HPW-TP-0400.04
01 November 1996
(Supercedes HPW-TP-0400.03)

TEST PROCEDURE

SHARP INSTRUMENT PENETRATION OF BODY ARMOR

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SECTION 1.0 INTRODUCTION

1.1 Background

1.1.1 Prior revisions of this standard assumed that an implement configured generally in the shape of an ice pick would more readily penetrate body armor than any other hand-delivered configuration.

1.1.2 The procedures of those prior revisions were based on impact energies rather than fixed mass and fixed velocity requirements. Subsequent testing has demonstrated varying combinations of mass and velocity, while producing identical impact energies, may produce significantly differing results.

1.1.3 Finally, those earlier procedures did not address the likelihood of a heavily weighted, dropped, "ice pick", bending under column loading and snapping at or near the mid-point of its length, and

1.1.3.1 Whether that breakage constituted a "pass", or a "no-test" requiring retest(?).

1.1.3.2 Whether penetration, after that breakage, by the still weighted, rigid stub of the ice pick constituted failure(?).

1.1.4 In support of this revision, H.P. White Laboratory, Inc. conducted a series of tests intended to measure the velocity of a hand-delivered impact and to determine the "effective mass" of that impact, i.e., the implement weight AND the effective mass of the hand and forearm.

1.2 Objective

1.2.1 The objective of this STANDARD is to supplement existing ballistic testing procedures and to establish a consistent and reliable means of evaluating the resistance to sharp instrument penetration of body armor.

1.2.1.1 The objective of this REVISION is to incorporate changes intended to more accurately and reliably reflect the actual conditions of a pointed/edged instrument assault.

1.3 Scope of Testing

1.3.1 The revised procedures are intended to reflect the effect of hand-delivered impacts of sharp, pointed instruments whose point or tip is not offset more than 3/4 inch from the center-line of the clenched fist(s) delivering the impact.

1.3.1.1 Specifically exempted from these procedures are axes, picks, hatchets, claw hammers, mauls, adzes and any other similar devices whose line of action is generally offset from its grip.

1.3.1 The scope of these testing procedures is limited to evaluating the resistance of body armor to attacks from four levels of hand-held threats -

1) Small, Single-Edged (pocket), Knives,

2) Double-Edged, Dagger Blades,

3) Large, Double-Edged (bayonet) Blades, and

4) Pointed, High Length-Over-Diameter Ratio Implements (ice pick).

1.4 Disclaimer

1.4.1 Compliance with the testing procedures presented herein will not relieve the manufacturer, distributor, or user of all specific and implied liabilities to which they would otherwise be exposed, nor does compliance with these procedures imply any transferral of any portion of the manufacturer’s or distributor’s product liability exposure to H.P. White Laboratory, Inc., whether or not testing--conducted to demonstrate this compliance--is conducted by H.P. White Laboratory, Inc.

1.4.2 The procedures contained herein are offered to the manufacturer (and others with a direct or indirect interest in personal safety) as a means of evaluating the design and performance of puncture resistant body armor. Nothing contained herein is to be construed as a guarantee, warranty, or endorsement by H.P. White Laboratory, Inc.--or its personnel--of the design or performance of any puncture resistant body armor.

SECTION 2.0 PROCEDURES

2.1 General

2.1.1 The basis of these procedures is the creation of a consistent and repeatable sharp/pointed instrument impact which is representative of:

a) a typical sharp/pointed instrument which may be used to defeat the protection of body armor intended to resist such a threat, and

b) the maximum energy with which such an instrument could be hand-delivered by a healthy, athletic male with no physical infirmities.

2.1.2 The essential characteristics of the implements selected for these tests reflect four categories of sharp/pointed threats.

2.1.2.1 **POINTED, ROUND (SCRATCH-AWL) BLADE** (see Figure -04A).

2.1.2.2 **SMALL, SINGLE-EDGED KNIFE BLADE** (see Figure -04B).

2.1.2.3 **DOUBLE-EDGED DAGGER BLADE** (see Figure -04C).

2.1.2.4 **LARGE, DOUBLE-EDGED (BAYONET) BLADE** (see Figure -04D).

2.1.3 The maximum kinetic energy and impact velocity with which such an implement could be hand-delivered was determined experimentally using suitable participants who repeatedly delivered blows with a variety of one-handed and two-handed motions. From this recorded data effective mass (implement, hand, forearm) was determined.

2.1.4 These resultant values of effective impact mass and impact velocity are replicated by air-gun firings onto a vertically oriented, clay backed panel of armor.

2.2 Sampling

2.2.1 Two complete armor assemblies (front, back, and sides as appropriate) shall constitute a TEST SAMPLE. Each panel of a multi-panel armor is to be tested - one each wet and dry.

2.2.1.1 A separate test sample shall be submitted for each of the categories of threat to be tested (see 2.1.2).

2.2.2 Additional samples of the armor may be required in order to satisfy the requirements of 2.6.4 should unfair trials require retesting (3.4.4).

2.3 Set-Up

2.3.1 In preparation for these tests, a suitable fixture shall be developed which will launch the sabotted penetrators horizontally to produce zero degree obliquity impacts at the specified impact velocities.

2.3.2 A rectangular volume of non-hardening modelling clay measuring 24 inches x 24 inches x 4 inches within a five-sided container will be positioned with its 4 inch dimension in the horizontal plane. The clay will be free of air, its exposed impact surface smooth, even, and perpendicular to the flight path of the penetrator.

2.3.3 Velocity sensors shall be positioned to record the velocity of the sabotted penetrator within 16.0 inches of the point of impact.

2.4 Drop Test Verification

2.4.1 Prior to conducting tests of each sample of body armor, drop trials will be conducted to verify the suitability of the clay backing.

2.4.2 The clay verification drop weight (Figure -04E) will be dropped three times from a height of 78.74 inches (2 meters) to impact the clay backing surface at locations sufficiently dispersed so as to prevent overlapping of the disturbed areas of the clay resulting from previous drop trials. The depth of the impression of each of the three trials shall not exceed 1.10 inches, nor be less than 0.90 inches. If this condition is not satisfied, the clay shall not be used for testing. Another clay backing satisfying this condition shall be used.

2.4.2.1 Alternatively, the drop weight may be fired horizontally into the clay. For a valid Verification Test, the velocity must be between 20.5 and 20.6 feet per second.

2.4.3 Once the clay backing has satisfied the above condition, testing should begin immediately. The clay should be removed from its temperature conditioning chamber for only as long as is required to complete the testing. If the clay plasticity is questionable, verification testing may be repeated, or another clay backing complying with the provisions of paragraph 2.4.2 may be substituted.

2.5 Point/Edge Verification

2.5.1 Prior to each test trial the point of the test penetrator(s) and the cutting edge(s) of the knife test penetrator(s) shall be tested to insure minimum sharpness. All point/edge verification testing shall be conducted with the sabot attached to the penetrator, i.e., 2.74 - 2.78 pound assembly weight.

2.5.1.1 The edge of knife penetrators shall be tested with a Razor Edge Systems, Inc., Edge Tester, or equivalent, at 1/2 inch intervals over its entire length.

2.5.1.2 The pointed tips of the penetrator(s) shall be tested by positioning the sabotted penetrator vertically, tip up, with the tip in contact with a supported (zero vertical velocity), framed, single sheet of 24 pound, 25% cotton paper. The framed paper assembly shall weigh 0.5 ± .01 pound and, when released, the force of gravity shall cause the paper to be penetrated by the penetrator to a minimum back-side protrusion of 3.0 inches.

2.5.2 Any edged penetrator which fails to satisfy the provisions of 2.5.1.1 AND 2.5.1.2 shall be resharpened and retested until the resharpened penetrator satisfied BOTH requirements.

2.5.2.1 Scratch-Awl penetrators need satisfy only 2.5.1.2.

2.6 Testing Procedure

2.6.1 The test sample will be pressed onto the surface of the clay to a sufficient depth to assure intimate contact between the clay backing and all portions of the rear surface of the test panel. If a convex test sample is to be tested, clay will be built up behind the sample so as to occupy the volume defined by the inner, concave surface. Intimate contact is to be made between the clay and the inner side of the test sample.

2.6.2 The clay and test panel will be positioned vertically in a manner which assures its rigidity in the vertical plane and that the anticipated point of impact is normal (± 2 degrees) to the line of translation of the sabotted penetrator. For rigid, convex armor, the line of translation shall be normal (± 2 degrees) to the tangent of the curve at the intended impact location.

2.6.3 The center of impact shall be no closer than 2 inches to the edge of the test sample, nor closer than 2 inches to the center of impact of a prior trial.

2.6.4 The number of required fair impacts of each panel of the armor shall be determined prior to testing and shall be a maximum of five or the maximum, up to five, which comply with 3.3.

2.6.5 Five fair impact trials will be conducted on each panel of armor tested or until the limitation(s) of 2.6.3 prevent further fair impacts. After each trial, the depth of the impression in the clay backing will be recorded to within 0.01 inches, and a determination of compliance or non-compliance (see 3.4) recorded.

2.6.6 Prior to each impact trial, the sharpness of the point and edge of the test penetrator shall be verified in accordance with 2.5.

2.7 Materials

2.7.1 The following materials and fixtures are required to complete these tests:

a) Clay, Non-Hardening, Roma Plastilina No. 1 (no substitutes).

b) Fixture, Test, Launching.

c) Fixture, Clay Verification, Figure -04E (or equivalent).

d) Weight, Drop, Clay Verification, Figure -04E (no substitutes).

e) Assembly, Penetrator, Scratch-Awl (see Figure -04A).

f) Assembly, Penetrator, Small Knife (see Figure -04B).

g) Assembly, Penetrator, Dagger (see Figure -05C).

h) Assembly, Penetrator, Bayonet (see Figure -04D).

i) Edge Tester, Razor Edge Systems, Inc., P.O. Box 150, Ely, MN, 55731.

SECTION 3.0 DEFINITIONS AND REQUIREMENTS

3.1 General

3.1.1 The general definitions, requirements, and acceptance criteria of this procedure are based on NIJ-STD-0101.03, BALLISTIC RESISTANCE OF POLICE BODY ARMOR, dated April 1987, but are not necessarily endorsed by anyone other than H.P. White Laboratory, Inc.

3.1.2 Each panel configuration of the armor (front, back, groin protector, etc.) shall be tested in the DRY condition in accordance with 2.6.5.

3.1.3 Each panel of the armor (front, back, groin protector, etc.) shall be tested in the WET condition in accordance with 2.6.5 after having been wet conditioned in accordance with the procedures of NIJ-STD-0101.03.

3.2 Clay Verification Test

3.2.1 The depth of the impression in the clay backing of each of the three fair clay verification trials (see Paragraph 2.4) shall be 1.0 inch plus or minus 0.1 inch. Any fair drop test which does not satisfy this requirement will disqualify the clay backing from use in testing, despite the number of other fair drop tests which meet this requirement.

3.2.2 The clay shall be temperature conditioned and retested until this requirement is satisfied, or another clay-filled container whose plasticity is determined to be in compliance may be substituted.

3.2.3 The depth of the impression in the clay will be measured from a horizontal reference line between the surface of two undisturbed areas of the clay vertically to the deepest point of the impression. Clay exuded at the periphery of the impression (cratering) may be removed to facilitate this measurement.

3.3 Fair Trials

3.3.1 Each of the required trials must comply with the following FAIR trial requirements--all others will be termed UNFAIR. Unfair trials shall be repeated pursuant to paragraph 2.6.5 until the required number of trials is obtained.

3.3.2 The weight of the sabotted penetrator shall be no less than 2.74 nor more than 2.78 pounds.

3.3.3 The velocity of the sabotted penetrator when determined as specified in 2.3.3 shall be no less than 49 nor more than 50 feet per second.

3.3.3.1 Otherwise fair trials which impact at velocities in excess of 50 fps, but which do not penetrate nor produce excessive deformation, shall be declared FAIR.

3.3.3.2 Otherwise fair trials which impact at velocities of less than 49 fps and which penetrate or produce excessive deformations shall be declared FAIR.

3.3.4 The sabotted penetrator shall impact the test sample within 2 degrees of the perpendicular to a tangent at the point of impact.

3.3.4.1 Otherwise fair trials which impact at obliquities in excess of 2 degrees which penetrate or which produce excessive deformation, shall be declared FAIR.

3.3.5 The disturbed area of the clay backing or the test sample of each trial shall not extend to the periphery of the sample or clay backing, nor shall it overlap the disturbed area of any other trial.

3.3.6 The sabotted penetrator shall fully exit the launching fixture and be in free flight prior to impacting the test panel, and its orientation shall be unrestrained after that impact.

3.3.7 Otherwise fair trials which cause the penetrator to be deflected or which result in breakage of the penetrator shall be declared FAIR and the findings of 3.4 shall apply to the initial impact AND to the secondary impact (if any) of the broken penetrator stub.

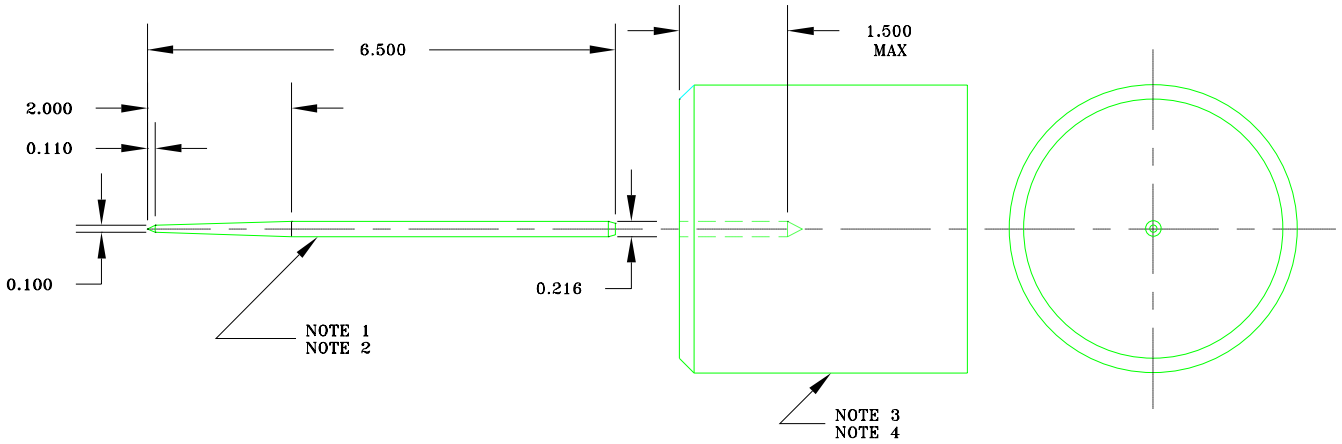
3.4 Test Sample Acceptance Criteria

3.4.1 Any fair trial which does not penetrate the rear surface of the test sample AND which does not produce an impression in the clay backing in excess of 1.73 inches (44mm) will be termed as being in compliance with the requirements of this procedure.

3.4.2 Any fair trial which penetrates the rear surface of the test sample AND/OR which produces an impression in the clay backing in excess of 1.73 inches (44mm), shall be deemed a fair trial and shall fail the test sample.

3.4.2.1 Any fair trial which penetrates the test sample or deforms the clay in excess of that stipulated in paragraph 3.4.2 shall fail the test sample, despite the number of other trials which may have produced results complying with 3.4.1.

3.4.3 Any trial deemed an unfair trial shall be repeated until the required number of fair trials have been met (see 2.6.4).



NOTES:

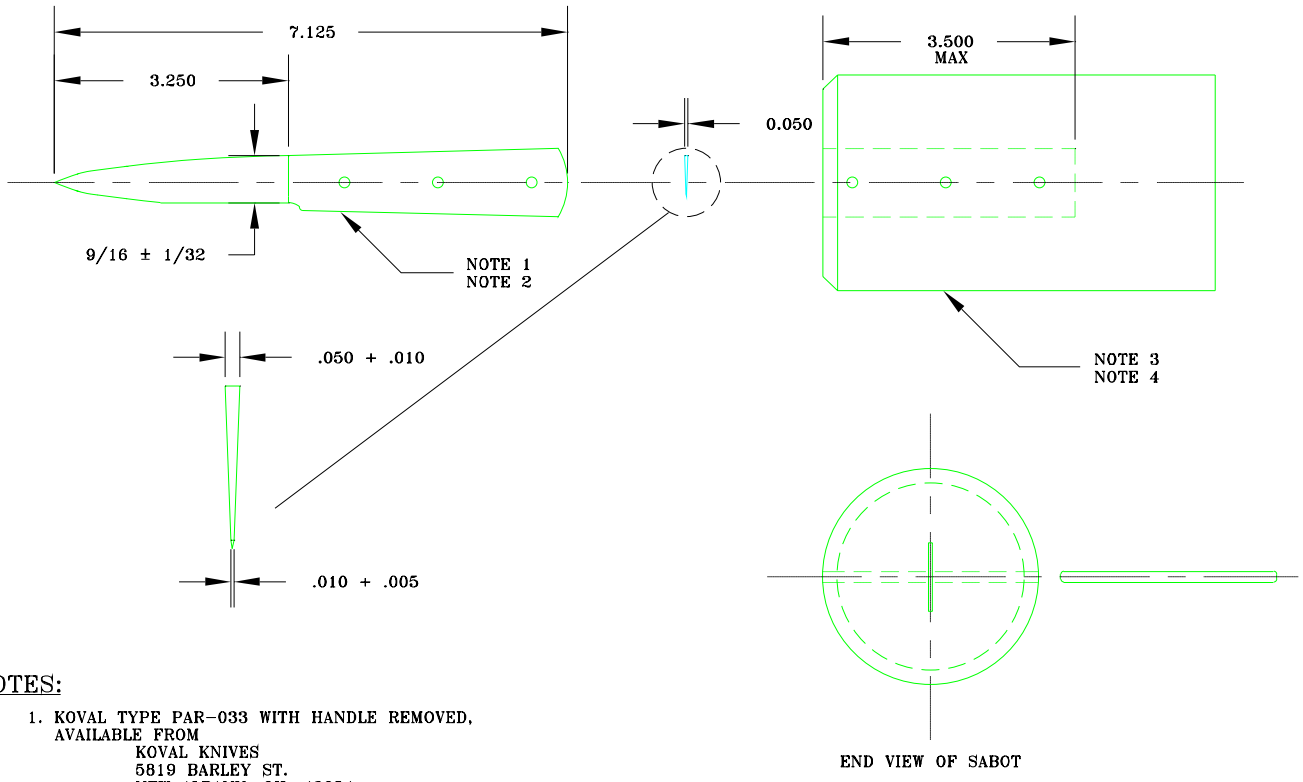
1. STANLEY SCRATCH AWL, MODEL 69-007
   WITH HANDLE REMOVED. AVAILABLE FROM
   STANLEY TOOLS
   600 MYRTLE STREET
   NEW BRITIAN, CT. 06005

2. HARDNESS, ROCKWELL: C50-55

3. SABOT MATERIAL, SIZE AND SHAPE OPTIONAL.
   ADJUST DIMENSIONS TO TOTAL ASSEMBLY
   WEIGHT (SABOT AND AWL) OF 2.74 - 2.78 POUNDS.

4. SCRATCH AWL AND SABOT JOINED IN A MANNER
   WHICH INSURES THEY REMAIN JOINED THROUGHOUT
   TEST IMPACT WITH ARMOR.

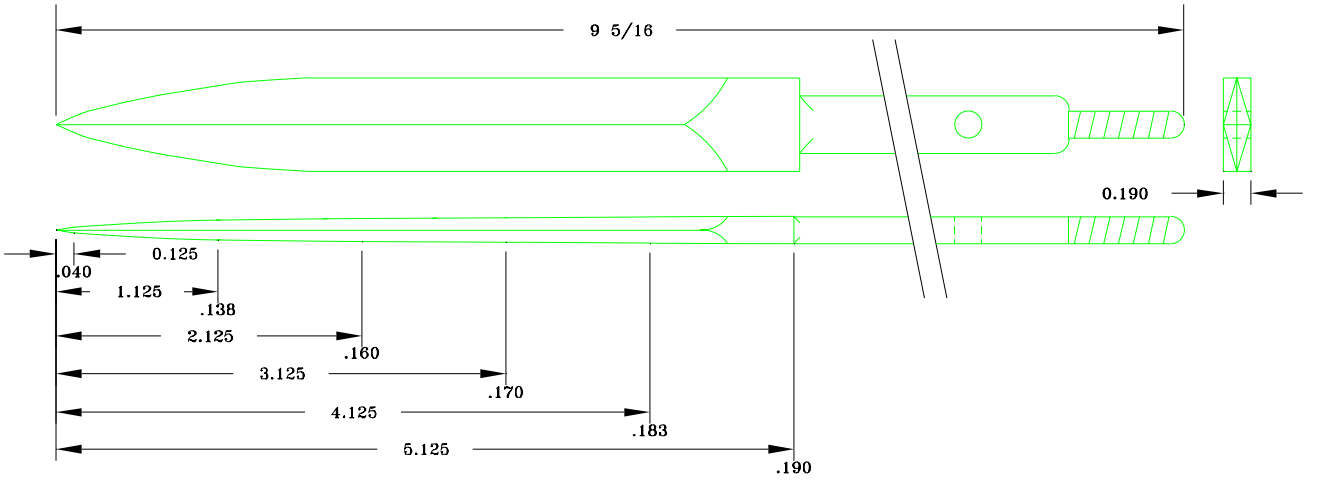
HPW-TP-0400.04A	H.P. White Laboratory Inc.
DWG FILE: C:\DRAW\DRD\AWL-PICK	TEST PENETRATOR SCRATCH AWL (ICE PICK)
SCALE 0 1 2 INCHES	Job No. | Date: Nov. 1996

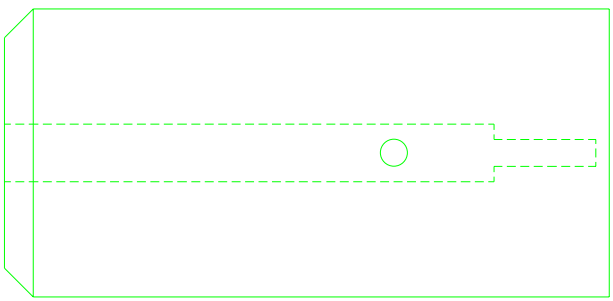


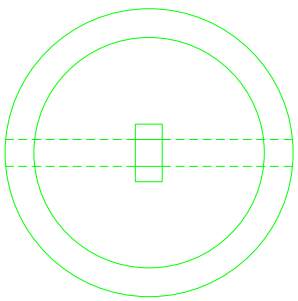
NOTES:

1. KOVAL TYPE PAR-033 WITH HANDLE REMOVED, AVAILABLE FROM
   KOVAL KNIVES
   5819 BARLEY ST.
   NEW ALBANY, OH. 43054
2. HARDNESS: ROCKWELL C 54 - 56
3. SABOT MATERIAL, SIZE AND SHAPE OPTIONAL. ADJUST DIMENSIONS TO TOTAL ASSEMBLY WEIGHT (SABOT & KNIFE BLADE) OF 2.74 - 2.78 POUNDS.
4. KNIFE BLADE AND SABOT JOINED IN A MANNER WHICH INSURES THEY REMAIN JOINED THROUGHOUT TEST IMPACT WITH ARMOR.

HPW-TP-0400.04B	H.P. White Laboratory Inc.
DWG FILE: C:\DRD\SM-KNIFE	
MATERIAL: CARBON STEEL 1075	TEST PENETRATOR SMALL KNIFE
SCALE 0 1 2 INCHES	Job No. | Date: Nov. 1996



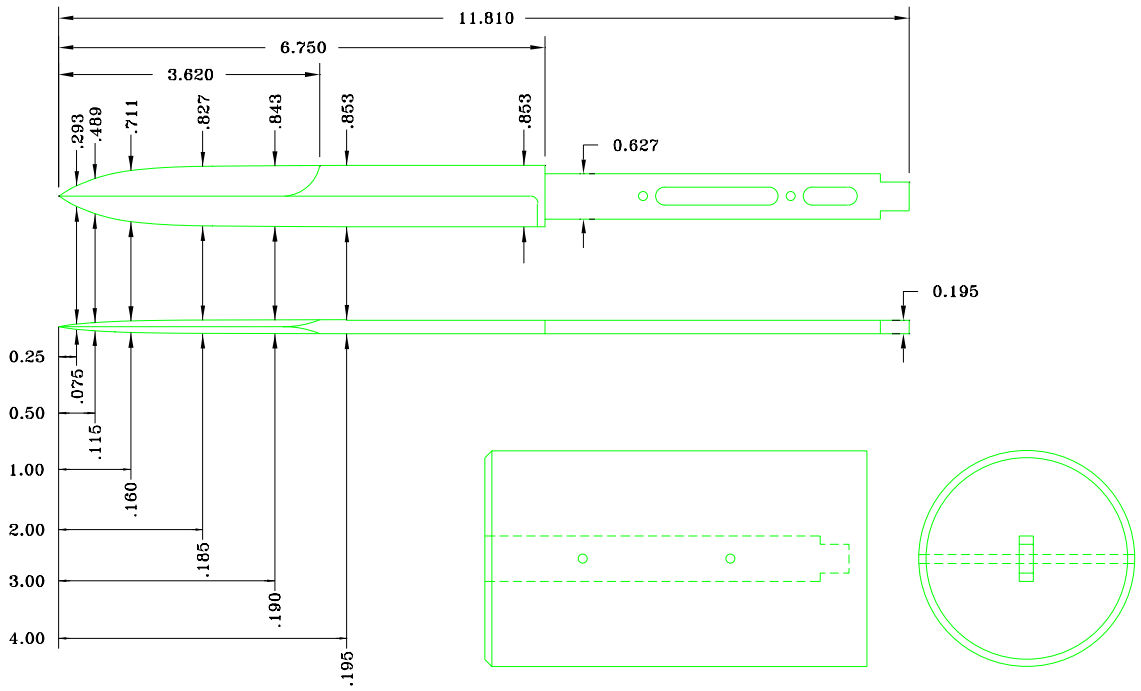




NOTES:

1. DOUBLE EDGE DAGGER, KOVAL NO. 131 BL WITH HANDLE REMOVED, AVAILABLE FROM
   KOVAL KNIVES
   5819 BARLEY ST.
   NEW ALBANY, OH. 43054
2. HARDNESS; ROCKWELL C54
3. SABOT MATERIAL, SIZE AND SHAPE OPTIONAL. ADJUST DIMENSIONS TO TOTAL ASSEMBLY WEIGHT (SABOT & DAGGER) OF 2.74 – 2.78 POUNDS.
4. DAGGER AND SABOT JOINED IN A MANNER WHICH INSURES THEY REMAIN JOINED THROUGHOUT TEST IMPACT WITH ARMOR.

HPW-TP-0400.04C	H.P. White Laboratory Inc.
DWG FILE: C:\DRD\DAGGER	
MATERIAL: CARBON STEEL	TEST PENETRATOR DOUBLE EDGED DAGGER
SCALE 0 .5 1 INCHES	Job No. | Date: Nov. 1996



NOTES:

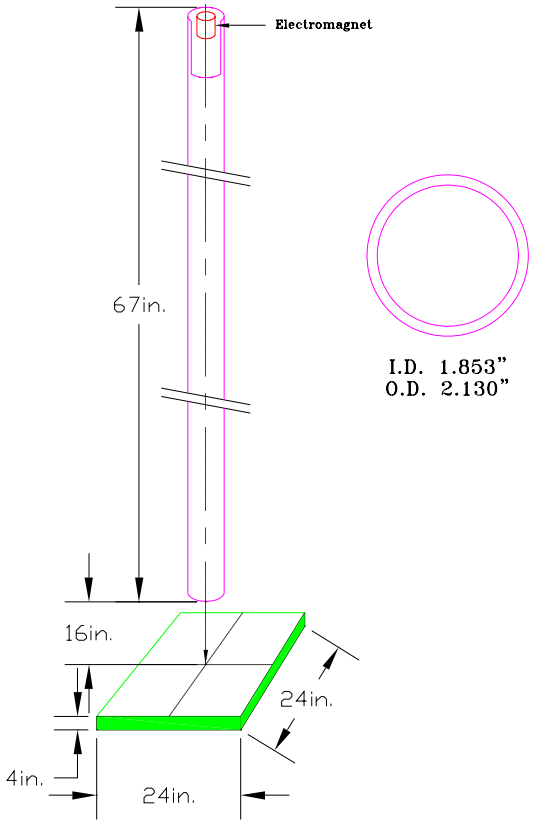
1. BAYONET WITH HANDLE REMOVED
   U.S. MILITARY, MODEL M7
   BAYONET, P/N 11010077
   BLADE ONLY, P/N 11010066

2. HARDNESS; ROCKWELL C 47-53

3. SABOT MATERIAL, SIZE AND SHAPE OPTIONAL. ADJUST DIMENSIONS TO TOTAL ASSEMBLY WEIGHT (SABOT & BAYONET) OF 2.74 - 2.78 POUNDS.

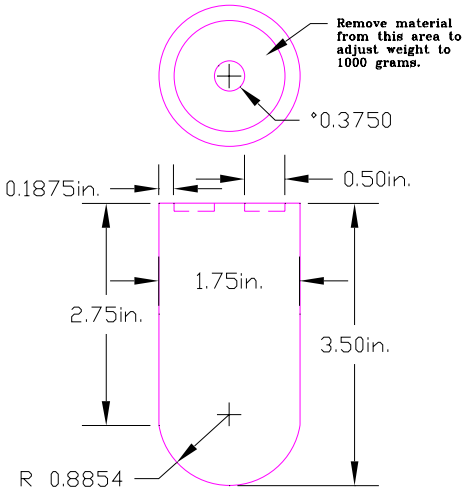
4. BAYONET AND SABOT JOINED IN A MANNER WHICH INSURES THEY REMAIN JOINED THROUGHOUT TEST IMPACT WITH ARMOR.

HPW-TP-0400.04D	H.P. White Laboratory Inc.
DWG FILE: C:\DRD\BAYONET	TEST PENETRATOR BAYONET (U.S. ARMY M7)
MATERIAL: STEEL 1080	
SCALE 0 1 2 INCHES	Job No. / Date: Nov. 1996



I.D. 1.853"
O.D. 2.130"

CLAY VERIFICATION WEIGHT



MATERIAL:		ENGINEERING SPEC:			PROJECTION	SCALE:
		TOLERANCES UNLESS NOTED		INCH	m m	
		LINEAR ±				
CASE DEPTH		ANGLES ±				
HARDNESS		RADII				
SURFACE TREATMENT		EDGE/CORNER BREAKS	OUTSIDE MAX			
			INSIDE MAX			
					DESIGNER:	DRAWN BY:
					DSGN APPRO:	DWG CHK:

H.P. White Laboratory Inc.

FILE NAME: C:\DRAW\DRD\CLAVERFX.DWG	CLAY VERIFICATION FIXTURE HPW TP-0400.04E
CONTRACT NO.:	
JOB NO.:	
DRWG. NO.:	DATE: May 8, 1997

REVISIONS RECORD SHEET

Revision	Date	Type	Dia. (in)	Length (in)	L/D	Hardness Rc	Wgt. (lbs.)	Hgt. (in)	KE (in-lb)	Mom. (lb-s)	Vel. (ft/s)
0200.00	10/15/83	Awl	1/4	6-3/4	27:1	NA	18.5	102	1887	NA	NA
0200.01	02/03/87	Pick	0.163	7	27:1	42	18.5	102	1887	NA	NA
0400.00	07/22/88	Pick	0.163	7	27:1	42	20.5	92	1886	NA	NA
0400.01 (a)	07/00/90	Pick	0.163	7	27:1	42	20.5	92	1886	NA	NA
0400.02	09/00/90	Pick	0.163	7	NA(b)	42-44	40.0	47.15	1886	NA	NA
0400.03	11/23/94	Pick	0.163	7	NA(b)	55-58(c,d)	40.0	47.15	1886	19.8	15.9
0400.04 (e)	11/01/96	Awl	0.216	6.5	30:1	50-55	2.76	NA	1286	4.28	50.0
		Knife	NA	7.1	NA	54-56	2.76	NA	1286	4.28	50.0
		Dagger	NA	9.3	NA	54-56	2.76	NA	1286	4.28	50.0
		Bayonet	NA	11.8	NA	47-53	2.76	NA	1286	4.28	50.0

(a) Minor clerical changes and rewording of HPW-TP-0400.00.
(b) No length to diameter ratio specified, but instead a 15:1 point taper ratio.
(c) Based on pick manufacturers' advice. All picks made to 55-58 Rc Hardness; none made to 42 Rc Hardness.
(d) Based on pick manufacturers' advice, alloy S.A.E. Specification Number 1060.
(e) Extensive revision. Changed from Drop Test to Air-Gun Testing.

27 September 1996

MEMORANDUM

SUBJECT: Backup information for revision **HPW-TP-0400.04, SHARP INSTRUMENT PENETRATION OF BODY ARMOR**

The basis for the perceived dissatisfaction with existent standards, including earlier revisions of this standard, is -

1. Excessive energy level of the threat,

2. Required level of impact energy is developed by variable combinations of weight and impact velocity,

3. Type (shape, weight and hardness) of the threat implement,

4. Interpretation of test implement breakage during testing, and

5. Backing material used to conduct testing.

Our testing to date has been limited to attempts to define the energy level of a perceived threat. This testing was conducted by 6 athletic males whose body weight (150 to 215 pounds) and height (5′ 7" to 6′ 3") was representative of an estimated 80-90% of adult males.

The procedures described below were intended to determine the energy levels of a typical "stabbing" motion in terms of IMPACT VELOCITY **AND EFFECTIVE MASS** i.e., mass of the implement **AND** the mass of the hand and forearms(s) of the attacker.

ENERGY LEVEL TESTING (Items 01 and 02, above)

The test implement weighed 8 ounces and was fabricated from a 3.0 inch diameter, hemispherical, metal impact face to which was attached a 1.25 inch diameter, 12.0 inch long tubular, metal handle (see Figure 01).

The test implement was used to impact a 4 inch thick, block of plastilina clay conditioned in accordance with NIJ-STD-0101.03. The test impacts were delivered with five differing motions by each of the test individuals.

1. **DOUBLE HANDED, OVERHEAD** (chopping) motion onto a horizontally oriented clay surface,

2. **SINGLE HANDED, OVERHEAD** (chopping) motion onto a horizontally oriented clay surface.

3. **SINGLE HANDED, SIDEARM** (horizontal) motion onto a vertically oriented clay surface,

4. **SINGLE HANDED, SIDEARM, CROSS BODY** (horizontal) motion onto a vertically oriented clay surface, and

5. **SINGLE HANDED, FRONTAL THRUST** (horizontal) motion onto a vertically oriented clay surface.

All testing was conducted with the longitudinal axis of the gripped handle of the implement forming a 90◦ (approximate) angle with the longitudinal axis of the forearm(s). In all but the **THRUST** Tests the hemispherical impact face was adjacent to the little finger of the gripping hand. The **THRUST** Tests were conducted with the hemispherical impact face adjacent to the thumb and index finger of the gripping hand.

Foil, make-circuits were positioned on the face of the clay and 2.125 inches in front of the clay. The time between "making" of these circuits was recorded on an elapsed time counter (chronograph), and used to determine implement velocities 1.063 inches from impact with the clay.

The depth of the deformation of each impact was measured from the pre-test, undisturbed surface of the clay. The test implement was then fired from an air cannon to impact the same clay block at the velocities measured during our human trials. The Air Gun Tests were conducted with additional weight added incrementally to the test implement to produce the deformations of the human trials.

The results of the human impact trials are shown in Tables I and II. The individual and average, highest impact velocities (47.4 and 41.9 fps, respectively) were developed by the same delivery motion - **SINGLE HANDED OVERHEAD.**

The individual and average deepest clay deformations (48 and 35mm, respectively) were developed by the same delivery motion, but different from that of the highest impact velocities - **DOUBLE HANDED OVERHEAD.**

The Air Gun Tests demonstrate the empirically derived, **EFFECTIVE** weight of a hand-delivered attack producing the velocities and deformations of our Human Tests varied between 1.7 and 2.76 pounds over the full range of delivery motions tested (see Table III).

An EFFECTIVE weight of 2.76 pounds seems to be representative of the maximum mass of a knife and hand combination. A combination of this weight and a velocity of 45 fps produces an energy level of 87 foot-pounds and a clay deformation of 48mm. This combination is representative of the worst case conditions measured in the laboratory.

Since an actual attack may involve a large, experienced attacker, possibly under the influence of drugs and adrenalin, a safety factor must be added to the laboratory measurement. Lacking a reliable and authoritative basis to the contrary, we intend to increase the maximum energy level by 20% to 105 foot-pounds. If the effective weight is kept at 2.76 pounds, then the striking velocity increases to 49.3 fps, for a clay deformation of 58mm. The procedures will specify this weight and striking velocity to the exclusion of all others.

TEST IMPLEMENTS (Item 03, above)

It is our intention to develop a major revision of our existing standard which accepts the argument that differing configurations of penetrators may produce dramatically differing results and provides for four categories of protection characterized by the test implements -round-pointed (ice pick), single edged (pocket) knife, double edged (dagger) knife and large, double edged (bayonet) knife. Figures 2 and 3 show some representative implements.

PENETRATOR BREAKAGE (Item 04, above)

It is our intention to develop a major revision of our existing standard which -

a) Accepts the argument that penetration of the armor by the broken penetrator should be considered a fair penetration, providing the broken, penetrator stub is not artificially driven through the armor by the restrained, continued application of the drop weight,

b) Accepts the argument that deflection or breakage of the penetrator without penetration of the armor should reflect favorably on the armor,

c) Utilizes a free-flight, air-gun-launched methodology to satisfy (a) and (b), above.

BACKING MATERIAL (Item 05, above)

Our testing has demonstrated that a hand delivered impact of the same clay backing material as used in ballistic resistant body armor (NIJ-STD-0101.03), may provide back-face deformations in excess of that which is considered lethal by that standard (44mm). Therefore, it is our intent to develop a standard which includes a dual pass/fail criteria -penetration and deformation.

While ballistic gelatin may prove to be a more realistic backing material than clay, it still is a compromise with respect to representation of the variations of the human torso - bone supported and non-bone supported tissue. While clay backing may be more of a compromise, its use is preferable to gelatin for pragmatic reasons.

a) The cost of testing of a single panel of armor on gelatin will increase by as much as $500.00, and

b) Back-face deformation cannot, without further increasing test costs, be recorded in gelatin.

TABLE I. HUMAN TRIALS STATISTICS

Stroke	Velocity (fps)			Depth (mm)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Single Handed Overhead	37.7	47.4	41.9	19	35	29
Double Handed Overhead	29.5	45.2	36.8	24	48	35
Single Handed Frontal Thrust	19.4	37.7	28.3	13	28	19
Single Handed Sidearm	35.8	45.7	39.9	18	36	24
Single Handed Sidearm Cross Body	29.5	45.4	36.8	14	25	20

TABLE II. SUMMARY OF RESULTS (HUMAN TRIALS)

Range of Impact Velocities (fps)	Human Tests				
	Trials	Velocity		Deformation	
		Maximum (fps)	Average (fps)	Maximum (mm)	Average (mm)
19.0 - 25.0	4	24.3	22.2	18	14.8
25.1 - 30.0	4	29.5	28.6	24	18.0
30.1 - 35.0	10	34.6	32.4	26	21.0
35.1 - 40.0	14	39.4	37.9	45	23.0
40.1 - 45.0	9	43.0	42.1	33	28.1
45.1 - 50.0	5	47.4	45.9	43	34.2
OVERALL	**46**	**47.4**	**38.4**	**45**	**25.1**

TABLE III. SUMMARY OF RESULTS (AIR GUN TESTS)

Range Of Impact Velocities	1.70 Pounds Impacter		2.25 Pounds Impacter		2.76 Pounds Impacter		5.74 Pounds Impacter	
	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.
19.0 - 25.0 (fps)								
Velocities(fps)	NA		24.6	24.0(2)	23.9	23.9(2)	24.9	24.9(2)
Deformation(mm)	NA		15.0	14.5(2)		(2)	25.0	25.0(2)
Energy(ft-lbs)	NA		21.1	20.1(2)	24.5	24.5(2)	55.3	55.3(2)
25.1 - 30.0 (fps)								
Velocities(fps)	27.5	27.1(2)	29.7(1)		29.7	29.2(2)		
Deformation(mm)	15.0	14.0(2)	21.0(1)		24.0	24.0(2)		
Energy(ft-lbs)	20.0	19.4(2)	30.8(1)		37.8	36.5(2)		
30.1 - 35.0 (fps)								
Velocities(fps)	32.3	32.2(2)	35.1	33.3(3)	32.2(1)		30.6	30.6(2)
Deformation(mm)	19.0	18.5(2)	23.0	22.7(2)	27.0(1)		33.0	33.0(2)
Energy(ft-lbs)	27.5	27.4(2)	43.0	38.7(2)	44.4(1)		83.5	83.5(2)
35.1 - 40.0 (fps)								
Velocities(fps)	39.9	38.4(3)	38.1	37.6(2)	39.5	37.6(5)	38.7	37.8(2)
Deformation(mm)	25.0	23.7(3)	25.0	24.5(2)	39.0	35.8(5)	43.0	43.0(2)
Energy(ft-lbs)	42.0	38.9(3)	50.7	49.4(2)	66.9	60.6(5)	133.5	127.4(2)
40.1 - 45.0 (fps)								
Velocities(fps)	44.6	43.2(5)	43.4	42.4(3)	41.9	41.8(2)	NA	
Deformation(mm)	31.0	29.8(5)	32.0	29.0(3)	46.0	45.0(2)	NA	
Energy(ft-lbs)	52.5	49.3(5)	65.8	62.8(3)	75.2	74.9(2)	NA	
45.1 - 50.0 (fps)								
Velocities(fps)	48.6	48.4(2)	49.0	47.7(4)	46.0	45.7(2)	NA	
Deformation(mm)	31.0	31.0(2)	36.0	35.8(4)	51.0	50.5(2)	NA	
Energy(ft-lbs)	42.3	61.8(2)	83.9	79.5(4)	90.7	89.5(2)	NA	
50.1 - 55.0 (fps)								
Velocities(fps)	52.4	52.4(2)						
Deformation(mm)	34.0	33.5(2)						
Energy(ft-lbs)	72.5	72.5(2)						
OVERALL								
Velocities(fps)	52.4	40.7(16)	49.0	38.2(15)	46.0	30.8(15)	38.7	31.0(6)
Deformation(mm)	34.0	25.9(16)	36.0	25.9(15)	51.0	29.7(15)	43.0	33.7(6)
Energy(ft-lbs)	72.5	43.7(16)	83.9	51.0(15)	90.7	40.7(15)	133.5	85.6(6)

( ) Parenthesized numbers are number of trials included in averaging.