pronounced stretching of the inner layers.

The lower set of cavity molds shows a comparison of 200, 400, and 1500 denier samples of the same areal density in virgin material and a 400 denier sample after hot and cold cycling. The conclusions for this series of tests are shown under the photos.

Environmental Test Results - Ballistic

[illegible]
200 DENIER (61-63)
8 PLY
VIRGIN
.38 CAL @ 7[illegible] FT/SEC

7
200 DENIER (61-63)
8 PLY
HOT WASH
.38 CAL @ 760 FT/SEC

#13
200 DENIER (61-63)
8 PLY
COLD WASH
.38 CAL @ 800 FT/SEC

51
200 DENIER
8 PLY
HOT & COLD CYCLE
.38 CAL @ 770 FT/SEC

- INCREASED CAVITY SIZE DUE TO WASHING

[illegible]
200 DENIER (61-63)
[illegible] PLY
VIRGIN
.38 CAL @ 792 FT/SEC

40
400 DENIER (32-32)
7 PLY
VIRGIN
.38 CAL @ 794 FT/SEC

#25
400 DENIER (32-32)
7 PLY
HOT & COLD CYCLE

49
1500 DENIER
5 PLY
.38 CAL @ 790 FT/SEC

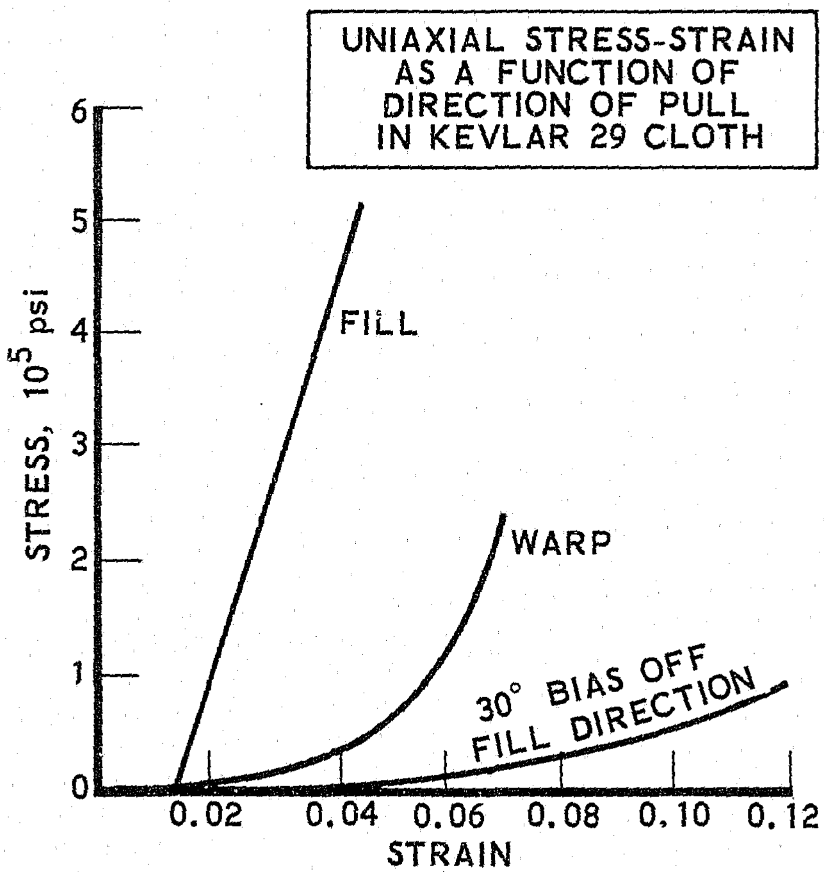
- 200 DENIER & 400 DENIER EQUAL DENSITIES YIELD SIMILAR CAVITIES
- HOT & COLD CYCLING SHOWS LITTLE EFFECT
- EQUAL DENSITY OF 1500 DENIER SHOWS ENLARGED CAVITY

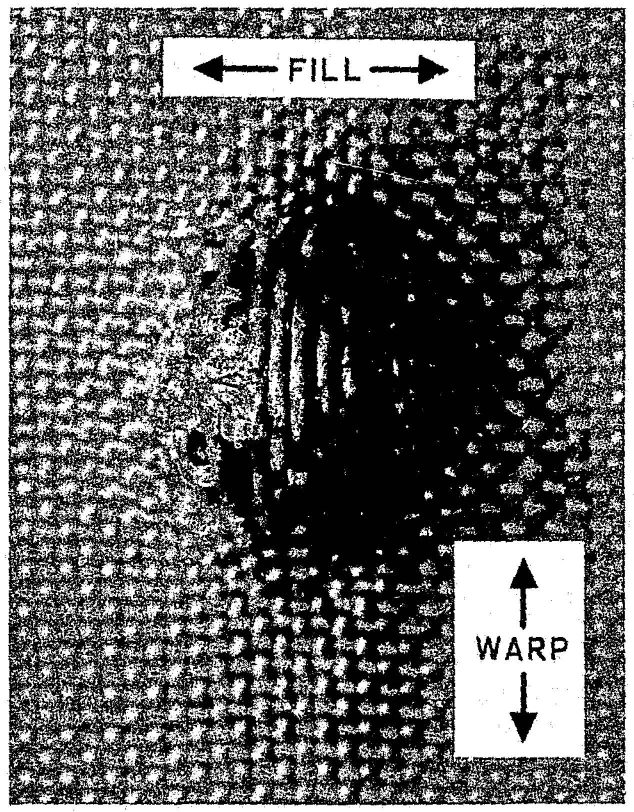
V-87961 - Material Weaving Improvements

The present weaving process produces fabric in which the warp yarns are highly crimped relative to the fill yarns, i.e., the warp yarns loop over and under the relative straight fill yarns. As a result, the fill yarns are stressed much sooner than the warp yarns when the fabric is deformed, and failure is initiated in the fill yarns. A fabric having the warp and fill yarns equally balanced should result in a more uniform and efficient distribution of stresses in the fabric.

Material Weaving Improvements

- PROBLEM-WARP FIBERS PROVIDE LOW INITIAL ENERGY ABSORPTION





KEVLAR CHARPY IMPACT

- POTENTIAL IMPROVEMENT - SPECIFY TENSION BALANCE IN WEAVING PROCESS BETWEEN WARP AND FILL FIBERS

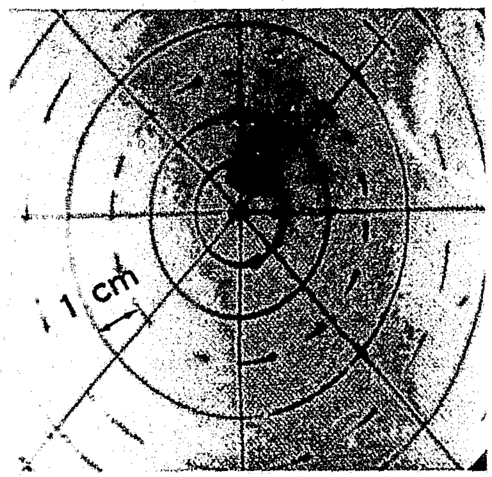
V-87449 - Ballistic Interaction Process

This series of pictures display the complex nature of the deformation of woven fabric. Initial loading of the fabric (t=100 microseconds) is on the fill (horizontal) fibers only, resulting in the diamond pattern. Further loading (t=500 and 960 microseconds) stresses the warp (vertical) fibers also, resulting in the rectangular shaped pattern. A balanced weave (i.e., even tension in warp and fill fibers) would result in a square pattern throughout the impact displacement interval.

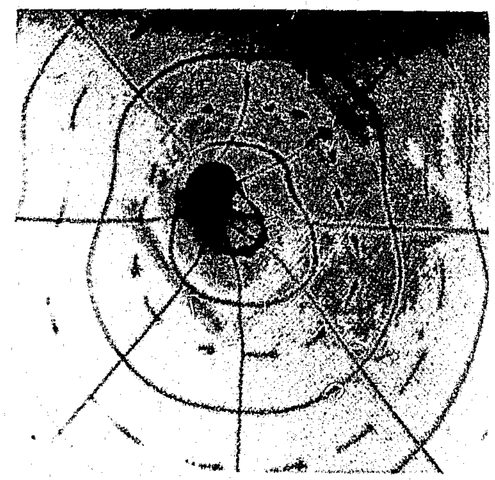
FRONT VIEW

Ballistic Interaction Process

- LIVERMORE DATA
- GELATIN BACKING
- 7 PLY - KEVLAR - 400-2 DENIER - 38 x 38 WEAVE
- .38 cal 158 gr ROUND NOSE, 685 ft/sec

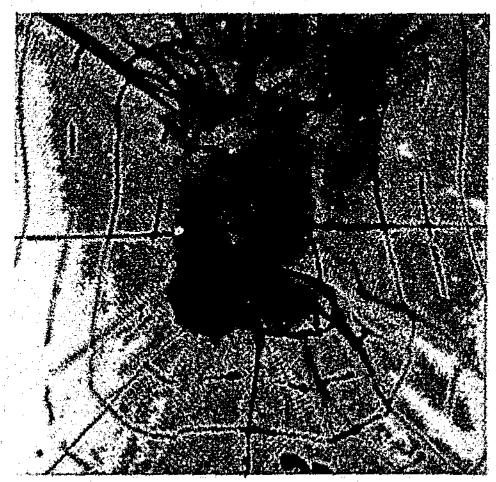


t = 0



t = 100 μs

t = 500 μs

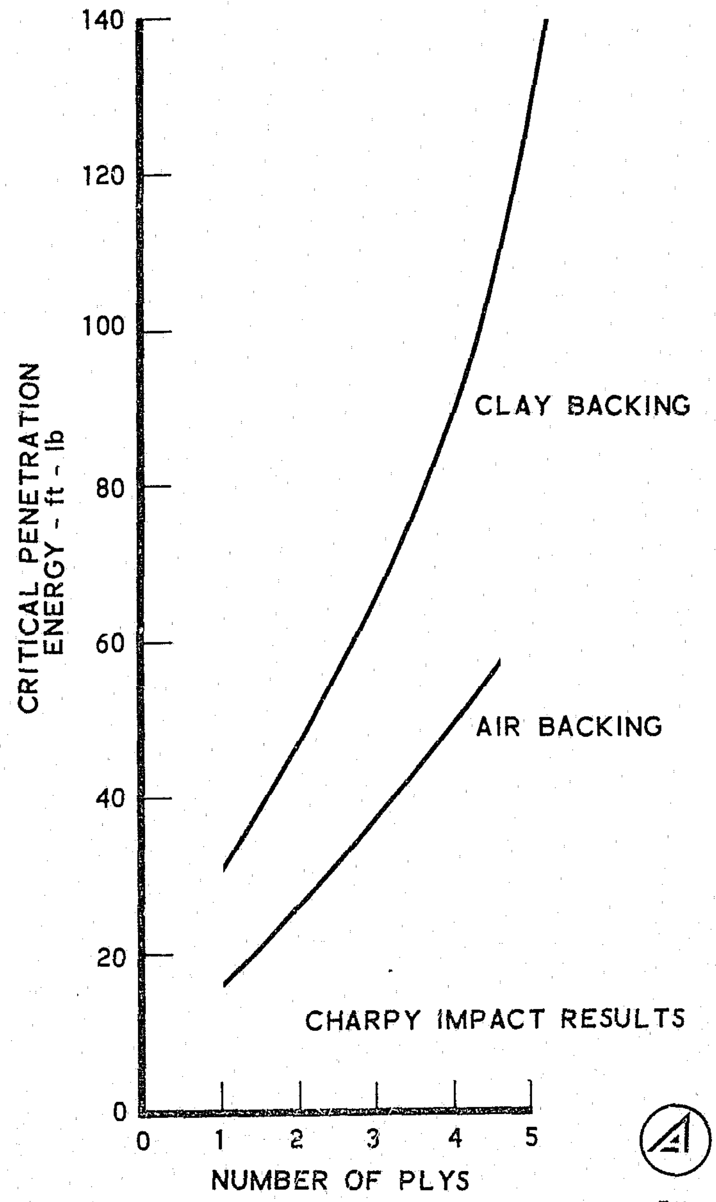


t = 960 μs

Upon impact, the bullet's energy is transferred to both soft armor and backing material. This is displayed in the figure. Little energy is absorbed in displacing the air behind the soft armor. As a result, 4 plies of armor are defeated with 50 foot pounds of energy. When the air is replaced with a clay backing, 85 foot pounds of energy are required to defeat the same 4 plies of armor. Thus, approximately 35 foot pounds of energy have been transferred to the clay in the process.

Effects of Backing Materials on Ballistic Interaction

- PROTECTIVE FABRICS PREVENT BULLET PENETRATION AND DISTRIBUTE ENERGY OVER LARGER AREA OF BACKING
  - ABSORBS PORTION OF ENERGY WITHOUT PENETRATION
  - ENERGY DISTRIBUTION IS PARTIALLY DEPENDENT ON BACKING MATERIAL
- BACKING MATERIAL EXTREMES
  - AIR-MOST OF THE ENERGY IS ABSORBED BY THE FABRIC. DEFORMATIONS MEASURED WITH HIGH SPEED PHOTOGRAPHY
  - CLAY DEFORMS PLASTICALLY RESULTING IN LARGE ENERGY ABSORPTION. ENABLES DISCRIMINATION BETWEEN CAVITIES FROM DIFFERENT BALLISTIC MATERIALS
  - GELATIN DEFORMS ELASTICALLY AND THE ENERGY ABSORPTION CHARACTERISTIC IS BETWEEN AIR AND CLAY. SIMULATES HUMAN TISSUE BETTER THAN AIR OR CLAY. HIGH SPEED PHOTOGRAPHY REQUIRED FOR VOLUMETRIC MEASUREMENTS OF CAVITIES
  - BONE RIGID ELASTIC MINIMUM ENERGY ABSORPTION OR DEFORMATION. ENERGY TRANSFERRED TO BONE USUALLY—POSSIBLY RESULTING IN FRACTURES



V-87987 R1 - Blunt Trauma Correlation

The correlation of parameters affecting backface signatures and the live/die capability of animals based on physical and physiological parameters provides a basis for predictive modelling of blunt trauma response. The data presented in these charts are based on historical data available from the Army files and published literature. The projectile-induced blunt trauma data on animals were evaluated for validity and applicability. A correlation analysis of selected data sets involving responses to impacts in the thorax resulted in the development of two predictive models. These included a four parameter model containing only physical parameters, and an eight parameter model containing both physical and physiological parameters.

Although these models represent the best correlations possible with the available data, they should be considered provisional until a larger data base becomes available.

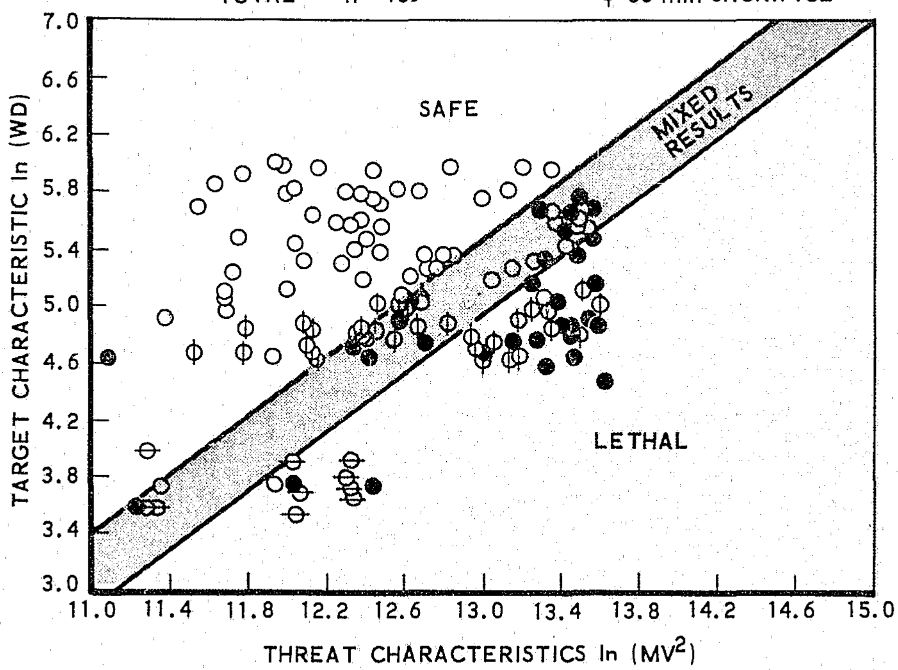
Blunt Trauma Correlation

- REVIEW AND ANALYSIS OF EXISTING ANIMAL TEST DATA
- DEFINITION OF POTENTIAL MODELS FOR PREDICTION OF MEDICAL RESULTS

DATA SOURCES:

AMC-EA-FY 73	n = 46
EA-AD HOC	n = 28
LWL	n = 20
LOVELACE	n = 45
TOTAL	n = 139

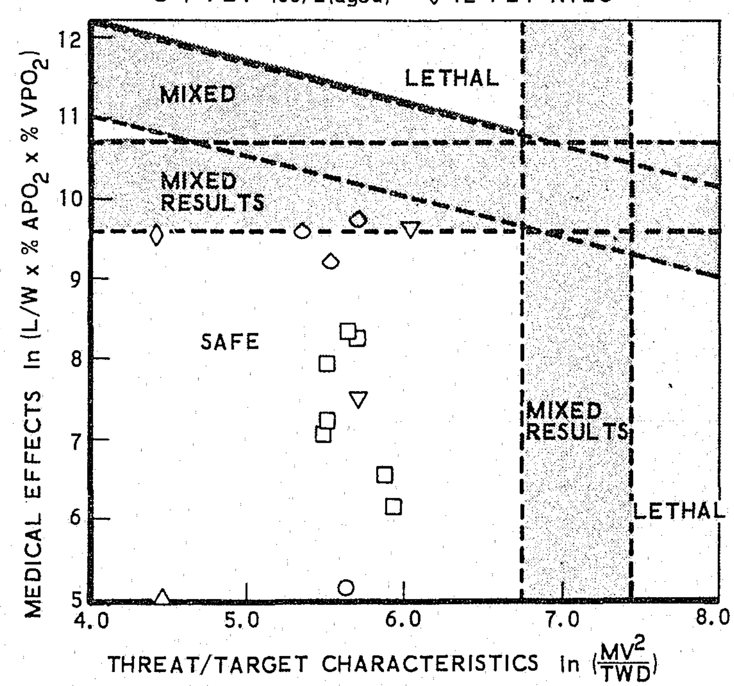
● DIED
○ LIVED
⊖ STERNUM IMPACT
⦶ 30 min SACRIFICE



PREDICTIVE MODEL (4 parameters)

BACKFACE SIGNATURE DATA

○ 5 PLY 400/2 △ 9 PLY 400/2
□ 7 PLY 400/2 ▽ 7 PLY 200
◇ 7 PLY 400/2(aged) ◊ 12 PLY NYLO



PREDICTIVE/PHYSIOLOGICAL MODEL (8 parameters)

The lightweight protective garment is to have the following capabilities against either the .22 caliber bullet at 1000 feet per second or the .38 caliber bullet at 800 feet per second:

1. The garment should prevent penetration by the bullet into the chest, abdomen, or back.
2. Any blunt trauma effects requiring surgical repair should permit a survivability of greater than 90%.
3. An adult male wearing the garment should be able to walk away after being shot in the chest or abdomen.

For conditions 2 and 3, it is assumed the patient will receive medical attention at a hospital within one hour.

The anatomy in the accompanying diagram is assumed to be protected by a garment made of 7 plies of the baseline material that covers the thorax, abdomen, and back. The organs (darkened areas) would be sufficiently damaged by a bullet impacting their area to require surgery or intensive care monitoring of the patient. Vulnerability then, with regard to body armor, is the condition when the victim's body requires surgery or intensive care monitoring after a non-penetrating bullet impact.

The percentage of vulnerable areas will vary according to the design of the protective garment. Based on test results obtained from the Edgewood Arsenal Biomedical Laboratory, the number of plies of the baseline material necessary to convert most of the vulnerable areas into invulnerable areas would probably be too heavy and conspicuous to incorporate into a garment.

The predicted survivability and surgery percentages with and without the protective garment are shown. These values will vary with the type of garment worn and the areas of body protected.

V-87985 R1

Preliminary Vulnerability Assessment

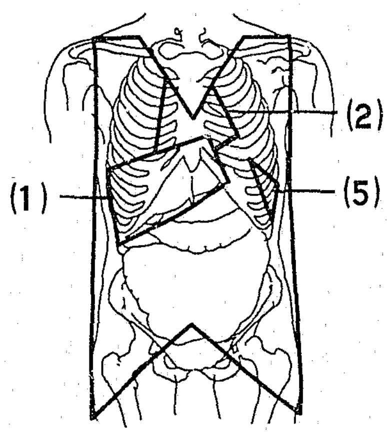
- ANALYSIS ASSUMPTIONS
  - SPORT COAT COVERAGE (7 plies Kevlar 400)
  - NO PENETRATION (.38 cal special, 800 fps)
  - HOSPITAL ATTENTION WITHIN ONE HOUR
  - BLUNT TRAUMA CORRELATION RESULTS
  - ORGAN FRIABILITY TESTS (Liver, Spleen, Heart, Kidney)
  - RANDOM DISTRIBUTION OF HITS

- PRELIMINARY RESULTS (Edgewood Arsenal)
  - SURVIVAL PROBABILITY

WITH GARMENT	95-99%
WITHOUT GARMENT	75-93%

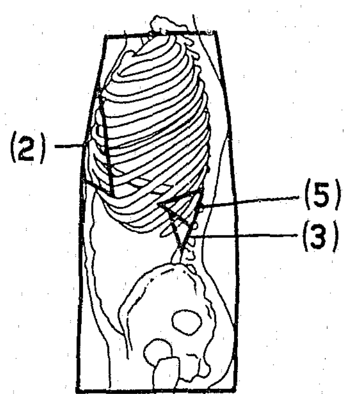
  - SURGERY PROBABILITY

WITH GARMENT	7 - 10%
WITHOUT GARMENT	82 - 100%



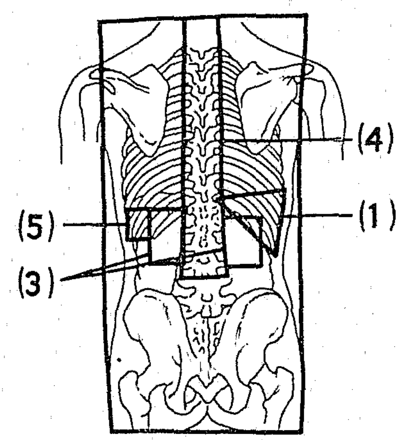
VULNERABLE AREA
(Frontal)

HEART	~ 5.1%
SPLEEN	~ 0.8%
LIVER	~11.9%



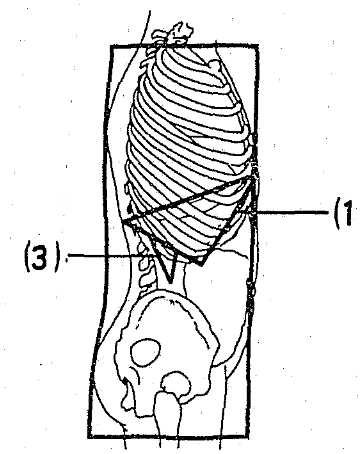
VULNERABLE AREA
(Left)

HEART	~ 3.2%
SPLEEN	~ 1.5%
KIDNEY	~ 0.4%



VULNERABLE AREA
(Back)

SPLEEN	~ 1.1%
KIDNEY	~ 4.7%
SPINE	~13.7%
LIVER	~ 3.2%



VULNERABLE AREA
(Right)

LIVER	~ 8.7%
KIDNEY	~ 0.7%

(1) LIVER (2) LUNG (3) KIDNEY (4) SPINE (5) SPLEEN

V-87895 - Assault Data on Protected Officers

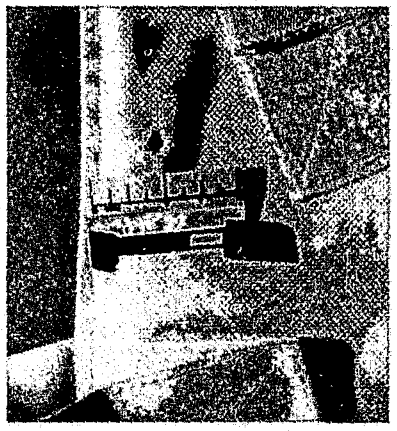
During recent months, three California officers were shot with handguns while wearing commercial body armor. All three were wearing vests of 18-ply ballistic nylon. A Los Angeles officer was shot in the chest area with a .32 caliber automatic, while a San Francisco officer and a San Bernardino officer were hit in the chest with .38 specials. In each instance, the wound location was such that there was a high probability that it would have been fatal without the protective garment.

All three officers were interviewed and the effects of the impact assessed. Both the Los Angeles officer and the San Bernardino officer returned the assailants' gunfire. In Los Angeles the assailant surrendered to the officer, but the San Bernardino assailant was fatally wounded. In San Francisco, the gunman fled before the officer could recover. In each case, the trauma wound behind the point of impact was similar. This was an abrasion immediately behind the point of impact and the development of a 2- to 3-inch bruise. The Los Angeles officer received medical treatment in an emergency room and was released, but in contrast the other two officers were hospitalized for observation.

Subsequent to the assaults, samples of the vests involved in the three incidents were obtained and ballistic tests were run to simulate the actual assault conditions. Similar weapon types and ammunition were used and the points of impact on the garments were duplicated. The tests were made with plastilina No. 1 as backing and cavity molds were taken. These tests were then compared with similar Kevlar tests where the trauma effects had been previously measured.

Assault Data on Protected Officers

- THREE RECENT ASSAULTS IN CALIFORNIA ON OFFICERS WEARING SOFT BODY ARMOR VESTS
- SIMILAR BACKGROUND
  - VEST SELF PURCHASED
  - WORN ESSENTIALLY EVERYDAY FOR PAST YEAR
- SIMILAR ASSAULT CONDITIONS
  - ALL SHOT IN CHEST AREA WITH .38 OR .32 CALIBER WEAPONS
  - SOFT ARMOR STOPPED BULLETS IN EACH CASE (18 Plies Nylon)
  - INTERVENING MATERIAL (Nametag, Leather Jacket, Arm) REDUCED LOADING ON VEST
  - HIGH PROBABILITY OF DEATH IF NO ARMOR HAD BEEN WORN
- SIMILAR RESULTS
  - ALL ENDED UP WITH CHEST BRUISE AND BACK ON JOB WITHIN DAYS
  - EACH OFFICER ABLE TO IMMEDIATELY DEFEND HIMSELF (Minimum Psychological Shock)
- TEST DUPLICATION OF ASSAULT CONDITIONS (Vest, Weapon Type, Ammunition)
  - QUALITATIVE BACKFACE LOADING IN CLAY
  - COMPARISON WITH SIMILAR LOADINGS AND MEDICAL TESTS WITH KEVLAR
  - PREDICTABLE MINIMUM BODY DAMAGE



V-87960 R1 - Ballistic Test Summary (Kevlar)

The baseline Kevlar fabric was tested over the past year under the ballistic impact conditions identified in the chart. These tests were performed both by The Aerospace Corporation and Edgewood Arsenal Biophysics Laboratory. The degree of blunt trauma acceptance for each of the ballistic threats was established by means of tests and analysis at the Edgewood Arsenal Laboratory. Cavity deformation and high-speed photographic measurements were made in some cases to estimate the degree of trauma.

Very limited testing was performed for the higher energy threats (i.e., .45 automatic, 9mm, and .357 magnum). Additional evaluation and testing for these higher energy threats are currently being performed. Efforts have also been initiated on devising methods of alleviating the blunt trauma effects for these higher energy threats. No testing has been performed for the .44 magnum, primarily because of the suspected severe trauma effects and the lack of statistical data to show the .44 magnum to be a common threat. Limited amounts of testing will be performed at a later time.

Ballistic Test Summary (Kevlar)

- BASELINE KEVLAR FABRIC - 400 DENIER, 2 PLY, 36x36 WEAVE (0.055 lb/ft^2 per ply)
- KEVLAR 1000 DENIER, 31x31 WEAVE (0.06 lb/ft^2 per ply) GIVES SIMILAR PROTECTION

THREAT	BULLET WEIGHT	VELOCITY (fps)	No. OF PLIES REQUIRED	PENETRATION	TRAUMA EFFECT
.38 SPECIAL	158 gr.	800	3	NONE	UNACCEPTABLE
.38 SPECIAL	158 gr.	800	5	NONE	ACCEPTABLE
.38 CAL HIGH VEL	115 gr.	1000	7	NONE	ACCEPTABLE
.22 CAL	40 gr.	1000	7	PARTIAL	ACCEPTABLE
.45 AUTO	230 gr.	850	7	NONE	MARGINALLY ACCEPTABLE
9 MM	124 gr.	1100	18	PARTIAL	MARGINALLY ACCEPTABLE
.357 MAG	158 gr.	1200	15	PARTIAL	QUESTIONABLE
.44 MAG	240 gr.	1400	TBD	TBD	TBD

V-87954 - Kevlar Material Specifications

In the early development stages, a number of Kevlar fabrics were evaluated. In order to optimize fiber size and weave parameters, The Aerospace Corporation, with the help of DuPont, generated a 400-2 Kevlar 29 weaving specification. Prior to the Aerospace effort, no weaving specifications existed for this ballistic fabric.

The chart shows the important parameters necessary to weave a good quality ballistic fabric of 400 denier. The chart also shows initial steps for a similar specification generated for 1000-1 Kevlar 29, which may equal the strength and ballistic resistance of the 400-2 Kevlar but has a substantially lower cost.

Kevlar Material Specifications

V-87954

- BASELINE KEVLAR 29 400 DENIER FABRIC SPEC (Ref. Aerospace Weaving Specification)

STYLE:	100
YARN:	400 DENIER, 267 FILAMENTS, 2 PLY, 3 TWIST PER INCH, "Z" TWIST
YARN COUNT:	36 WARP, 36 FILL
WEAVE:	1x1 PLAIN WEAVE
FINISH:	CLOTH SHALL BE SCOURED
WEIGHT:	8 oz/yd^2
COST:	UNDER $15.00 PER YARD WOVEN ($14.50 per pound yarn)
SCHEDULE:	2-3 MONTH LEAD TIME IF YARN AND WEAVING LOOMS ARE AVAILABLE

- POTENTIAL BASELINE WITH 1000 DENIER KEVLAR 29
  - AVAILABILITY AND LOWER COST (<$10 per pound)
  - SIMILAR WEIGHT TO STRENGTH (31x31 thread count)
  - SIMILAR FLEXIBILITY AND TAILORING
  - BLUNT TRAUMA TO BE CONFIRMED

V-87955 R1 - Other Kevlar Applications

Kevlar has found many applications in both the civilian and military markets. The major market is in tire cord where it replaces steel and other nonmetallic materials. In composite form, Kevlar is used in lightweight structural members for aircraft, armor for helicopters, winding material for rocket motor cases, and in miscellaneous helicopter components.

Two additional applications have been recently investigated: the use of Kevlar to protect scuba divers from shark bites and to protect a trainer's arm in sentry dog training.

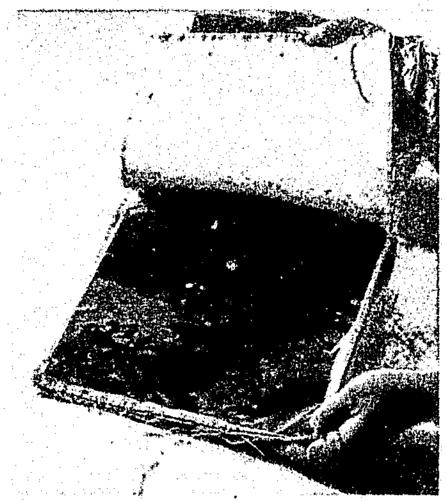
In the first case, a sample of the material was provided to the U.S. Navy which conducted a series of tests in the Pacific Ocean wherein sharks were incited to attack a dummy arm protected with Kevlar. After a number of attacks, the sample was inspected and showed no penetration beyond the third ply.

In the other experiment, the trainer's arm was wrapped in approximately eight layers of Kevlar and a coat was then slipped over the protected arm. After a number of attacks, the coat sleeve was shredded but the Kevlar was not penetrated and the trainer was unharmed.

Other Kevlar Applications

- PROTECTIVE GARMENTS
  - WET SUIT SHARK BITE PROTECTION
  - SENTRY DOG ATTACK TRAINING
  - BUTCHER APRONS
- PARACHUTES/SAILS
  - LIGHTWEIGHT LOW-VOLUME HEAT-RESISTANT CHUTES FOR EJECTION SEATS
  - CARGO AND WEAPON DELIVERY CHUTES
  - CUP DEFENDER YACHTS (Kevlar Fill, Dacron Warp)
- AUTOMOBILE TIRES
  - HIGH-STRENGTH REPLACEMENT FOR POLYESTER FIBER OR STEEL CORD
- STRUCTURAL MEMBERS
  - ROCKET CASES
  - AIRCRAFT INTERIORS (L-1011)

SHARK ATTACKS



NO PENETRATION BELOW THIRD LAYER

V-87893 - Prototype Garments

Prototype garment development and fabrication proceeded along two paths. The first approach was to initiate the fabrication of standard-type protective garments which would be acceptable to the departments participating in the wearability tests. This resulted in the development of a variety of uniform components with the protective material built in (e. g., jackets, coats), and a number of civilian garments (e. g., sport coats and dress vests) and special purpose garments (undershirts, body shirts, external vests). Approximately 75 garments have been fabricated and are deployed for testing. The second approach was to produce experimental garments and other items of protection for evaluation. These items comprise approximately 25 different types (arm protectors, dickeys, jump suits, etc.), which are currently being fabricated for evaluation.

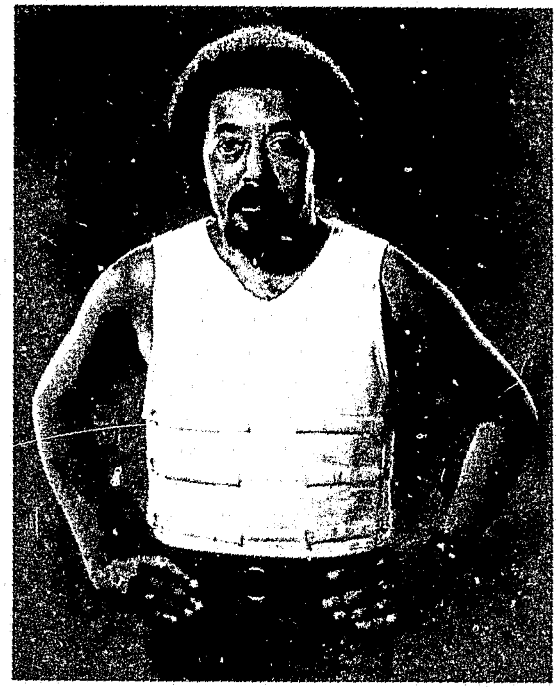
To obtain an estimate of the difficulty of fabricating this material into garments, several independent manufacturers were selected to make them.

Prototype Garments

APPROXIMATELY 25 SEPARATE DESIGNS
EVALUATED FOR CONTINUOUS WEAR APPLICATION

- THREE BASIC GARMENT TYPES

UNDERWEAR

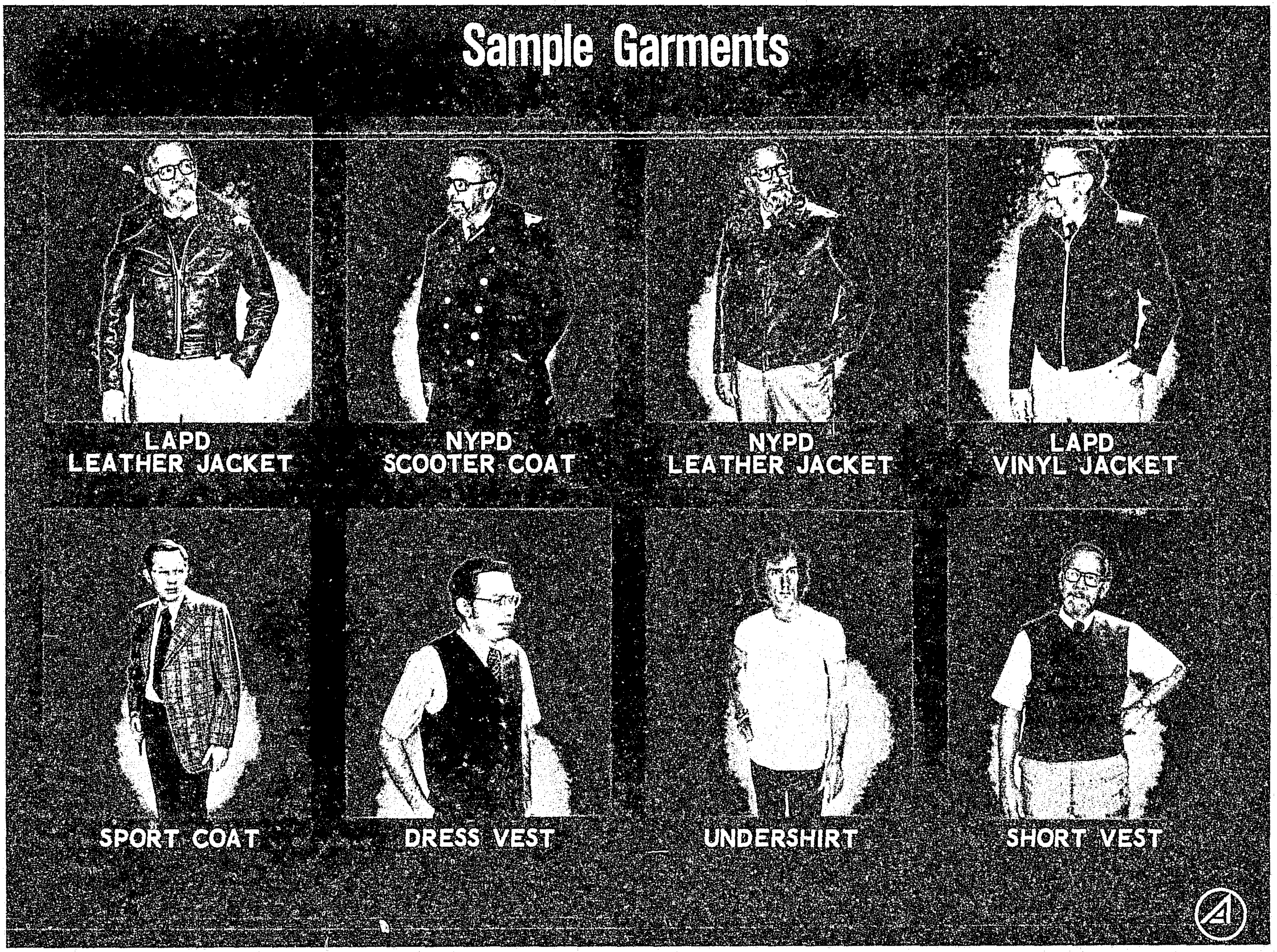


POLICE
INTEGRATED
UNIFORM

PLAINCLOTHES

V-83427 - Sample Garments

This chart shows some of the garments fabricated for the wearability test. The top set is representative of the uniform components into which the ballistic material has been incorporated. In the bottom row, the sport coat and dress vest are representative of civilian garments which integrate the material while the other two garments represent special-purpose types.


Sample Garments
LAPD LEATHER JACKET
NYPD SCOOTER COAT
NYPD LEATHER JACKET
LAPD VINYL JACKET
SPORT COAT
DRESS VEST
UNDERSHIRT
SHORT VEST

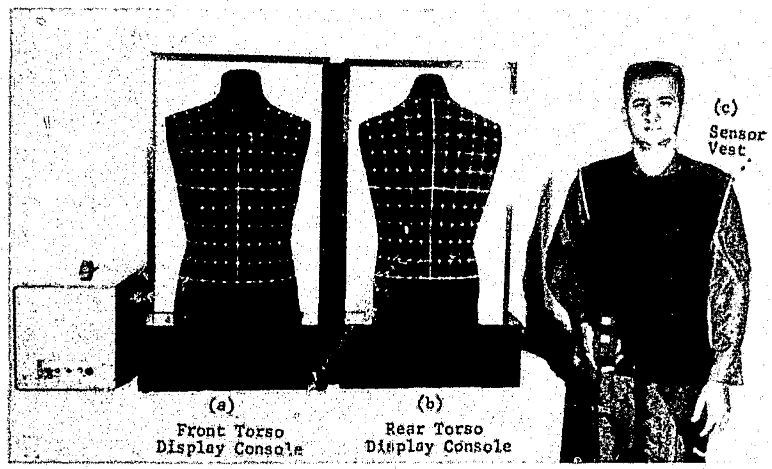
V-87957 R1 - Anatomical Load Distribution Analyzer

Normally, protective body armor is empirically designed and prototypes are fabricated which are evaluated and later transposed into items of protection used for field evaluation. The field evaluation determines whether the items are an improvement over existing garments and aids in establishing their acceptability by the users. The results of these evaluations are usually subjective and depend upon observations made by persons wearing prototype garments during various operational scenarios. As part of the evaluations, questionnaires in which the test participant is asked to comment on characteristics of a garment are analyzed. However, it is seldom that quantitative information can be derived from these time-consuming and expensive evaluation tests.

The measurement of stresses acting on the body is an important approach to the continuing effort to analyze and reduce the discomfort of wearing protective garments. To meet this need, the design, development, and fabrication of a full-scale anatomical load distribution analyzer was undertaken by the U. S. Army Natick Laboratories. This device presents instantaneous and continuous visual data related to loads on the human torso.

Anatomical Load Distribution Analyzer

- ARMY NATICK LABORATORIES CAPABILITY (equipment has patent pending)
- INSTRUMENT TO EVALUATE AND IMPROVE THE DESIGN OF PROTECTIVE GARMENTS
- CAPABLE OF MEASURING AND DISPLAYING
    - PRESSURE
    - PRESSURE CHANGES
    - LOAD MAGNITUDE
    - DISTRIBUTION OF FORCES TRANSMITTED TO THE TORSO BY THE GARMENT



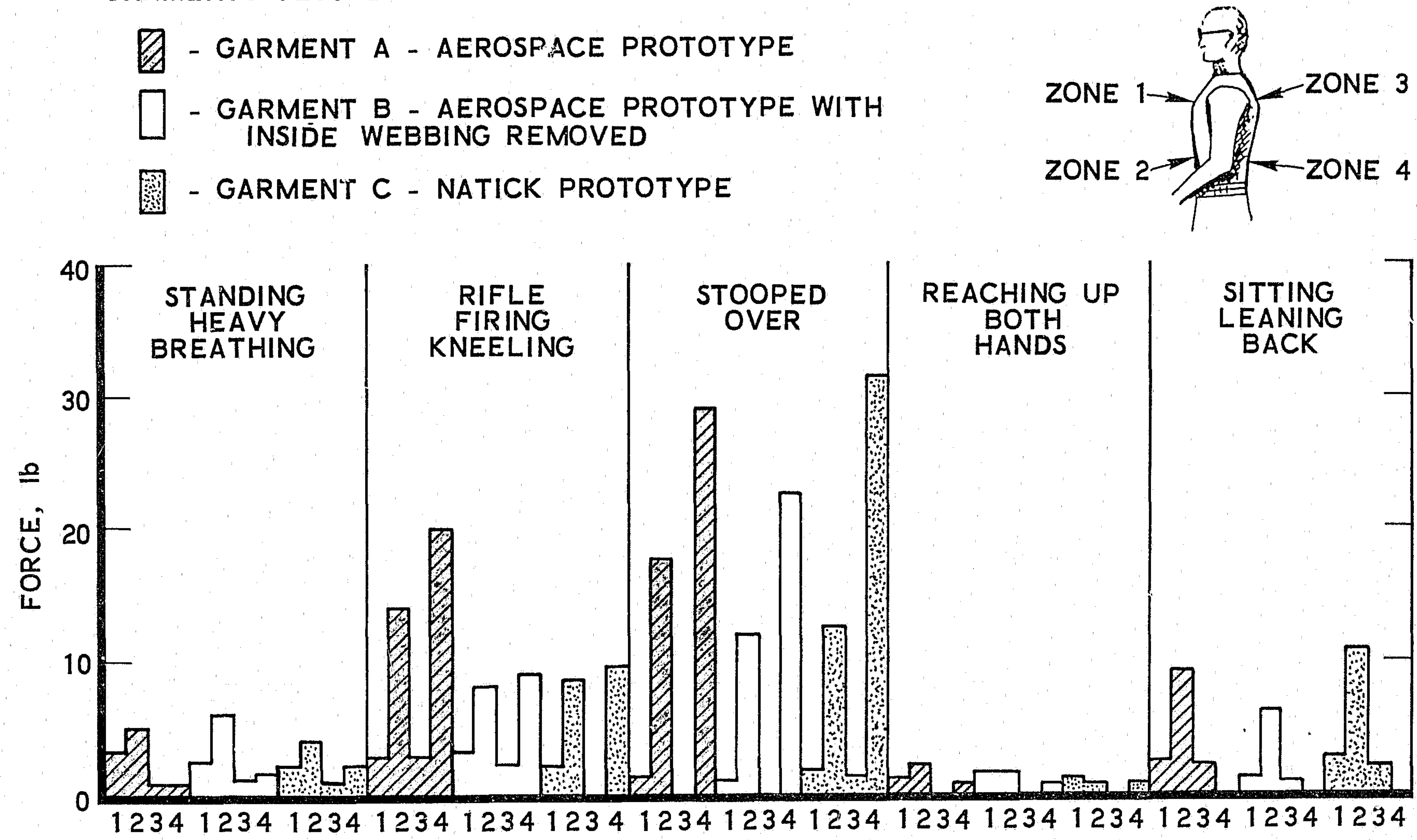
- CONSISTS OF:
    - 248 MINIATURE LOAD SENSORS
    - "3D" UNIT TO VISUALLY DISPLAY LOADS

V-87958 - Typical Anatomical Load Measurements

This chart shows the results of a preliminary analysis of anatomical load measurements using the load profile analyzer. The purpose was to obtain objective baseline data for experimental ballistic undergarments for law enforcement personnel. These data were then used to improve the design, fit, and acceptability of the undergarments. In the tests, loads imposed at different zones on a subject while performing simulated psycho-motor tasks were measured. Data were recorded for the following eight activities: Standing-Heavy Breathing, Rifle Firing-Standing, Rifle Firing-Kneeling, Stooped Over, Reaching Up-Both Hands, Reaching for Holster - Right Hand to Left Side, Reaching Forward - Both Hands, and Sitting - Leaning Back. Data for five of these are shown.

Typical Anatomical Load Measurements

- ARMY NATICK LABORATORIES TESTS
- GARMENTS TESTED WERE 7 PLY KEVLAR UNDERGARMENTS



V-83496 R3 - Pilot Wearability Test

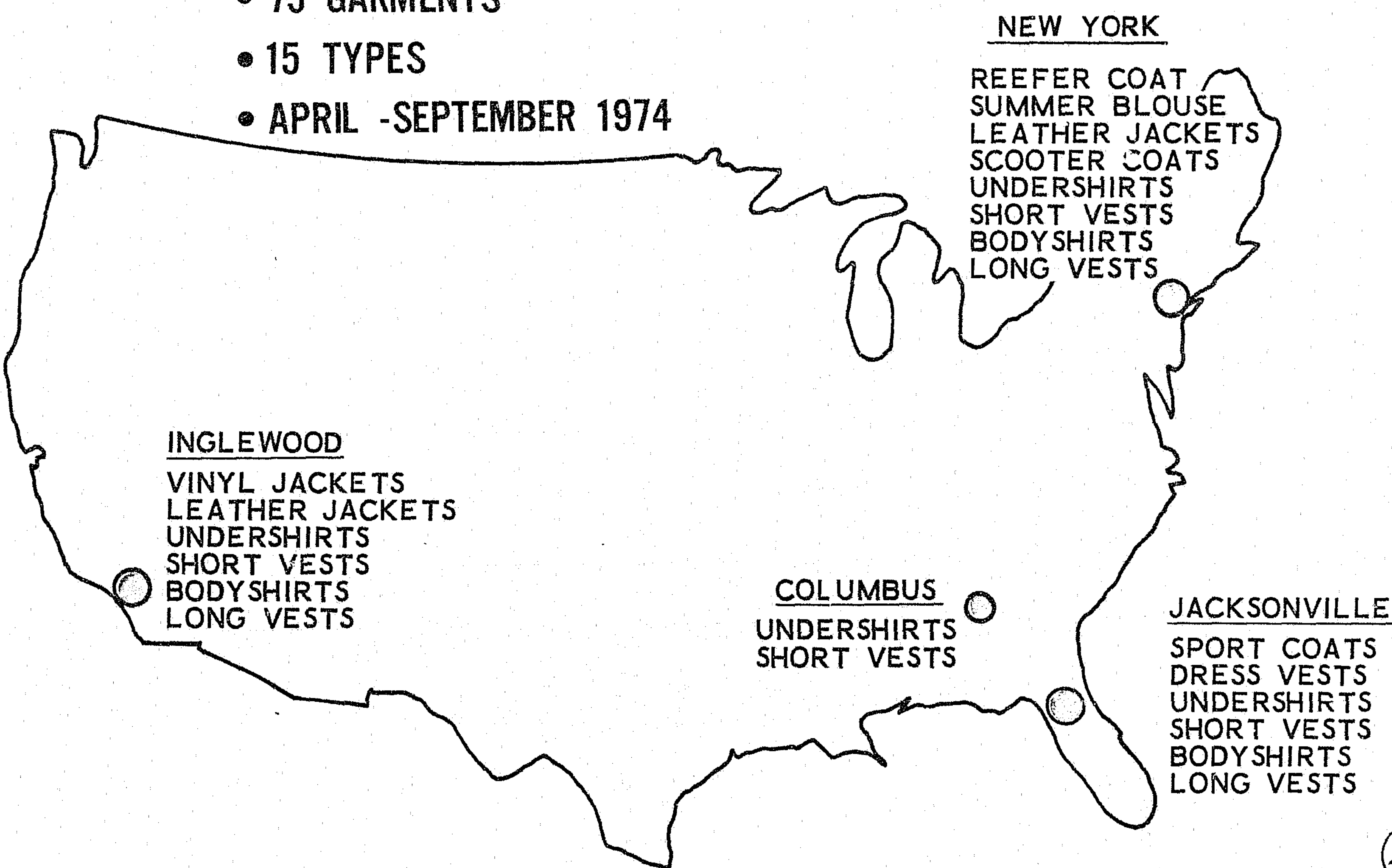
This chart shows the distribution of the prototype garments employed in the pilot wearability test program. Since the test program did not begin until April in New York, late May in Jacksonville, and late June in Inglewood, California, the tests were run during the hottest part of the year. As a result, the integrated garments were seldom worn.

The tests in Columbus were conducted by a night stake-out team and the discomfort of the garments due to heat was not as evident.

At the time the tests were planned, the fabricated garments represented those estimated to be of most interest to the departments and were the best designs available. Since these garments were fabricated in parallel with the development activity, improvements uncovered as development progressed could not be incorporated. The development effort and the preliminary data from the wearability test program have indicated a number of design improvements which will be incorporated in the garments procured for the field evaluation test.

Pilot Wearability Test

- FOUR LOCATIONS
- 75 GARMENTS
- 15 TYPES
- APRIL -SEPTEMBER 1974



V-87897 R1 - Typical Wearability Test Results

The test results for the undershirt in New York are typical of those obtained from the wearability test program.

Tests in Jacksonville, Florida were completed in the week of September 9 but the results have not been reduced. Preliminary verbal inputs indicated that the provided designs were too warm for comfortable wear in the summer climate. As a result, the design of the basic undershirt has been modified and an alternative undergarment has been designed.

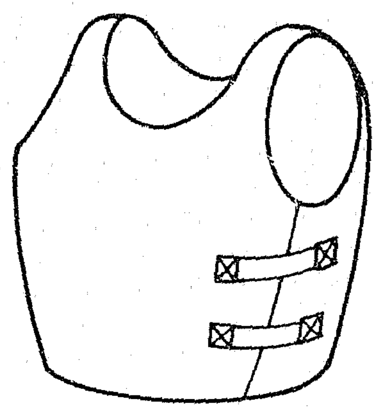
The test program is still under way in Inglewood, California.

In general, the personnel participating in the tests like the concept of the lightweight, inconspicuous garments. However, the problems uncovered need to be alleviated.

V-87897 R1

Typical Wearability Test Results

- GARMENT TYPE: UNDERSHIRT, SIDE PROTECTION
- LOCATION: NEW YORK CITY - SPECIAL FORCES
- WEAR PERIOD: APRIL TO AUGUST 1974
- EXPERIENCE: 7 OFFICERS WITH 42 WEEKLY REPORTS
- SHIFT: 37% AM 4% PM 55% BOTH 4% OTHER
- ASSIGNMENTS: 74% AUTO PATROL 20% FOOT PATROL 6% OTHER
- WEAR HISTORY: 70% FULL TIME 20% HALF TIME 10% VERY LITTLE
- DISCOMFORT: 74% HOT 20% RIDES UP



QUALITATIVE WEAR SUMMARY (Percent)

	AGREE	NEUTRAL	DISAGREE
EASY ON/OFF	95	1	4
FITS WELL	80	10	9
FREE MOVEMENT	98	-	-
EASY WEAPON ACCESS	100	-	-
NORMAL MANEUVERABILITY	98	2	-
NO CHANGE IN COMFORT	32	16	35

V-87892 - Wearability Test Conclusions

The wearability tests at the four locations around the United States were conducted between April and September 1974. In all areas the weather was hot and humid. As a result, many of the integrated garments could not be worn. In all locations, the undergarments appeared to be the most liked, although the outer vests were well liked since they were an occasional wear item. The two main objections were the heat containment of the garments and in some cases their tendency to ride up on the wearer. A number of changes have been incorporated in the undershirt design to relieve these two conditions. The arm holes have been enlarged to allow more ventilation and also to minimize chafing if the garment does ride up. Greater adjustment has been provided to ensure proper fit. In addition, a new undergarment has been designed in the form of shaped front and back panels to alleviate the heat problem in the hot and humid areas at the expense of some side protection.

There were only mild complaints of hindrances to movement and weapon access. In the stress condition of subduing a suspect, there were no indications that the garments interfered with the performance of the officers' duties.

A number of operational methods were uncovered which will increase the efficiency and utility of future testing as indicated on the chart. The key is the dedication of the police department test coordinator and the motivation of the officers participating in the test in terms of the importance of the test program to them and their contributions to it.

V-87892

Wearability Test Conclusions

- GARMENT DESIGN
  - UNDERWEAR GARMENTS ACCEPTED AS MOST APPLICABLE
  - CAREFUL UNDERWEAR FITTING OR ADJUSTABLE TAKEUPS REQUIRED
  - UNDERWEAR SIDE PROTECTION MAY BE TRADED OFF FOR COMFORT IN HIGH TEMPERATURE/HUMIDITY SITUATIONS
  - MOST GARMENT TYPES ALLOW GOOD MOBILITY AND EASY WEAPON ACCESS
  - NO HINDRANCE FOUND IN 5 INCIDENTS INVOLVING PURSUIT AND PHYSICAL APPREHENSION OF SUSPECTS
- TESTING METHOD
  - SPECIAL POLICE COORDINATOR DESIRABLE
  - INDIVIDUAL FITTING OF GARMENTS IMPORTANT
  - WEARER ORIENTATION DESIRABLE
  - BALLISTIC DEMONSTRATIONS OR FILMS REQUIRED FOR WEARER'S CONFIDENCE IN THIN MATERIAL

V-83572 R2 - Field Evaluation Planning

This chart depicts the flow of activity in planning a field test program. The first block represents the critical planning activity in which all of the objectives are defined and the program scope is determined through trade-off analyses. The criteria to verify the attainment of these objectives are then defined and the value of the objectives weighed against the program costs and schedule. From this analysis, a limited program is identified to maximize the return on the investment.

The test planning function is an iterative-type procedure whereby a number of objectives are carried through the planning flow on a preliminary basis for the purpose of trade-off analysis, and one or more approaches may be carried through detailed planning for final selection among the alternatives.

V-84498 R5 - Field Evaluation Objectives

By applying the rationale and approach from a previous chart to the potential major objectives of the program, those which can be obtained within reasonable cost and schedule constraints reduce to those shown on this chart. The objectives which are associated with specific medical correlation of blunt trauma effects in specific critical areas require an excessive number of garments or an excessively long test period. Consequently, the cost benefit to be derived from such a program would be low and is better accomplished through other test programs (e. g., laboratory tests, medical tests, other correlations). Similarly, the assessment of the reaction of the criminal element and/or public to the use of body armor by law enforcement personnel is beyond the specific scope of the field evaluation program. With the introduction of the improved protective armor and other soft armors, a more general program could be envisioned to investigate these effects.

The primary emphasis then becomes that of demonstrating broad user acceptance, wearability and comfort of the garments. Since the law enforcement personnel who will be wearing these garments are, in the course of their duties, exposed to assault threats, the existence of the garments will afford them protection. The degree of this protection can then be evaluated. Finally, the quantity of garments produced will allow the investigation and evaluation of the methods and techniques used to fabricate the garments with respect to future large-scale production.

The summation of the data derived from the development and field evaluation programs can then be assembled into a comprehensive data package for technology transfer.

Field Evaluation Objectives

FIELD EVALUATION OBJECTIVE	ANALYSIS PARAMETERS	SITE CONSIDERATIONS	EQUIPMENT CONSIDERATIONS
• DEMONSTRATE BROAD USER ACCEPTANCE	MULTIPLE GARMENT STYLES WITH POSITIVE ATTITUDINAL SURVEYS	MULTIPLE DEPARTMENT EXPOSURE	1000
• OBTAIN DATA ON GARMENT WEAR CHARACTERISTICS	MULTIPLE GARMENT TYPES WORN FOR APPROXIMATELY ONE YEAR WITH PERIODIC GARMENT INSPECTION	MULTIPLE SITES, GEOGRAPHIC DISTRIBUTION	1000
• OBTAIN DATA ON PERFORMANCE	FIVE THREAT ASSAULTS IN PROTECTED AREA	MULTIPLE SITES HIGH ASSAULT RATE	5000
	SINGLE THREAT ASSAULT IN PROTECTED AREA	ONE OR MORE SITES HIGH ASSAULT RATE	1000
• DEMONSTRATE ABILITY TO COST EFFECTIVELY PRODUCE GARMENTS	MASS PRODUCTION FABRICATION OF TYPES AND STYLES TO ASSESS QUALITY CONTROL AND COST	NOT APPLICABLE	1000

V-87896 - Field Evaluation Summary

The National Institute of Law Enforcement and Criminal Justice and The Aerospace Corporation are currently identifying the cities that are to participate in the field evaluation program. Sixteen candidate cities have been contacted and specific data have been received that will be used in the evaluation and selection process. Preliminary data indicate that 3000 to 5000 garments are required for field evaluation to meet all test objectives. As a result of the contacts with the cities and a review of the data presented, it appears that approximately 4000 garments are required, with the majority the undershirt type.

Three procurement actions have been initiated: (1) procurement of 15,000 yards of Kevlar 400 denier, 2-twist, 36 × 36 pics to the inch, (2) procurement of 3000 undershirts of two different styles, and (3) procurement of integrated and special-purpose garments.

Current planning calls for the initiation of the test program in February 1975.

V-87896

Field Evaluation Summary

- FIELD TEST UP TO 5000 GARMENTS
- TEST DURATION NOMINALLY ONE YEAR BEGINNING EARLY CY 75
- SIXTEEN CANDIDATE CITIES SELECTED AND VISITED
- HIGH INTEREST SHOWN BY CANDIDATE CITIES
- PLANNED COMPETITIVE PROCUREMENTS
  - MATERIAL - 15,000 YARDS (Oct 74)
  - GARMENTS - 3000 UNDERSHIRTS (Nov 74)
  - GARMENTS - 1000 INTEGRATED UNIFORMS (Dec 74)

V-83604 R1 - Garment Production Plan

These are the preliminary ground rules and assumptions which are being made in terms of producing the protective garments for the field evaluation test program.

The material specification for weaving the basic yarn into ballistic material has been prepared. Specifications for the non-integrated garments are in process. In those cases where the material will be integrated into a standard uniform component, an addendum specification will be prepared on the methods and techniques to be employed.

Rigid quality control requirements will be included in all specifications to ensure quality production of all garments.

V-83604 R1

Garment Production Plan

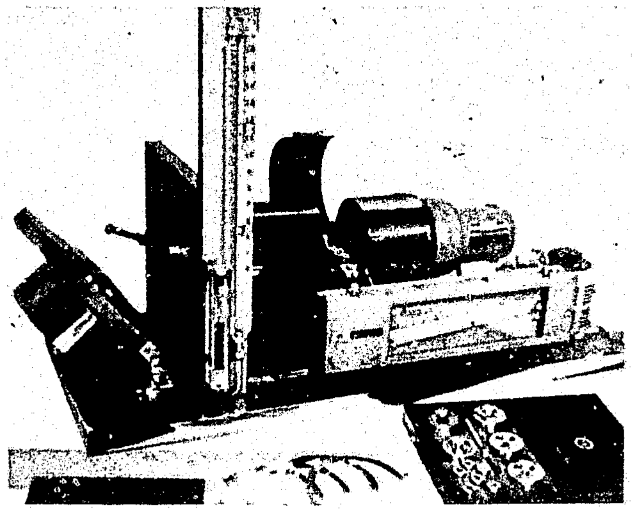
- ASSUMPTIONS
  - FIELD TEST GARMENTS (~ 3000) AVAILABLE 1 FEB 1975
  - TWO BASELINE GARMENT TYPES FOR EACH LOCATION
  - TWO REPRESENTATIVE INTEGRATED UNIFORM TYPES FOR EACH OF SIX LOCATIONS
  - APPROXIMATELY 15,000 YARDS OF PROTECTIVE MATERIAL
- SPECIFICATIONS TO BE PREPARED FOR BOTH PROTECTIVE MATERIAL AND GARMENTS
- COMPETITIVE PROCUREMENTS
  - MATERIALS - SINGLE WEAVER
  - GARMENTS - SINGLE FABRICATOR FOR BASELINE GARMENTS
    - MULTIPLE FABRICATORS FOR INTEGRATED UNIFORM TYPES
- STRINGENT QUALITY CONTROL PROCEDURES AT BOTH THE MATERIAL AND GARMENT LEVELS

V-86609 R2 - Quality Control - Air Permeability

The chart presents a quality control test for determining the tightness of the woven fabric. If loose or missed yarns are not detected during in-process inspection, the air permeability test data will reveal these defects. The permeability data verify that the weaving parameters have been consistent.

In essence, the permeability test consists of measuring the rate of air flow through the material.

Quality Control - Air Permeability



- PURPOSE OF TESTS IS TO DETERMINE TIGHTNESS OF WOVEN FABRIC
- AIR PERMEABILITY IS A GOOD QUALITY CONTROL CHECK TO ENSURE PROPER TENSION HAS BEEN APPLIED TO THE FILL AND WARP YARNS DURING THE WEAVING PROCESS

TYPICAL AIR PERMEABILITY VALUES

MATERIAL		AIR PERMEABILITY (cfm)
400/2	38 x 38	28
400/2	38 x 38 (Scotch Guard)	46
400/2	32 x 32	70
1000/1	31 x 31	<5
400/1	65 x 65	<5
400/1	65 x 40	<5
200/1	62 x 58	10
BALLISTIC NYLON	23 x 20	8.4

V-84084 - Medical Plan

In a test program of this size and duration, it is probable that some law enforcement personnel will be assaulted while wearing the protective garments. In such cases the garments will prevent a number of fatalities within the weapon threat constraints when the projectile impacts the protective material. However, there will be blunt trauma effects transmitted through the material into the body. A medical plan will be prepared to ensure the best possible treatment in a timely manner. The plan will draw on the best available local medical personnel for immediate treatment and on a team of experts from the Army and private practice for the investigation and analysis of blunt trauma effects.

Human use factor considerations will be developed and implemented in line with the guide lines developed by the Department of Health, Education, and Welfare (HEW).

V-84084

Medical Plan

- IDENTIFY SITES WITH SUPERIOR MEDICAL FACILITIES
  - PERSONNEL WITH TRAUMA EXPERIENCE
  - FACILITIES TO TREAT AND OBSERVE TRAUMA
- DEFINE WOUND EXPECTANCY AND TYPES FOR ON-SITE MEDICAL PERSONNEL
  - CARE AND TREATMENT OF WOUND TYPE
  - PRESERVATION OF DESIRED BLUNT TRAUMA DATA
- PROVIDE A QUICK REACTION INVESTIGATIVE TEAM
  - EDGEWOOD PERSONNEL
  - AEROSPACE CONSULTANT (Dr. J. Benfield)
  - OTHERS
- HUMAN USE FACTORS
  - EDUCATIONAL (capabilities, limitations, and objectives)
  - MEDICAL
  - LEGAL
  - SIGN-OFF

V-88058 - Future Efforts

Development and testing activities to date have validated the limited protection concept associated with the .38 special threat (.158 grain bullet at 800 feet per second), both from the point of view of penetration and blunt trauma. The emphasis has been on demonstrating the basic concepts rather than on improving the material.

Future efforts will be directed toward improving lightweight body armor to increase the level of threat protection, reduce blunt trauma effects, and increase the knowledge of the interaction phenomena and the understanding of the medical correlation between the cavity and the wound.

These efforts have been initiated, but the data and results obtained so far are of a very preliminary nature. However, the direction and approach to be followed has, in some cases, been indicated. As these data become available, the results will be supplied to industry and the user as appropriate through the technology transfer function.

V-88058

Future Efforts

- CONTINUE NEW MATERIALS EVALUATION
- INVESTIGATION OF BLUNT TRAUMA ALLEVIATION MECHANISMS
- INVESTIGATE HIGHER ENERGY BALLISTIC THREATS (9 mm, .357 magnum)
- COMPLETE PHENOMENOLOGY TASKS
  - SOFT ARMOR MODELLING
  - BACKFACE CAVITIES/BLUNT TRAUMA MEDICAL CORRELATION

V-88059 R1 - Lightweight Body Armor Program Support - NBS/LESL

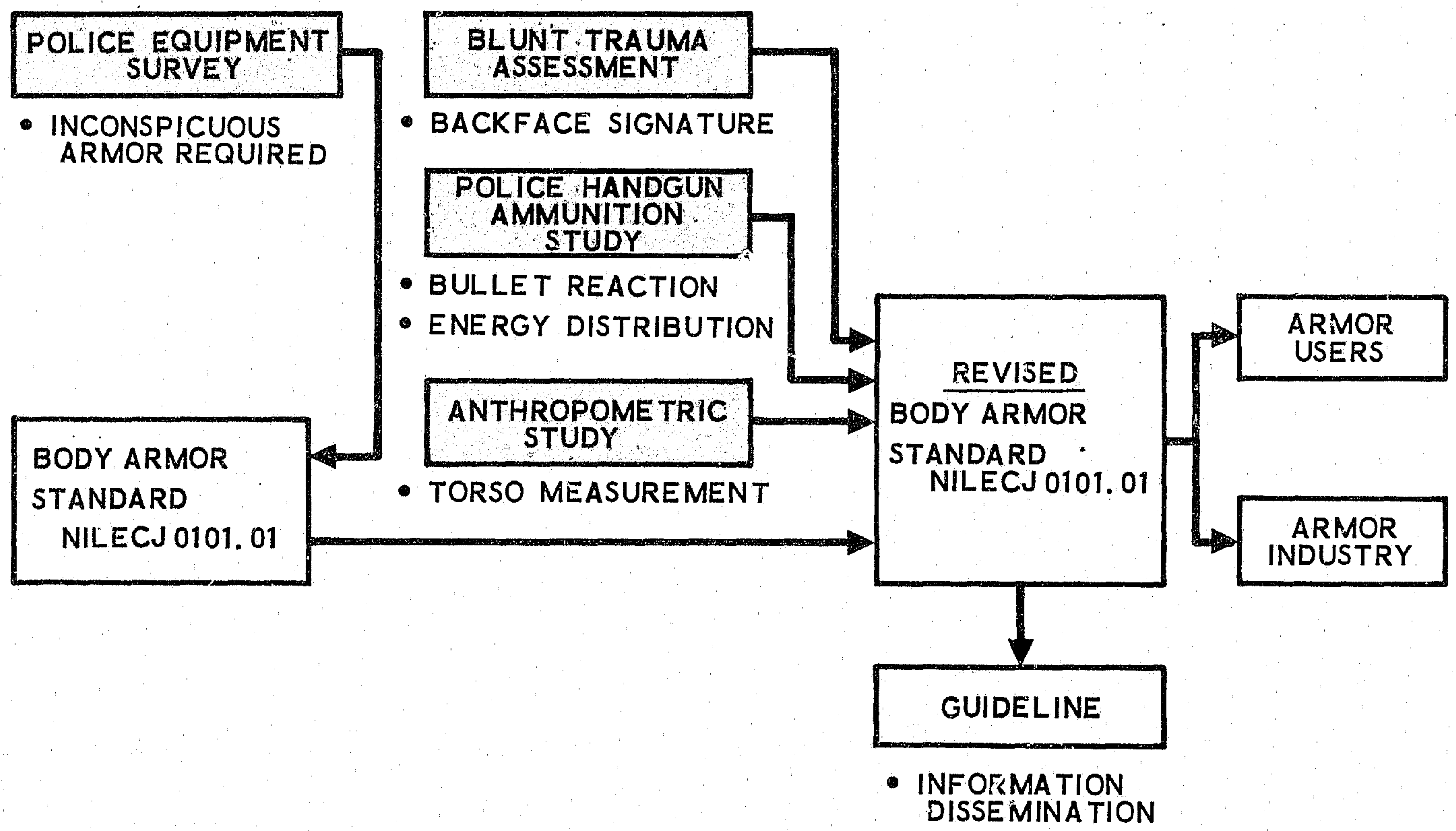
The Law Enforcement Standards Laboratory (LESL) of the National Bureau of Standards (NBS), responds to the needs of the National Institute of Law Enforcement and Criminal Justice in several ways. Primarily, the LESL mission is to conduct research and testing on highly specialized law enforcement equipment items intended to culminate in national voluntary performance standards, guidelines, and reports for these items. Because of the expertise accumulated in conducting this research and because of the varied laboratory facilities available at NBS, the Institute often finds it helpful to consult with LESL scientists and engineers concerning other projects within the Institute. This is the case with body armor.

LESL began investigating body armor back in 1970 and has never really stopped. This project produced the first NILECJ Police Equipment Standard which is presently under revision. Several of the areas under revision directly affect the lightweight body armor development efforts, e.g., the requirement for assessing the protection afforded by such armor against deformation without penetration - the so-called blunt trauma problem, the requirement for environmental conditioning of the test armor, and the requirement for penetration of such armor by knives. LESL is producing this type of data on all commercially available body armors.

In turn, new developments in the detailed examination of Kevlar are passed on to LESL and are incorporated into their standards and guidelines. The work on blunt trauma being carried out at the Edgewood Arsenal Biophysics Laboratory will hopefully provide the necessary correlation between physiological and physical data on the deforming armor which LESL requires before it can establish a meaningful performance requirement and test procedure. The data being generated by The Aerospace Corporation on in-the-field use, laundering, wear, etc. will aid in determining if there are important performance requirements in these areas that should be addressed in the standard for police body armor.

Lightweight Body Armor Program Support

NATIONAL BUREAU OF STANDARDS - LESL



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