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ARMALITE RIFLE (AR15) WOUND BALLISTICS TRIALS.

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Porton Technical Paper No. 904
Date: 7th October, 1964
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ARMALITE RIFLE (AR15)
WOUND BALLISTICS TRIALS.

By

Major F.P. Thoresby, R.A.M.C.

SUMMARY

1. Trials have been carried out to examine the wounding effects of the Armalite Rifle (AR15) in comparison with those of the F.N. (L.1.A.1) rifle under controlled laboratory conditions at 15 yd and 100 yd ranges using gelatine tissue models and a standard wound path in anaesthetised sheep.

2. The results tend to confirm the findings of a U.S. combat evaluation that the Armalite rifle is capable of producing very severe wounds at short range (up to 100 yards).

3. At the 15 yd range, the AR15 with Norma rounds was more effective than the F.N. (L.1.A.1); with Remington rounds the AR15 was as effective as the F.N. At the 100 yd range, the AR15 with Norma rounds was slightly superior to the F.N., whilst the AR15 with Remington rounds was slightly inferior.

4. There are indications that the AR15 is more effective with a 1/14 twist barrel than with a 1/12 twist barrel, the difference being very small with the Remington round but more marked with the Norma round.

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Porton Technical Paper No. 904
Date: 7th October, 1964
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ARMALITE RIFLE (AR15)

WOUND BALLISTICS TRIALS

By

Major F.P. Thoresby, R.A.M.C.

1. INTRODUCTION

Evaluation trials covering aspects other than the wound ballistics of the 0.223 in. calibre AR15 rifle were carried out at Enfield (1). The outstanding logistic feature of this weapon is the light weight of both the rifle (6.5 lb as against 9.75 lb for the L1A1) and the ammunition (0.025 lb/round as against 0.054 for the L2A2). Reports of the wounding power of the AR15 have been somewhat conflicting. A combat evaluation carried out in South Vietnam (2) reported very severe effects whilst a more limited trial with goats in Malaya (3) indicated an inferior wounding power of the AR15 to that of the L1A1. The present trials were carried out to examine the wounding effects of the AR15 in comparison with those of the L1A1 under controlled laboratory conditions at close range (15 yd) and at 100 yd, using standard gelatine tissue models, and a standard wound path in anaesthetised sheep.

2. METHODS

Rifles and Ammunition

The following weapons were used:-

AR15 Colt Armalite 0.223 in. calibre, 18.2 in. long barrels with 1/14 and 1/12 riflings.

L1A1 (F.N.) 0.300 in. (7.62 mm) calibre, 19 in. long barrel with 1/12 rifling (used at 100 yd range).

0.300 in. (7.62 mm) calibre barrel, 19.0 in. long, mounted in a Mann pressure housing, 1/12 rifling (used at 15 yd range).

A modified C.D.E.E. rifle rest was used with the AR15 at the 15 yd range, and an Enfield rest at the 100 yd range.

The ammunition used was as follows:-

0.223 in. calibre, commercial Norma and Remington (Batch RA 0016).
0.300 in (7.62 mm) L2A2 standard rounds

Gelatine Tissue Models

The standard gelatine blocks were made of 20% acid-treated pigskin gelatine and measured 6 x 6 x 10 inches. The temperature of the interior of the block was measured after firing and was within the range 18-20°C. Differences in the wound ballistics properties of gelatine are small with variation in temperature below 21°C (4), therefore no correction was made for the slight variation in temperature. The round was aimed to pass through the centre of the block along the long axis.

After firing, the end, side, and top of the block were photographed to record the missile track with a view to determining the exact position of the onset of tumbling. Any bullet fragments in the block were dissected out, weighed and photographed.

Animals

Adult ewes, weighing 150-200 lb were deeply anaesthetised with chloroform and placed in a supine position on a modified operating table with a hydraulic lift and full tilting adjustments. An aiming mark was placed over the 4th - 5th intercostal space in the mid-axillary line and aligned with the fixed trajectory of the bullet. This alignment gave a thoracic path which included the lungs and the thick myocardium of the ventricles. This path was considered to be the nearest approximation in the sheep to the 15 cm "Erect Man" soft tissue or gelatine path (5), and offered the advantages that the muscle mass involved (heart) was not relaxed by anaesthesia and there was no danger of wound complication by impact with major bones. Any animal not dying immediately after firing was sacrificed with an overdose of anaesthetic. Immediate autopsies were carried out, the wound path length measured, and photographic records made. The wound track was dissected and the abdominal contents examined for remote injury due to cavitation.

Because comparative assessment of wound severity is to some extent subjective, all the dissections and subsequent analyses were carried out by the same observer.

Velocity and Energy Measurement

Strike velocities were measured using conducting paper screens, over a 2 ft base, operating Cintel microsecond chronometers. At 15 yd range small 'break' screens (6) were used; at 100 yds large (5 x 5 in.) Enfield 'make' screens were used. Efforts were made to measure emergent velocities at both ranges using the large Enfield screens but with limited success.

For the indoor gelatine trials, high speed cinematograph records were made using a Fastax camera operating nominally at 12,000 frames/sec and synchronised by a 'Goose' control with the electrically operated firing mechanism. Time markings on the films were produced by an accurate 1000 c/s oscillator. Each film was analysed by projecting to the exact full size on a large card screen. The front tip of each bullet image was marked, frame by frame, the maximum temporary cavity was outlined, and the distance to tumbling marked. From these records, graphs were constructed to show the distance travelled by the bullet with time, immediately before and after entering the gelatine block, These data were combined for each combination of round and weapon tested to give an average retardation curve. The curves, shown in Figure 3, were used to calculate the missile velocity and energy at any point in the track.

3. RESULTS

Gelatine Experiments

15 yd Range

(a) Six shots were fired into gelatine targets with each combination of weapon and round tested. Peak cavity volumes were calculated from the card tracings of the longitudinal cross sectional area of the peak cavity using the formula of Dziemian and Herget (7). This formula strictly applies to a cylindrical gelatine block, but the error in applying it to a rectangular block is not so large that the results cannot be used for comparative purposes. The average values for the strike energy, the energy absorbed by the whole block, and the cavitation volumes, are presented in Table 1. In the case of the AR15 rounds, almost all the energy of the bullet was dissipated within the gelatine. Fragmentation of the AR15 rounds occurred and when some fragments emerged their velocities, estimated from ciné records, were so low that their energies were almost negligible in comparison with the strike energies. More energy was transferred to the gelatine from the L2A2 round but this amounted to only 2/3 of the strike energy, and the cavitational volume per unit of energy absorbed was significantly less than those for the AR15 rounds. The scatter in the cavitation data for the AR15 rounds was too large to allow comparisons to be drawn between the types of round or the effects of barrel twist.

(b) It has been shown (5) that a more reliable criterion of wounding power than the volume of the temporary cavity is the energy (ΔE) absorbed during the penetration of the first 15 cm of a gelatine tissue model, the energy absorbed in the first 1 cm being ignored as representing a non-incapacitating superficial wound. Values for $\Delta E/Es$, where Es = strike energy, were calculated from the data in Fig. 3 for the various rounds and are expressed as percentages in Table 2 which also contains comparative U.S. data (8)(9). This ratio can also be derived from a measurement of the distance (d) to tumbling by the formula (8):

$$100\,\Delta E/Es = Y = 9614/d^{2.2693}$$

Values for d were measured from full scale photographs of the gelatine blocks (e.g. Figs. 1 and 2) by backward projection of the divergent paths and the outline of the permanent cavity to give the point at which tumbling commenced. This measurement correlated more closely with data from ciné records than did measuring the narrow stable track and correcting for end-effects as used in the derivation of the comparable U.S. data (8). The calculated values for Y are included in Table 2 and are seen to correspond closely with the values for $\Delta E/Es$. The values of ΔE indicate that the AR15 Remington and the L2A2 rounds have similar wounding power at this range (15 yd) whilst that of the AR15 Norma round is superior to both. The values of $\Delta E/Es$ indicate that the wounding efficiency of all the AR15 rounds at 15 yd range is considerably higher than that of the L2A2.

(c) The probability (Phk) that a random hit would incapacitate (10) has been derived from the following functions of ΔE by Dziemian (5)(11):

(Defence situation. 100% incapacitation only, within 30 seconds):

$$Phk = 1/1 + e^{-(-5.825 + 1.624 \log\Delta E)}$$

(Assault situation. Including partial incapacitation within 30 seconds):

$$Phk = 1/1 + e^{-(-3.023 + 1.651 \log\Delta E)}$$

where ΔE is expressed in Joules. Values for Phk calculated for the various rounds are given in Table 3, which includes comparable U.S. results, and again indicate similarity in the wounding power of the AR15 Remington and L2A2 and the superiority of the AR15 Norma.

(d) Typical fragments found in the gelatine from Remington and Norma rounds are shown in Fig.4. These were similar for the two types of round in number and size except for the presence of the nose cap of the Norma round (1/14) where all the fragments remained in the block (see Table 1).

Animal Experiments

The results of the animal experiments are given in Tables 4 (15 yd range) and 5 (100 yd range). Typical features of the wounds are illustrated in Figures 5-10. The terms used in the Tables and Figures are explained as follows:

Wound Path: The distance travelled by the missile in the body, measured on the removed thoracic cage (Fig. 6), the thickness of the skin being ignored.

Exit Wounds: Major and minor dimensions are given where the wound was irregular, otherwise the approximate diameter is given (Fig. 7(a)(b)).

Heart Path: A wound track passing through any portion of the myocardium.

Wound Types: (Figures 8 - 10).

(a) Perforating (P): Where the path through the thoracic contents was predominantly regular in outline, i.e. an injury typical of that due to a fairly stable bullet with a clearly defined track through each organ in its path.

(b) Explosive (E): Extensive disruption of tissues, usually associated with other evidence of large cavitation such as 'blast' markings on the lung surface.

Lung Markings: Haematoma following the pattern of the ribs similar to those seen as a result of blast injuries. The degree of this effect reflects the extent of cavitation and has been graded arbitrarily as 1-4 in severity (Fig. 9).

Stomach Bruising: Sub-diaphragmatic haematoma of the muscular [illegible] portion of the sheep stomach due to the rapid expansion of the diaphragm during cavitation in the thorax.

Fragments found: These were usually the nose fragments (Fig.10(b)) with or without complete or partial extrusion of the core. Where no fragments are indicated in the Tables the presence of small fragments in the body could not be excluded as no suitable X-ray facilities were available.

For comparative purposes the data in Tables 4 and 5 relating to true Heart Paths only are summarised in Table 6. Of the eight AR15 shots at 15 yd range, 7/8 produced explosive type wounds with additional evidence of extensive cavitation. The number of L1A1 shots was too small for a valid comparison of the effects with those of the AR15, but the results suggest that the L2A2 round was less effective. At the 100 yd range, 11/20 AR15 shots and a similar proportion, 3/5, of the L1A1 shots produced explosive type wounds. Comparison of the effects of the two types of AR15 round shows little difference at the 15 yd range between the Remington and Norma, but at the 100 yd range the Norma round produced a larger proportion (8/11) of explosive wounds than did the Remington (3/9) and the average lung marking grade was higher.

With all the rounds tested and at both ranges, the entrance wounds were small (e.g. Fig. 5). In some cases the round completely or partially perforated a rib on entry but no correlation was found between rib involvement and the total severity of the wound, and there was no evidence of diversion of the missile path. The exit wounds produced by the Remington round, irrespective of the type of internal wound, were regular in shape and of almost constant size, whereas the L2A2 exit wounds were larger and irregular (Table 5. Fig.7(a)(b)). Only a few Norma rounds perforated and the exit wounds were irregular but smaller than those of the L2A2.

4. DISCUSSION

Comparison of the values of the amount of energy absorbed in the first 15 cm of gelatine at a range of 15 yd (Table 2) indicates that the AR15 Norma round is more effective than the Remington or L2A2 rounds at this range. The superiority of the Norma round is also shown by comparison of the Phk values (Table 3) and by the results of the animal experiments (Table 6). At this range the Remington and L2A2 rounds appear to be equally effective. The animal results at the 100 yd range indicate that the Norma round is slightly more effective than the L2A2 which is now slightly more effective than the Remington. There are indications (Tables 1 - 6) in both gelatine and animal results that the rounds fired from 1/14 twist barrels are slightly more effective than those fired from 1/12 barrels; this marginal difference is more noticeable in the case of the higher velocity Norma rounds (Fig.3) (Tables 2, 6).

The data in Tables 2 and 3 show good agreement between the present results and U.S.A. results (8)(9) with the exception of the values for the Remington (1/14) round. There appears (Table 2) to be a correlation between the striking velocity of the round and the amount of energy ΔE liberated in the gelatine block for the AR15 rounds, the efficiency factor ($\Delta E/Es$) increasing with striking velocity. However the value of $\Delta E/Es$ for the U.S. Remington 1/14 round is considerably higher than would be expected from such a correlation.

Examination of samples of Remington bullets of a similar type to those used in the U.S. trials has shown no apparent difference to the commercial Remington rounds used in the present trials. The photograph in Figure 11 shows (1 the U.S. Remington bullet, (2 the Remington bullet as used in the present trials, (3 the Norma bullet.

The animal results (Table 5) indicate that with the lower velocity Remington round there is a critical path length below which the wounds are perforating and above which the wounds are explosive in type; this distance appears to be in the region of 15 cm. With the higher velocity Norma round, all the wounds were explosive in type with the exception of one, where the path length was shortest (8 cm). With the L2A2 round this effect was not apparent. It is possible, therefore, that with short experimental wound paths, not representative of those likely to occur in man, the wounding power of the AR15, especially with Remington rounds, may be underestimated. This factor may have contributed to the discrepancy between combat evaluation (2) and the results found with random wounding of goats (3).

Fragmentation of the AR15 rounds occurred at the short range (15 yd) especially with the higher velocity Norma round. At the 100 yd range, no fragmentation of the Remington round was observed and the incidence of fragmentation in the Norma round was reduced, especially with the 1/12 barrel. No fragments were found with the L2A2 round, but in the present experiments the wound path was chosen to avoid impact with large bones. Fragmentation of fully jacketed rounds is not uncommon as it depends on the rate of retardation of the round which may be high if dense tissues, such as bone, are involved, or if the impact velocity of the round is high, as may occur at very short ranges. There are many references (12 - 16) to fragmentation of fully jacketed rounds in wounds where bone was involved, and more recently fragmentation of 7.62 calibre rounds of high velocity was found to occur in gelatine (17) and in soft tissue (8).

5. CONCLUSIONS

(i) The evidence from the present results tends to confirm the findings of the U.S. combat evaluation (2) that the Armalite rifle is capable of producing very severe wounds at short ranges (up to 100 yd). The discrepancy between the combat evaluation and the results found with random wounding of goats (3) may have been due to the wound paths in the latter being too short for 'explosive' type (cavitational) wounds to have occurred.

(ii) At a range of 15 yd, the Norma AR15 round has a greater wounding power than the 7.62 mm F.N. round, the Remington AR15 and the F.N. round being about equally effective. At a range of 100 yd, the Norma AR15 round is slightly superior in wounding power to the F.N. round and the Remington AR15 slightly inferior, but the differences are marginal.

(iii) There are indications that the AR15 round fired from a 1/14 twist rifle barrel is more effective than when it is fired from a 1/12 barrel, the difference being small with the Remington round and more marked with the Norma round.

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FPT/HLW

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/ (These reports have now been combined and issued as C.R.D.L.R. 3204, 1964)

TABLE 1

Cavitation and Energy Absorption in Gelatine Blocks

(15 yd. range. Whole Block Data)

	Remington 1/14	Remington 1/12	Norma 1/14	Norma 1/12	L.2.A.2.
Missile Weight (grains)	55	55	55	55	148
Strike Velocity f/s ± S.D.	3030 40	3030 29	3200 21	3230 23	2650 16
Strike Energy (Ec) ft.lb. ± S.D.	1119 31	1134 18	1257 15	1276 20	2318 30
Energy Absorbed (whole Block) ft.lb. ± S.D.	1094 34	1118 17	1257 15	1270 20	1554 132
Wt. of emergent fragments grains ± S.D.	34 6	35 1	0 -	28 5	148 0
Peak cavity volume per unit energy absorbed cc/ft.lb. ± S.D.	3.90 0.77	3.75 0.25	3.66 0.32	4.11 0.41	3.07 0.57

(Strike velocities measured by paper screen technique)

TABLE 2

Energy Absorption (1-15 cm.) in Gelatine Blocks.

(mean values)

	C. D. E. E. Data					U. S. A. Data		
Range	15 yd. (13.7 metres)					10 metres		50 metres
	Remington		Norma		L.2.A.2.	U.S. Remington		M80
Missile	1/14	1/12	1/14	1/12		1/14	1/12	
Strike Velocity ft/sec.	2980	3000	3200	3210	2625	3130	3130	2730
Velocity at 1 cm penetration ft/sec.	2690	2740	2790	2810	2540	-	-	-
Velocity at 15 cm penetration ft/sec	1400	1475	740	1100	2100	-	-	-
Energy at strike Es. ft.lb.	1090	1100	1256	1260	2280	1208	1208	2429
Energy absorbed ΔE (1-15 cm) ft.lb.	645	630	883	816	670	969	708	780
Distance to tumbling (d) cm. ± S.D.	8.7 1.7	9.5 0.4	8.5 1.0	9.0 1.9	11.7 3.4	8.2 1.9	13.3 3.7	11.5 2.0
Y %	69	58	74	66	36	81	27	38
ΔE/Es %	59	57	71	65	37	82	60	32

(Strike velocities derived from cine photographic records)

TABLE 3

Probabilities of Incapacitation (Phk). Gelatine Block Data

(mean values)

	C. D. E. E. Data					U. S. A. Data		
Range	15 yd. (13.7 metres)					10 metres		50 metres
	Remington		Norma		L.2.A.2.	U.S. Remington		M80
Missile	1/14	1/12	1/14	1/12		1/14	1/12	
Δ E Joules	875	856	1198	1107	908	1332	972	1059
Δ E/Es	0.59	0.57	0.71	0.65	0.37	0.82	0.60	0.32
Phk Defence 30 sec 100%	0.260	0.257	0.306	0.293	0.266	0.338	0.284	0.297
Phk Assault 30 sec.	0.863	0.861	0.887	0.882	0.865	0.890	0.859	0.866

TABLE 4

Animal Experiments. 15 yd. (13.7 metre) range

Missile	Shot No.	Striking velocity (ft/sec)	Wound path (cm)	Exit Wound (cm)	Heart Path	Wound type	Lung marking grade	Stomach bruising	Fragments found
Remington 1/14	9 10 11	3060 3060 3070	16.5 21.0 12.0	7 x 5 - 9 x 5	+ + +	P E E	1 3 2	- + +	- + -
Remington 1/12	3 4	3110 3060	12.0 24.0	1.5 1.5	+ -	E P	4 2	- wound	- -
Norma 1/14	7 8	3240 3240	12.0 19.0	- -	+ +	E E	3 4	- -	+ +
Norma 1/12	1 2	3270 3270	15.5 13.5	- 5 x 4	+ +	E E	3 3	+ +	+ -
L.2.A.2	5 6	2700 2660	22.0 11.5	8 x 5 5 x 3	+ +	E P	- 1	- -	- -

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TABLE 5

Animal Experiments 100 yd. (91.4 metres) range

Missile	Shot No.	Striking velocity (ft/sec)	Wound Path (cm)	Exit Wound (cm)	Heart Path	Wound Type	Lung Marking Grade	Stomach bruising	Fragments found
Remington 1/14	5	2660	9	5	-	P	1	-	-
	6	-	12	5	+	P	-	-	-
	7	2690	11	5	+	P	-	-	-
	8	2710	18	5	-	E	3	-	-
	9	2670	20	5	+	E	3	+	-
Remington 1/12	17	2680	13	3.5	+	P	2	-	-
	18	2770	18	3.5	+	P	1	-	-
	19	2760	19	4	+	E	2	-	-
	20	2750	16	4	-	E	2	-	-
	21	2800	15	4	+	P	-	-	-
	22	2780	16	4.5	+	E	-	-	-
	23	-	14	3.5	+	P	1	-	-
Norma 1/14	1	2890	12	-	+	E	2	-	+
	2	2860	19	-	+	E	1	+	+
	3	2840	25	-	-	E	3	Wound	+
	4	2860	14	-	+	E	2	-	+
	10	-	21	-	+	E	4	+	+
	32	2860	6	3.5x5	-	P	1	-	-
	33	-	13	-	+	E	1	+	+
Norma 1/12	11	2880	14	-	+	E	1	-	+
	12	-	13.5	7x5	+	E	2	-	-
	13	2880	13.5	7x5	+	E	1	Wound	-
	14	2910	17	-	+	E	2	Wound	+
	15	2940	14.5	-	+	E	2	-	+
	16	2920	10	7.5x5	+	E	1	-	-

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TABLE 5 (Cont'd.)

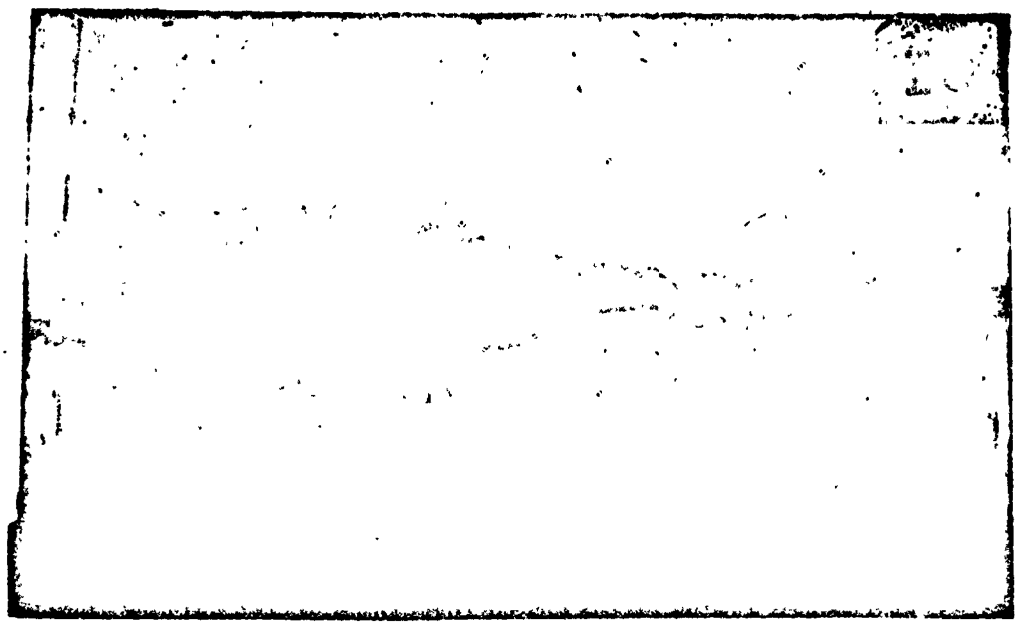
Missile	Shot No.	Striking velocity (ft/sec.)	Wound Path (cm)	Exit Wound (cm)	Heart Path	Wound Type	Lung Marking Grade	Stomach bruising	Fragments found
L.2.A.2.	24	2470	13	9x5	-	E	1	-	-
	25	2450	19.5	9x4.5	-	E	3	-	-
	26	-	10	9x4	+	P	-	-	-
	27	2450	13.5	8.5x4	+	E	1	-	-
	28	2430	19.5	10x5	-	P	2	-	-
	29	-	16.5	9x5	+	E	2	-	-
	30	2460	14.5	10.5	+	P	1	-	-
	31	2445	17.5	9x5	+	E	2	-	-

Table 6

Animal Experiments. Summary of 'Heart Path' Data

Range	Missile	Number of Animals	Striking velocity (average) (ft/sec)	Wound Path (average) (cm)	Exit Wounds	E type Wounds	Lung Markings (average grading)
15 yd (13.7 metres)	Remington 1/14	3	3070	16	2/3	2/3	2
	Remington 1/12	1	3110	12	1/1	1/1	4
	Norma 1/14	2	3240	15	0/2	2/2	3
	Norma 1/12	2	3270	14	1/2	2/2	3
	L212	2	2680	16	2/2	1/2	-
100 yd (91.4 metres)	Remington 1/14	3	2680	14	3/3	1/3	1
	Remington 1/12	6	2760	16	6/6	2/6	0.75
	Norma 1/14	5	2870	16	0/5	5/5	2
	Norma 1/12	6	2915	14	3/6	3/6	1.5
	L212	5	2450	14	5/5	3/5	1

(a) R. 1:14



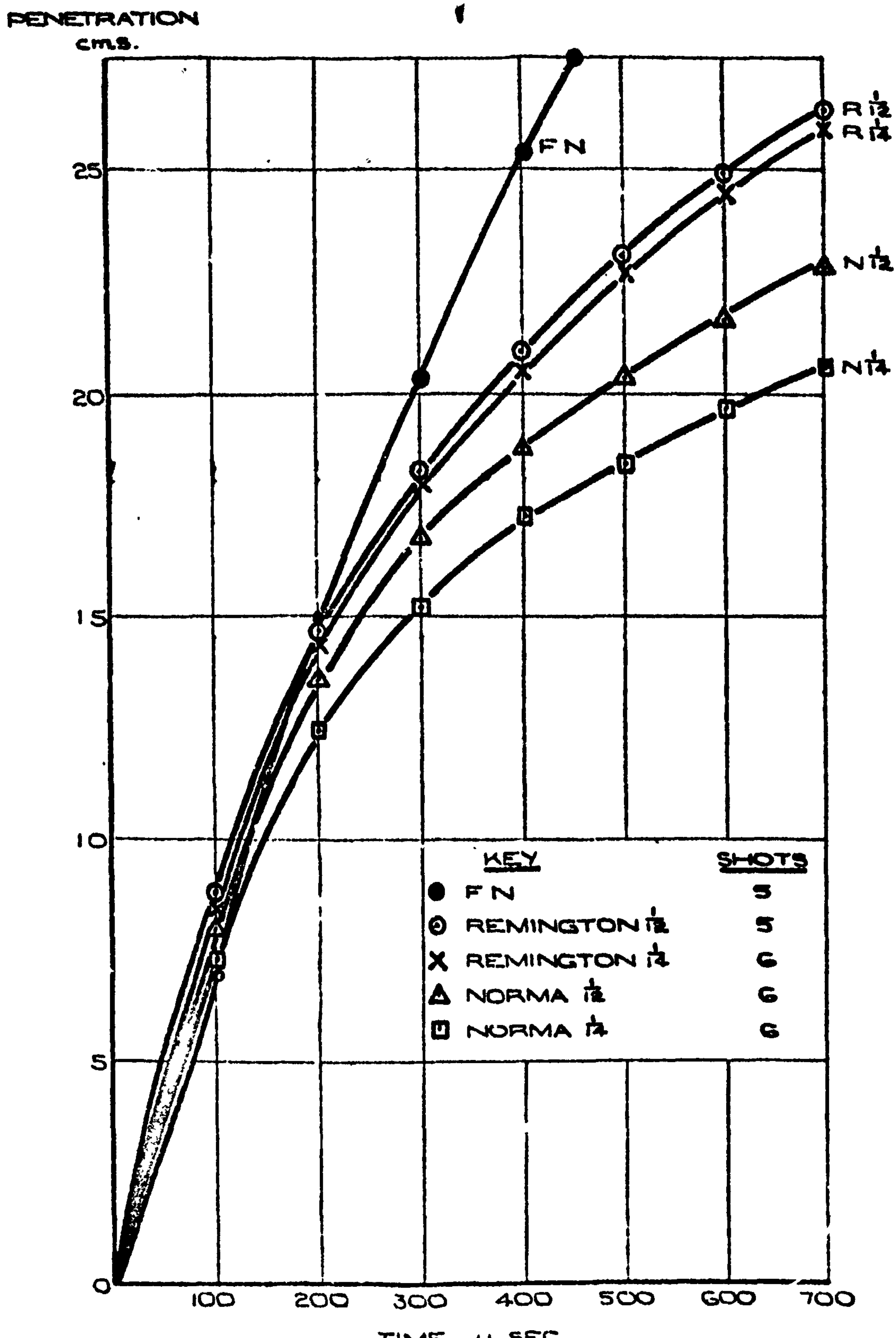
(b) F.N.

Fig.1 GELATINE BLOCKS (15 yds.)

(a) N. 1:14 (15yds.)

(b) N. 1:12 (100yds.)

Fig.2 GELATINE BLOCKS (NORMA)



RETARDATION IN 20 % GELATINE BLOCKS.
(MEAN VALUES).

FIG 3

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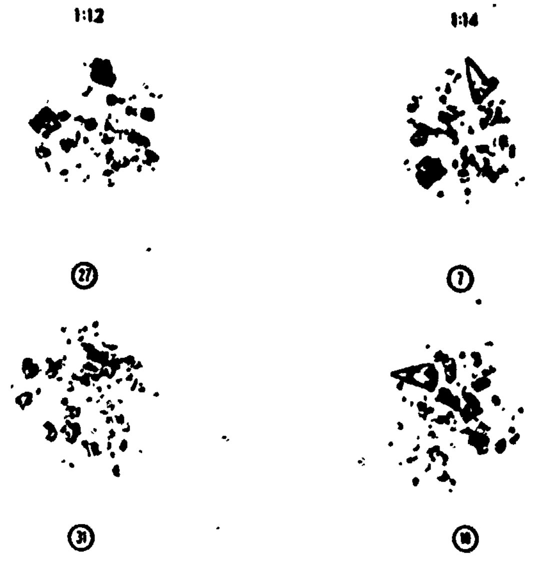
(a) Remington



(b) Norma

Fig. 4 FRAGMENTS FROM GELATINE BLOCKS. (15yds.)

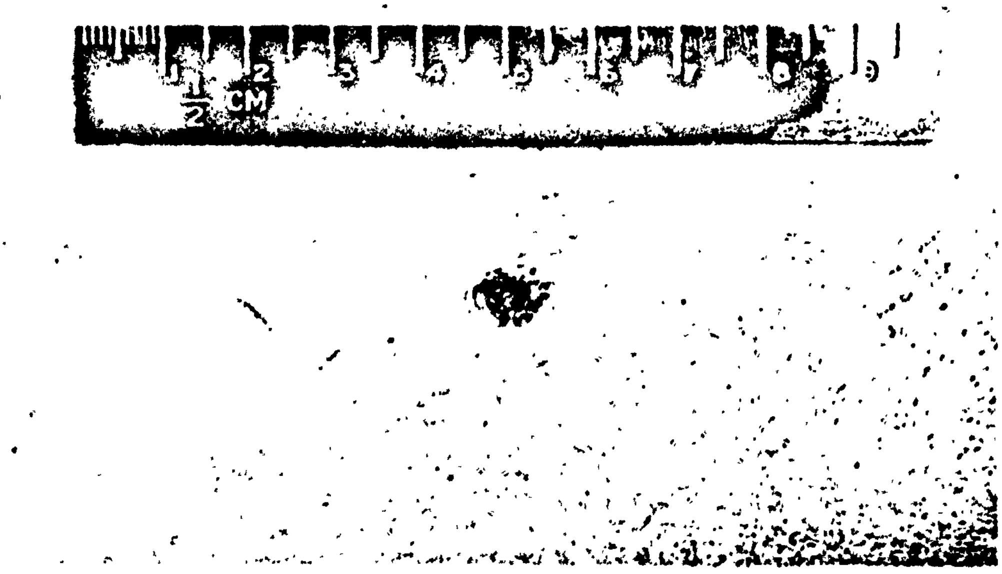


Fig. 5 ENTRANCE WOUND. R. 1:14 (15yds.)

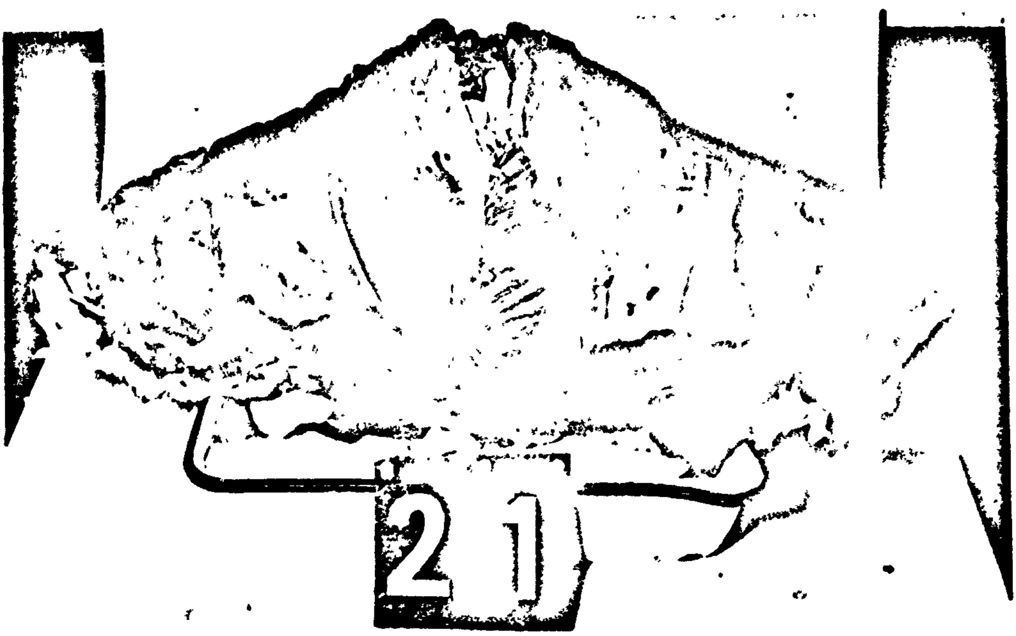
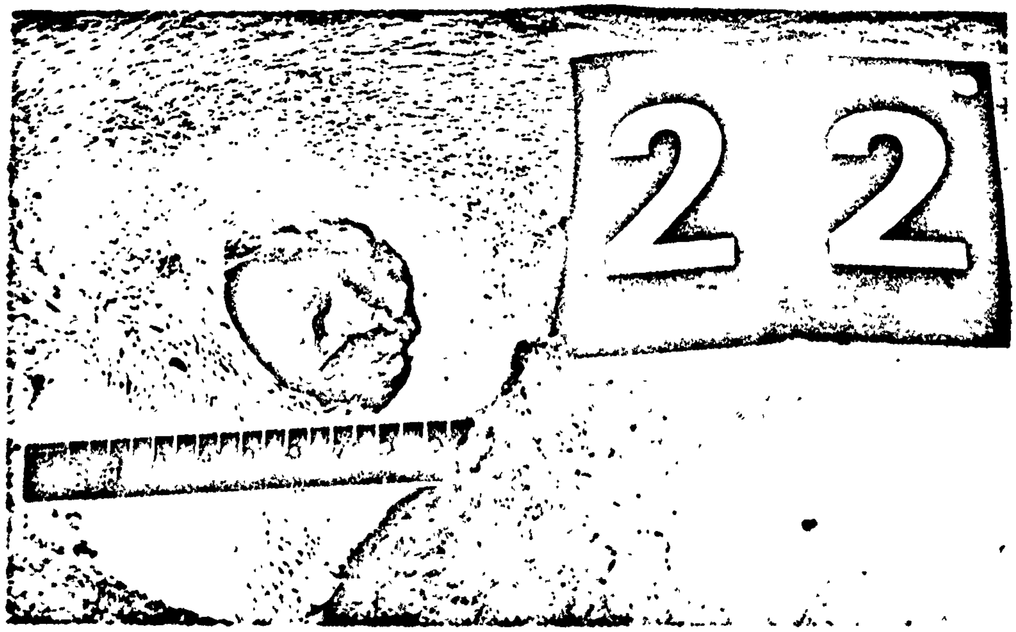
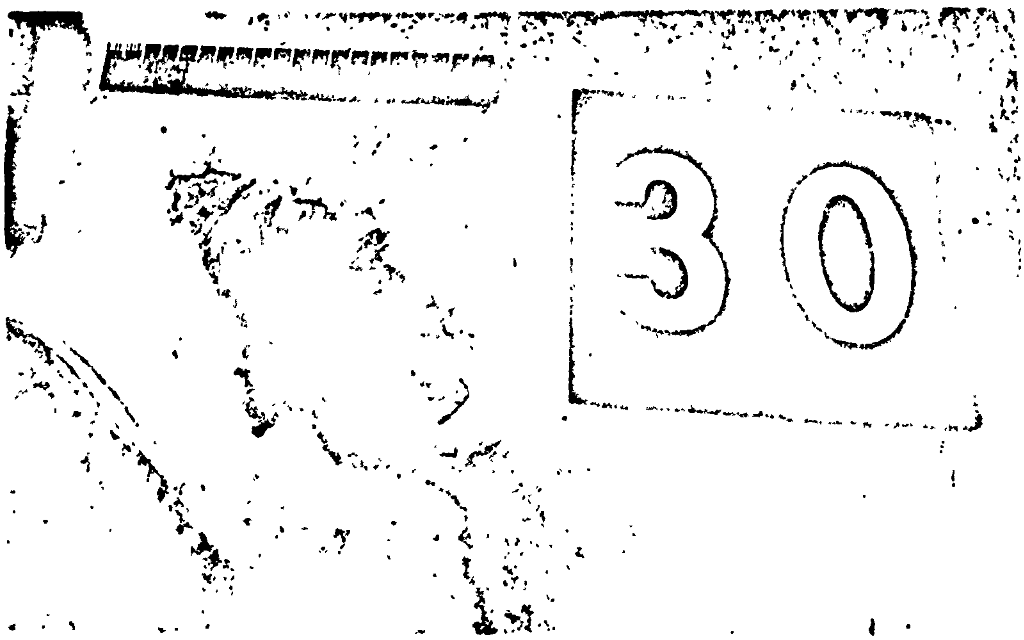


Fig. 6 THORACIC CAGE. R. 1:12 (100yds.)

Arrow marks entrance

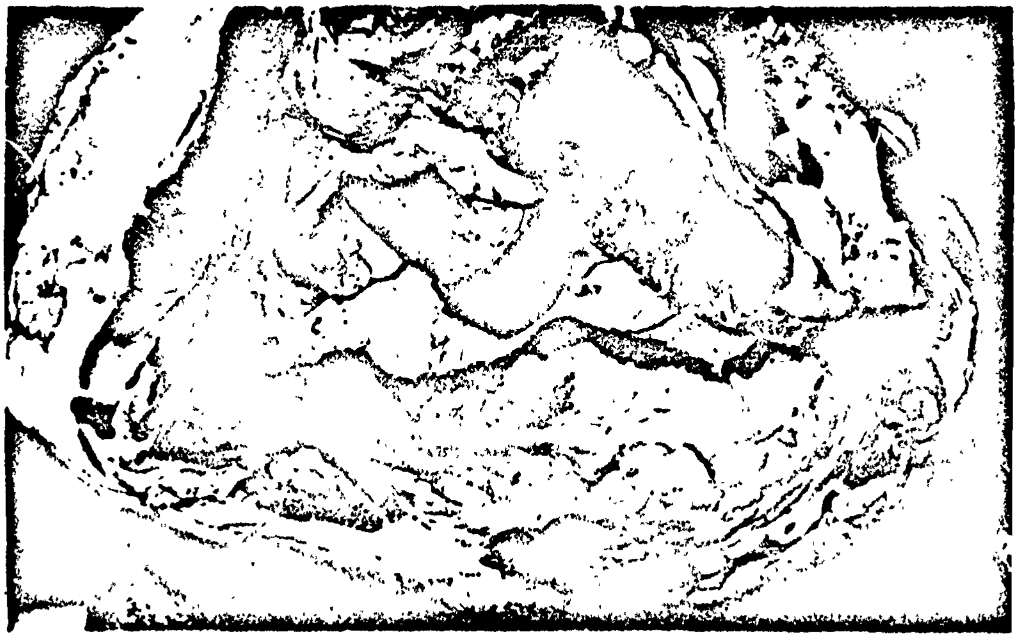


(a) Circular R. 1:12 (100yds.)

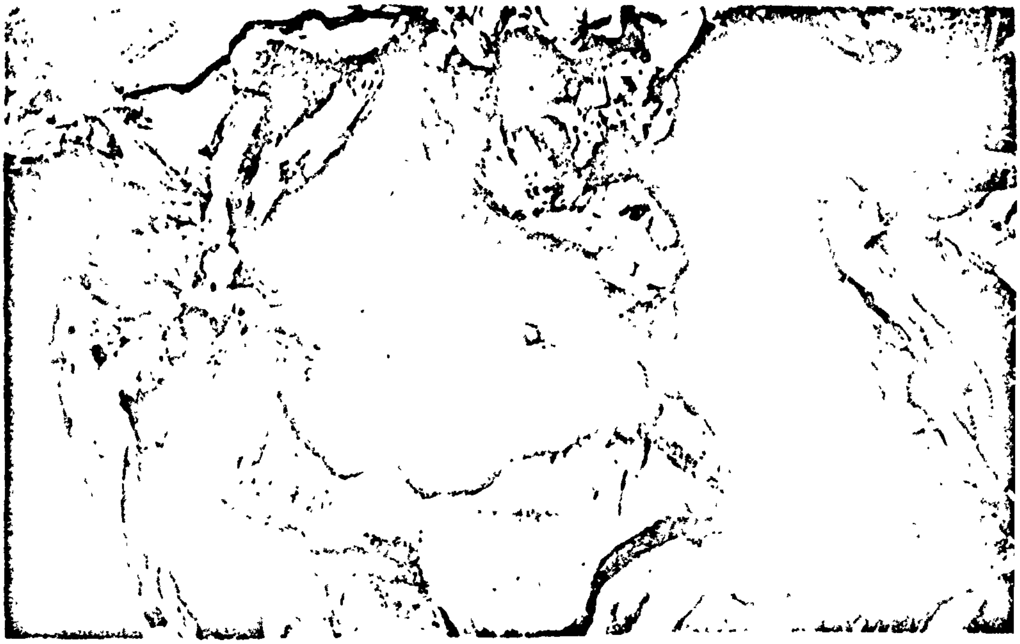


(b) Irregular F.N. (100 yds.)

Fig. 7 EXIT WOUNDS.

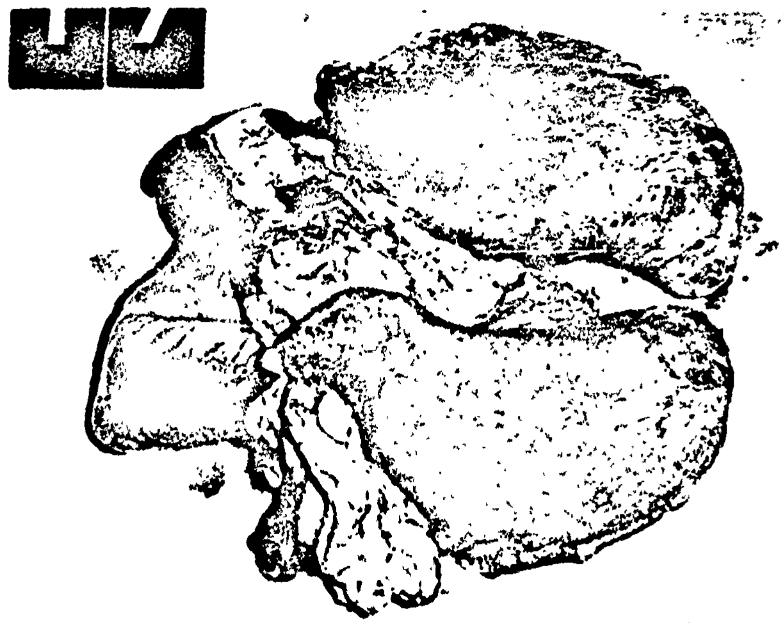


(a) 'Perforating' F.N. (15yds.)



(b) 'Explosive' N.1:14 (15yds.)

Fig. 8 THORACIC CONTENTS, IN SITU.



(a) 'Perforating' R. 1:12 (100yds.)

(b) 'Explosive' N. 1:14 (15yds.)

Fig. 9 THORACIC CONTENTS, DORSAL SURFACES.

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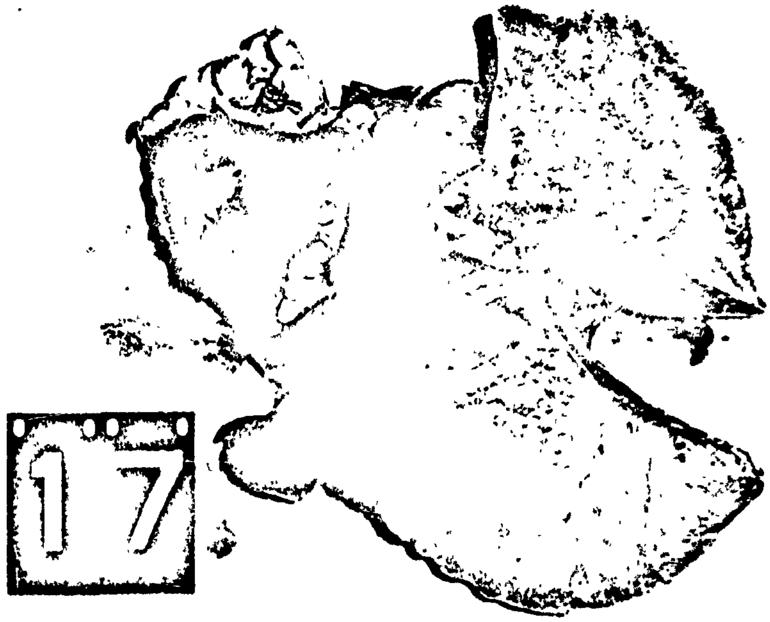
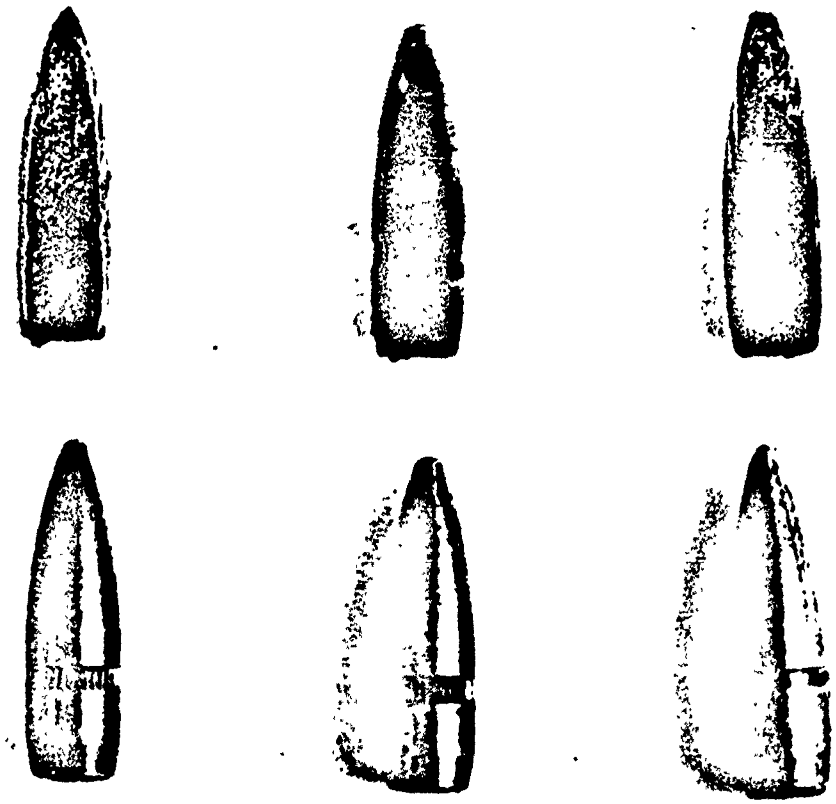


(a) 'Perforating' R. 1:12 (100yds.)

(b) 'Explosive' N.1:14 (15yds.)

Fig.10 THORACIC CONTENTS, VENTRAL SURFACES.



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