Technical Report: NAVTRADEVCEN IH-78

INVESTIGATION INTO MATERIALS AND DESIGNS OF SMALL ARMS TARGETS FOR "TRAINFIRE" MECHANISMS

Robert B. Terry

Electronics Laboratory

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NAVAL TRAINING DEVICE CENTER

ORLANDO, FLORIDA

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ABSTRACT

This report describes an investigation into "silhouette" and "realistic" target designs and materials that possess improved environmental and scoring characteristics when used with the impact actuated pop-up "Trainfire" target mechanism. The actual firing test results narrowed the material selection for the two completely different designs to two modern plastic materials having the common superior capability of absorbing several thousand service rifle rounds with uniformly high scoring, when used in "Trainfire" marksmanship devices.

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Approved:

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FOREWORD

During wartime, combat training is intensified and compressed timewise, with small arms marksmanship training availing itself of remotely controlled silhouette targets in natural settings, to reduce supporting manpower requirements and promote realism. A replacement for the currently issued silhouette kneeling (E type) Ordnance Corps Drawing #8426438 fiberboard target is the subject of this investigation.

For the tremendous number of men involved in training, any reduction in training time and/or cost is a very important item to consider.

The target improvements which this report describes constitutes a materials research effort which shows the result of the proper application of modern materials to an old problem. The plastic material, during and after range testing with actual service rounds, exhibited weatherproofness, high hit accuracy in the scoring mechanism and extraordinary high bullet hole capacity. The usefulness of this silhouette target is further enhanced by attaching a realistic appearing "aggressor" three-dimensional element to be used where advanced guerilla training is conducted.

Testing was confined almost exclusively to the small arms firing range for this project because no laboratory test can at present duplicate the performance of target material when punctured by high velocity spitzer bullets.

This report describes the investigations into the basic requirements for both the silhouette and "realistic" three-dimensional targets, the steps leading to the selection of the two final materials and designs by means of the actual firing program. Regardless of the phenomenal target life achieved, as described herein, this breakthrough should be augmented by the awareness of the constant development of new material properties which could be expected to provide future improvements in this area.

The author wishes to acknowledge the contributions of RAI Research Inc. Long Island City, who under Contract N61339-1820, were responsible for obtaining various sample materials, performing certain measurements and fabricating the targets used for testing.

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Project Engineer
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I. INTRODUCTION

A. Background

Traditionally, military marksmanship training has been conducted on paper bullseye targets at known distances on open firing ranges employing pit crews to score the targets as they were hit. The targets were secured to counterbalanced vertical frames which alternately disappeared into pits below ground level (safety) where they were scored, holes pasted up and returned to view for the next shot. This required at least one man per firing point in the pit detail; a costly, time consuming operation, considering the large number of armed forces scheduled on a rotating basis thru the various training echelons to prepare for current assignments. To reduce the manpower requirements, a remote-controlled, hit-actuated, pop-up target mechanism with automatic scoring has been developed.

Another factor which is being emphasized in combat marksmanship training in the Army is appropriate realism. This has manifested itself in the 100% utilization of silhouette targets in the Army "Trainfire" disappearing (pop-up) target mechanism (M31A1: Army, 3C52: Navy) used on Record Courses of Fire. The silhouette most often used is that of a kneeling man with the pop-up mechanism planted in a shallow pit whose depth (target height) is inversely proportional to the shooting distance. These targets are situated in semi-cleared terrain at distances of from 50 meters to 350 meters with the targets under remote control of the range officer, except for the recruit's scoring hits which automatically lower the target indicating a "kill." The Army whose range of equipment on which proficiency must be attained is very great, feels that it gets the most marksmanship for the dollar using "Trainfire"; the Marine Corps, who consider themselves primarily small-arms specialists with only a limited amount of formal support equipment generally available, place more emphasis on rifle marksmanship training by becoming proficient on the bullseye target and progressing to the silhouette pop-up (3C52)(A and B Courses) on the combat environmental ranges where the silhouettes appear at surprise locations for limited intervals and realistically fall when hit, thus enhancing training realism.

It can be seen above that progress has been made in two distinct areas--manpower economy, and increased combat marksmanship realism. One is accomplished by eliminating the target pit detail and the other by employing a target representing the silhouette of a kneeling soldier, which when hit falls down to indicate a kill.

B. Silhouette Target

Both services use essentially the same "Trainfire mechanism" to present a target which, when hit by a bullet, is lowered (falls) automatically. The usual course of fire utilizes the device in the automatic mode when hit, and is remotely raised to the vertical position (visible to the trainee) by the range officer when the firing exercise or course is in progress. This mechanism has a target holder that grips the lower edge of the silhouette target and has two vibration-sensitive microswitches (figure 1) which operate the mechanism to lower the target when a bullet induces shock and vibration to the target and in turn to the microswitches.

The target currently used in the pop-up mechanism is of fiberboard construction selected as a result of a study by the Rock Island Arsenal Laboratory (1). The fiberboard selected consisted of a large percentage of long virgin kraft sulfate fibers plus a small amount of jute fibers (reclaim), calendered very heavily and coated on both sides with a water repellent resin. In actual practice this target has several faults. It is subject to moisture saturation upon being holed by bullets, thus causing loss of rigidity with attendant pop-up failure, i.e., the material does not absorb and transmit enough projectile energy to insure actuation of the device under all conditions. To reduce this type of failure at some locations, the targets are removed indoors each night which necessitates excessive range-detail work before and after the day's firing. Another fault of the current "issue" target material is that bullet passage delaminates the exit area, reducing the material thickness and producing a hole full bullet size, thus reducing the chances of recording a second hit in the same hole (an age-old complaint in target shooting). The delamination process, see Figure 1, not only reduces the target's rigidity but the blown-out area invites additional moisture penetration. The vibration-transmitting ability of the target is appreciably reduced after approximately 300 rounds, without introducing moisture or water during the test.

Recognition of a continuing requirement for a superior small arms target has resulted in the fabrication of many experimental targets of various materials such as sheet steel, aluminum, fiberglass, etc., however, all of these materials have eliminated themselves either due to high cost or high maintenance in the field. The

(1) See List of References

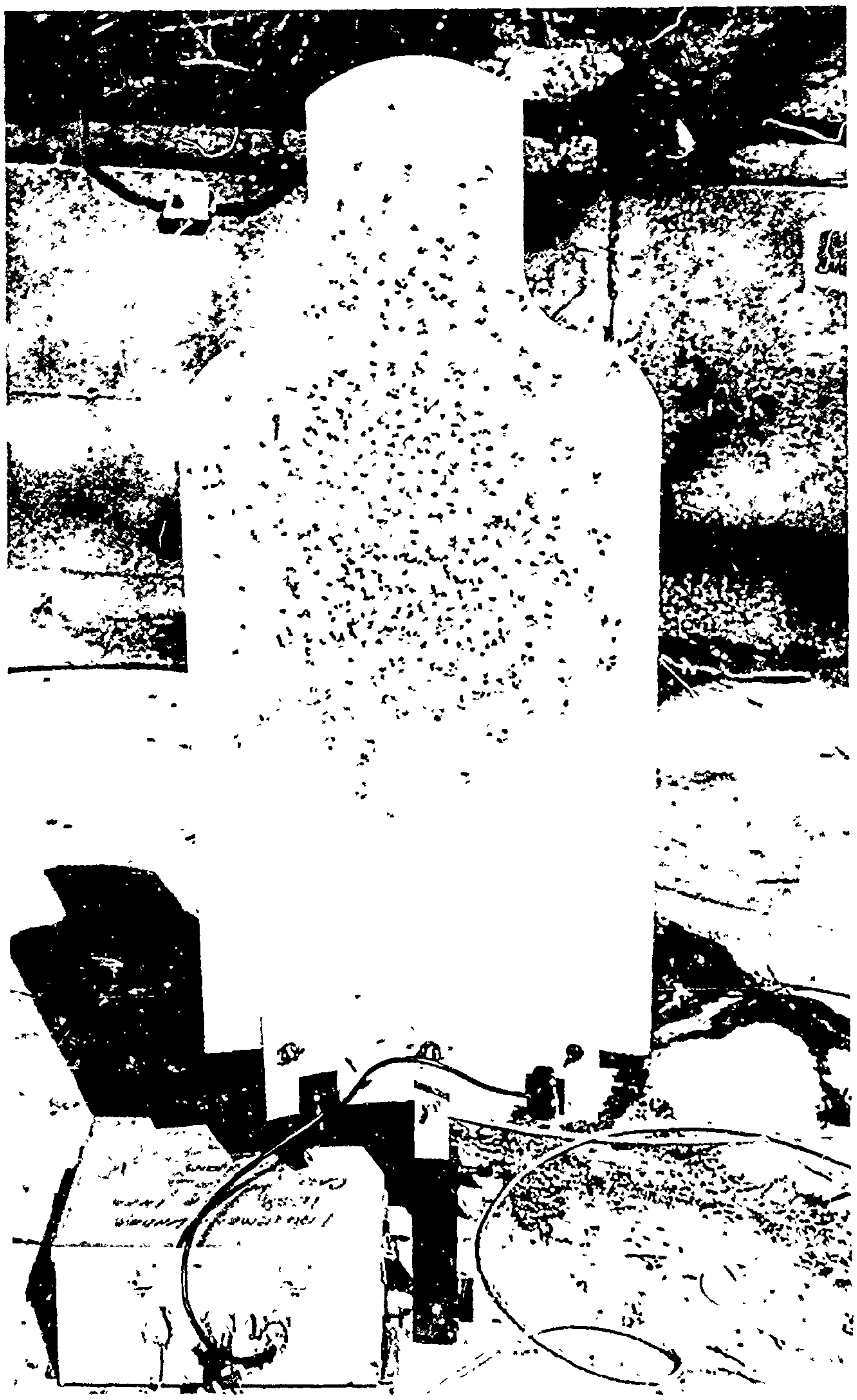

Figure 1. Rear view of Current Issue Fiberboard Target after 600 Rounds. Microswitches are shown in foreground.

fiberboard target remains the lowest initial cost material thus far--approximating 35 cents each depending on the quantity in the procurement order. This investigation has as one phase, the determination of the influences on the target material which make the present target unsatisfactory in order to provide a material and/or design which would be superior environmentally and have, as a minimum, the same response to rifle fire in the device.

C. Target Realism

Another phase of investigation running concurrently was to increase realism of the environmental range's pop-up targets. It has been recognized that the plain solid-colored silhouette target does not satisfactorily or realistically depict an enemy, who is officially known as an "Aggressor," having his own actual table of organization, uniforms, etc., as described in Reference (2). Since this regiment exists to help guerilla training, targets with similar recognition features would be desirable including a three-dimensional effect. This 3-D realistic "Aggressor" would mount over or onto either the existing target or the result of the silhouette target study and be used in the "Trainfire" devices. Three-dimensional realistic targets utilizing heavy closed cell foam have been used for "running-deer" type targets which also fall when hit in "vital" area. The areas have sensing means and the moving mechanism contains electro-hydraulic power to raise and lower the 3-D (deer or man) figure. Thus far these devices have operated on tracks, are expensive to install, and require a large range area. The requirement for a 3-D element to be used with a standard outline silhouette target in the pop-up device immediately imposed a drastic weight limitation, as the device becomes overloaded at a target weight of approximately 5½ lbs. The usual solution to this problem is a flexible polyvinlchloride (PVC) closed cell foam material which does not retain water but is relatively heavy. This problem was attacked by investigating open cell polyurethane foams because they can be formed, have low densities (approximately two pounds per cubic foot) and resist bullet destruction extremely well. Bullet holes were less than 0.1-inch diameter (.30-caliber rifle). Several water-repellant coatings to seal the foam and impart the "aggressor" uniform colors to the 3-D target were tried before a flexible urethane coating was found that did not adversely affect the bullet hole size and yet still greatly retarded water entry. In developing the attachable realistic 3-D target element several very important factors or requirements had to be considered: these were determined largely at the outset to be; light weight (silhouette backplate plus 3-D element to be less than 5.5 lbs.), high bullet hole capacity, fabrication feasibility and cost, water/moisture pickup, and hit response of the combination in the "Trainfire" mechanism.

II. SUBJECT

Materials for, and designs of, silhouette and three-dimensional "realistic" small arms targets were investigated and tested in "Trainfire" mechanisms under actual range conditions to evolve and develop targets that would satisfy the requirements for training on environmental small arms ranges at military installations.

III. OBJECTIVE

The objective of this investigation was to provide the material and design data for several types of small arms targets, to be used in the "Trainfire" mechanism, which have superior characteristics to that of the target in current use.

IV. DEFINITION OF THE PROBLEM

Initially, the problem was to determine the influences on the target material which make the current fiberboard target unsatisfactory. Since the target mechanism is activated by a bullet hit transmitting vibrations down the target to the holder clamp where two clipped-on vibration microswitches (4BS3 Honeywell, Micro Switch Division) (figure 1) activate the mechanism which signals a hit by lowering the target (disappears). It can be seen that the propagation of vibration waves by the target is vital to the operation of the system and therefore the target material must have a degree of rigidity or stiffness to insure the reception of vibrations at the holder. This immediately rules out soft absorbing type materials for the basic silhouette target which is rigidly clamped into the holder. Since the mechanism can handle two targets and the current specification on the fiberboard target (Ordnance Part No. 8426438 target, kneeling) is 2.75 lbs. maximum, there is in effect a weight limitation of 5.5 lbs. for any target or combination target (only one target is used in the device in actual practice). The 3-D realistic portion with its attendant bulk limits the materials to very low density types. These fall into the open cell plastic foam classification which of course is subject to moisture/water pick up, necessitating some form of waterproofing to achieve a satisfactory water repellant quality. Fiberboards although initially waterproof absorb water upon receiving bullet holes. One foam (polyethylene) appears to be ideal but can't be formed at present in a mold; it has to be cut.

An important requirement of any target is the cost aspect. The obvious increased cost of the plastic target has to be balanced by increased life, therefore it is necessary that the replacement target exhibit a good degree of durability under actual firing and environmental conditions. In order to have increased life the material has to resist destruction, i.e., loss of material. The fiberboard which is of laminated construction loses the material from the bullet hole plus additional delaminated material surrounding the hole. Therefore, it becomes weaker, less rigid and more flexible. What is needed is obviously a material which the pointed bullet pushes aside and then springs back to effect a partial or full closure and still absorb enough energy from the bullet to vibrate the rigidly maintained (although holed) target board. In the case of the 3-D element, which is necessarily low density foam, the same condition must prevail except for the rigidity factor.

The problem can be summed up as primarily a materials investigation and secondarily a design search to obtain a silhouette target that scores well, has long life on the range under fire and can resist the elements (to reduce field handling). The "realistic" 3-D attachable element must have long life, be realistic (aggressor features), and resist the elements.

V. PROCEDURE

Initial Testing

The Rock Island Report (1) on fiberboard targets evaluated a number of test measurements on sample target materials in order to determine whether a laboratory measurement program could evaluate a material as to its effectiveness as a range target. Modulus of elasticity, puncture resistance, impact penetration, bursting strength (Mullen) were salient tests performed, but, no reliable indication appeared that could eliminate the actual firing tests in the mechanism to conclusively test for acceptability. Therefore, testing ultimately was finalized at the firing range with the exception of certain water tests on material which for obvious reasons were carried out under simulated controlled rain conditions.

Investigations into material for an improved flat silhouette target started in the area of improving blotting papers and cardboards by impregnating or soaking in various resinous materials to achieve water/moisture repellancy. The results indicated that another avenue of approach was needed and available materials on the market were tested for this target application.

Moisture pick up was evaluated by a submersion test for the high density materials, and a rain test for the foams (3-D element) which was equivalent to a 4-inch rainfall. This was done by two methods: (a) for small material samples, a can with .008" holes was used to drop water from 2 feet until 66 mil. liters per square inch had been deposited; (b) for testing the full size "aggressor" 3-D figure a spray trajectory hose nozzle was set up with receptacles placed close to the test specimen until an average depth of 4 inches was accumulated in six glass beakers. The water/moisture absorption in many instances immediately eliminated some of the materials and, in the case of the open cell foams, indicated that a water repellant coating would be necessary that would be flexible and would not cause bullet holes to become larger than in the foam itself.

At the outset, preliminary bullet hole testing was done in the indoor range on samples of material for the silhouette and foam targets; rubber holding bands for the 3-D element; and paint for both materials. An M1 Carbine .30-caliber, round-nose 111 grain bullet at 1970 f.p.s. was used. The carbine was fired from a machine rest so that small samples could be tested. It was found later that in many instances, especially in the low density foam, that the slow blunt bullet made a larger hole than the high speed spitzer (pointed) bullet of the service rifle (M14) and the shock imparted to the pop-up mechanism was greater than the 7.62 mm

(.30 cal.) at 2700 f.p.s. As a matter of current interest, verbal reports indicate that the new .223 caliber 3200 f.p.s. M16 rifle bullet (spitzer) gives very poor responses on the fiber-board target. Again a basic fact is brought out that the target has to absorb sufficient energy from the bullet to induce vibrations (or rattle) in the relatively rigid target material to operate the system and indicate a "kill."

When the initial or preliminary testing pointed out the two materials most likely to produce an acceptable two-element target, i.e., a silhouette flat target and an attachable "realistic" 3-D element, larger size test samples were made up for outdoor testing with the service rifle (M14) at distances varying from 25 meters to 90 meters to ascertain if the higher velocity and pointed bullet would produce different size holes in the material. Some materials showed a slightly larger bullet hole when the round-nose bullet was used in the carbine; also activation of the target device appeared slightly better due to the round-nose bullet giving up more energy to the material and producing a greater vibration wave overall. All testing was then done with the M14 to insure that results would be evaluated under closely simulated actual conditions.

The "Trainfire" device (3C52) is very similar to the Army Model 31A1. Both have a curved (15-inch radius) target clamp which lends stiffness to the target by bending the lower part (in the clamp) concave. The clamp or holder has two rubber pads glued to the metal portion to keep the spring clamps of the vibration micro-switches from slipping off in operation.

Since testing was done under conditions closely identical to those in the field, the rifle was fired from a bench rest rather than a machine rest. Although hits were distributed all over the target, the greater percentage were concentrated in the upper portion of the two target elements. This is where the targets in the field receive the most hits. Various heights of exposure are employed to compensate for the different ranges to each "surprise appearance" target in the series comprising a course of fire for qualification or training on an environmental (heavily overgrown jungle) range. Since the distance available (up to 90 meters) for testing had no discernible effect on the target functioning ability, the firing was done from approximately 25 meters so as to preclude questionable hits. If the firer felt that he missed (called the shot out) another bullet was fired to fill out the string (usually 20 rounds, capacity of the M14 magazine).

Early in the testing with the pop-up mechanism, it was suspected that the microswitches might not be giving a true picture of the target's ability. While a set of new switches was being obtained, another pop-up device (different design) with the same type of microswitches was used as a back-up device until the original device could be fitted with new switches (3-5 'g' value). This back-up device proved that testing without new switches could give poor results and some of the data reflects this condition, therefore, many tests had to be run in both devices in order to obtain data that was faithful to the targets. When the new set of microswitches was installed in the old device, testing was then limited to this device to insure uniformity of test conditions.

Materials Investigated and Results (Silhouette Target Phase)

Initially, the attack on the problem was made on the basis that an improvement of the current wax-impregnated fiberboard material could be made by improving the coating or impregnation of a paperboard substitute, such as pressed board, plastic impregnated paper and paper laminate. Pressed board has the stiffness to operate the hit actuated system but its water absorption would have to be reduced. These materials were soaked in solvent solutions of resin or wax, dried and immersed for 24 hours in water and weighed for water gain. The impregnation in most cases of high-density paper structures resulted in a surface coating only. In other instances the impregnation changed the physical properties of the material from a stiff board to one that was brittle or soft. Some paper boards still absorbed water when the solvent was removed after soaking.

Results showed that waterproofing to a degree could be accomplished, but the resulting material was not able to surpass the Rock Island Fiberboard Specification for the silhouette target when tested in the target mechanism.

Tables 1 and 2 tabulate the water immersion and impregnation results on the commercial paperboards and the resin impregnated paperboards.

This line of investigation was terminated when a satisfactory plastic material was found that had superior properties to that of any of the paperboards tested. Concurrent with the pressed paper material investigation phase, the plastics in solid form for the silhouette target and the foam type for the 3-D element appeared to hold more promise than the initially cheaper, treated paperboards. According to the Rock Island Fiberboard Study, included in (1), material for this target should have a minimum of at least 13,000 psi. modulus of elasticity when wet, be as thick as possible, and have a very high degree of weatherproofness and, of course, have longevity under fire, i.e., resists destruction by small arms fire.

The following plastic materials were considered for this application with weight and raw material cost indicated for a .060-inch thick plain silhouette of 4.66 sq. ft. area:

Material	Target Wt. Lbs.	Cost
Phenolic Laminate (1/64")	0.47	$ 1.63
Cellulose Acetate	-	2.19
Rigid Vinyl	2.05	1.49
Linear Polyethylene	1.40	0.98
Cellulose Acetate Butyrate	-	2.35
Polypropylene	1.30	1.12

It can be seen that linear polyethylene and the polyprophylenes look superior costwise and have low density. The laminates are very brittle and shattered under rifle fire, which eliminated them. Of the two, polyethylene can be crosslinked by gamma radiation to induce so-called "memory" which tends to return the target to its original condition after firing. Lower material cost of polyethylene also was a factor. Nylon was eliminated from consideration due to its cost. Flat targets were constructed of 60 and 75 mil. polyethylene and tried out in the pop-up device to determine its resistance to flexing or whipping as the device raises and lowers the target rapidly in use. The 60 mil. sheet would be 1.4 lbs. against 1.75 lbs. for the 75 mil. thick sheet silhouette. To operate the hit-impact microswitches, stiffness is necessary and light weight is desirable because a 3-D element has to be carried to provide realism and together must not overload the device. Truncated flutes shown in Figure were vacuum formed vertically except for the clamp area (center lo edge). This strengthened the target so that the flexing condition was eliminated from further consideration throughout the remainder of the develo nt. A target was successfully tested with 1.8 lbs. mounted halfway (20 inches) from the clamp. The target stiffness was unaffected by a 6-inch thick block of foam mounted on it and was bullet tested for device operation.

Since several requirements had to be met in order to proceed further and numerous plastics were ruled out on cost alone, or

Figure 2. Front View of .075-inch Thick Linear Polyethylene Vertical Flute Target Mounted in 3C52 Target Holding Clamp.

shattered on bullet impact, those that looked good had to be examined on the basis of hole size and length of service on the range. Polyvinyl chloride sheet 60 mil. (2 lbs.) produced holes several times the .30-caliber bullet hole size. Ethylene vinyl acetate produced holes 0.15 inches in diameter, however, the material is removed from the hole whereas the bullet holes in polyethylene 60 mil. thick were .187- to .195-inch diameter with no loss of material. Holes only .225 inch were made by three bullets passing through the same hole. Linear polyethylene is almost completely impervious to water, activates the mechanism well, is relatively low in cost, and has the property of retaining the material when a bullet pierces it, i.e., no material is lost; it is pushed or cratered aside leaving the stiffness, as far as can be ascertained, unaffected. Another remarkable characteristic of polyethylene (which could be used) is that of bullet-hole closure when the material is heated to 135-140°C, see Figure 3. Bullet holes .190-inch diameter have been closed down to .055 inch by this process. This process relieves the internal strains set up in the material by bullet forming. A 15-megarad irradiation dose exhibits a similar property although not so pronounced as annealing. These unusual properties resulted in this material being chosen for the silhouette target.

Certain design details and the optimum thickness of the material were established later as the result of very extensive testing in the pop-up mechanism on the firing range using the service rifle during varying weather conditions ranging from below freezing to over 90°F and from rain and snow to very low humidity.

Testing the Silhouette Designs

Testing the silhouette designs made of linear high density polyethylene in the Device 3C52 pop-up device with the M14 service rifle bullet led to several forms of stiffening ribs or flute designs incorporated with different weights or thicknesses of the actual target material. Targets were made and tested having the following thicknesses: .050", .060", .075" and .093", all with ribs or flutes. Also testing and evaluation was made with the 3-D foam "aggressor" element attached to the silhouette basic target to effect a two-element or combination target.

As a control target a new fiberboard target was tested in the 3C52 mechanism for accuracy of response. The results are given in Table 3 which indicates a response accuracy of 96% for the first 200 rounds and 80.5% for the 200 rounds between 400 and 600. The middle 200 rounds were evaluated in a device with old microswitches which gave only a 68% response. The total of 400 was 353 responses giving an average of 88%. Obviously the target becomes useless

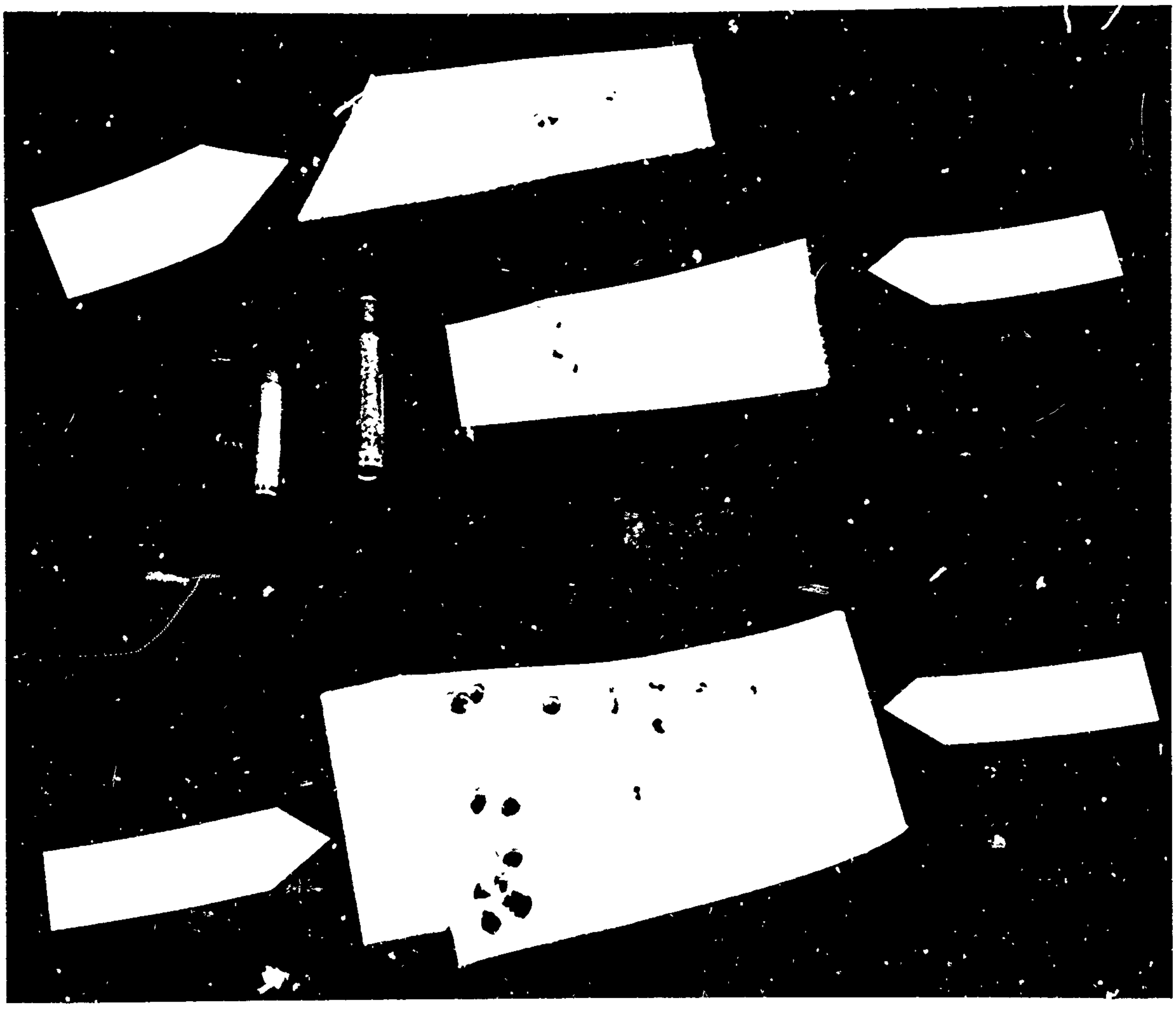

Figure 3. Three pieces of Linear Polyethylene holed by .30 Caliber Rounds. Exit hole side shown.

A. 75 mil thick
B. 75 mil heated 5 min. at 135°C
C. 130 mil thick
D. 130 mil heated 5 min. at 135°C

between 200 and 400 rounds. This is because the bullets (high velocity) blow out pieces of the fiberboard each time the target is hit, leaving a lot of pieces of paper in back of the target on the ground. This lowers the vital property of stiffness, resulting in reduced transmission of vibrations to the micro's. The delaminated or blown-out areas (Figure 1) are also susceptible to moisture pick-up as the targets are not impregnated but only coated with a wax. The fiberboard is calendered or rolled very tightly so that impregnation is only surface deep. Introduction of moisture softens the board and further reduces its response.

A 60 mil target (1½ lbs.) of linear polyethylene with vertical ribs or trapezoidal flutes (see Figure 4) was bullet tested until 1870 rounds had been fired through it. The response scoring is listed in Table 4, which indicates an overall score of 85.3% (1596/1870). This result, however, has to be broken down into two categories: response with old microswitches and the score with new switches. It must be visualized that the two devices were used in tandem to give two target hits with one shot and to check the device operations against each other to assure comparative results while accumulating hits in the targets to establish bullet hole life. The breakdown of scoring response for the 60 mil target is as follows: 840/1054 gives 80% (old microswitches), 756/816 is 92.6% (new switches). The final 100 rounds in the target registered 93%. This first 60 mil PE silhouette with 1870 hits (Figure 4) through it and still registering 93% shows a material loss as follows:

Original weight	-	635 grams
Final weight	-	632 grams
Loss		3 grams

A comparison of the 60 mil target and the control "issue" target scoring accuracy vs target life can be made as follows:

Target			
Fiberboard		Vertical rib 60 mil PE	
# Rounds	% Score	# Rounds	% Score
0-200	96	0-200	93
201-400	-	201-400	-
401-600	80.5	401-600	92.6
		1770-1870	93.0

All responses recorded above are with new microswitches.

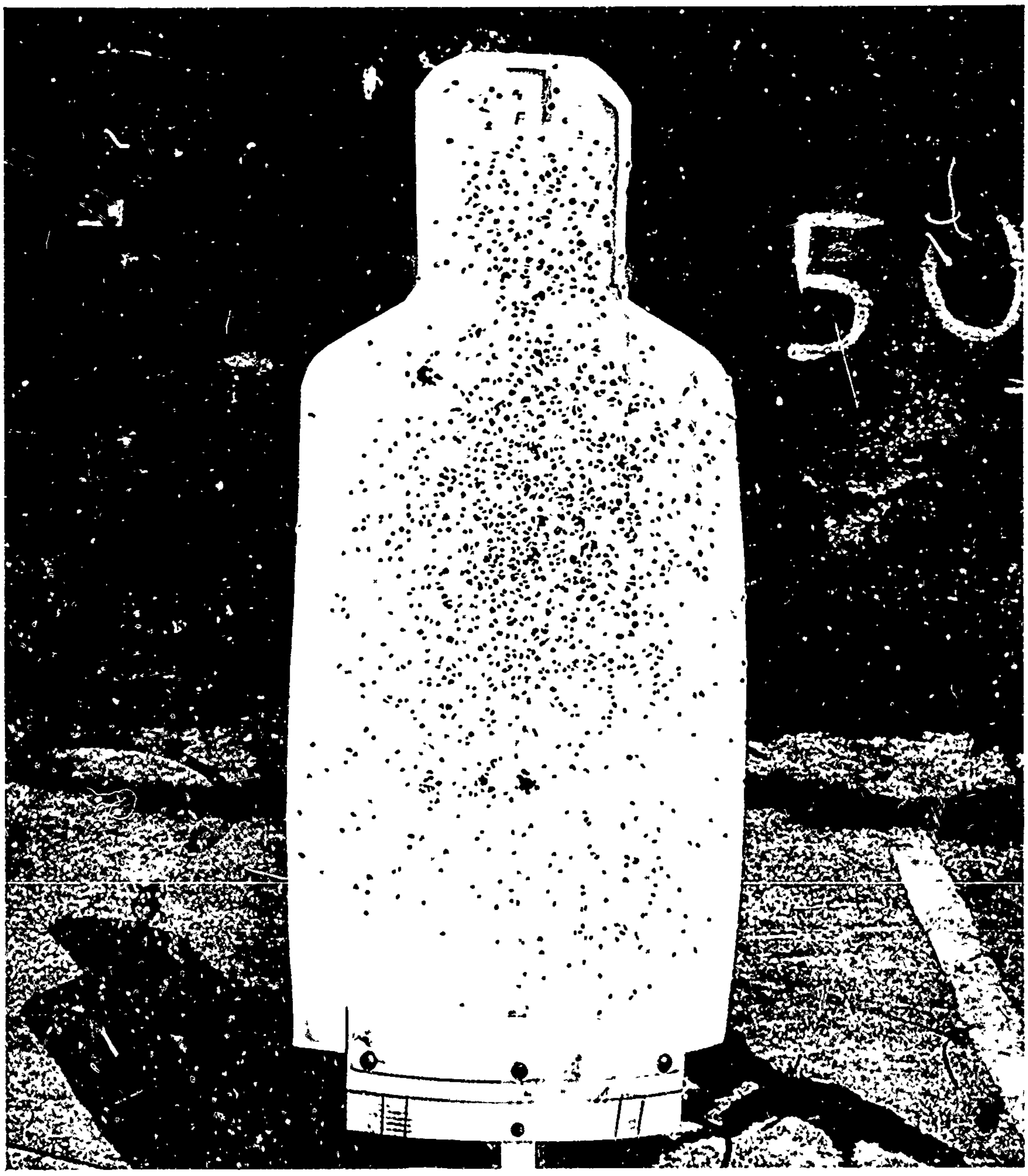

Figure 4. Front View of .060-inch Thick Linear Polyethylene Target Mounted in 3C52 Target Holding Clamp. Shown after 1870 hits.

Another 60 mil target tested in a device with new switches only, gave the following:

Rounds	Score	%
100	93	93
200	184	92
98	96	98.2 (30 cal carbine)
200	183	91.5
200	182	91
160	144	90
Totals 958	882	92.3

A .075-inch thick polyethylene target was fabricated and similarly tested on the range. The 75 mil targets averaged approximately 200 grams heavier than the 60 mil thick targets. The target weight varies somewhat, as the extrusion process to make the sheet in small batches is not a continual flow where everything can be completely stabilized, also the trimming (by hand) gives a variance. The 60 mil averaged 7 grams heavier than the nominal weight of 620 grams. The 75 mil targets were really closer to 80 mil and therefore averaged 50 grams above the nominal 783 grams for a 75 mil target.

The 75 mil target was tested up to 1734 rounds (Table 5). The scoring response, with new microswitches only, is 398/420 which gives a 95% average.

A comparison of the 75 mil target with the "issue" fiberboard target reveals that the device scoring accuracy for the two targets was as follows:

New Switches	75 mil plastic	Fiberboard
Round #	317-436	201-400
Score	96.8%	80.5%

Old Switches	75 mil plastic	Fiberboard
Round #	437-676	201-400
Score	87	68

These results derived from Table 5 indicate that the polyethylene targets, tested with the same two sets of hit impact switches under identical conditions, scored an average of 18% higher with either old or new microswitches registering.

A polyethylene target with the same flutes formed into it, but .050 inches thick (nominally 520 grams) weighing 527 grams, was fabricated for testing to determine the lightest (cheaper) target for the requirement. This target was not extensively tested as the previous testing had already indicated that the heavier 75 mil target was superior to the 60 mil target in the mechanism. As testing progressed it became obvious that the heavier the plastic target, the higher it scored under test.

The results of the 50 mil target test were as follows:

# Rounds	Scored	%	Microswitch
160	129	80	Old
200	187	93.5	New

A fabrication uniformity problem arises with designs under 60 mils thick in that the formed (under heat and vacuum) thickness cannot be controlled uniformly over the entire target area, giving varying degrees of rigidity and energy absorption.

One of the objectional effects on the polyethylene formed targets is the inward bowing of the shoulder area of the target towards the side of bullet entry. This deformation (Figure 5) which becomes apparent at approximately 500 rounds is caused most probably by the phenomenon of no loss of material when holed by bullets. The material is dented slightly in the bullet direction so that we have a dimpling process plus the cratered hole, all of which creates a tendency to bend along the vertical flute axis. Since the bottom edge of the target is rigidly clamped in a 15-inch radius with the opening to the rear, resistance to the inward bowing is developed in the lower position of the target; however, the upper portion (shoulder) develops a bow of 2½-3 inches in depth after approximately 1,000 rounds.

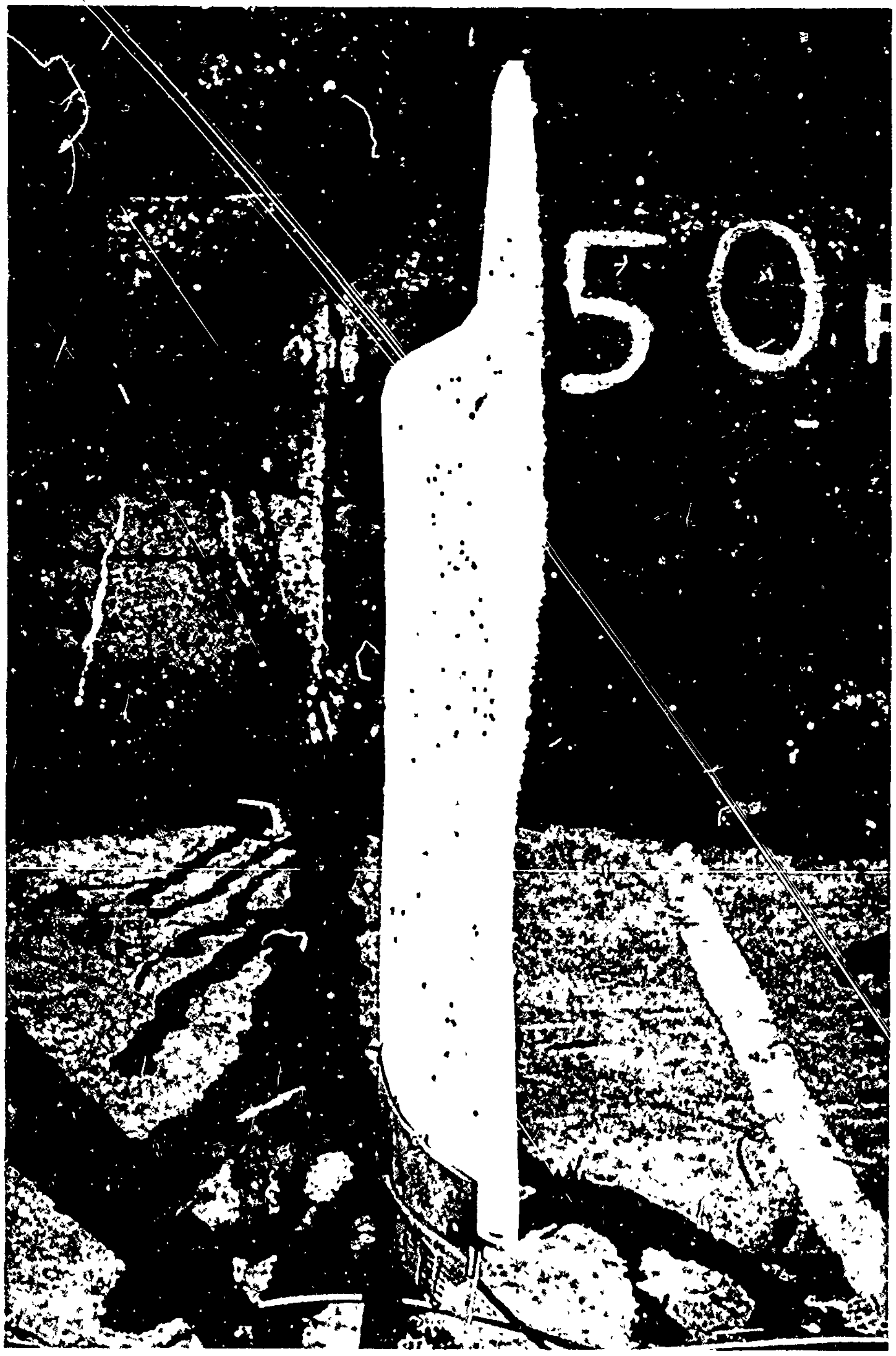

Figure 5. Side View showing Bow Developed in Target (.060") after 1870 Rounds.

A .90 mil target (approximately 950 grams) was fabricated to gather data on a heavier gage (.090") target in order to substantiate the hypothesis that the weight (thickness) of the target adds to its response accuracy. The supposition here is that a thicker identical material will extract or absorb more energy from a bullet and cause a greater shock (vibration) to the target with better microswitch activation (higher score). A blunt-nose bullet (30 cal. carbine 111 grain 1960 fps) has a more pronounced absorption factor on the same material. Both factors, thickness and shock, have a pronounced effect on the effectiveness of the target design. Table 6 gives the data from a test conducted on a 90 mil vertical fluted polyethylene target, The results show that the heavier target (2.1 lbs) has better accuracy. Its response was 949/960 with a score of 98.8%.

Testing was halted when the amount of bowing became pronounced. An attempt to compensate for this bowing effect was made by reversing a target in the holder after 500 rounds (1½" bow). Continued testing did not straighten the target but further warping appeared to be halted. A 75 mil target was reversed after 1472 hits and 600 more put in but no discernible changes in the target dimensions could be detected. It appeared that the deformation process could not be reversed but could be halted by turning the target before too great a bow was formed. Since the plastic continues to deform for at least one hour subsequent to firing, the optimum turnaround for each thickness of target was not definitely established, however, it can be said that 500 rounds is a maximum before reversing the target. It is not felt that this is a practical modus operandi because on a given course of fire different distances will be used, resulting in varying numbers of rounds passing through each target at any given point in time. Therefore, keeping track of the hits would be very objectionable to the range personnel, and if these targets are to be used with the three-dimensional realistic attachable "aggressor" element, the target reversing cycle would be even more of a task.

Three variations of the vertical flute design were fabricated to develop a cure for the "bowing" of the silhouette shoulders. These were:

(1) Vertical flute targets with horizontal bars or flutes in the upper half.

(2) Vertical flute target with herringbone flutes or ribs in upper half (X rib).

(3) Vertical flute design with horizontal cross flutes throughout (waffle design).

Firing results included 60 and 75 mil thickness targets with various designs as above, with the data in Table 7. One target with 1100 rounds through it lost a total amount of material of one (1) gram. The "waffle" design with equal size flutes vertically and horizontally gave a response of 92.7%, however, one microswitch had to be replaced at 1,000 rounds which would result in a score of 93.5% if 200 suspected rounds are eliminated. The total data for the first "waffle" design is detailed in Table 8. A similar target of 819 grams weight and "waffle" design was tested for a total of 2,440 rounds with 2,272 responses for a scoring accuracy of 93.2%. Detailed test data is available in Table 9. The target has some forward bowing which is not visible from the firing line. No shoulder "bowing" is measurable. This design was finalized for field tests and would be pigmented (1%) with color No. 34102, olive drab, of Federal color standard 595 to have a camouflage effect.

"Aggressor" Foam Target Element.

Concurrently with the investigation for an improved basic silhouette target, research was begun on a three-dimensional "realistic" element to be added upon or fastened to the silhouette (flat) target in the "Trainfire" disappearing target mechanism (Navy 3C52). Since the device has a weight limitation on the target it can handle, it was at once realized that the use of a plastic foam would be the only feasible method of adding 3-D (volume) to the target at a minimal weight penalty. The 3-D element had to have the characteristics of long life under bullet penetration, light weight, and moisture resistance to provide all-weather storage in the device overnight and possible operation during a rainfall (4 inches). Other factors in selecting a foam are cost and producibility.

The foams were tested for bullet hole size primarily, i.e., material removed from a slab of foam when penetrated by a bullet. This could be evaluated visually by holding the material up to a light source to see how much light was visible. It was observed that foam samples less than approximately one-half inch thick produced bigger holes than those of thicker material. The foams evaluated were closed cell polyethylene, open and closed cell vinyl chloride, closed and open cell types of polyurethanes, and silicones (figure 6). Again the laboratory type measurements such as those of the ASTM cannot substitute for actual shooting. No test subjects the material to deformation at the rate that a bullet does. The elongation and very low strength of the flexible foams appear to be properties that produce small holes. The holes were measured (with a micrometer) with a tolerance estimated at $\pm$.010 inch since these holes are not smooth nor uniform in most cases. The results are presented in Table 10.

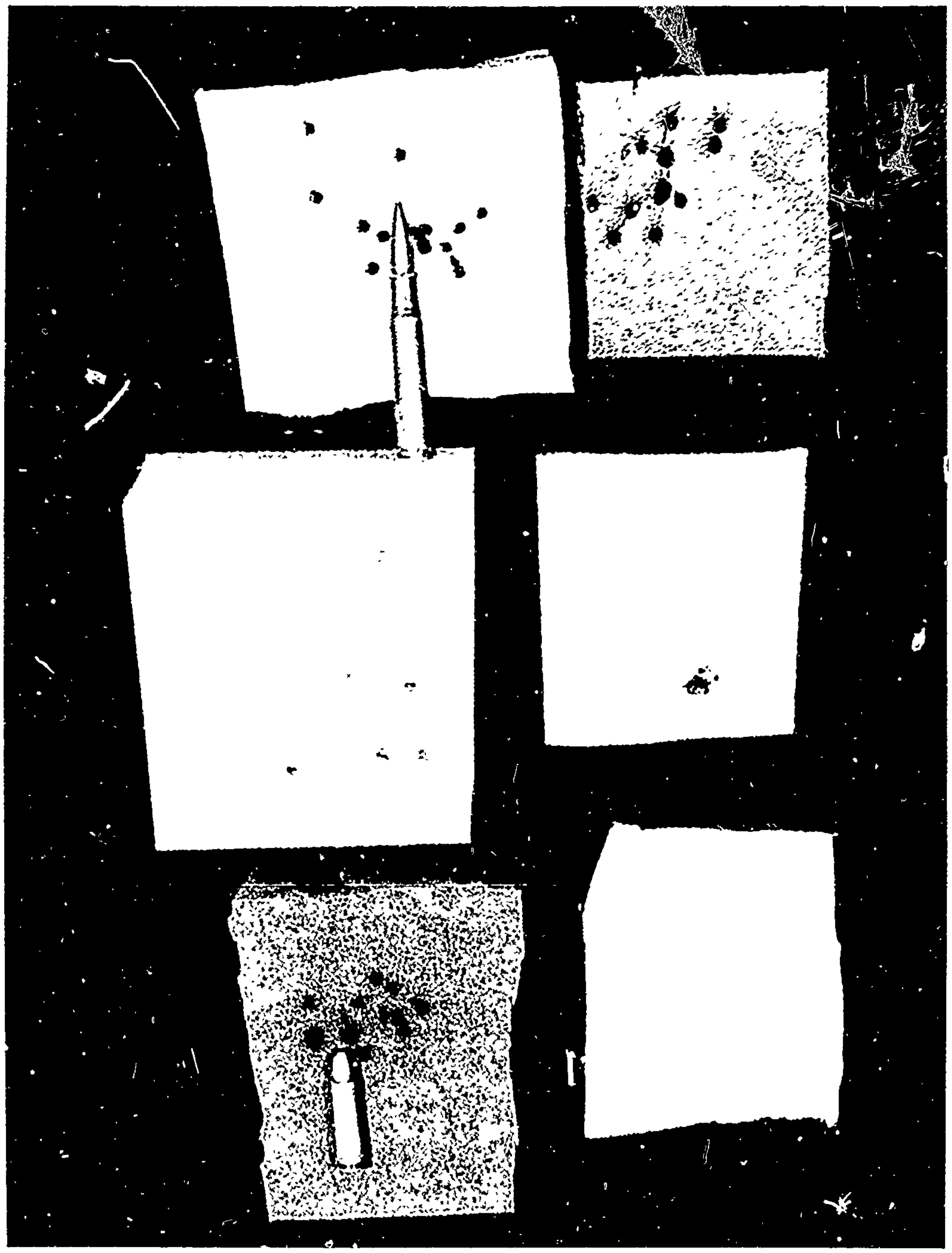

Figure 6. Bullet Entry Holes in Three Types of Foam

Top - Open Cell Vinyl
Center - 1/2" and 2" Polyethylene Foam
Bottom - Open Cell Urethane

The polyethylene foam appears to be perfect, that is; it is closed cell, low density (2 lbs/cu.ft.) and produces small holes from bullets (figure 6). At present it cannot be formed by molding, but has to be cut which, due to cost, eliminates it. It is expected that future development will produce a moldable product. Vinyl foams (closed cell) are good from the moisture standpoint and hole sizes are satisfactory but the molding process does not give sharp features. Open-cell urethanes (flexible) have advantages over the other foams; low density, very small hole size and can be molded (figure 7). It has a disadvantage in that as an open-cell material it can absorb water when the skin (from molding) is opened. This problem has been solved by coating the 3-D target with a flexible waterproof paint. A flexible urethane paint has been found which provides sufficient resistance to rain to be acceptable. Prior to the coating technique, impregnating the foams with waterproof resins such as asphalt and silicones were tried but resulted in increases in the foam density. Since the foam element had to resemble an "Aggressor" soldier, Reference (2) page 17, was used as a model to depict the representation. Realism was to be enhanced by using the colors shown in the FM so that the paint had to be waterproof and color of the foam element. Paints that penetrated the surface of the foam produced a rigid thickness to the foam skin which was opened or blown out during firing. The organosols tested fell into this category. Testing for moisture proofness was made on a foam element painted and complete except for final attaching bands. This target had 2,972 hits, primarily in the mid-chest area (no misses) and was therefore unusually susceptible to penetration by rain or spray. A 4-inch simulated rain was deposited on the foam element in a horizontal (target down) position. The foam element was 2 lbs., 1 oz. before the water spray and it picked up 2 lbs., 4 oz. of water for a total weight of 6 lbs., 8 oz. Total dry weight of element plus 90 mil silhouette target (1003 grams) was 4 lbs., 4 oz. After draining for approximately 3 hours the weight was 5 lbs., 13 oz. or a gain of 2 lbs., 8 oz. Tests with the target in the up, or vertical position resulted in only a 1 lb., 8½ oz. water pick-up which drained to 15 oz. in 15 minutes and to 10 oz. overnight. In this position draining takes place out the bottom of the foam element. The water actually was directed approximately 45 degrees to the upright target, a severe condition. In actual field use it is anticipated that 3,000 rounds (minimum) would be fired through it, but with the holes much more evenly distributed than in the test, figure 8 and would result in a more favorable water pick-up ratio. The foam chosen for the target element was a Witco open cell polyurethane designated as Witco 501.

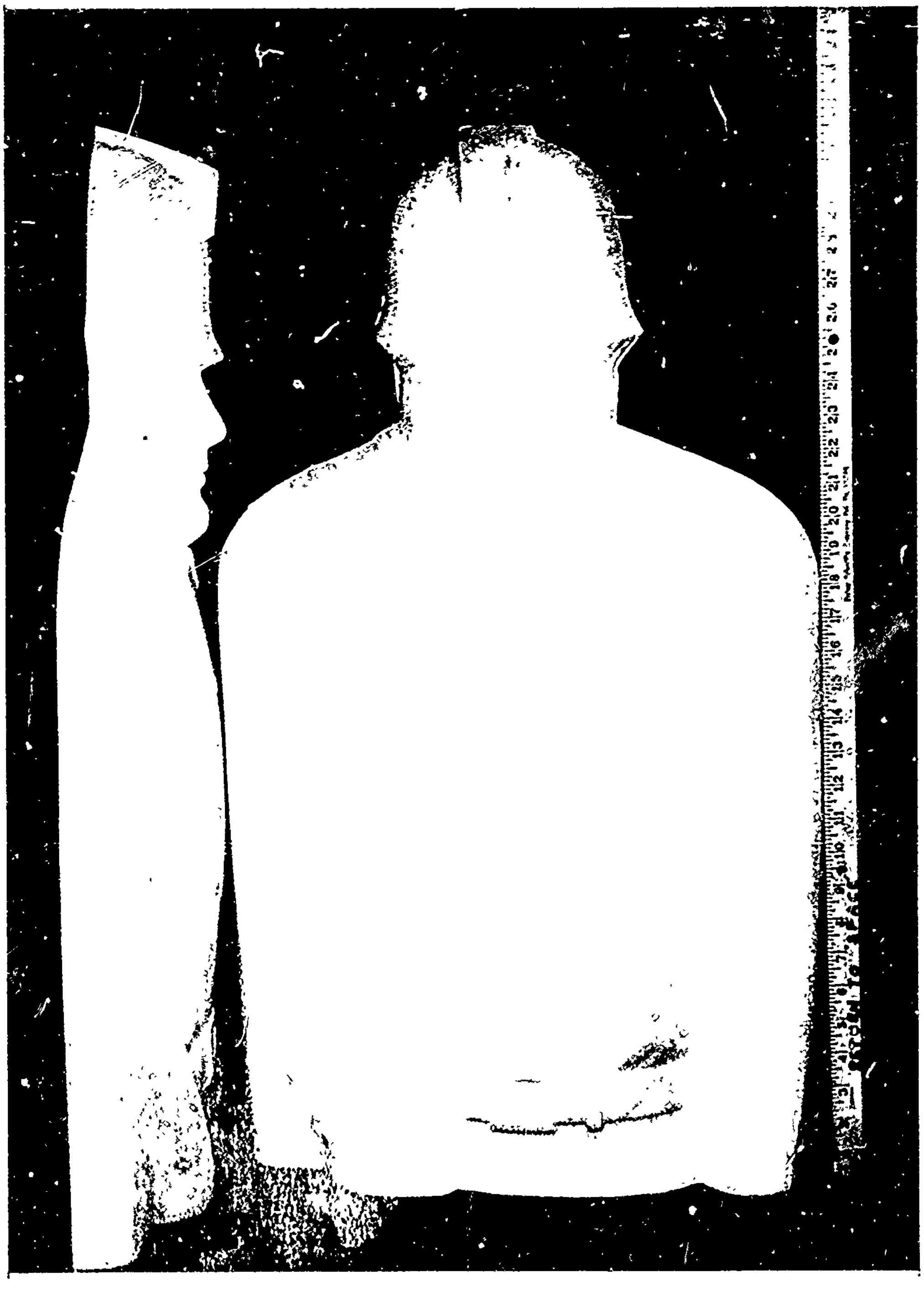

Figure 7. Front and Side Views of Three-Dimensional Foam Target Element Prior to Coating.

Figure 8. Front View of Foam Element after being hit by 1000 Rounds of 30-Caliber Ammunition.

Testing Plastic Silhouette Target and "Aggressor" Foam 3-D Element as a Composite Target.

The silhouette target with vertical flutes and 75 mils thick was used with the foam element to determine the scoring properties of the combination. The rubber band investigation, for attaching the element to the polyethylene (P.C.) silhouette backboard target, had not been concluded so cloth straps were temporarily used to hold the foam element to the backboard or basic flat target. Table 11 shows that the scoring gets better as the shooting progresses and then decays when the fluted backboard is reversed in the holder and the foam element fastened to the reverse side. This is reasonable (872 hits 93.2%) because the silhouette target is flat for approximately 500 rounds and then bows inward, leaving the foam element contacting the outside edges and lower part of the silhouette target. This lesser contact is thought to reduce the slight vibration suppression which exists where broad full contact is maintained. This is verified by rounds 573-872 scoring 96.4%. The reversal further reduced the score to 86.4% because of the heavy centerline contact due to the previous bowing in the upper portion of the target. Reversing of the 75-mil target was an attempt to alleviate the bowing due to the deformation of the target. The foam element was tested on a 60-mil vertical flute target and 400 rounds fired through it with a resultant scoring response of 352/400 or 88%. The "aggressor" foam element was attached to another 75-mil vertical flute polyethylene target and 500 rounds fired through it for a score of 95.4%. The foam element was removed and the silhouette reversed and another 500 rounds fired through it for a result of 98%. It can be seen from this direct test that the combination target is about 2.5% lower in accuracy than the plain silhouette target alone. The slight amount of absorption can be readily observed. Table 12 shows this rather clearly. Another previous observation is again verified, i.e., with this additional element carried "piggy back" a basic silhouette target of 75 mils thickness is necessary. The combination target weighed 1.8 (75 mil) plus 1.9 lbs. (foam) or a total of 3.7 lbs. The 3C52 device operated with this load for 2972 cycles and did not overheat, indicating that under the normal duty cycle at the training ranges the devices could carry a heavier load (target) without overheating.

Since the combination target with a 75-mil backplate scores acceptably with the vertical flute design, testing had to be carried out on the silhouette target of "waffle" pattern design (figure 9), as this ultimately solved the bowing problem and was the design which finally met the requirements. Firing results with the polyethylene 75-mil "waffle" design and the foam element combined, scored 91.5%.

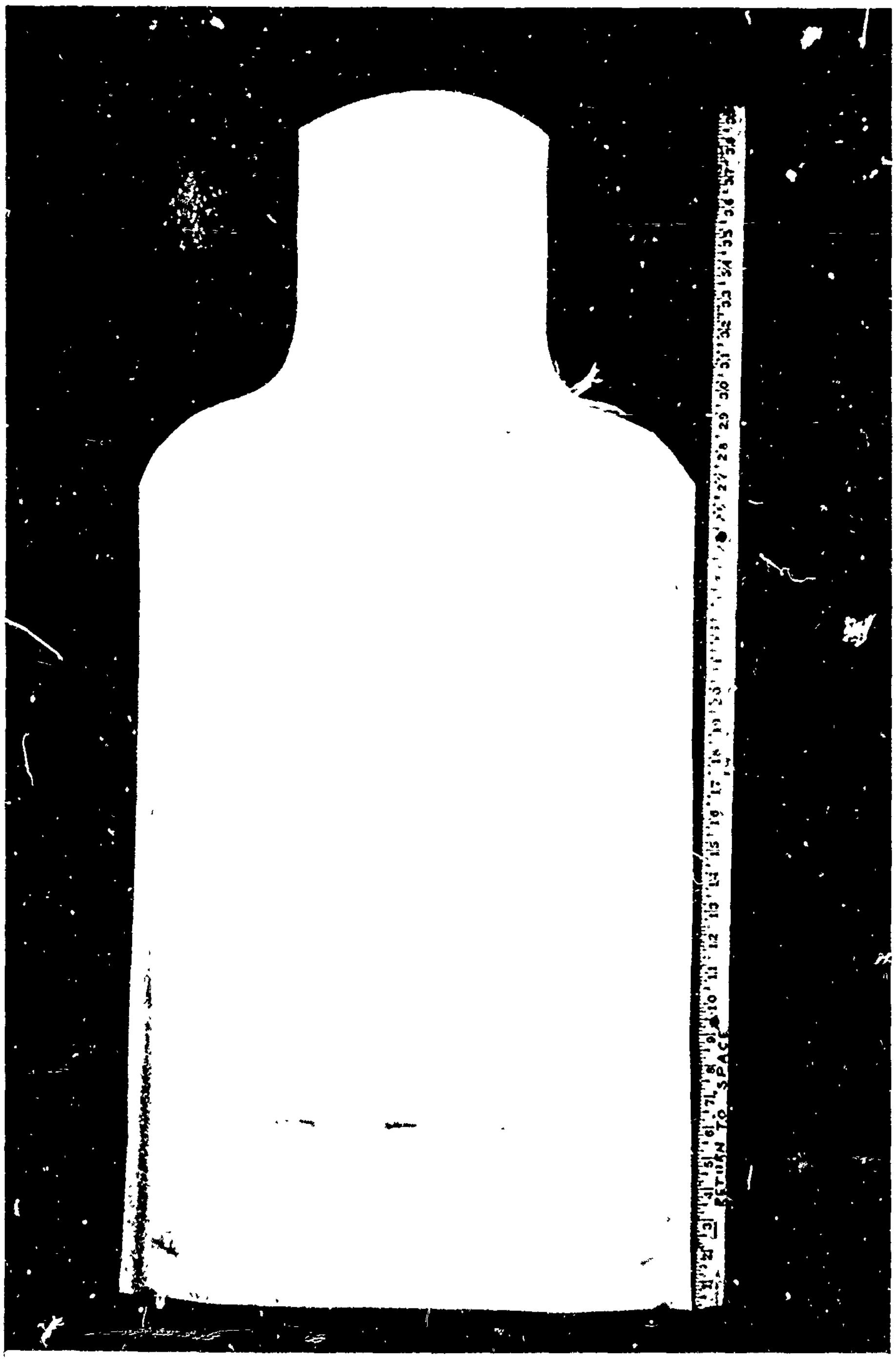

Figure 9. Front View of Final Target Design

VI. TARGET COST FACTORS

The polyethylene "waffle" pattern design silhouette target can be made by three processes depending on design and quantity:

1. Vacuum or pressure forming
2. Injection molding
3. Extrusion

The first process is slow with low mold cost and, in small batches, is reasonable in cost ($1 each per 50,000).

The second process -- injection molding -- is a molding process which for huge quantities (250,000) could bring the unit cost down to 75¢ approximately. Here the mold cost is upwards of $20,000 each with a minimum of two involved.

The third process -- extrusion -- requires parallel flutes, grooves, or ribs lengthwise to insure the continuous flow process.

With the waffle design (cross flutes) a second forming process would be necessary. Costs here are estimated to be in between the costs of the other processes.

The 3-D foam element of polyurethane in adequate quantities could be obtained for approximately $5 a unit minus the painting (aggressor uniform). Tooling has been estimated to be $6500 which can be broken down as $500 for first mold and $100 each for 60 more. These molds are necessary to keep the foam batch going. The molding takes approximately 20 minutes each.

These target costs appear to be high initially, but the useable life is approximately 7 times for the silhouette polyethylene unit over the fiberboard unit; that is, cost/life is in reality lower when one considers a 30-35¢ cost for the fiberboard target in quantity. This would bring the p.e. target lower in cost without adding in the intangibles of reduced range details and better scoring. The cost of the foam element which provides realism and long life cannot be compared to any existing similar target because none exists. Cost has to be calculated against the value of the realism injected into training in the field. It appears that this type of realism is needed when makeshift faces are found taped on the silhouette heads of the present olive drab fiberboard targets recovered from training sites.

VII. CONCLUSIONS

Laboratory measurements on the materials were used only to screen out those which limited firing experience established would not perform well. This was in line with the conclusion reached in Reference (1). To use the actual service rifle firing test results as the primary criteria for determining the suitability of the material and design for ultimate field applications rather than attempting to translate laboratory data directly into field results.

The optimum material and design for a flat silhouette replacement target for use in the pop-up devices installed at Army and Marine Corp training centers, was a modified "waffle" design (figure 9), 80-mil linear polyethylene plastic conforming to the outline of a kneeling man (Ordnance Corps Drawing 8426438) and to Color 34102 of the Federal Color Standard 595. Actual firing tests proved that this material can be subjected to over 2,000 hits (figure 2) with the service rifle, firing the 7.62mm spitzer 150-grain bullet at approximately 2700 fps muzzle velocity. Firing was conducted from a bench at approximately 25 meters with the target fully exposed in the "trainfire" mechanism. Accuracy, defined as device actuations, was consistently well above 90%, i.e., 93.7% or 1969/2100 hits. This target material is impervious to weather conditions and is almost totally immune to bullet blowout, thereby accounting for its long life under the destructive conditions of actual shooting. A representative target lost three grams of material after 2,000 hits. Due to this unexpected feature of the material, the possibility of salvage appears feasible, which could reduce the overall cost.

The polyurethane foam three-dimensional "aggressor" soldier representation (figure 8) which, in use, is slipped over a silhouette type target, has good realism and is capable of a life of at least 3,000 rounds in the pop-up mechanism. It has weather-resistant qualities superior to the fiberboard issue target and higher scoring when combined with the polyethylene silhouette target in the trainfire device.

The cost of the silhouette polyethylene "waffle" pattern target is lower than the "issue" fiberboard target based on cost/hit life. The reduced range detail work involved and possible scrap value are bonus items, as well as the all-important ability to maintain a high-level scoring throughout a life of more than 2000 rounds.

Test data prove that the heavier gauges of the polyethylene in the silhouette target produce more accurate responses to the bullet puncture. Since a weight factor (precluded) targets of more than approximately 2 lbs., the 75-mil target was optimum for this investigation, combining cost and weight factors to produce an acceptable target.

It can be concluded that designs which employ rigid material and provide good paths to help propagate the shock waves (from the bullet) will insure good scoring.

Material which does not blow out has longer life as a target for small arms fire. It also appears that rigidity is enhanced by the cratering effect (no loss of material) on polyethylene. Scoring accuracy does not degrade noticeably even after 2,000 rounds for the polyethylene and 3,000 rounds for the polyurethane.

VIII. RECOMMENDATIONS

1. It is recommended that the two target elements be obtained in quantity and evaluated by the services in the field under actual training conditions

2. It is also recommended, in connection with 1, above, that the silhouette polyethylene and foam elements be tested and evaluated separately, that is, combined and the silhouette alone.

3. It is strongly recommended that the two target elements be tested with the new M-16 .223 caliber 3200 fps bullet. It is felt that these plastic materials will perform in a like manner with the small bullet.

4. It is recommended that the target holders of Device 3C52 be modified to increase clamping ability.

5. It is felt that the target weight limitation that the mechanism imposes on the target's scoring ability will not be a detrimental factor, and scoring accuracy can approach 100% for solid hits.

6. It is felt that in view of the unusual performance of these plastics that they be tested with .50-caliber and 20mm bullets to see if long life will still prevail.

7. It is recommended that technical progress in development of polyethylene foam be followed as this could well be an ideal material for this purpose. At present it is not foamed.

IX. REFERENCES

1. The Development of Fiberboard Targets for the M31A1 Trainfire Mechanism: Rock Island Arsenal Laboratory Report Number 63-2879 of 5 September 1963.

2. Aggressor, The Maneuver Enemy. Army Field Manual FM 30-101 Department of the Army, 27 April 1961 plus Change 1 of 27 April 1962

Table 1

Effect of Water Immersion on Commercial Paperboards

Sample #	% Wt. Gain/Hrs. Immersion	Results
1	21.6/1	Soft
2	14.6/1	Soft
8	1.47/24	Falling Apart
9	31.0/24	Falling Apart
10	2.0/24	Soft
12	19.6/24	Falling Apart
15	68.4/24	Falling Apart
16	64.1/24	Falling Apart
18	64.0/24	Falling Apart
19	72.0/24	Falling Apart
26	53.2/24	Falling Apart
27	49.4/24	Falling Apart
30	43.4/24	Falling Apart

Table 2

Effect of Water Immersion on Resin Impregnated Paperboards

Sample #	Paperboard	Impregnating Resin	% Wt. Gain/Hrs. Immersion	Results
1	Blotting Paper	#25-1103	0	Too Brittle
2	Blotting Paper	Plastisol #12	3.5/1	Coated Not Impregnated
3	Blotting Paper	Plastisol #12	Very High	Coated Not Impregnated
4	Absorbent-1	Plastisol #12	Very High	Coated Not Impregnated
5	Blotting Paper	Plastisol #12	Very High	Coated Not Impregnated
6	Absorbent-1	Plastisol #12	Very High	Coated Not Impregnated
7	Blotting Paper	Plastisol #12	Very High	Too Thick
11	Corrugated Board	Sealite 125	.001/1	Brittle
14	Absorbent	5% P.E. Sol	49.7/24	-
17	Paper -1	5% P.E. Sol	56.0/24	-
22	Absorbent	5% P.E. Sol	39.7/24	-
23	Paper -2	Plastisol #12	4.57/24	-
24	Paper -2	Plastisol #12	17.7/24	-
25	Paper -2	5% P.E. Sol	38.5/24	Too Thick
28	Paper -2	Vinyl Chloride Sol	48.6/24	-
29	Paper -2	Plastisol 32-1	48.7/24	-

Addendum to Table 2

Impregnating Solutions

Plastisol #12	Points by Weight
Opalon 410 Monsanto vinyl chloride	47
Dioctyl phthalate	37
Nuodex 849	3
Nuodex V132	3
#25-1103	
National Starch; vinyl acrylic thermosetting resin emulsion	
Sealite 125	
Humble Oil & Refining Company, a petroleum wax	
Polyethylene Solution	
Polyethylene	5
Xylene	95
Vinyl Chloride Solution 35-1	
Vinyl chloride (Opalon 410 Monsanto)	10
Methyl ethyl ketone	45
Tetrahydrofuran	45
Vinyl Chloride Solution 32-1	
Opalon 410	15
Tetrahydrofuran	85

Table 3

3C52 Mechanism Actuations with "Issue" Fiberboard Control Target

Hits on Target	Scoring Responses	Accuracy %
200 (1-200)	192	96
200 (201-400)	135	68
200 (401-600)	161	80.5
	Average	88% *

* Average excluding rounds (201-400) which were subject to scoring with older microswitches in device.

Table 4

Vertical Rib 60 mil Linear Polyethylene Target tested in two pop-up devices with old and new vibration switches:

Rounds Fired	Hits Scored	%	Switch
234	206	88.0	Old
100	83	83.0	Old
116	109	94.0	New
100	94	94	New
120	94	78.3	Old
140	128	91.4	New
160	150	93.8	New
200	159	78.4	Old
200	154	77.0	Old
200	182	91.0	New
200	138	69.0	Old
100	93	93.0	New
Totals 1,870	1,596	85.3	Old/New

Table 5

Firing Data for the .075" Linear Polyethylene Target with Vertical Ribs. 150-grain spitzer bullet, 2750 fps except as noted.

Rounds Fired	Hits Scored	%	Microswitch
100	98	98	New
116	103	89	Old
100	91	91	Old
120	116	96.8	New
140	130	93	Old
100	79	79	Old
200	148	74	Old
98 (Carbine)	97	99	Old
200	137	68.5	Old
200	152	76	Old
160	115	72	Old
200	184	92	New
1,734	1,450	83.5	Old/New

Table 6

Firing Data on a 90-mil Polyethylene Vertical Fluted Target in Device 3C52 with New Microswitches.

# Rounds	Hits Scored	%
100	99	99
200	200	100
200	191	95.5
160	159	99.4
200	200	100
100	100	100
960	949	98.8

Table 7

Results of Testing Vertical Flute Target Designs with Various Cross Rib Designs.

Target	# Rounds	Score	%	Evaluation
60 MIL X RIB	500	459	91.8	Low response
75 MIL X RIB	1560	1472	94.4	Bows vertically
3 Horiz. Bars	1100	1063	96.7	Bows about lower horizontal flute excessively
75 MIL (849 gms.)				
2 Horiz. Bars	400	159	79.5	Low score
75 MIL (806.3 gms.)				
Waffle (806.5 gms.)	1600	1483	92.7	One microswitch replaced at 1000 rounds. Target slightly bowed, vertically.

Table 8

75-mil Polyethylene Target of "Waffle" Pattern Design (806.5 grams).

# Rounds	Hits Scored	%
200	193	96.5
200	193	96.5
200	195	97.5
200	188	94.0
200	175	87.5
200	187	93.5 New Microswitch installed
200	182	91
200	170	85
1,600	1,483	92.7 Average

Table 9

.075" Linear Polyethylene "Waffle" Design 819 gram Target.

# Rounds	Hits Scored	%	Remarks
100	96	96	
200	193	96.5	
200	189	94.5	
200	192	96	
200	187	93.5	
200	185	92.5	Adjusted micro.
200	190	95	
200	184	92	
200	189	94.5	
200	179	89.5	(Flash hider damaged, some misses possible).
200	185	92.5	
20	19	95	
200	183	91.5	
120	101	84.4	
2,440	2,272	93.2 Average	

Table 10

Bullet Hole Size in Foam Samples from 30-caliber Bullets.

Sample #	Type	Density lbs/cuft	Entry Hole Size MM	Exit Hole Size MM	Visibility thru Hole
1	Closed cell vinyl	6.2	3	4	Light visible.
2	" " "	4.9	3	3	" "
3	" " "	5.1	3	3	" "
4	Open Cell Vinyl	6.9	2	2	" "
5	Closed " "	6.1	2	2	" "
6	Open cell urethane	4.1	2	3	no " "
7	" " "	1.7	3	4	little " "
8	" " "	1.3	2	3	no " "
9	" " "	1.6	2	3	no " "
10	" " "	3.6	3	4	little " "
11	" " "	2.1	2	4	little " "
12	" " "	1.8	3	4	" "
13	Closed cell polyethylene	2.0	3	4	little " "
14	Open cell urethane	1.8	3	3	little " "
15	" " "	1.8	1.5	2.5	little " "
16	" " "	1.3	1.0	1.5	no " "
17	" " "	1.3	1.5	2.0	no " "
18	" " "	2.2	2.0	3.0	little " "
19	" " "	1.8	1.5	2.0	no " "
20	" " "	1.8	1.5	3.0	no " "
21	" " vinyl	6.2	3.5	3.5	" "

Table 11

Test Data with 75-mil Silhouette Polyethylene Vertical Flute Target with Three-Dimensional "Aggressor" Foam Element Attached.

# Rounds	Hits Scored	%
75	66	96.5
200	183	91.5
97	89	91.8
100	93	93
100	91	91
100	97	97
100	99	99
100	96	96
200	174	87 (Target reversed, Element bearing on ℄ of bow on P.E. Target)
200	179	89.5
200	175	87.5
200	167	83.5
200	169	84.5
1,872	1,678	89.5

Score before target reversal 814/872 93.3%

Score after target reversal 864/1000 86.4%

Table 12

Firing Data with "Aggressor" Foam Element Attached to and Detached from a 75-mil Polyethylene Silhouette Target.

# Rounds	Hits Scored	%
200	186	93
200	195	97.5
100	96	96
100	94	94 Foam removed, target reversed
100	100	100
100	100	100
200	196	98
1,000	967	96.7

With foam element 477/500 95.4%

Without foam element 490/500 98%

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13. ABSTRACT

This report describes an investigation into "silhouette" and "realistic" target designs and materials that possess improved environmental and scoring characteristics when used with the impact actuated pop-up "Trainfire" target mechanism. The actual firing test results narrowed the material selection for the two completely different designs to two modern plastic materials having the common superior capability of absorbing several thousand service rifle rounds with uniformly high scoring, when used in "Trainfire" marksmanship devices.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Device 3C52 (Navy) M31A1 (Army)						
Disappearing Target Mechanism						
"Trainfire"						
Pop-up Target						
Silhouette Target						
Linear Polyethylene Material						
Polyurethane Material						
Small Arms Scoring						
Marksmanship Training						
Aggressor 3-D Target						
Target Materials						
Waffle Pattern Design						