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FIN STABILISED DISCARDING SABOT SHELL
PROGRESS OF DESIGN

R.G. HOLTON

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ARMAMENTS DESIGN ESTABLISHMENT

TECHNICAL REPORT

No. 3/49

FIN STABILISED DISCARDING SABOT SHELL

PROGRESS OF DESIGN

R. G. Holton A.M.I.Meoh.E.

Abstract

This report details the progress - to date - in firing a fin stabilised sub-calibre shell at high velocity from a smooth bore gun. A previous Report (A. D. E. Tech. Report 5/48) discusses the method of calculating the stresses in the shell body due to firing, and since all firings carried out have not revealed any abnormal functioning of the shell body as such, no major changes have been made in this part of the design. This report, therefore, is concerned only with the development of the discarding sabot and the tail unit.

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Phone: Sevenoaks 2301.

May, 1949.

CONTENTS

| | Page |
|--------------------|------|
| Introduction | 1 |
| Appendix A | 12 |
| Appendix B | 13 |
| Appendix C | 15 |
| Appendix D | 17 |
| Appendix E | 18 |
| Appendix F | 19 |
| Appendix G | 21 |
| Appendix H | 23 |
| Appendix J | 25 |
| Appendices K and L | 27 |

Introduction

A Fin-stabilised, Discarding Sabot Shell is a sub calibre projectile which can be fired from a smooth bore gun. Stability in flight is obtained by a suitable design of tail unit having four fins. Pressure (in the gun) is applied to the sub-calibre shell through the medium of a centrally disposed sabot consisting of four sectors which are discarded at the muzzle. High reduction ratios (Parent calibre/Sub calibre) are possible and hence high velocity.

The shell has high length/sub calibre ratio. Its high cross sectional density and low air resistance result in reduced times of flight to a given target.

Design A

German Peenemunde Pfeil Geschosse 10.5/4.5 cm.

This type of projectile was discovered among German experimental work after the 1939-45 war. A German design is shown in Fig. 1.

Firing Results

A trial was carried out by the Ordnance Board with captured German shell. The trial is reported in O.B. Proceeding Q.4697. The results show that the shell was unsatisfactory, several breaking up or missing the target. Accuracy was assessed on two series of three rounds each. This accuracy should be compared with that of British designs reported herein.

Design B

British 5.4/2.2 inch - D2(L)2150/GE/557

It was decided to commence work on this type of shell in C.E.A.D. in 1945 and a convenient equipment was selected, i.e. the Service Q.F.5.25 inch Mk. II gun, which could be smooth bored to 5.4 inch by removing the rifling, giving about 40 calibres shot travel.

The design shown in Fig. 2 was prepared. A very high velocity was desired, and the shell and sabot were lightened as much as possible to this end.

The British 2.2 inch sub-projectile was supported in the gun bore similarly to the German design, i.e., by the central sabot and the tail fins, both these features being of bore diameter. The projectile was separately loaded into the gun chamber up to ramming stops provided at the rear edge of the tail fins.

The sabot on this design consisted of four equal sectors secured around the sub-projectile by a plastic ring screwed on to the central boss. The plastic ring was intended to fracture under gas pressure in the gun, leaving the four sectors free to discard at the muzzle.

The steel sabot carried no rubber sealing ring at this stage, but the thin rear skirt shown in Fig. 2 was known from recoveries to expand under gas pressure to form some measure of seal, but fired shell nevertheless showed considerable gas wash on the duralumin tail unit, indicating lack of sealing.

Provision was not made on this design to produce rotation of the shell in flight - the leading edge of the tail fins being faired off symmetrically on each flank.

Firing Results

A trial report is given in Appendix A.

A second firing with the same design of projectile is reported in Appendix B and photographic records of the shell in flight at about 140 feet from the muzzle are given in Figs. 3, 4 and 5.

Design C

British 5.4/2.2 inch - D2(L)3074/E/557 = Sealing Ring
D2(L)3198/E/557 = Sabot
D2(L)2150/GE/557 = Shell

Firings with a non-discarding sabot proof shot, fitted with a simple form of rubber seal, resulted in the gas wash on the tail unit being eliminated. The shell shown in Fig. 2 were therefore fitted with a modified sabot and a rubber sealing ring - see Fig. 6.

It can be seen that the thin rear skirt of the sabot in Fig. 2 was removed and the plastic securing ring omitted, the sabot sectors being held in position by the rubber sealing ring.

Firing results

A trial with this combination is given in Appendix C. This was a firing for functioning only, while the following Appendix D gives results of the same projectile fired for accuracy determination. The tail fins in the trial Appendix D were faired off on one side only at the leading edge. The relatively slow rotation (estimated 1000 r.p.m.) which this would impart to the shell was considered to even out any mechanical eccentricities.

The supposition in Appendix C that the accuracy in the trial Appendix D precludes damage to tail fins by discarding sectors is not supported by later firings - see conclusions to Design G, (repeat).

Design D

British 5.4/1.9 - D2(L)2657/GE/635

The satisfactory functioning and accuracy of the above designs B and C decided C.F.A.D. to produce a shell of better ballistic shape and performance. The design is shown in Fig. 7. The sub-projectile in this design was supported in the gun bore similarly to designs B and C.

Initial firings were carried out with the design as shown, i.e. with sabot sectors secured by plastic ring and without sealing ring. Projectiles of this type were already being manufactured whilst the effectiveness of a sealing ring was being proved on design C.

Firing results

See under design E.

Design E

British 5.4/1.9 - D2(L)2657/GE/635 = Shell & Sabot
D2(L)3844/E/635 = Sealing Ring

The plastic securing ring in Fig. 7 was soon replaced by a rubber sealing ring attached to the sabot by adhesive. The design is shown in Fig. 15 attached to the sabot from design D.

Firing Results - Designs D and E

A firing carried out at night, and using "Arditron" flash photography, is reported in Appendix E. Photographs of the shell in flight are also given in Figs. 8 - 14, being taken at about 140 feet from gun.

Conclusions

The functioning of both types (D and E) was unsatisfactory; the photographs show that the tail units were either damaged locally or the complete tail unit was missing, and the projectiles had yaw of varying degree.

It is important to note here that the gun in use showed no bore wear and the performance of the shell could not be associated therefore with a worn gun.

By comparing Designs D and E with B and C, it was considered that malfunctioning could be attributed to the tail unit attachment to shell body, which was much weaker in designs D and E. Damage or fracture would then occur due to bore acceleration and/or side slap, or again to muzzle blast.

Design F

British 5.4/1.9 (Proof Shot) - D2(L)3844/E/635 = Sealing Ring
D2(L)2751/X/651 = Shot
D2(L)2844/E/651 = Sabot

To confirm the above conclusions, a trial was fired with proof shot having a steel body with steel tail fins welded thereto. The design is shown in Fig. 17. The sabot and sealing ring shown were the same as those fitted to design E (Fig. 15).

Firing Results

The trial is reported in Appendix G. Photographs of hessian screen as struck by projectile and sabot sectors are given in Figs. 18, 19 & 20.

Conclusions

The photographs again show that the projectile did not function correctly. The pattern on the screen is irregular, the projectile is unstable and recoveries had severely buckled tail fins. It was evident that failure was not due to tail weakness.

An examination of the gun bore revealed considerable scoring at this stage, the diameter being irregularly oversize up to .027 inches. It was considered that incorrect functioning would continue in this gun, since the sabot sectors would expand into the oversize parts of the bore, and the consequently reduced engagement between the buttress threads on the projectile would result in failure at this point. A new gun was therefore introduced.

Design E (repeat)

British 5.4/1.9 Design Nos. as for E (previous)

It was decided to fire projectiles of this design in the new gun, but at lower pressures than had been used previously, although the higher pressures were still within the design limits of the shell. The object was to find a pressure at which the shell would function so that trials could continue.

Firing Results

The trial is reported in Appendix F.

Conclusions

The results record continued incorrect functioning and break up of projectile.

Comparison was again made between design D/E and B/C. Attention was drawn to the difference in shape of the sabot sectors, particularly at the outer diameter. After much consideration and examination of gun and shell recoveries the following conclusions were derived:-

It would appear that during the build up of pressure in the chamber, the rear face of the tail unit received an impulse from the pressure wave before this reaches the sabot, which is some 16 inches forward. This impulse moves the sub-projectile forward, causing the sabot sectors to expand into the bore via the medium of the buttress thread, and the four sectors then rotate about the rear point X (see Fig. 16(a)) until the front edge Y makes contact with the gun bore. Thereafter, the projectile behaves at random in the gun, the discards and/or sub-projectile scoring the bore and breaking off the tail unit. Damage to three recovered sabot sectors from this trial are consistent with this view, while further support is given by damage in the gun bore around shot start position, and which could be associated with the edge Y (above). The buttress threads on these three sectors were severely flattened; those on Round 3 were undamaged. The correct behaviour of Round 3 is attributed to the very low pressure recorded - 8.9 tons/sq. inch.

Previous correct functioning of designs B and C (5.4/2.2) can be associated with the much longer rear skirt on the sabot (see Fig. 16(b)) where overturning of the sectors about point X (a) is not possible.

It is considered here, subject to later confirmation, that the presence of sabot-sectors ahead of the sub-projectile in flight, as shown in Figs. 8 - 14, is associated with the sectors becoming disengaged, or partly so, from the sub-projectile in the gun. They may then be freely accelerated either in the gun, or at the muzzle by blast, and so move at a higher velocity than the sub-projectile and in advance of it for a short distance. Photographs of the correctly functioning 5.4/2.2 Design B and C do not show this phenomenon.

Design G

British 5.4/1.9 - D2(L)2657/GE/635 = Shell
D2(L)3910/E/635 = Sabot

It was now agreed to fit a new sabot to the sub-projectile shown in Fig. 7. The design of the sabot, with a rubber sealing ring fitted, is shown in Fig. 21. The four sectors of the sabot were secured around the sub-projectile by a plastic ring, the sealing ring being secured with adhesive. The plastic ring was broken manually after loading in the gun, in order to ensure free separation of the sectors at the muzzle; the rubber sealing ring was also cut radially in four places for the same reason, and these cuts were arranged out of line with the joints between the four sabot sectors to prevent gas leak.

It can be seen that the sabot design is very similar to that in Fig. 2, and the overturning of the sectors in the gun as discussed in conclusions to Design E (repeat) is avoided.

Firing Results

See Appendix H with photograph of pattern on hessian screen in Fig. 22. Note that the sealing ring shown on the design was omitted in this firing, but was included in the repeat trial for range and accuracy.

Conclusions

The photograph of the hessian screen (Fig. 22) shows sub-projectile signatures (with coloured square surround) and sabot sector signatures (with circular surround of same colour respectively). The sub-projectiles showed very little yaw, and sectors were spread at about 5 feet radius from sub-projectile at the screen distance.

The correct functioning of the longer bore fitting sabot was thus proved.

The firing results show that one round broke up. (The additional correct signature on the screen photograph is of a 5.4/2.2 round which was fired for comparison). It was thought that the cause of break up of this round was due to assymetrical loading of the propellant around the tail unit, resulting in unbalanced pressures around the tail in the gun. A different view arose from later firings - see conclusions to Design J (Tail units).

Design G (repeat) Design Nos. as for G (above)

A firing for range accuracy was carried out with this design.

Firing Results

See Appendix J. Note that sealing rings were used in this firing.

Conclusions

During this firing it was observed from the yaw cards that several rounds had one tail fin missing.

This was found to be so on the recovered projectiles, which in several cases showed damage to the leading edge of other fins and which was not considered due to landing on sand. It was assumed that the damage was caused by impact with the sabot sectors which had not spread wide enough to pass the tail fins on discarding. It is hoped to gain more information on this by the use of radio flash photography at positions close to the gun muzzle. Projectiles with tail fins damaged or missing ranged equally well with those having complete tails. It is concluded from this that the tail area is excessive, and the projectile is over-stabilized, i.e. a shell with three fins is still stable provided it rotates to even out the unbalanced tail, while its reduced drag is offset by the probable persistent yaw, such that its ranging properties are consistent with a shell having four fins with less yaw.

If the design can be arranged so that the tail fins remain undamaged the tail area may be reduced and the projectile will be upset less by the muzzle blast.

In spite of the damaged tail units it can be seen that the line accuracy is very satisfactory. A range accuracy at graze is shown in the results but the target accuracy at some point on the upward trajectory, consistent with A.A. fire, would be less than this. Later firings with Radar tracking are considered desirable to check this.

The ballistic coefficient 1.8 was assumed for purposes of calculating M.V. from O.V. in the results. The figure calculated from range results is 1.719.

Design H (5.4/1.9) and Design J (5.4/2.48) Design H = D2(L)2657/GE/635 = Shell
D2(L)3769/X/651 = Sabot
Design J = D2(L)3663/GF/759 = Shell
D2(L)3822/X/759 = Sabot

The previous firings were carried out in a new gun, in which the sabot fitted very closely. It was now considered essential that the sabot design should accommodate itself to worn gun conditions, where the present design would result in reduced engagement of the buttress threads between sabot and sub-projectile.

The design of sabot shown in Fig. 23 was fitted to the sub-projectile in Design D, as shown. The same type of sabot was fitted concurrently to the larger shell design (5.4/2.48) shown in Fig. 24, where a V.T. fuze can be accommodated in the nose. This double cavity shell was designed on the basis of A.D.E. Tech. Report 5/48.

The steel sabot sectors on these two designs were secured to the sub-projectile by a plastic (rubber ebonite) ring. This ring is very similar to a design which has been used successfully on spin stabilized shell. A rubber sealing ring is held in the dovetailed recess in the plastic ring and gas pressure applied in the gun forces the slightly deformable plastic into the wedge-shaped annulus, between the sabot and the gun bore, thus taking up any normal gun wear and ensuring at the same time a close engagement of the buttress thread.

The plastic ring and rubber sealing ring, being partly cut through in manufacture, are stripped off by the muzzle blast, leaving the sabot sectors free to separate from the sub-projectile.

A preliminary firing of this type of sabot, fitted to a 5.4/1.9 proof shot, had shown promise of success. The low pressure of about 10 tons/sq. inch was used, however, as this was the level at which the 1.9 sub-projectiles were found to function. It was thought that the excessive muzzle blast, caused by the low expansion ratio of the heavier charges used in the 5.25 gun (S.B. to 5.4), was affecting the initial flight of the projectile.

A new gun was now available (7.5 inch, Mk. VI lined down to 5.4 S.B. - shot travel 65 calibres, proofed with F.S. non-D.S. Proof Shot at 23.8 tons/sq.inch/6200 ft./sec.) and this was used in a trial of both Designs H and J. Two types of tail unit were fitted to Design H; that shown in Fig. 23 was connected to the shell body by the extended duralumin stem, and this was thought to be a source of weakness.

An alternative to the swept back tail unit shown was therefore included in this trial; this was a square form of tail unit being secured to the body similarly to design M Fig. 24.

Firing Results

These are shown in Appendices K and L.

Conclusions

Reference Appendix K (Design H), 5.4/1.9.

The results show that the shell, with either type of tail unit, continues to behave erratically, and yaws considerably or breaks up. ("Break up" means invariably that the complete tail unit is missing on the yaw card). The gun bore was examined carefully during this firing, and no damage could be observed such as had been found on previous guns when sabot failures had occurred. From this it was considered that the design of discard was functioning satisfactorily, even at the higher pressures recorded.

Reference Appendix L (Design J) 5.4/2.48

The four rounds here ranged fairly satisfactorily with little yaw, but the separation of the sabot sectors is not always regular as judged by the holes in the screen. This is also a feature of the pattern given on the screen by Design H, and it may be that the plastic ring, although weakened in four places, is not breaking readily at the muzzle and the steel sectors do in fact separate unevenly. On the other hand the pattern may be influenced by the yaw of the projectile and this must be eliminated as far as possible.

Attention is now centred on the tail unit design. It is found on all recoveries that the diameter across pairs of fins is reduced by amounts up to .25" below the unfired size, and the reduction is greater at the rear of the tail than at the forward edge. It is evident that this is due to rapid side-slap and wear in the gun, and if the shell is swinging across the bore at the instant the sabot leaves the muzzle, then it will continue to yaw in that direction until the tail unit is clear of the bore and can begin its function of stabilizing the shell; by this time the projectile is in a position to be yawed further by muzzle blast, which may even remove the tail unit completely.

Both the amount of reduction (in tail diameter) and the degree of yaw on the cards were noticeably greater than when the shorter gun was used; the wear would be less, due to shorter bore travel, and this would be reflected in the degree of yaw. The Design J behaved better in flight than Design H; the longer distance between sabot and tail provides better bore control and hence less tendency to yaw at exit from the gun, while its heavier mass would resist the effect of muzzle blast to increase the yaw. See under Designs P, etc.

The following designs have been prepared but have not been fired yet. A further report will be issued showing the results of trials with them.

Discarding Sabots

Design K Sabot = D2(L)4322/X/651

The design of composite discard, referred to in Designs H and J, had plastic bands of bore diameter. It has been found, however, that the plastic band, when used on spin stabilized shell, can be fired quite satisfactorily through a gun having a lead at the forward end of the chamber and it should be possible to adopt this in a smooth bore gun, allowing the lead to wear forward in the normal manner. In a further Design K (not shown) the plastic band will therefore be about .20 inches larger than the gun bore, and the shell will be fired from a modified gun having a suitable chamber and lead.

Design L Sabot = D2(L)3939/X/635

It has become evident that the sabot is becoming an expensive manufacturing item in quantity production, in addition to being a weight which, for internal ballistic reasons, should be a minimum. The Design L (see Fig. 25) has been arranged in an effort to reduce these objections. The principle of the deformable plastic has been retained, the shape simplified and lightened as much as is considered possible. The complicated form of the four sectors makes the stressing of it by calculation extremely difficult, and the design is being proved by practical trials.

Design M Sabot = D2(L)4064/E/635

The use of the plastic bands in Designs H, K and L in a Service role has yet to be found satisfactory. The plastic may react unfavourably to a gun heated to some temperature, yet to be determined by high rates of fire.

The supply of a suitable plastic (rubber ebonite) may also be difficult in an emergency.

A design of sabot (see Fig. 26) has been prepared in an effort to avoid these objections. It consists of the usual four sectors, secured to the sub-projectile by a small ebonite ring, which fractures in the gun under gas pressure. The four sectors are provided with deformable flanges at front and rear of the outer diameter; these flanges will be swaged down by the gun lead, while the rear flange will continue to make contact with the (worn) gun bore due to expansion under gas pressure. The previous all steel sabots - Designs B, C, D, E and G - had a common objection, in that the hardness of the heat treated steel used in their particular designs would wear severely a gun having a chamber lead. This Design M, therefore, has the four sectors coated on the outer diameter with electro deposited nickel in order to provide a soft surface for bore contact.

Tail Units

In the conclusions to Fig. 24 the design and wear of tail units is discussed. It is obvious that the wear on the tail fins must be prevented, or some other form of bore support adopted, in order to project the shell satisfactorily from the gun. Various types of pad have been added to the tail fins to achieve this.

Design N D2(L)3830/E/635

As a first thought the design of tail unit shown in Fig. 27 was arranged. The projections on the tail fins, normally used as ramming stops, were supported as shown by plugs of hard rubber and also plastic rubber ebonite. Reduction of the projections will occur in the gun lead, while the plugs are intended to exert outward pressure to keep the projections in contact with the bore. In view of the degree of wear on the tail fins now apparent in longer guns, it is not anticipated that this design will succeed.

Design P D2(L)3992/E/635

The design shown in Fig. 28 is a further thought on this problem. Here a plastic (rubber ebonite) shoe is fitted over the edge of each fin and is secured by a pin. The plastic, being resilient, will be reduced in the gun lead; it has been found already that this type of plastic wears very little in passing through the gun.

At the muzzle the gas pressure will act on the rear underside of the shoes to strip them off the fins. It is considered that this design would be suitable for run up in a cartridge case similarly to the next design.

Design Q D2(L)4053/X/635

The design shown in Fig. 29 has also been prepared. This design was prompted by the foregoing wear problem, and by the problem of run up-in a tapered cartridge case. (See Cartridge case designs - Fixed Ammunition). The larger plastic (rubber ebonite) shoes are fitted over the fins, and hinged therein on the large rear plastic pin; the forward end of the shoe carries a smaller crosspin of plastic which rests on the edge of the fin. The shoe is held to the fin by a small pin. During run-up in a tapered cartridge case the small forward pin is reduced, imposing a comparatively small pressure and drag on the cartridge case. The shoe as a whole can then pass through the gun lead to maintain a bearing surface in the gun similarly to Design P. At the muzzle the gas pressure on the rear face of the shoe hinges it upward around the large rear pin and strips off the whole shoe forward.

Further designs to be considered are a more robust bore support attached to the rear of the tail. This is to be rejected at the muzzle by gas pressure retained in the tail unit boss. The fins will not be used as bore supports here.

The soft iron insert or "combs" shown on the German tail unit (Fig. 1) will also be tried, although it is expected that wear will still occur but in reduced degree.

Alternatively, a long central sabot is to be designed, having about $1\frac{1}{2}$ parent calibre length with bore diameters at its front and rear ends. No tail support would be necessary in the gun in this design.

Both this design and the previous one have the objection of increased discarding weight with its reflections on ballistics and equipment weight. The long central sabot can be made of light alloy to reduce its weight; this means, however, that the buttress thread must be considerably longer since the strength of the light alloy is less than that of steel. The necessarily longer thread on the shell body means a reduced cavity, particularly in double cavity shell, and therefore the explosive capacity is reduced.

Fixed Ammunition. Design R. 3.0/1.2 D2(L)4056/SK/808

It has been pointed out that the previous designs and trials were of separately loaded ammunition. The calibres used are typical Service sizes, but it is evident that for fixed ammunition the cartridge case must extend forward to the central sabot, and there is no suitable equipment available for providing case attached F.S.D.S. shell of this calibre.

It was therefore agreed in 1947 that small scale trials with case attached shell would be carried out. The design of round shown in Fig. 30 has been prepared and is being manufactured.

The sub-projectile is intended only as a carrier for various types of sabot and tail unit to determine the most efficient design. The shoes on the tail unit are extended to make contact with the walls of the cartridge case, which is extended forward and turned over the front of the sabot, being secured thereto by the narrow plastic ring shown. (This ring also fractures as the steel sabot sectors separates at the muzzle). The complete projectile is assembled to the case by insertion through the rear end. Filling of the propellant charge is also made through this aperture, which is afterwards closed by the screwed base plug shown.

Fixed Ammunition - Railed Case - Design S D2(L)4315/GF/841

It can be seen that the Design R of cartridge case, provides a slowly tapered run-up for the tail fins with their fitted "shoes", passing without any violent changes into the gun lead. The particular propellant volume required is obtained by extending the tapered case rearward, but the larger the volume required the longer does the case become, and the longer is the complete round. This length factor can be objectionable from a loading and ramming point of view. Again, if the volume required is relatively small, the (shorter) rearward extended taper produces a base diameter, on the case, which is so small that it will be weak if a screwed hole is formed in it large enough to pass the projectile through on assembly.

The above objections have been overcome by the design shown in Fig. 31. Here the required volume of cartridge case may be obtained in shorter lengths of larger diameter, and the large case mouth diameter contains a sleeve to house the sabot on the shell. Four grooved rails extend rearward from this sleeve, and the tail fins and shoes run forward in these rails. (A preliminary firing of several rounds, using separate ammunition, has shown that rails, attached to the case by two screws or rivets, remain in position).

The method of assembly then is:-

- (a) Assemble rails to case.
- (b) Insert complete shell, tail first, in mouth of case, with fins between adjacent rails.
- (c) Support shell on suitable central plunger in tail unit, and push it inside case until "shoes" are in rear of rails.
- (d) Rotate shell until fins are in line with grooves in rails, and bring up shell until shoes contact groove surface.
- (e) Force sleeve into case mouth and over sabot, until sleeve is in contact with front end of rails.
- (f) Cone the mouth of case over the sleeve (and sabot where possible) and secure with screwed ring on sabot.
- (g) Fill propellant (granular) through rear of case.
- (h) Assemble screwed base plug and primer.

Firings with above complete rounds have not been carried out to date.

Guns

Two items particular to the gun have yet to be investigated.

(a) Vented Muzzle

The Germans claimed that adequate muzzle venting improved the shell accuracy, by removing the initial disturbance due to muzzle blast. This complication is not a desirable one and although it will be tried experimentally, it will be avoided if possible.

(b) Tapered Bore

It is thought that the wear (occurring at present on the tail fins) could be accommodated in a tapered bore, thereby eliminating the increasing side slap of the shell in the gun. This also will be tried but it will require the use of a sabot similar to Designs H, K and L. If the sabot of design such as M is used in a tapered bore, the vibration of the overhung forward end of the shell will cause the deformable skirt bands on the sabot to collapse, thereby losing control of the sub-projectile at this point. If the skirt is made stiff enough to resist this tendency, it is felt that the finely tapered bore will wear unduly.

APPENDIX A

5.4/2.2 F.S.D.S. Shell

Range and Accuracy Trial

Fired at Shoeburyness on 30th and 31st December, 1946.
 Attended by Col. Speechly, Cdr. Ascherson
 and Mr. Dear.

Object:- To obtain data to allow the ballistic coefficient of these rounds to be calculated. Also to see whether these unspun rounds would have an unacceptably large dispersion.

Equipment:- Gun - 5.4 Smooth Bore No. L. 2832
 Mounting - B.L. 5.5" C.P. Mk. 2 No. 17.

Ammunition:- 5.4/2.2 F.S.D.S. Shell filled inert and weighted to 12.25 lb. The shell had tail fins .4" thick with equal 10° chamfer on each edge of fin. Design D2(L)2150/GE/557 no sealing ring fitted

Cartridge Cases and Primers:- 5.25 in. Service. No cartridge lids.

Charge:- N.S. 198-054 30 lb.

Conditions:- Q.E. 10° fired over sand. Gusty wind blowing from right flank approximately 90° to line of fire (velocity 20-60 ft/sec).

Remarks:

The trial was begun on the morning of the 30th and the first round (A) was fired successfully although due to the visibility then prevailing, no fall of shot was observed. On attempting to load the second round (B) the projectile jammed in the shot seating and was only removed after extreme difficulty which probably resulted in damage to the ballistic cap.

After this mishap with round (B) the other 4 rounds were more critically examined and it was found that the plastic discs which keep the sabot segments in place did not pull up tight as designed. The rounds were then reassembled and the sabot segments were secured in place by means of silk cord and all rounds were then loaded and unloaded.

The trial was continued on the following morning, but round (B), which may have been damaged, was held back until the last. The table below gives the results obtained.

| Round | Press. corrected t.s.i. | O.V. ft/sec. | Range yd. | Line yd. |
|-------|----------------------------|-----------------|--------------|-------------|
| A | - | 4422 | - | - |
| E | 13.0 15.2 | 4502 | 12935 | 236.4R |
| C | 14.0 | 4454 | 13517 | 87.5L |
| D | 14.5 | 4472 | 13343 | 34.5L |
| F | 14.7 | 4578 | 13797 | 75.5R |
| B | 14.4 | 4499 | 13667 | 83.5L |
| Mean | 14.5 | 4501 | 13452 | 21.3R |
| M.D. | 0.3 | 31 | 2502 | 107.74 |

The results shown here should be compared with S.A.B.'s estimates of a range of 13000 yd. at a velocity of 4600 ft/sec, with a ballistic coefficient (new law) of 1.2. From the results it would appear that the actual ballistic coefficient is slightly better than S.A.B.'s provisional estimate.

This trial does seem to confirm, however, the low pressures and correspondingly low velocities which are obtained with the present round.

5.4/2.2 F.S.D.S. Shell

Photographic Trial in conjunction with C.S.A.R.

Fired at Shoeburyness on 7th and 8th January, 1947.

Object:- To obtain photographs of the projectile in flight with a view, at a later date, to repeating the trial with rounds fired at increasingly high pressures until the actual break-up of the projectile occurs. Also to obtain, if possible, photographs of the discarding sabots.

Equipment:- Gun - 5.4 Smooth Bore No. L.2832.
Mounting - 5.25 C.P.

Ammunition:- 5.4/2.2 F.S.D.S. Shell filled inert, and also one round of F.S.N.D.S. proof shot. The shell had tail fins .4" thick with equal 10° chamfer on each edge of fin.

Cartridge Case and Primers:- 5.25 in. Service. No cartridge lids.

Charge:- N.S.198-054 30 lb.

Conditions:- Q.E. 1° fired over sand.

Camera Equipment:- Was disposed by C.S.A.R. at a mean distance of about 140 ft. from the muzzle of the gun.

Velocities:- Were measured by Duddell, and a single yaw card was obtained from each round.

Remarks.

The proof shot was fired on 7.1.47 so as to fix the line for photographic reasons and the pressure obtained with this round was 12.7 tons/sq.in. It was then decided to load the 4 rounds so as to ensure that they would load when required.

Round I was loaded successfully, but the second round to be tried, H, jammed in the shot seating and on extraction the plastic locking ring broke. It was decided not to load any further rounds.

The actual photographic trial could not take place that evening, due to climatic conditions (snow).

On the following morning a new plastic locking ring was made for round H by S. of E., Shoeburyness. This was somewhat thicker than the original ring - .25 x 4.8 in diameter. No serious difficulty was experienced in loading these 4 round when required, although it had been expected that round H, which had jammed before, would give trouble.

| Round. | Corrected pressure tons/sq.in. | O.V. Ft/sec. | Remarks. |
|--------|--------------------------------|--------------|----------------------|
| I | 14.6 | 4555 | - |
| L | 15.1 | 4610 | - |
| K | 14.3 | 4535 | Short skirted sabot |
| H | 13.9 | 4430 | Thicker locking ring |

An examination of the yaw cards showed that all the rounds were exceptionally good for yaw. There was a suspicion that round K was slightly worse than the other 3. The spread of the sabot segments at the camera position was rather more than expected and in any future trial it would probably be necessary to put the cameras slightly further away from the line of fire of the gun.

One of the segments struck the railway wagon carrying the camera; another of the fragments damaged the microphone stand. Good photographs appear to have been obtained of all rounds.

APPENDIX C

D.2.A. Trial No. 114

5.4/2.2 F.S.D.S. Shell

Trial to Investigate Functioning of Discards with Moulded Rubber Ring

Fired at Shoeburyness on Monday, 11th August 1947 and attended by Mr. Aitchison and Mr. Dear.

Object:- To investigate whether a moulded rubber sealing ring would affect functioning of the discards.

Equipment:- Q.F. 5.4" Smooth Bore No. L.2832. Mounting, B.L. 5.5" C.P. Mk. II, No.17. Projectiles: 5.4/2.2 F.S.D.S. Shell to Design D2(L)2150/GE/557, fitted with discards to D2(L)3198/E/557 and sealing rings to D2(L)3074/E/557.

Cartridge Cases and Primers:- Service 5.25". No cartridge case lids used.

Charge:- N/S 198-054.

Conditions:- Q.E. 1° and 30 minutes as given below. Fired over sand.

15' x 15' Hessian Screen, erected 125' from gun muzzle. Yaw Card 140' from gun.

Remarks:

Some of the original 5.4/2.2 Fin Stabilised Shell had their discards modified to Design D2(L)3198, so as to accommodate a moulded rubber sealing ring (Design D2(L)3074) made from rubber to Specification IRGP Mix. No. 4038C. It was not at all certain that this ring would break up sufficiently quickly on leaving the barrel to allow the discards to get clear of the tail. It was hoped, however, that by the use of a Hessian Screen and Yaw Card, together with a subsequent examination of the recovered rounds, it would be possible to decide whether the tail fins had in fact been struck by the discards. The following results were obtained:-

| Q.E. | Round No. | Weight | Charge Weight | Copper Pressure | Ramm- ing | Spread of Discards | Muzzle Velocity | Remarks |
|------|-----------|----------------------------|---------------|-----------------|-----------|--------------------|-----------------|----------------------------|
| 1° | 80 | 17 lb. 4 $\frac{3}{4}$ oz. | 30 lb. | 16.5 | 43.9 | 45" x 38" | | |
| 30' | 82 | 17 " 5 $\frac{1}{2}$ " | 30 " | 16.6 | 44.0 | 46" x 30" | 4690 | |
| " | 84 | 17 " 5 $\frac{1}{2}$ " | 30 " | 16.6 | 43.95 | 30" x 35" | 4736 | |
| " | 88 | 17 " 1 $\frac{3}{4}$ " | 32 " | 20.8 | 43.95 | 50" x 39" | 5121 | Slightly unsteady |
| " | 89 | 17 " 5 $\frac{1}{2}$ " | 32 " | 20.5 | 43.95 | 32" x 32" | 5069 | No Duddell used |
| " | 90 | 17 " 5 $\frac{1}{2}$ " | 32 " | 20.3 | 43.95 | | | Complete break up of shell |

It will be observed that for the first time with this round pressures of over 20 tons per square inch were obtained with a 32 lb. charge of N/S. This should be compared with previous firings in which a similar charge only gave pressures of 16 tons per square inch, the difference presumably being due to efficient sealing.

Unfortunately it was not possible to have the sand recovery party in the correct position to observe fall of shot and as a result of this only two rounds were recovered. Both of these shells exhibit markings along the body originating at the Sabot Buttress Thread and extending backwards towards the fins. Furthermore, two of the fins in each case have suffered damage, although it is not possible to separate out damage caused by the Duddell Wire Screens, the impact on the sand and possible collision with the discards. Without any other evidence it would appear that the discards are, in fact, not getting completely clear of the tail fins and are liable to cause damage. Trial No. 115, however, which was a Range and Accuracy Trial, rather tends to contradict this conclusion as accuracy was good and therefore there can have been little or no damage to the fins before impact with the sand.

D.2.A. Trial No. 115

Range and Accuracy Trial with Shell F.S.D.S.

5.4/2.2 Fitted with Rubber Sealing Rings

Fired at Shoeburyness on Tuesday, 12th August, and attended by Mr. Aitchison and Mr. Dear.

Object:- To investigate the effect on accuracy of using shell fitted with a tail to give slow rotation, and with moulded rubber sealing rings.

Equipment:- Q.F. 5.4" Smooth Bore No.L.2242. Mounting B.L. 5.5" C.P. Mk.II No.17.
Projectiles:5.4/2.2 F.S.D.S. shell to Design D2(L) 2150/GE/557 fitted with discards to D2(L) 3198/E/557 and rubber sealing rings to D2(L) 3074/E/557.

Conditions:- Q.F. 10° fired over sand.

Charge:- N/S 198-054 and 30 lbs.

Fired 12. 8. 47.

| Round No. | Proj. No. | Weight lbs. ozs. | Press (corrected) T.S.l. | M.V. ft/sec | Range Yds. | Line Yds. | Time of Flight secs. |
|-----------|-----------|--------------------|--------------------------|-------------|------------|-----------|----------------------|
| 2 | B 53 | 17 4 | 16.9 | 4732 | 13123 | 5.6R | N.R. |
| 3 | B 54 | 17 4 $\frac{1}{2}$ | 17.5 | 4804 | 13831 | 34.3L | 31.50 |
| 4 | B 55 | 17 4 $\frac{1}{2}$ | 17.8 | 4806 | 13191 | 6.2R | 29.62 |
| 5 | B 56 | 17 4 $\frac{1}{2}$ | 17.5 | 4793 | 13211 | 34.1R | 28.29 |
| 6 | B 60 | 17 4 | N.R. | 4747 | 12916 | 69.4R | 28.38 |
| 7 | B 64 | 17 4 $\frac{3}{4}$ | 17.2 | 4841 | 13761 | 0.6R | 29.40 |
| 8 | B 65 | 17 3 $\frac{3}{4}$ | 17.1 | 4785 | 13651 | 42.1L | 28.45 |
| 9 | B 66 | 17 4 | 17.1 | - | - | - | N.R. |
| Mean | | | 17.3 | 4787 | 13383 | 3.9R | 29.27 |
| M.D. | | | 0.26 | 26 | 312.1 | 27.86 | 0.90 |

Fired 13. 8. 47.

| Round No. | Proj. No. | Press. (corrected) T.S.l. | M.V. ft/sec. | Range Yds. | Line Yds. | Time of Flight sec. |
|-----------|-----------|---------------------------|--------------|------------|-----------|---------------------|
| 11 | B 67 | 17.7 | - | - | - | N.R. |
| 12 | B 68 | 17.5 | 4804 | 13779 | 7.1L | 28.70 |
| 13 | B 72 | 17.8 | 4819 | 13364 | 49.5L | 28.42 |
| 14 | B 76 | 18.2 | 4850 | 14380 | 27.3L | N.R. |
| 15 | B 77 | 17.5 | 4815 | 13741 | 51.7L | 28.88 |
| 16 | B 78 | 17.8 | 4842 | 14368 | 16.9L | 29.34 |
| 17 | B 79 | 17.9 | 4855 | 13985 | 58.9L | 28.5 |
| 18 | B 82 | 16.8 | 4855 | 14306 | 76.9L | N.R. |
| Mean | | 17.6 | 4834 | 13989 | 41.2L | 28.77 |
| M.D. | | 0.3 | 19 | 310.6 | 21.0 | 0.27 |

It is considered that the accuracy with this projectile is very acceptable.

APPENDIX E

EXPERIMENTAL ESTABLISHMENT, SHOEBOURNESS

Report No. 55/45/Q.5.

Object:- To investigate by flash photography the behaviour of the dis-cards of the F.S.D.S. shell.

Authority:- C.E.A.D. THV/9/1/3.A. Trial No. 122. Reqn. C.E.A.D.

Carried out on 30th October, 1947.

C.E.A.D. & C.S.A.R. were represented.

GUN:- Q.F. 5.4 inch S.R. No. L/2242. (31 E.F.C.)

MTG:- B.L. 5.5 inch C.P. Mk. 2 No. 17.

Charge:- Cartridge Q.F. 5.25 inch gun, filled N/S.198-054
Lot D.9545.R. (Stock).(8)
(For weights see report).

Charge and Air Temp. 58°F.

Projectile:- Shell Q.F. F.S.D.S. 5.4/1.9 inch, weighted H.E.S.(8)

Conditions:- Fired by night for M.V., Pressure and observation of functioning by flash photography.

Velocities:- BY Duddell.

| Rd. No. | Q. E. ° | Proj. No. | Ram. ins. | Charge weight lbs. | Pressure | | Velocities | | Time |
|---------|---------|-----------|-----------|--------------------|----------|-----------|----------------------|------|--------|
| | | | | | Observed | Corrected | T.I.S.D. = 99.22 ft. | | |
| | | | | | | | tons per sq. in. | | O.V. |
| | | | | | | | f. s. | | B.S.T. |
| 1 | 1 30 | 18 | 44.8 | 30 | 15.3 | 15.6 | 4551 | 4572 | 1900 |
| 2 | " | 19 | 44.75 | " | 15.7 | 16.0 | 3582 | 3601 | 2020 |
| 3 | " | 20 | " | 32 | 18.9 | 19.3 | N.O. | N.O. | 2040 |
| 4 | " | 22 | " | " | 18.5 | 18.9 | 4022 | 4042 | 2110 |
| 5 | " | 24 | " | " | 18.7 | 19.1 | 4134 | 4154 | 2140 |
| 6 | " | 25 | 44.8 | 30 | 15.6 | 15.9 | 3746 | 3766 | 2210 |

⊠ Hit near frame. Co = 1.8 N.L.

N.F. Round 6 was too indistinct to be read on the vernier and has only been glassed.

Photography by C.S.A.R. (Cambridge).

SHOEBOURNESS.
7/11/47

(Sgd.) G. Cooke Lt.Col.
for Superintendent of Experiments

APPENDIX F

Shell F.S.D.S. 5.4/1.9

C.E.A.D. Trial No. 134 - Fired Shoeburyness 25.6.48

Object:- To observe the functioning of this design of projectile as fired through hessian screen and recovered over water.

Equipment:-

Gun: Q.F. 5.25 inch S.B. to 5.405 inch. No. 2242 - New

Mounting: 5.5 inch C.P. Mk. II

Projectile: Design D2(L)2657/G.E./635 - 5.4/1.9 inch with rubber sealing ring to D2(L)3844/E/635 attached to sabot with Bostik cement.

Cartridges: 5.25 Service Cases. Lids removed before loading.

Primers: No. 17 Mk. 2n.

Charges: N.S. 198/054. Weight as detailed.

Conditions:- Q.E. 4°
Hessian Screen at 125 ft.

Observations:- Pressure.
Patterns on Hessian Screen.
Condition of Recoveries.

Results

| Round No. | Remaining distance Breech block - (rear of) to Tail unit - (rear of) | Charge | Pressure (corrected) | Pattern on Screen |
|-----------|--|--|-------------------------|---|
| 1 (A) | 44.55 ins. | 26 lbs. in case | 12.2 T.S.I. | Proj. B.S.O. No tail. 5 other holes 1.0 to 5.0 o'clock of projectile |
| 2 (C) | 44.55 ins. | 24 lbs. in case | 10.0 " | Proj. not B.S.O. 5 other holes high left to low right of projectile |
| 3 (D) | 44.55 ins. | 22 lbs. in case | 8.9 " | Proj. with tail on at about 10° yaw. 5 other holes 12 to 4 o'clock of projectile |
| 4 (E) | 44.6 ins. | 30 lbs. (26 in case 4 around tail) | 16.3 " | Proj. B.S.O. no tail unit. 5 other holes across screen above projectile |

EXPERIMENTAL ESTABLISHMENT, SHOEBOURNESS

Report No. 55/H.5/Q.6.

Object:- To determine the Pattern made by the shot and discards on a hessian screen placed 150 ft from muzzle.

Authority:- C.E.A.D. THV/9/2/1(24) dt. 12/1/48.
D.2.A. Trial 124.

Carried out on 4th February 1948.

Gun:- Q.F. 5.4 inch S.B. No. 2832 (I/1874).

Carriage:- B.L. 5.5 inch C.P. II No. 17.

Charge:- Cartridge Q.F. 5.4-inch gun filled:-
N/S 198-054 lot D.9545.R. 2/42. = 30 lbs.(Stock).

Charge and Air Temp. 45°F.

Primers Eleot. No. 17 Mk. 2.N. (Stock).

Projectile:- Shot Proof F.S.D.S. 5.4/1.9 . 6 in number.
To D2(L)2751/X/651 fitted discards to D2(L)2844/E/651
and S.Rings D2(L)3844/E/635.

Nos. X.5 X.6 X.7.
21 22 23

Conditions:- Fire rounds through 15' x 15' Hessian screen at 150 ft from muzzle for pattern of discards, recovery of shot and discards and photographs of pattern.

C.E.A.D. THV/9/2/1(24) dt. 12/1/48. D.2.A. Trial 124.

| Rd No. | Proj: No. | Charge Weight lbs. | Results | Remarks |
|--------|---------------|--------------------|----------------------------|--|
| | Q.E. 30 mins. | | | L. of F. "D" N. 63°E. |
| 1 | X.5 | 30 | 8 holes in Hessian Screen | Lay for all Rds. 18 ins. Rt. of laying cross on Hessian Screen |
| 2 | X.6 | 30 | 11 holes in Hessian Screen | |
| 3 | X.7 | " | 7 holes in Hessian Screen | |
| 4 | 21 | " | 6 holes in Hessian Screen | 1 segment recovered at 500 ft from muzzle. |
| 5 | 22 | " | 9 holes in Hessian Screen | Before firing sealing ring of proj: cut partly through in 4 places at approx. 90° apart. |
| 6 | 25 | 29 | 10 holes in Hessian Screen | Sealing ring treated as for Rd. 5. |

All rounds were wildly unsteady.

Photo. Nos. R.122 - R.127 of Discard patterns are attached.

SECURITY.
10/2/48

2 copies to C.E.A.D.
1 copy to S.O.B.

(Sgd) G. Cooke Lt. Col.

for Superintendent of Experiments.

APPENDIX H

Shell F.S.D.S. 5.4/1.9

C.E.A.D. Trial No. 134 (Continuation)

Fired Shoeburyness 14.7.48

Object:- To observe the functioning of this design of projectile as fired through hessian screen.

The lessons learned in the previous firing on 25.6.48 were applied.

Equipment:- As in previous trial, except projectiles, as follows:-

Shell F.S.D.S. 5.4/1.9 to D.2(L)2657/GE/635 but fitted with discards to D.2(L)3910/E/635.

No sealing ring fitted - discards secured with plastic ring around centre boss (5)

Conditions:- Q.E. as detailed.

Hessian screen at 125 ft.

Observations:- Pressure.

Q.E.

Pattern on screen.

Note:

At the commencement of this trial two rounds from a previous trial (Design E with narrow discards) were loaded in error. They were rammed by repeated blows on the tail unit, a practice which has been used at all trials. The first round broke up on firing. When rammed, the second round was observed to have two discard segments detached from the projectile, the other two segments being tilted backwards. This condition demonstrated the conclusion given in the conclusions to Design E (repeat), that the impact of gas pressure wave on rear face of tail unit unseats the discards at shot start if their bearing surface is narrow and located too far rearward.

RESULTS:

| Round No. | Body No. | Discard | Charge | Press (corrected) | Ramming distance | Q.E. | Pattern on Hessian Screen / 125 ft. |
|-----------|----------|---------|--------|-------------------|------------------|--------|--|
| 1 | 32 | D | 24 lb. | 10.1 T.S.I. | 44.55 ins. | 1° 5' | No yaw. Discards at 5 ft radius from projectile, equispaced. |
| 2 | 6 | E | 29 lb. | 14.8 " | 44.5 " | 1° 20' | Round broke up. 7 holes in screen |
| 3 | 71 | C | 24 lb. | 9.9 " | 44.55 " | 1° 48' | As in round 1. |
| 4 | 34 | A | 24 lb. | N.O. | 44.6 " | 1° 49' | As in round 1. |
| 5 | 63 | B | 29 lb. | 14.7 " | 44.6 " | 0° 42' | As in round 1. |

APPENDIX J

SHELL F. S. D. S. 5.4/1.9

Range and Accuracy Trial - C. E. A. D. No. 134

Fired 12/10/48 (over sand)

Equipment:-

Gun 5.25 inch Mark II S. B. to 5.405 No. 1875.

Mounting: Q.F. 5.5 inch C.P. Mark II No. 17.

Projectiles: Shell F.S.D.S. 5.4/1.9 to D2(L)2657/G.E./635.
Fitted Sabots to D2(L)3983/X/635 and Sealing rings to D2(L)3982/X/635.

Cartridge Cases: Service 5.25 inch - without lids.

Propellant: N.S. 198/054 lot D9548 - 24 lb.
(no tail charges)

Primers: Electric No. 17 Mark II.

Conditions:-

Q.E. 5°.

Plastic locking ring broken before loading charge.

Results overleaf.

METEOROLOGICAL REPORT

C.E.A.D. Trail No. 134 - Range and Accuracy

Carried out: 12/10/48.

| Rds. | Time BST | Assumed ht. to Vertex ft. | Follow- ing Wind ft. sec. | Cross Wind (R-L) ft. sec. | Ballistic Temp. Degs.F. | Barometer (M.S.L.) ins.Hg. | Tenuity Factor | Elastic- ity Temp. Degs.F. |
|------|-------------|------------------------------------|------------------------------------|------------------------------------|-------------------------------|----------------------------------|-------------------|----------------------------------|
| 2-20 | 1130 | 1200 | 21 | 4 | 63.1 | 29.96 | 0.996 | 63.2 |
| | 1215 | 1200 | 23 | 8 | 64.4 | 29.97 | 0.994 | 64.7 |
| | 1250 | 1200 | 25 | 6 | 64.4 | 29.96 | 0.993 | 64.6 |
| | 1430 | 1200 | 21 | 12 | 67.3 | 29.93 | 0.987 | 67.9 |
| | 1520 | 1200 | 41 | 14 | 64.5 | 29.90 | 0.991 | 64.8 |
| | 1610 | 1200 | 30 | 10 | 64.7 | 29.91 | 0.991 | 64.9 |

NOTE:- Ballistic Temperatures refer to standard of 61.7°F.
Elasticity Temperatures refer to standard of 61.4°F.

Meteorological Office,
SHOEBURYNESSE,
22nd October, 1948.

RESULTS

| Round No. | Proj. No. | Projectile Weight in gun in flight lb. oz. lb. oz. | Time of flight | Range Yards | Deviation Right (Yards) | Pressure Corrected Tons sq. in. | M.V. Ft./sec. | Remarks |
|-----------|-----------|--|-------------------|----------------|----------------------------|---------------------------------------|------------------|----------------------|
| 1 | 3 | 17 10 | 18.07 | 11938 | 3.0 | 12.3 | 3971 | Warmer Fell Short |
| 2 | 55 | 17 10 $\frac{3}{4}$ | N.O. | Not Located | | 12.2 | 3939 | |
| 3 | 11 | 17 12 $\frac{1}{4}$ | 18.03 | 11608 | 24.0 | 12.2 | 3998 | |
| 4 | 37 | 17 10 | 17.14 | 11825 | 6.0 | 12.2 | 3947 | |
| 5 | 39 | 17 10 | 17.14 | 11187 | 24.1 | 12.2 | 3940 | |
| 6 | 41 | 17 10 $\frac{3}{4}$ | 17.06 | 11191 | 22.1 | 12.2 | 3968 | |
| 7 | 45 | 17 10 | 17.64 | 11638 | 22.0 | 12.3 | 4007 | |
| 8 | 46 | 17 9 $\frac{1}{2}$ | 17.16 | 11806 | 17.0 | 12.3 | 4005 | |
| 9 | 50 | 17 10 $\frac{3}{4}$ | 17.10 | 11474 | 26.1 | 12.3 | 3975 | |
| 10 | 51 | 17 11 | N.O. | 11049 | 33.1 | 12.2 | 3990 | |
| 11 | 52 | 17 10 | 17.05 | 11845 | 26.0 | 12.2 | 3989 | |
| 12 | 53 | 17 11 | 16.80 | 12270 | 34.0 | 12.15 | 4037 | |
| 13 | 54 | 17 11 | 17.26 | 11917 | 38.0 | 12.3 | 4012 | |
| 14 | 57 | 17 10 | N.O. | 11920 | 40.0 | 12.3 | 4025 | |
| 15 | 59 | 17 10 $\frac{1}{2}$ | 17.00 | 11512 | 31.1 | 12.2 | 3995 | |
| 16 | 60 | 17 10 | N.O. | 11904 | 31.0 | 12.2 | 4006 | |
| 17 | 65 | 17 9 $\frac{1}{2}$ | 17.53 | 12030 | 33.0 | 12.3 | 4011 | |
| 18 | 67 | 17 9 $\frac{3}{4}$ | 17.25 | 11605 | 37.0 | 12.15 | 3995 | |
| 19 | 72 | 17 10 | 16.99 | 11476 | 18.1 | 12.3 | 3973 | |
| 20 | 74 | 17 11 $\frac{3}{4}$ | 16.97 | 11217 | 38.1 | 12.3 | 3979 | |
| | | Mean | 17.21 | 11637 | 27.8 | 12.24 | 3988 | |
| | | M.D. | 0.22 | 268.7 | 7.22 | .054 | 21.4 | |

NOTE: Pressures and pressure M.D. are suspect, as 12 ton coppers were used.

APPENDICES K AND L

Shell F.S.D.S. - C.E.A.D. Trial No. 128

Fired At Shoeburyness 20/12/48

Object:-

(a) To compare functioning of Shell F.S.D.S. 5.4/1.9 design H fitted with plastic banded sabots, and with (1) swept back tail fins attached to shell with duralumin stem, (2) tail units attached to shell with steel adaptor and with fins (front edge) square with axis.

(b) To observe functioning of the first delivery of Shell F.S.D.S. 5.4/2.48 design J fitted with plastic banded sabots.

Equipment:-

Gun: B.L. 7.5 inches lines down to 5.4 (S.P.) No.172.

Carriage: No. 15 Sleigh.

Charge: N.S. .198/.054 Projectiles A and B } weights as
N.P.S. .263/.066 Projectile C } detailed.

Projectiles: A:- Shell F.S.D.S. 5.4/1.9 to D2(L) 2657/G.E./635 fitted with sabots to D2(L) 3769/X/651 and tail units (swept back) to D2(L) 2662/E/635.

B:- As for A, but with tail units (square fronted) to D2(L) 3714/E/635.

C:- Shell F.S.D.S. 5.4/2.48 to D2(L) 3663/G.F./759 with sabots to D2(L) 3882/X/759.

Conditions:-

Q.E. 3°
Hessian Screen at 147 feet.
Yaw Card at 130 feet.
(M.V. not measured).

Firing 1

Projectiles A and B

| Round No. | Projectile No. | Charge lb. | Pressure (corrected) Tons/sq. in. | Yaw | Time of flight secs. | Range yards | Deviation yards | Pattern on Screen |
|-----------|----------------|------------|-----------------------------------|--------|----------------------|-------------|-----------------|-------------------------------------|
| 1 | A 61 | 38 | 14.2 | 3° | N.O. | 11680 | 65.1 R. | Three holes right of Proj. One left |
| 2 | B 43 | 38 | 14.3 | 20 | N.O. | Not seen | Not seen | Three holes below Proj. One above. |
| 3 | A 26 | 42 | 17.7 | B.S.O | N.O. | Not seen | Not seen | Round broke up. |
| 4 | B 12 | 42 | 17.35 | Missed | N.O. | Not seen | Not seen | Round broke up. |
| 5 | A 10 | 44 | 19.5 | 30 | 15.99 | 13091 | 62.3 R. | Three holes above Proj. One below. |
| 6 | B 1 | 44 | 19.7 | Missed | N.O. | Not seen | Not seen | Round B.S.O. |
| 7 | A 2 | 44 | 19.8 | Missed | N.O. | Not seen | Not seen | Round broke up. |

APPENDIX L

Firing 2

Projectile C

| | | | | | | | | |
|---|------|----|-------|-----|-------|-------|---------|---|
| 1 | C 7 | 45 | 15.7 | 1½° | N.O. | 12041 | 41.6 R. | Two holes at 2½ ft. from Proj. Two at 12". |
| 2 | C 2 | 47 | 16.7 | 30 | 13.65 | 12605 | 11.6 L. | - ditto - |
| 3 | C 5 | 47 | 17.35 | 20 | 13.10 | 12554 | 8.4 R. | - ditto - |
| 4 | C 10 | 47 | 17.1 | 20 | 13.77 | 13025 | 59.1 R. | Two holes at 2½ ft. One at 12" One at 6". |

NOTE:- A check firing for velocity with Projectiles A and B gave 5180 ft. sec./14.0 tons sq.in./38 lb. charge.

GERMAN 10.5/4.5CM (SMOOTH BORE) FIN STABILISED UNROTATED H.E. SHELL.

(10.5CM. PFEIL GESCHOSS)(EMPTY)

WEIGHT EMPTY 19LB. 4OZ. 10DR.

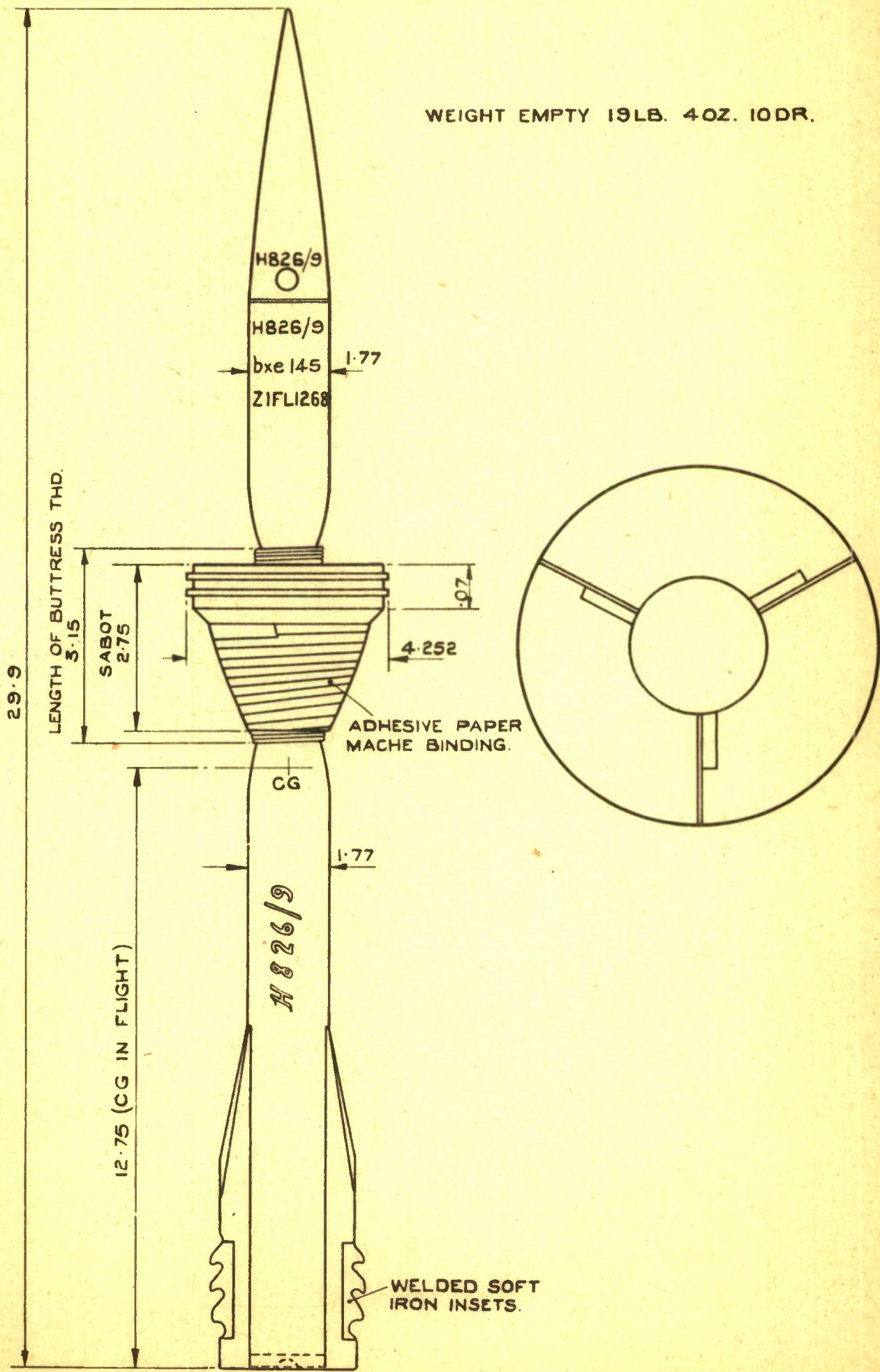


FIG. 2.

SHELL Q.F., H.E. F.S.D.S. 5.4/2.2 INCH
D.2 (L) 2150/GE/557

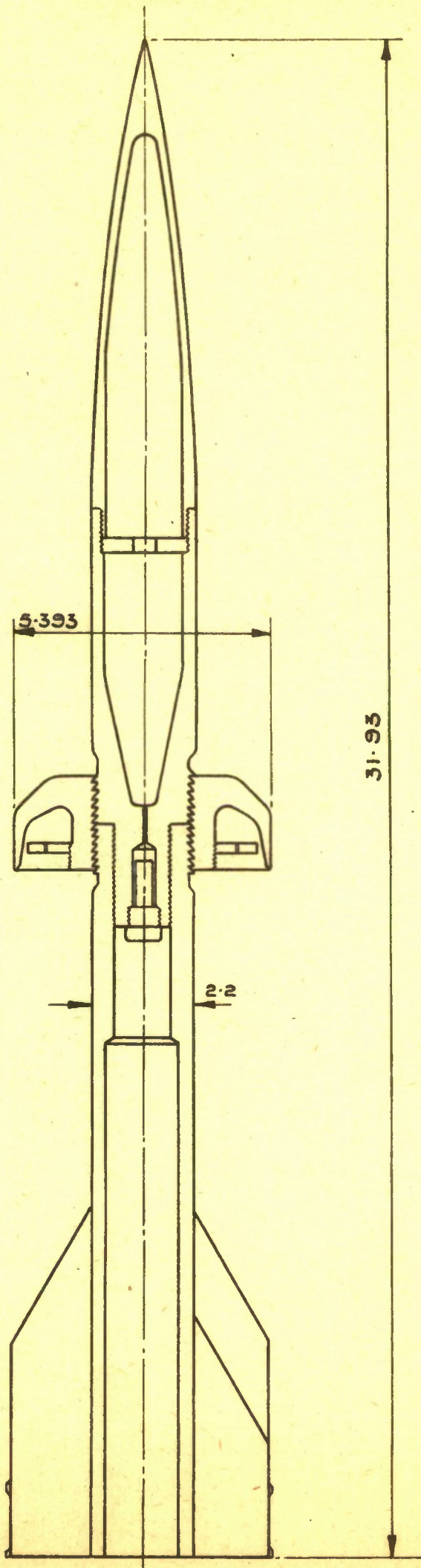
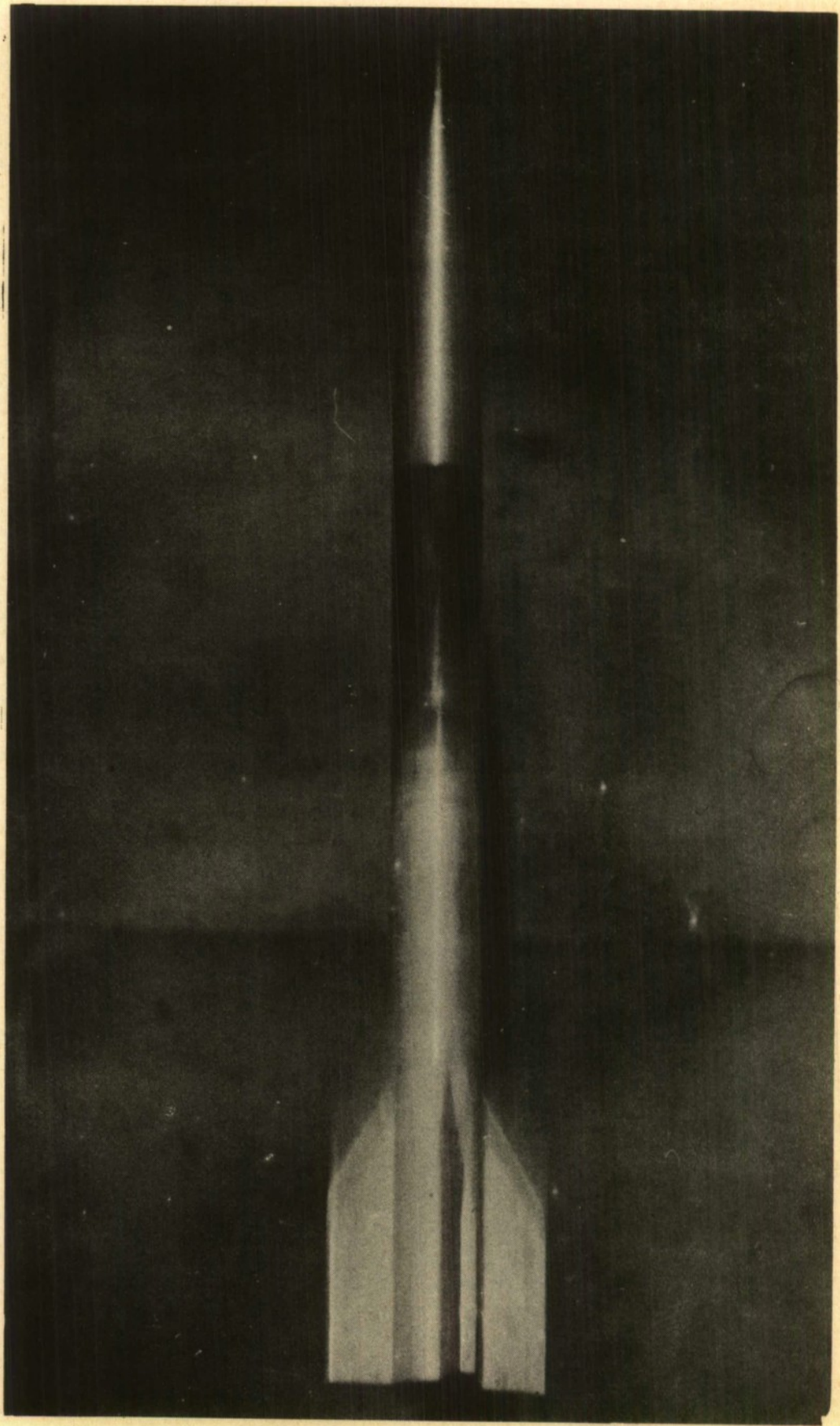
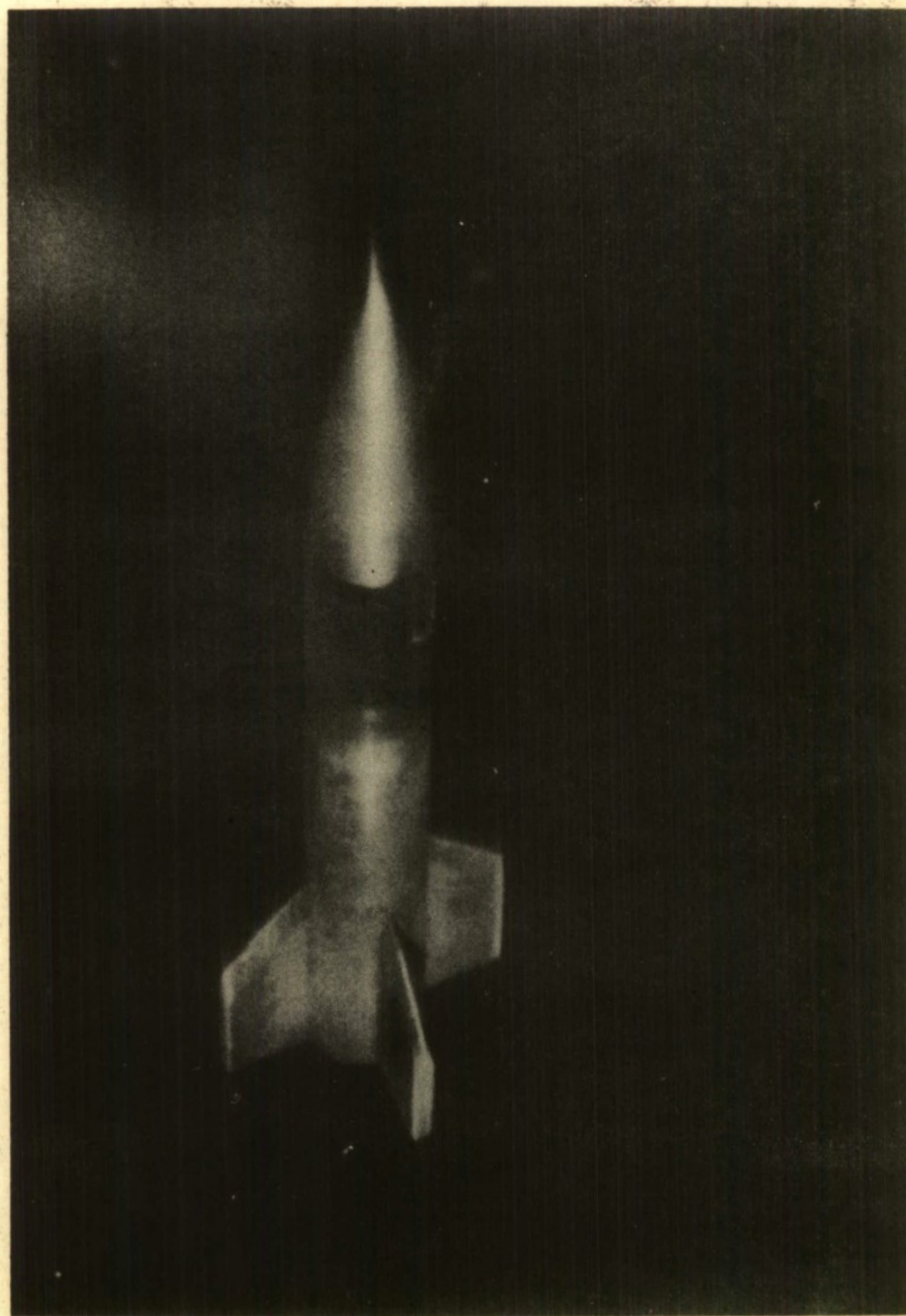


FIG. 3

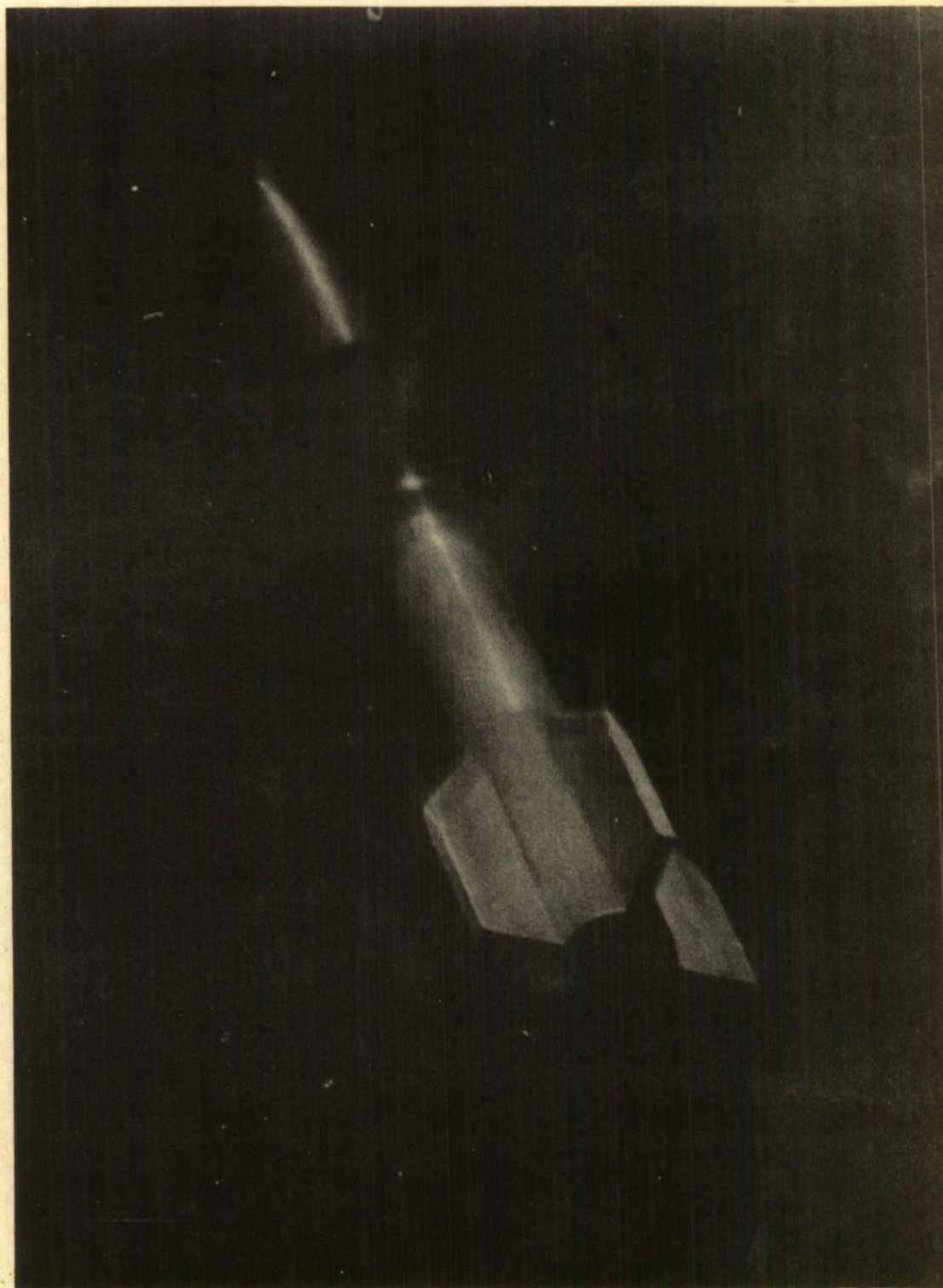
F. S. D. S. 5.4 / 2.2 INCH - PROJECTILE K"



F. S. D. S. 5·4 / 2·2 INCH PROJECTILE K"



F. S. D. S. 5.4 / 2.2 INCH - PROJECTILE K"



SHELL F.S.D.S. 5.4 / 2.2
SABOT FOR SHELL DESIGN "B"

SABOT = D.2. (L) 3198/E/557
SEALING RING = D.2. (L) 3074/E/557

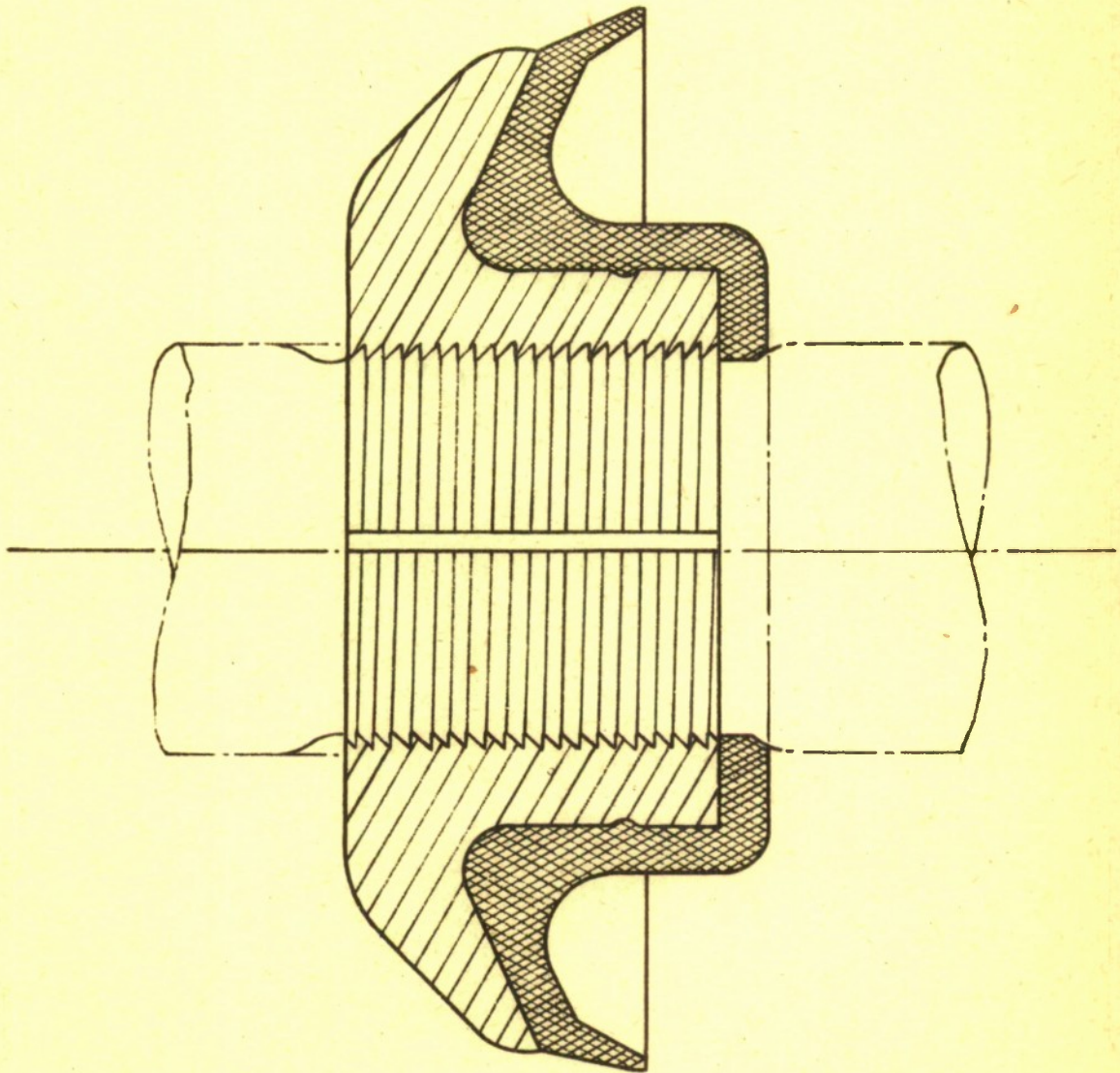
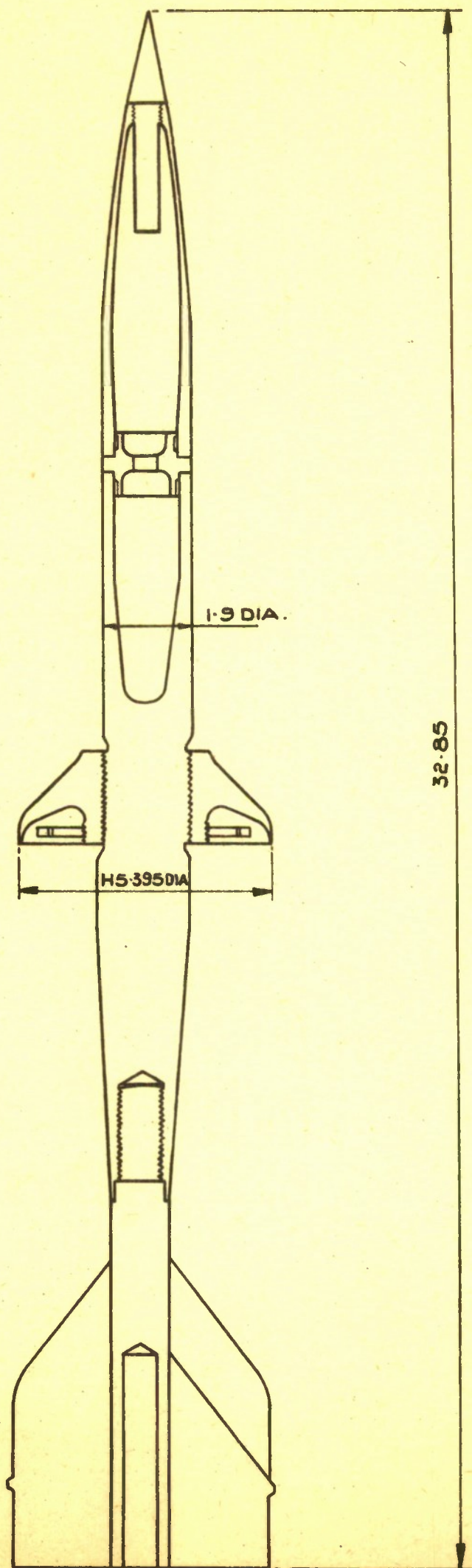


FIG. 7
SHELL Q.F.H.E. F.S.D.S. 5.4/19 INCH
D.2 (L) 2657/GE/635



A.D.E 3/49

SHELL F. S. D. S. 5.4 / 1.9 ROUND 1.
FIRED 30. 10. 47.



SHELL F. S. D. S. 5.4/1.9 ROUND I.
FIRED 30.10.47



FIG. 9

SHELL F. S. D. S. 5.4 / 1.9 ROUND 1.
FIRED 30.10.47



SHELL F. S. D. S. 5.4 / 1.9 - ROUND 2.
FIRED 30. 10. 47



FIG. II

SHELL F. S. D. S. 5.4 / 1.9 ROUND 5.
FIRED 30.10.47.



FIG. 12

SHELL F. S. D. S. 5.4 / 1.9 ROUND I.
FIRED 30.10.47



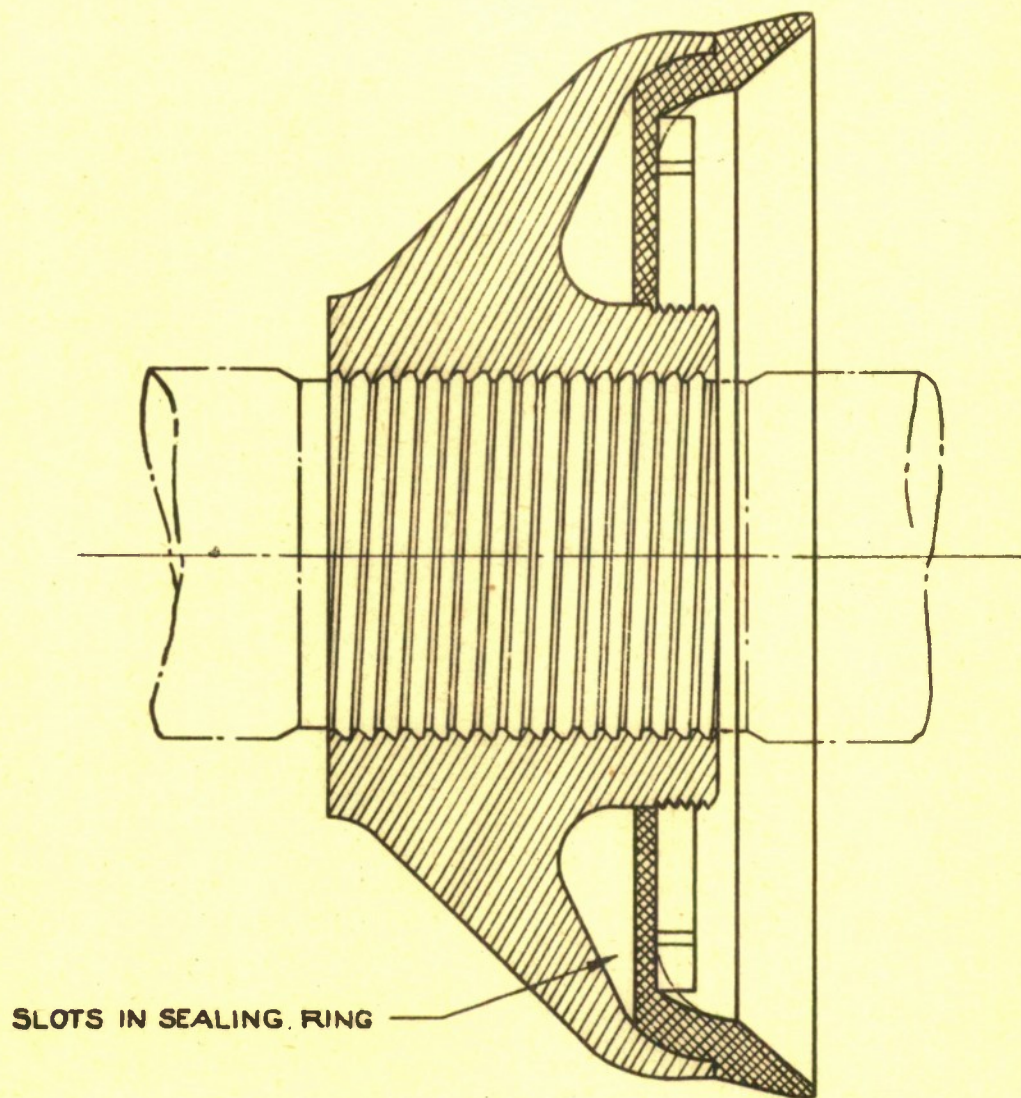
FIG. 13

SHELL F. S. D. S. 5.4 / 1.9 ROUND 2.
FIRED 30. 10. 47



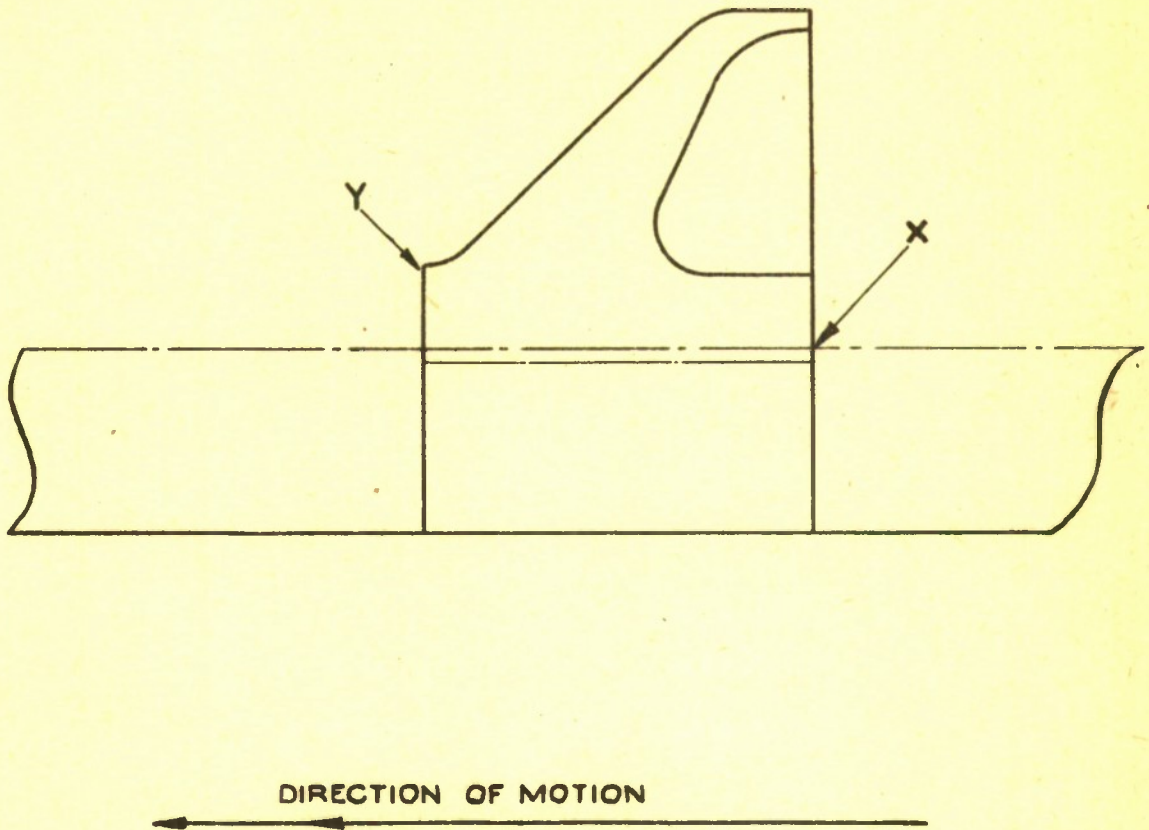
SEALING RING FOR SABOT FROM
DESIGN "D"

SEALING RING = D.2.(L) 3844/E/635

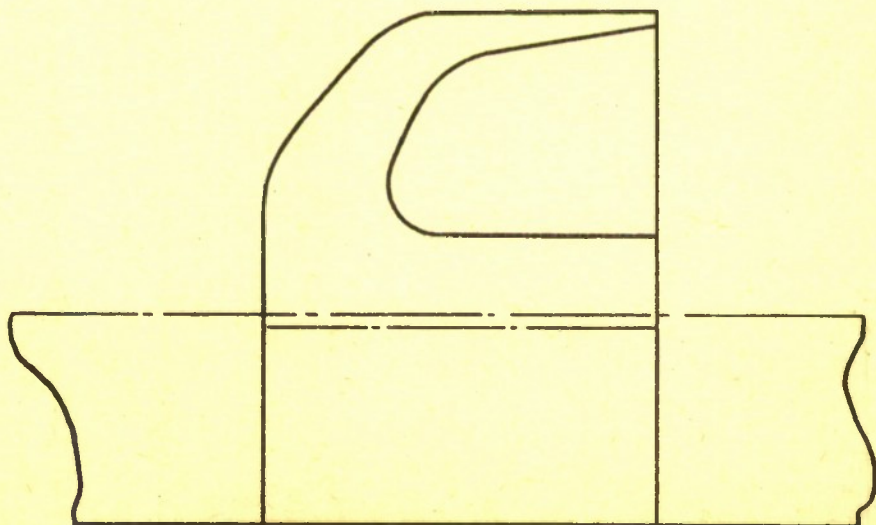


A.D.E 3/49

(a) DISCARD FOR 5.4/1.9 F.S.D.S.

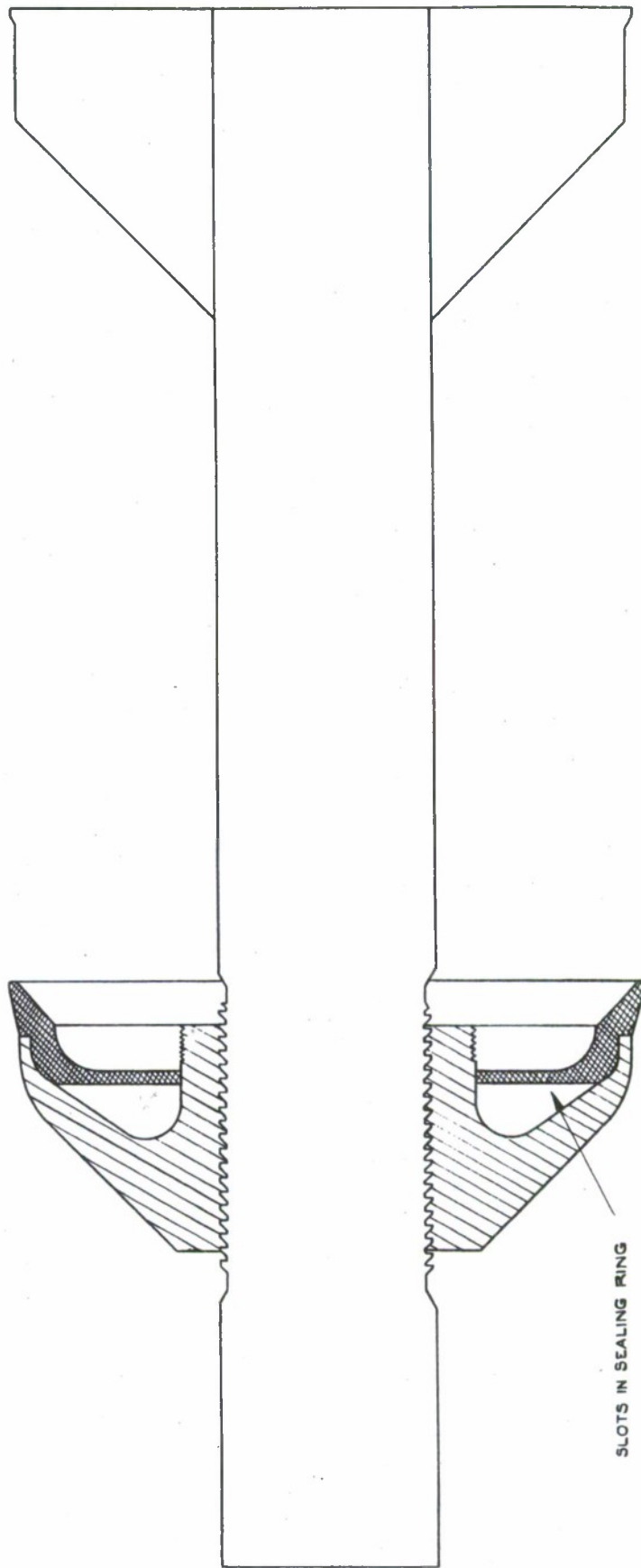


(b) DISCARD FOR 5.4/2.2 F.S.D.S.



SHOT, PROOF, REPRESENTING SHELL F.S.D.S. 5.4/1.9

SHOT = D.2 (L) 2751/X/651
SABOT = D.2 (L) 2844/E/651
SEALING RING = D.2 (L) 3844/E/635

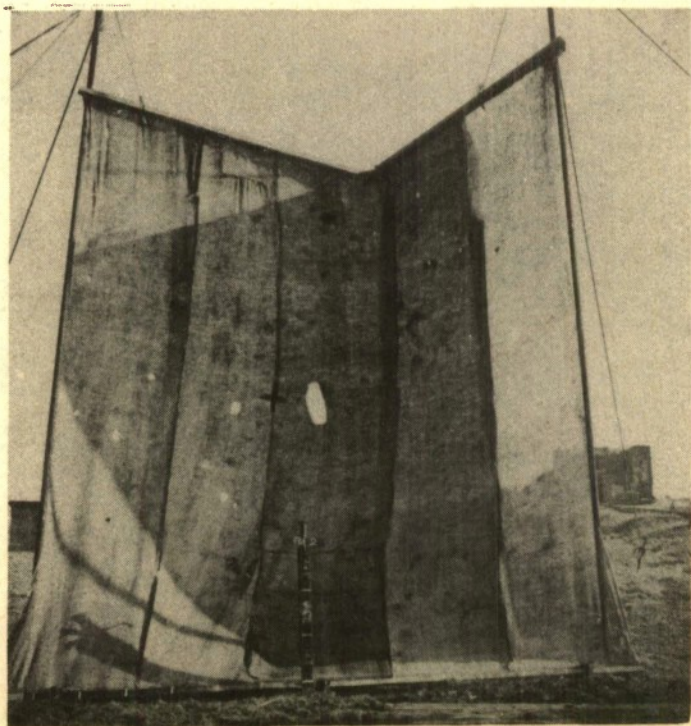


SLOTS IN SEALING RING

SHOT PROOF REPS SHELL F.S.D.S. 5·4/1·9

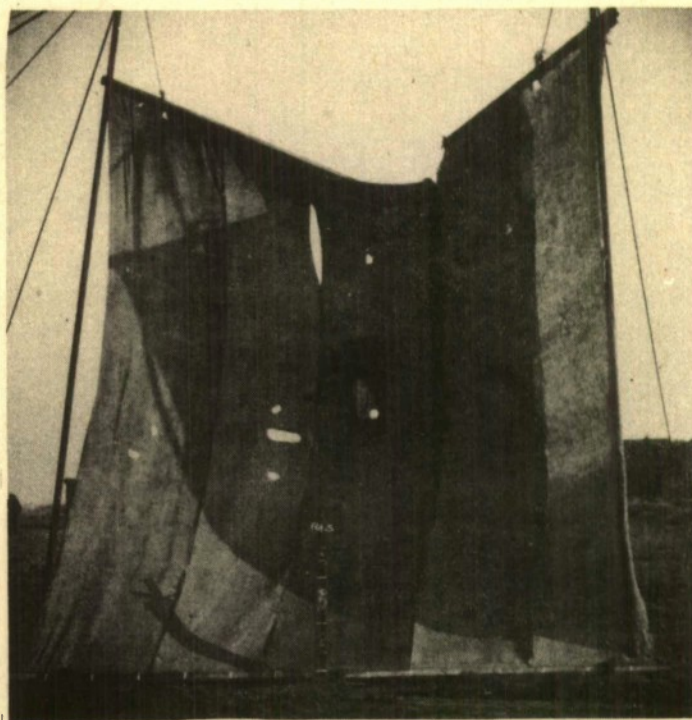


ROUND 1.

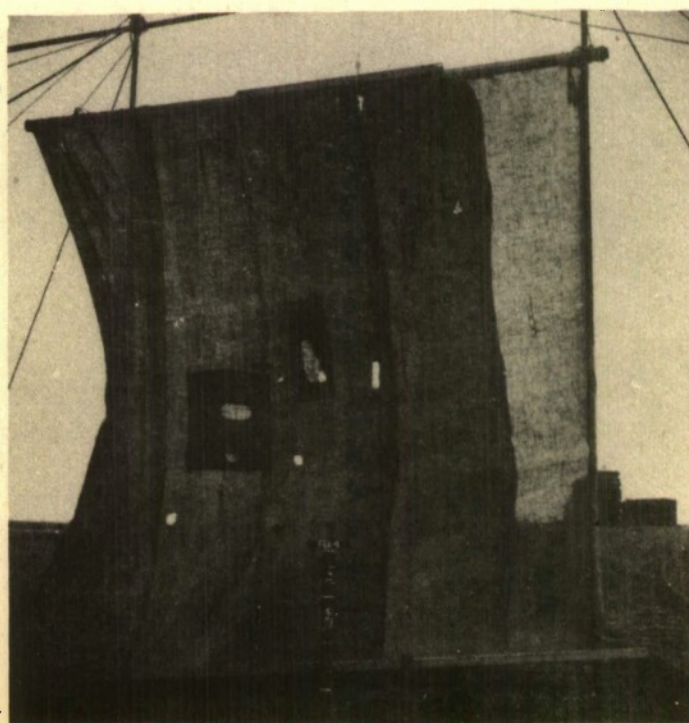


ROUND 2.

SHOT PROOF REPE SHELL F.S.D.S. 5·4/1·9

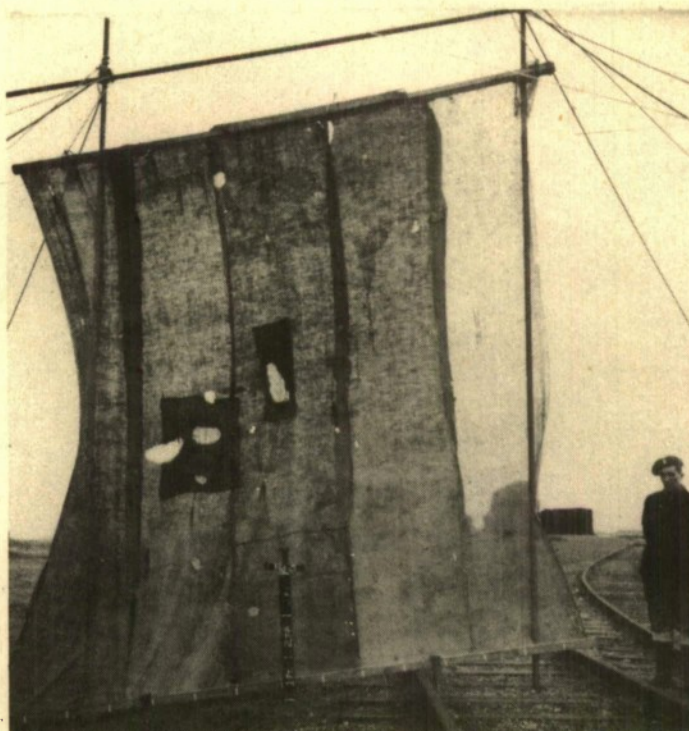


ROUND 3

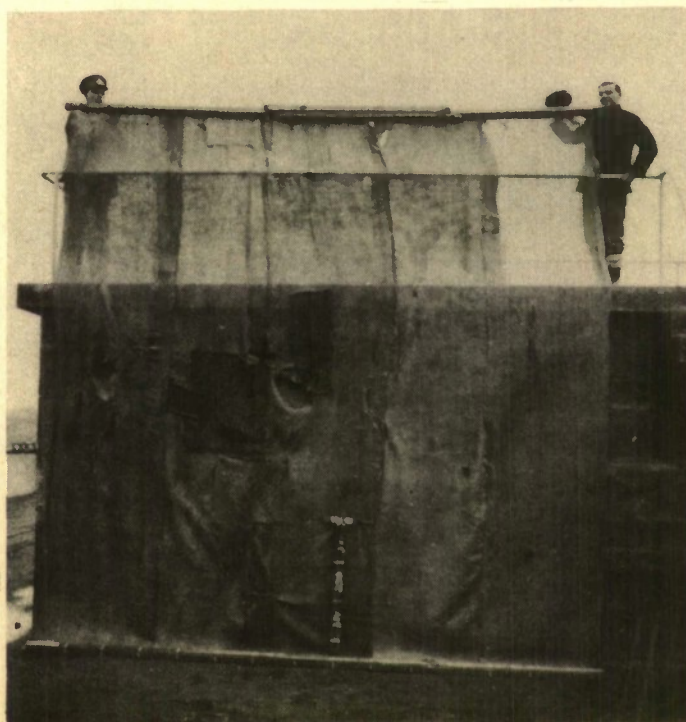


ROUND 4.

SHOT PROOF REP⁹ SHELL F.S.D.S. 5·4/1·9



ROUND 5.



ROUND 6.

SABOT DESIGN G.
FOR
SHELL . F. S. D. S. 5.4 / 1.9 DESIGN D.

SABOT = D 2 (L) 3910/E/635

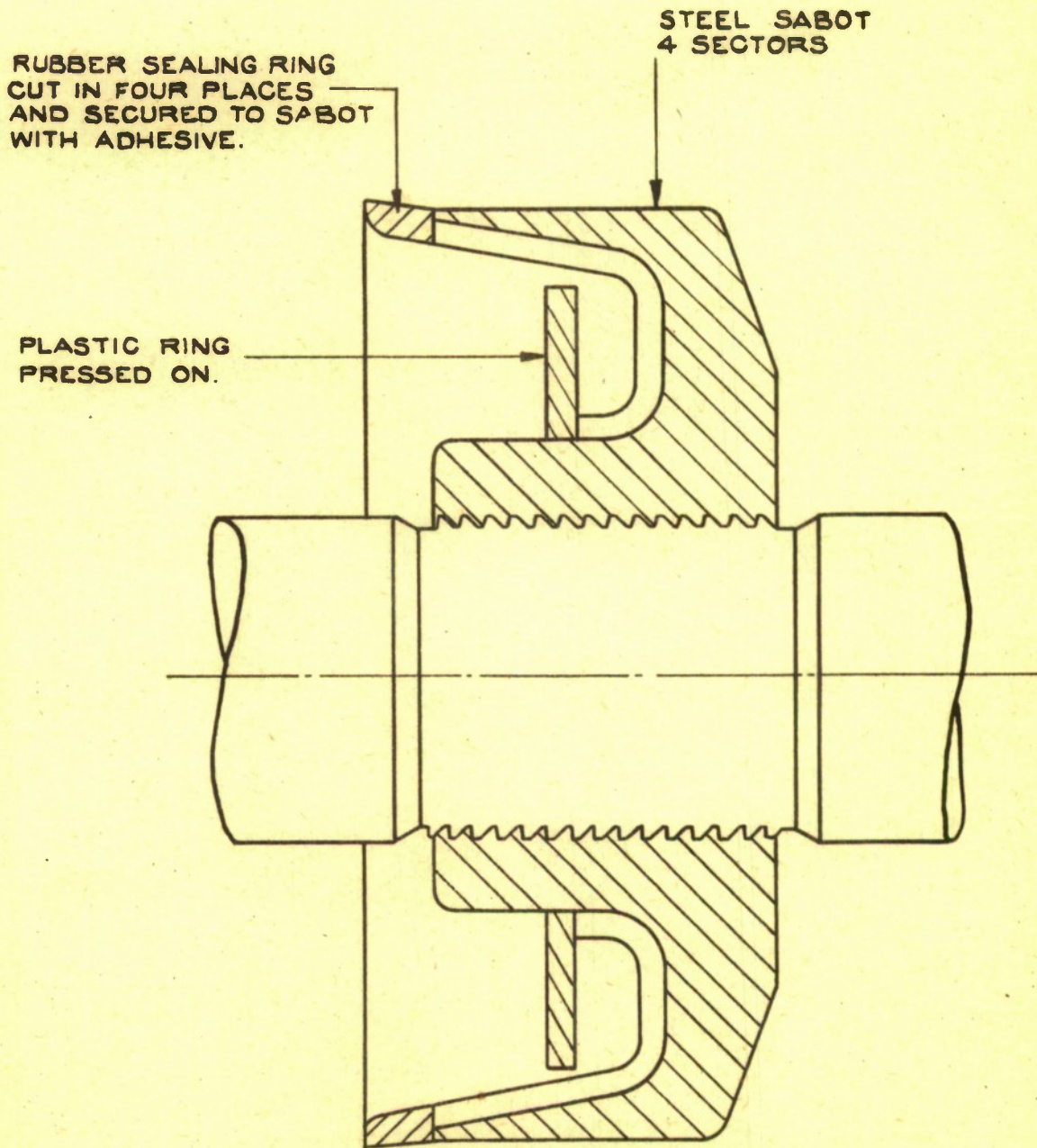


FIG. 22.

PATTERN ON HESSIAN SCREEN OF SHELL F.S.D.S. 5·4/1·9
DESIGN J WITH SABOT TO DESIGN "D"

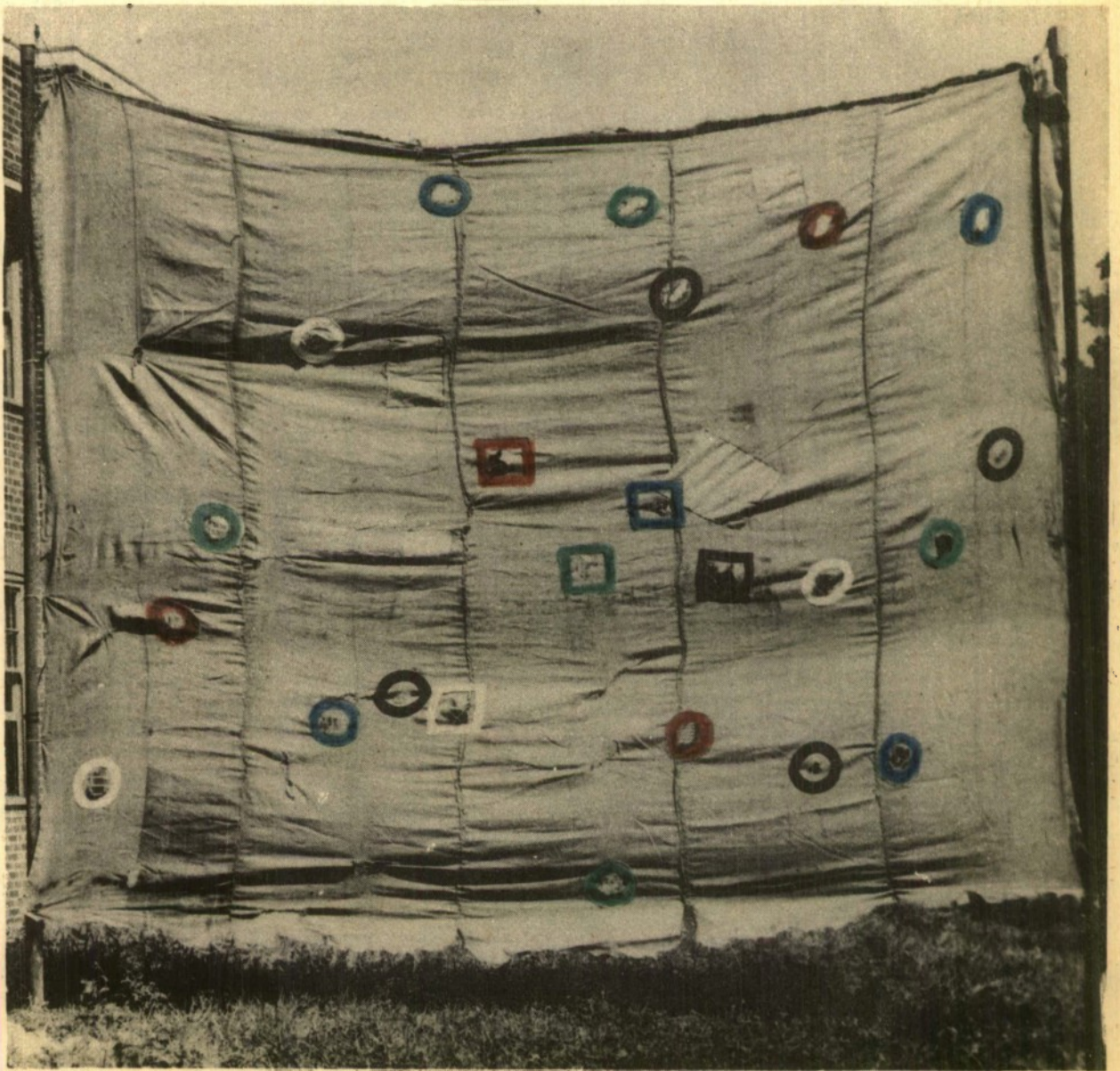
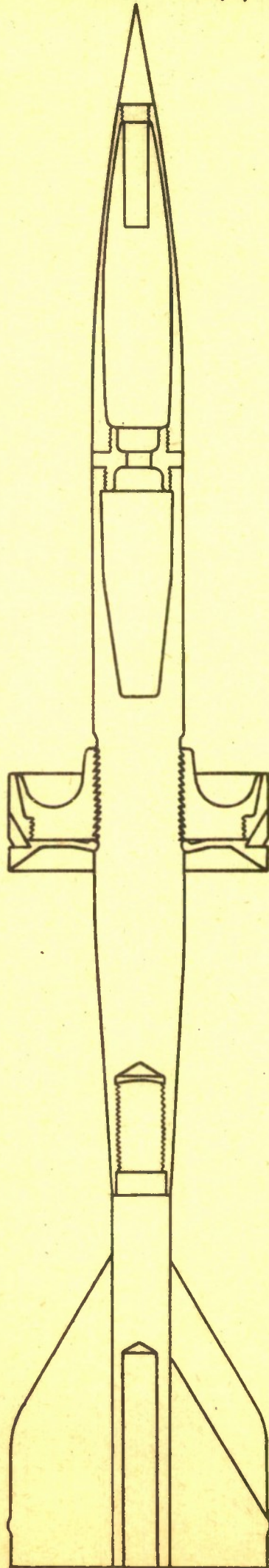


FIG. 23
SHELL, Q.F., H.E., F.S.D.S. 5.4/1.9 INCH.
SHELL = D.2(L) 2657/GE/635
SABOT = D.2(L) 3769/X/651

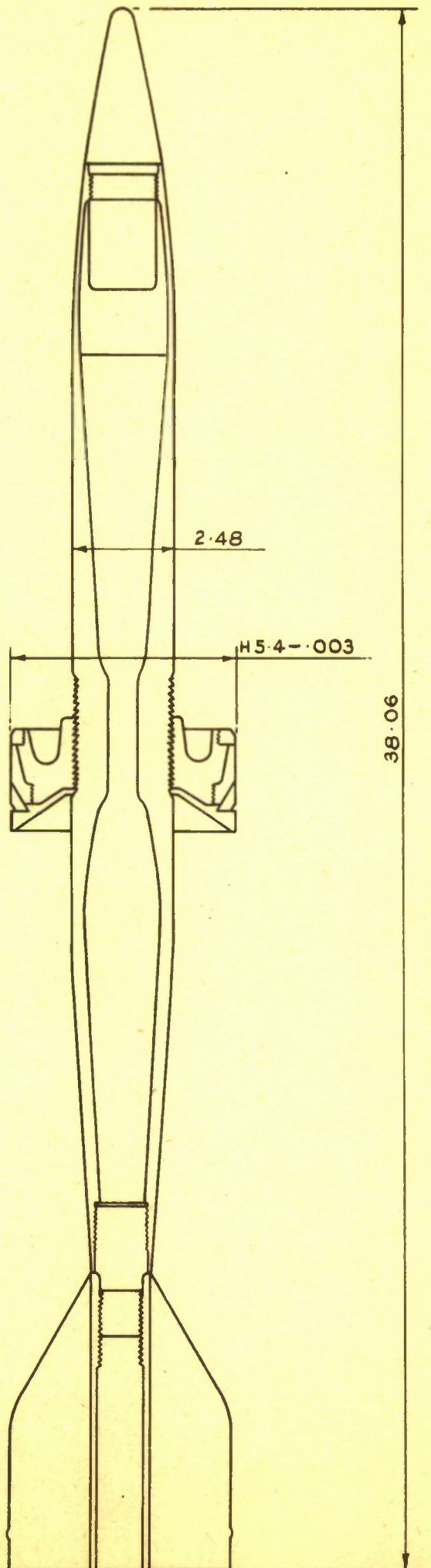


A.D.E. 3/49

SHELL F.S.D.S. 5.4/2.48

SHELL = D.2. (L) 3663/GF/759

SABOT = D.2 (L) 3822/X/759



SUB - ASSEMBLY OF DISCARDS TO BODY
D.2 (L) 3939/x|635

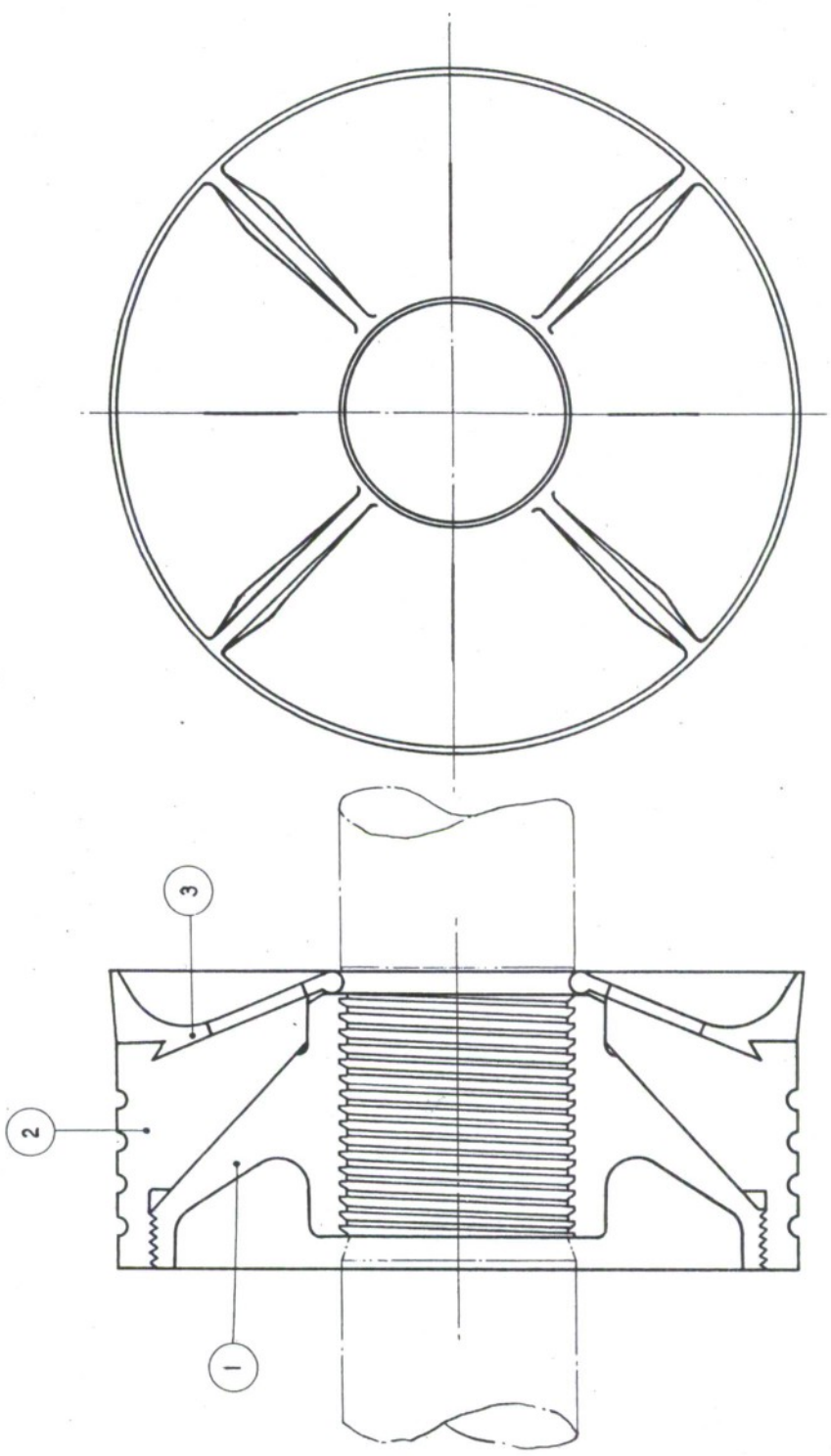
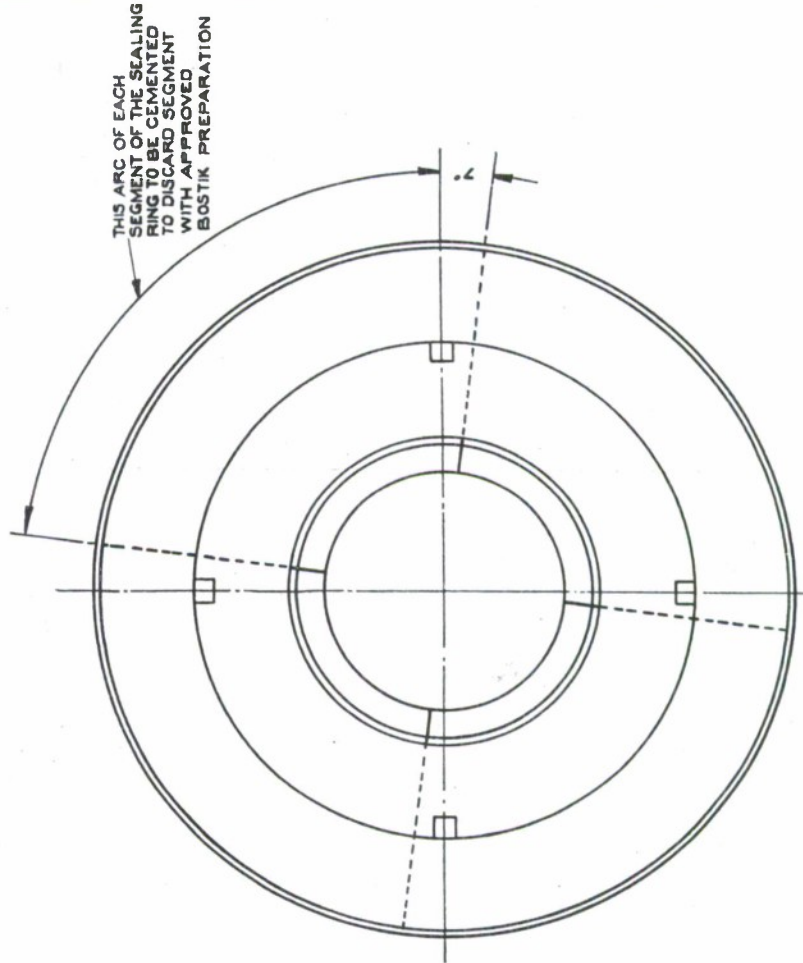
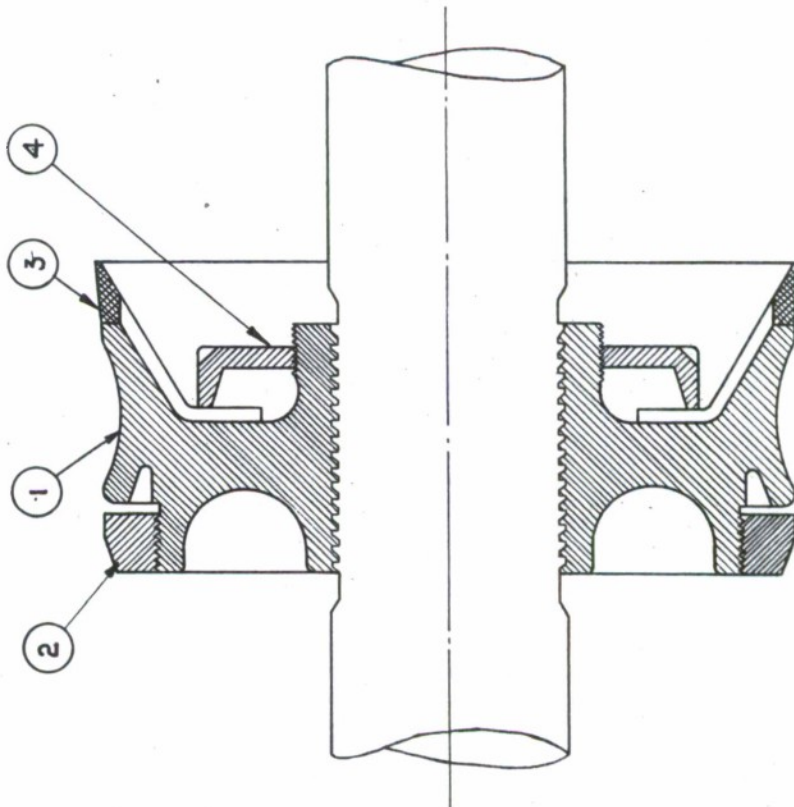


FIG. 26

SUB - ASSEMBLY OF DISCARDS

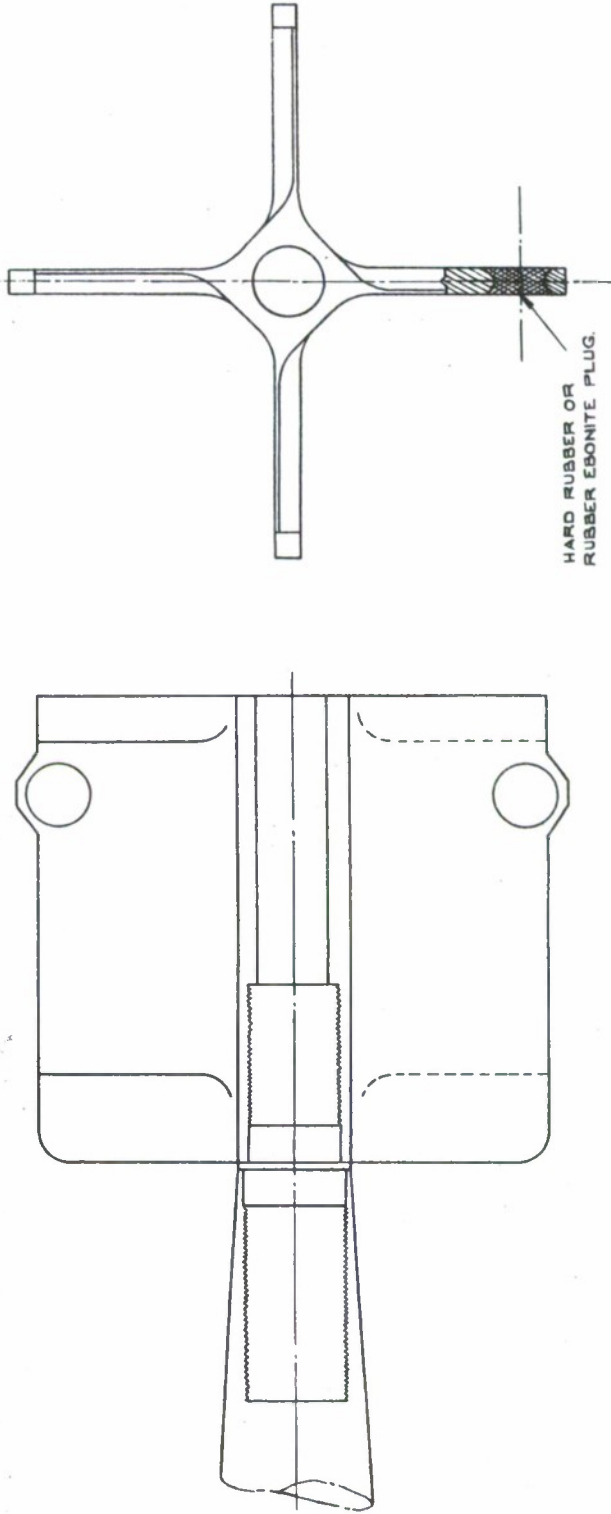
D.2. (L) 4064/E/635



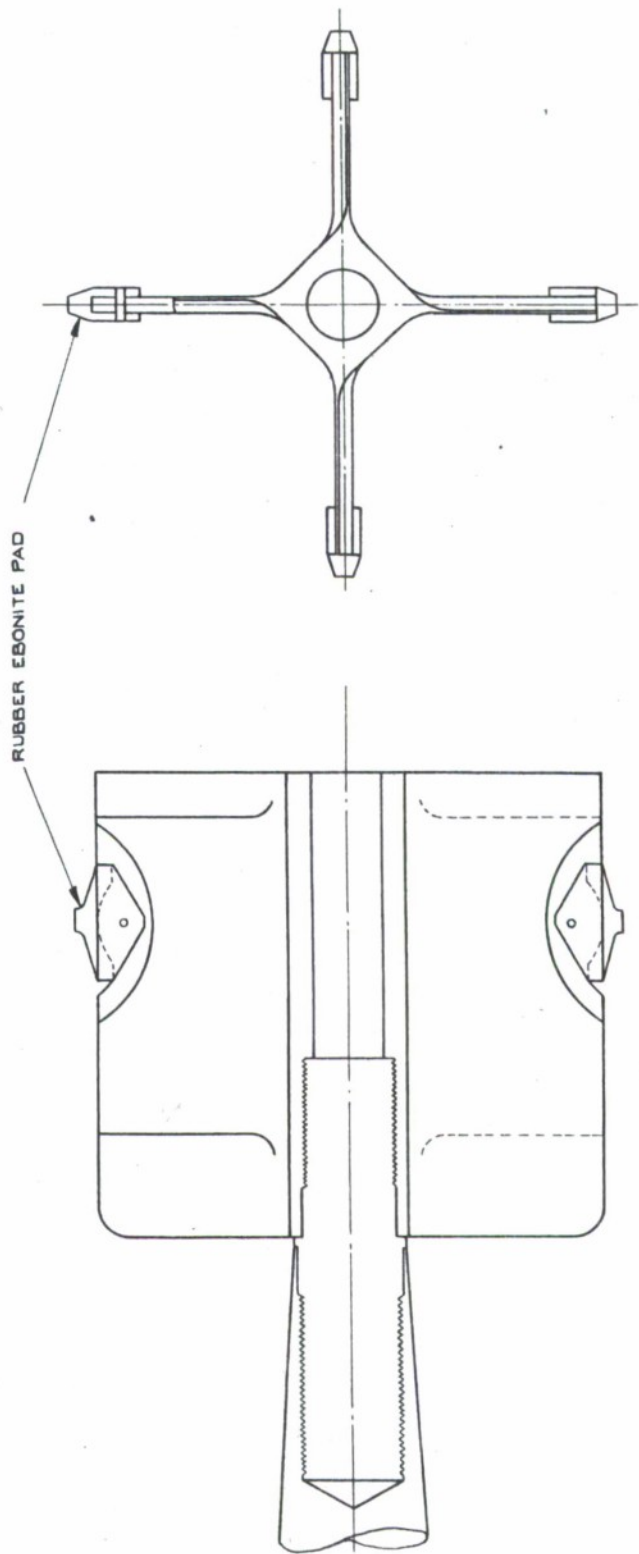
THIS ARC OF EACH
SEGMENT OF THE SEALING
RING TO BE CEMENTED
TO DISCARD SEGMENT
WITH APPROVED
BOSTIK PREPARATION

| LIST OF COMPONENTS | | |
|--------------------|----------------------------|------------|
| ITEM No. | DESIGNATION | No PER SET |
| 1 | BODY COMPRISING 4 SEGMENTS | 1 |
| 2 | LOCKING RING, OUTER | 1 |
| 3 | SEALING RING | 1 |
| 4 | LOCKING RING, INNER | 1 |

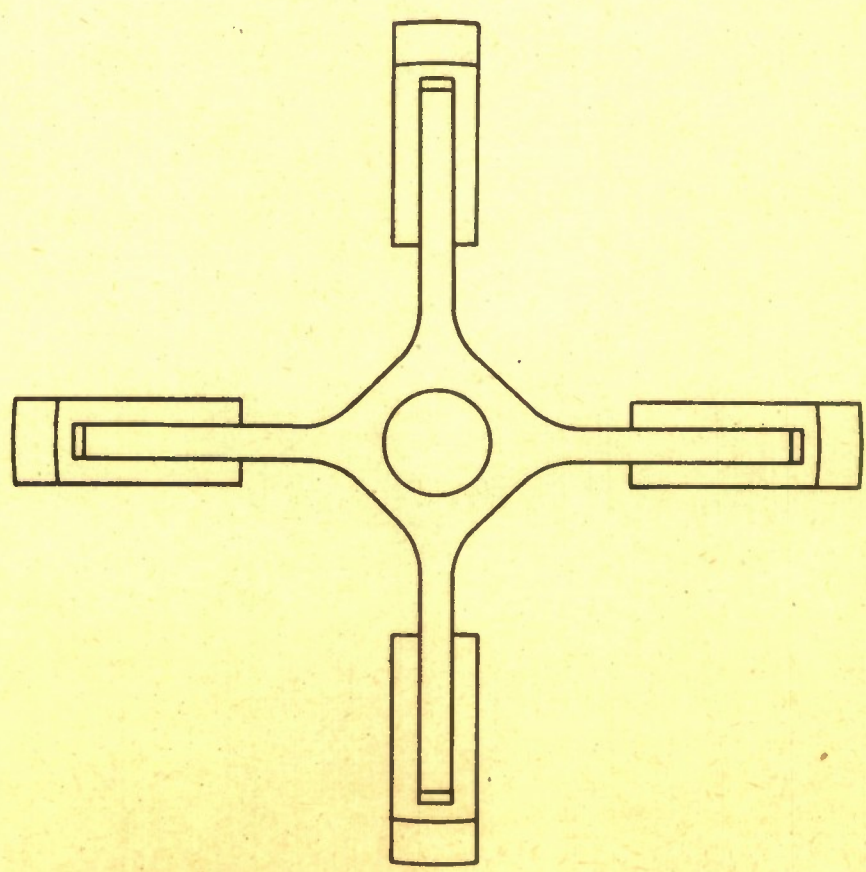
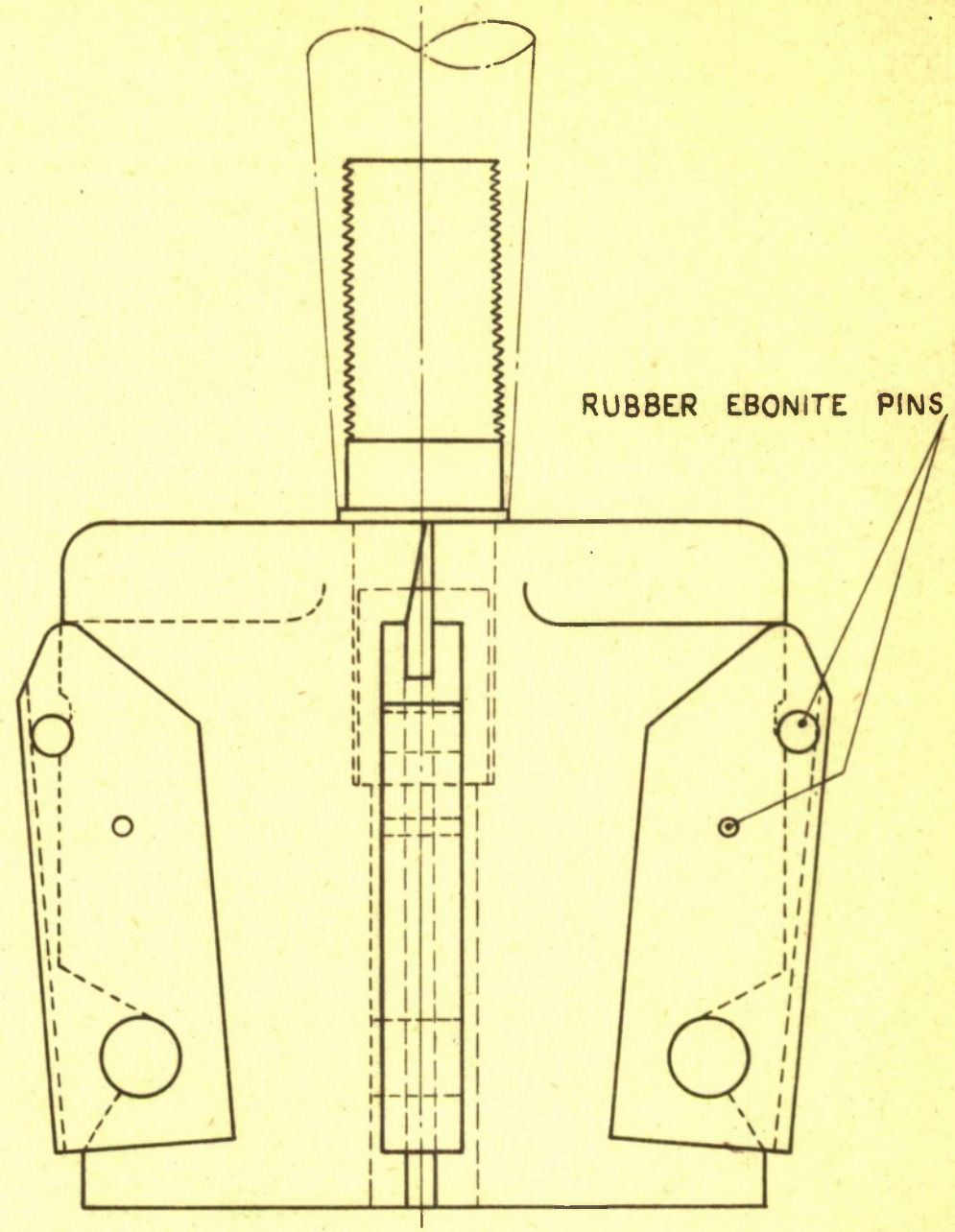
TAIL UNIT TO D2(L)3830/E/635



TAIL UNIT. TO D.2.(L) 3992/E/635



TAIL UNIT TO D.2.(L) 4053/X/635 FIG.29



A.D.E. 3/49

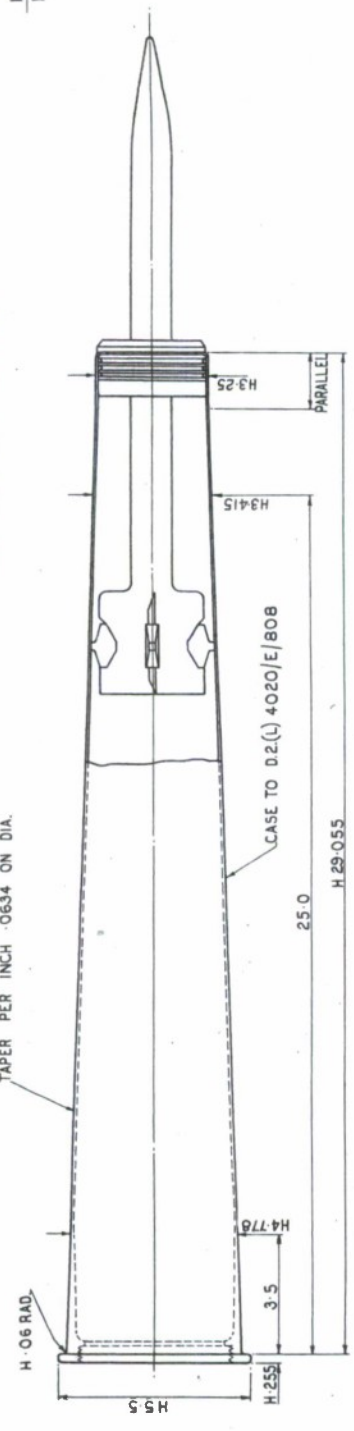
CARTRIDGE, Q. F., FIXED AMM., 3.0/1.2 F.S.D.S.
 TYPE 'A' (SINGLE TAPER .06) FOR USE WITH PROJ. TO D.2(L)3985/X/787 DISCARD TO D.2(L)3981/X/787
 TYPE 'B' (DOUBLE TAPER .03) FOR USE WITH PROJ. TO D.2(L)3985/X/787 DISCARD TO D.2(L)3981/X/787

THESE FIGURES DO NOT TAKE INTO ACCOUNT ANY STRETCH ON CASE WHICH MAY OCCUR WHEN MOUTH IS OPENED BY SHOT

H.29.275 (TYPE 'A') TO UNDERSIDE OF FLANGE
 H.38.275 (TYPE 'B')

MINIMUM CLEARANCE BETWEEN CASE AND CHAMBER .005 ON DIA.

TAPER PER INCH .0634 ON DIA.



DETAIL OF MOUTH AFTER SHOT HAS LEFT CASE.

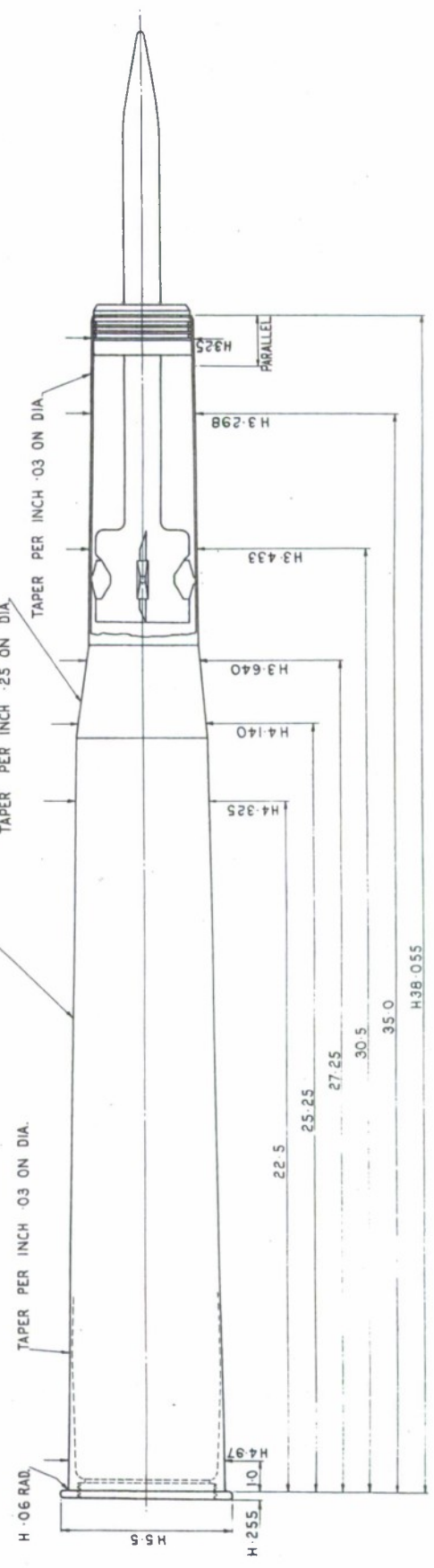
TYPE 'A'

CASE TO D.2(L)4022/E/808

TAPER PER INCH .03 ON DIA.

TAPER PER INCH .25 ON DIA.

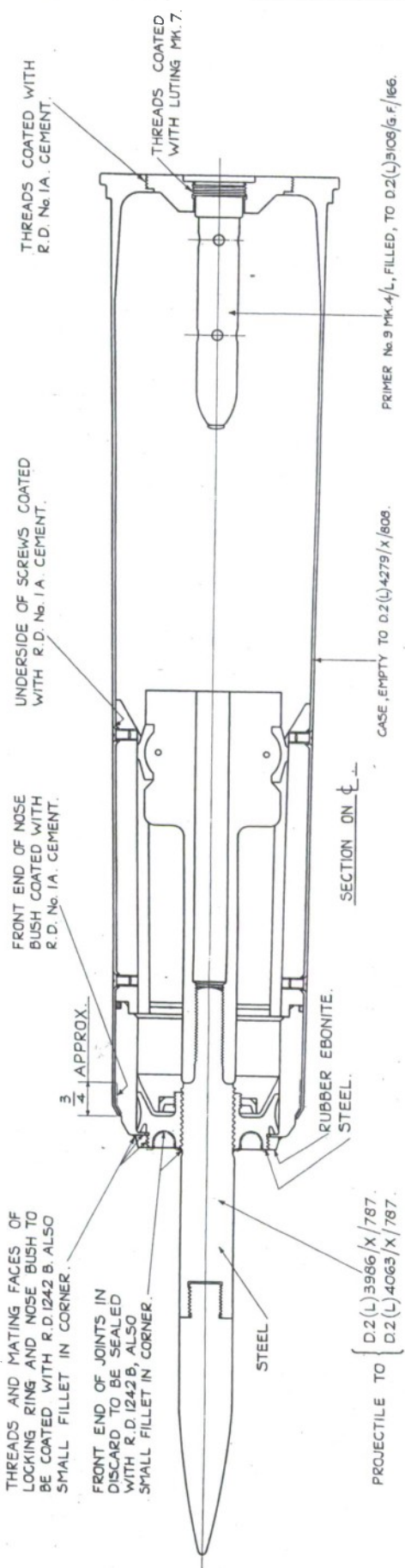
TAPER PER INCH .03 ON DIA.



TYPE 'B'

METHOD OF FILLING AND ASSEMBLING--CARTRIDGE, Q.F., 3.0 INCH.

SCREWED IN BASE, RAILS AND NOSE BUSH FOR 3.0/1.2 F.S.D.S.
 PROJECTILE TO D.2(L)3986/X/787 AND D.2(L)4063/X/787 FOR FIRING IN MODIFIED
 17 PR. GUN TO D.10(G)4181/187.



METHOD OF ASSEMBLING PROJECTILE INTO CASE.

- LOOSEN FIXING SCREWS SECURING RAILS.
- REMOVE NOSE BUSH, WITH RUBBER SEAL.
- REMOVE OUTER LOCKING RING FROM DISCARD.
- ENTER TAIL INTO CASE, WITH VANES BETWEEN RAILS. ROTATE UNTIL PADS ARE OPPOSITE GROOVES AND DRAW BACK.
- PUSH NOSE BUSH, WITH RUBBER SEAL IN POSITION, HARD AGAINST END OF RAILS.
- RE-TIGHTEN SCREWS AND FILE OFF HEADS FLUSH WITH CASE.
- REPLACE LOCKING RING AND SCREW HOME TIGHT.
- MOUTH OF CASE TURNED OVER ONTO NOSE BUSH.

NOTE.
 ALL COMPONENTS TO BE SEALED
 ARE BRASS UNLESS OTHERWISE
 STATED.

| MEAN EFFECTIVE CHAMBER CAPACITY 265 CU. IN. | |
|---|-------------|
| ESTIMATED WEIGHTS. | LB. OZ. DR. |
| CARTRIDGE ASSEMBLY, EMPTY | 17 9 3 |
| PROJECTILE 3.0/1.2 F.S.D.S. | 4 0 0 |
| PRIMER | 9 4 |
| TOTAL WEIGHT UNFILLED | 22 2 7 |

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