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PERMANENT RECORDS
of
RESEARCH AND DEVELOPMENT

THE R.D. GAINE AND ITS APPLICATION TO FUZES, PERCUSSION, BASE, DETONATING, LARGE AND MEDIUM

T.C. ROBERTS

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T.C. Roberts

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Table of Contents

List of Abbreviations

A.D. (R.D.Arm)	Assistant Director (Research Directorate of Armaments) (later D. Arm.D.)
A.R.D.	Armament Research Department
B and I Unit	Baffle and Ignition Unit
C.E.	Composition Exploding (Tetryl)
C.E.A.D.	Chief Engineer of Armament Design
C.I.N.O.	Chief Inspector of Naval Ordnance
C.S.A.R.	Chief Superintendent of Armament Research
C.S.R.D.	Chief Superintendent of Research Department (later C.S.A.R.)
C.S.O.F.	Chief Superintendent of Ordnance Factories
D.N.O.	Director of Naval Ordnance
I.N.O.	Inspector of Naval Ordnance
R.D.	Research Department (Royal Arsenal, Woolwich). (Later, Armament Research Department).
S. of D.	Superintendent of Design (later C.E.A.D.)
S. of E.	Superintendent of Experiments
U.P.	Unrotated Projectile

SECTION 1 ABSTRACT

The efficiency of the Fuze, Percussion, Base, Detonating, which far exceeds that of the igniferous fuze previously used, is due to the incorporation in it of the R.D. gaine which imparts a powerful detonative impulse to the shell filling after an appropriate delay. The novel feature introduced by the R.D. gaine is that C.E. is brought to detonation from ignition, in a space dependent on various factors, all of which had to be investigated before a satisfactory design could be submitted for approval. The method of filling had not only to bring the C.E. in the gaine to detonation within the permissible limits of space, but also to withstand the shock of discharge and of impact; it also had to be sufficiently simple to be reproducible without variation under manufacturing conditions. Within a few years of its application to the base fuze, the R.D. gaine had been brought to a high pitch of perfection. The ignitory system of the fuze is less perfect and is still under investigation.

The development of the R.D. gaine principle and its application to various stores, in particular the large and medium base fuzes, are reviewed. Sufficiently ample references have been provided to enable any particular section of the story to be followed in its entirety, and in order to enable the development of the more important items to be seen at a glance, composite drawings have been made from the corresponding DD/L designs. Details of certain branches of the work are given as appendices.

Note: Since this Record was compiled in 1945 changes have been made in the titles of various establishments in the Ministry of Supply: the Armament Research Department, for example, has been renamed the Armament Research Establishment.

SECTION 2 INTRODUCTION

The official enquiry into the Battle of Jutland established the fact that although the British guns were more powerful than the German, their shell effected less individual damage because the German shell fillings were brought to detonation whereas the British fillings merely exploded. This disclosure, supported by the experimental demonstration that 2 lb. of explosive detonated were equal in effect to at least 10 lb. merely exploded, led the Admiralty to press for a new type of initiator which would bring the shell fillings to detonation.

The difficulty of the problem lay in designing a type of inititor which would be sufficiently insensitive to withstand the shock of discharge from the gun and of impact on armour plate without giving rise to prematures, yet sufficiently powerful to give a considerable detonative impulse to the filling. The Admiralty was unwilling to sanction the use of a sensitive detonator which would require elaborate cushioning devices, thus complicating manufacture and increasing the sources of possible failure. Moreover, at that time, the only satisfactory detonant then in use was mercury fulminate which required careful handling in manufacture and transport and which deteriorated rapidly under tropical conditions.

As long ago as 1913 it was shown that C.E. could under certain conditions be brought to detonation by means of a gunpowder core, and a gaine embodying this device had been patented by the Coventry Ordnance Works. C.E. is a remarkably safe explosive but in combination with gunpowder it may give rise to a very sensitive mixture, so that it was necessary to contain the gunpowder in a separate chamber. This gaine, though successful up to a point, was unwieldy and could not be relied upon to detonate amatol, which, during the 1914-18 war, was used as a substitute for T.N.T. It was replaced by a smaller type with a detonator which ensured detonation of the shell filling but introduced all the difficulties for A.P. projectiles which the Admiralty wished to avoid.

For many years a substitute for the detonator-gaine was sought for unsuccessfully but finally, in 1922, by a happy combination of good fortune and acute observation, a member of the staff of the Research Department succeeded in bringing C.E. to detonation from ignition without the use of gunpowder. The importance of the discovery was immediately recognised by the Ordnance Committee who called for the development, on high priority, of a gaine embodying the new principle. Unfortunately facilities were not provided for an exhaustive examination of the underlying principles involved, the aim being merely to produce a gaine which would work satisfactorily. As a result of much trial and error, the required gaine was produced and ultimately incorporated in the large base fuze for naval shell. The undoubted success of the R.D. gaine principle in this fuze led to the designing of a medium base fuze for smaller natures of shell. Both of these fuzes passed into the Services, but other applications of the R.D. gaine have, for one reason or another, not been developed beyond the experimental stage.

PART I

SECTION 3 EVOLUTION OF THE R.D. GAINE

3.1 C.O.W. Gaine 1913 (Figure 1.a)

The first British detonating gaine was patented in 1913 by Lieutenant-Colonel Robinson Embury and Rear-Admiral Bacon of the Coventry Ordnance Works and in 1914 submitted to the Ordnance Board for consideration. Later modifications were brought out by Admiral Bacon and others during 1914. (British Patents Nos.9371/1913, 7350/1914, 23733/1914, 24305/1914) (O.B. Minutes 10035, 10640, 11070, 11481, 12376).

In the final C.O.W. gaine a column of C.E. under heavy lateral confinement was exploded by a gunpowder core. The base of the column was closed by a metal diaphragm below which was loose C.E. in a thin-walled chamber. On the explosion of the C.E. in the upper chamber the pressure rose, bursting the diaphragm, and producing detonation of the loose C.E. which in turn detonated the compressed C.E. or picric acid beneath it.

Experiments on this type of gaine were carried out in the Research Department to test whether detonation proceeded directly from ignition, but detonation was never obtained in the upper chamber. The presence of the metal diaphragm was an essential to success suggesting that detonation was produced in the lower chamber by bombardment with metal particles at a high temperature and velocity. On the other hand, it is not recorded whether the pressures attained in the upper chamber were as high without the diaphragm as with it. (O.B.Minutes 10156, 11070).

3.2. No.I Gaine 1914 (Figure 1.b)

The Service No.1 gaine was based on the principle of the C.O.W. gaine. It had passed the experimental stage and was about to come into Service when supply difficulties caused a new explosive, amatol, to be proposed for shell filling in place of lyddite or T.N.T. This explosive was more difficult to bring to detonation than the previous fillings and the No.1 gaine could not be relied on to give more than partial detonation. A 10-grain mercury fulminate detonator was therefore introduced into the top chamber, with good results. (O.B. Minutes 14521, 14639).

3.3. No.2 Gaine. 1915 (Figure 1.c, d, e)

The presence of a detonator in the so-called "detonator gaine" rendered the lower half unnecessary, thus enabling the gaine to be cut in two at the diaphragm and obviating the stripping of threads which had been a difficulty with the heavier type, although prematures originally ascribed to this fault were later thought to be due to the dangerously sensitive mixture produced by the combination of C.E. and gunpowder. The lower half of the gaine was replaced by trotyl exploders. (O.B.Minute 16208, O.C.Minute 12).

Trials in the gun showed that the detonator gaine was a great improvement on the No.1 gaine, but as there were still irregularities, a larger magazine containing gunpowder was introduced over the detonator (Figure 1.d). The Service form of this "magazine gaine" is shown in Figure 1.e, as No.2 Mark II gaine (original). Other modifications with different closing plugs, diaphragms of different thicknesses over the detonator and parallel or tapered magazines, were also tried. R.D.Report No.33, Experimental Study of the Detonation of Gaines).

Fuze, Percussion, Base, No.16 with C.O.W. Gaine Principle, 1915
x (R.L. Designs 20910A (1) and 21980)

Since a detonating base fuze for Naval shell was urgently required, it was decided to apply the C.O.W. gaine principle to the No.16 fuze. Detonation was obtained but the presence of a 10-grain fulminate detonator was regarded with disfavour and doubt was expressed by the Admiralty as to the advisability of adopting it for fuzes for large shell (O.C.Minute 599).

3.4 In 1916, D.N.O. requested the Ordnance Committee to take up the question of a delay action base fuze for use with Naval Service heavy A.P.C. shell filled T.N.T.; C.S.O.F. was to proceed with the combination of the No.16 fuze with delay and the principle of the C.O.W. gaine. A modification of a German delay action base fuze and gaine was also considered. x(R.L.Designs 21,130 and 22860) (O.C.Minutes 5825,6430).

3.5 In 1921, C.S.R.D. was asked by the Ordnance Committee to submit a report on an Austrian fuze embodying a gaine which worked on the principle of an explosive burning to detonation. x(R.L. Design 31050). C.S.R.D. reported that the gaine, which contained picric acid, nitroglycerine and guncotton, was too dangerous for Service use, but that a gaine on the same principle had been under consideration in the Research Department for some time. (O.C. Minutes 41897, 42019).

3.6 R.D.Gaine Designs 1991 and 10A, 1922, 1923(Figure 3.b and d)

Experiments in the Research Department on the "Baby Bomb" had led to the discovery that C.E., under certain conditions of confinement and density, could be detonated by means of a gunpowder in a separate container (see Appendix 1). It was shown that under sufficient confinement the pressures reached in the gaine were fairly constant and, within the limits observed, rose with increased confinement. (Table 2). A design of gaine R.D. No.1991, very similar to the type illustrated in Figure 3.b was, in 1923, submitted to the Ordnance Committee with the reservation that although it was the outcome of over 200 experiments it did not claim to represent the optimum conditions, the determination of which depended on the systematic examination of a number of factors, viz:-

1. the mechanical properties of the metal concerned;

2. the form and amount of the respective explosives;

3. the degree of confinement required by each of the explosives;

4. the mechanism of the explosive reaction.

This gaine passed successfully through a comprehensive series of trials in the 18-pr. gun but was considered too heavy and a lighter design No.10A was produced. (O.C./S.17, 1923). The principle of this gaine is different from that of the C.O.W. gaine in that detonation is obtained directly from ignition in consequence of a sudden rise of pressure and temperature sufficient to bring about molecular disintegration. In the C.O.W. gaine detonation was never obtained without the presence of the metal diaphragm.

x Not reproduced

3.7 R.D.Gaine Pattern 12, 1925 (Figure 4.b)

Continuation of the experiments outlined above established the result that consistent detonation of C.E. could be obtained without the use of gunpowder in a separate container, thus enabling the weight to be reduced still further. Ignitions of the C.E. could take place by means of a flash or electrically. The application of this device to mines, warheads, bombs and various types of shell was suggested, also the taking out of a comprehensive patent. (O.C./S.17. R.D./C/4677).*

The essential features of this simplified gaine, which came to be known as the R.D. gaine, are:-

1. the ignition chamber where compressed C.E. is ignited and raised to explosion;

2. the fire channel where explosion is converted to detonation;

3. the magazine where the detonative impulse is enhanced and transmitted to the shell filling.

Much work has since been carried out in establishing the optimum conditions for detonation, particularly in determining the best type of C.E. for the purpose and the best means of stemming it to the required density, also in improving the ignitory system, but the essential features of the gaine have never been altered since it was first submitted to the Ordnance Committee.

3.8 R.D. gaine with adapter for use with base fuze, 1924 (Figure 4.c, d, e)

Partly because the design of the base fuze was not settled and partly in order to utilise existing supplies of munitions, the R.D. gaine was in the first instance used with an adapter and much work was expended in determining a suitable form and material for this purpose. The Ordnance Committee, however, was not satisfied with the result and suggested that attention should be focussed instead on the embodiment of the R.D. gaine principle in a fuze of the No.16 type. Experiments along these lines had been carried cut in the Research Department during 1923, but owing to the uncertainty concerning the final design of base fuze to be adopted, had been allowed to lapse. (O.C.Memo."B" 7180, 7325).

DD/L/1000 In answer to the Ordnance Committee's request, a design DD/L/1000 of base fuze incorporating the R.D. gaine principle was brought out by S.of D. and formed a separate line of development (see Part II, p. 12). From the first the results were so promising that trials with the R.D. gaine as a separate entity tended to be held over and were finally suspended altogether. Experimental work was, however, continued on the gaine so that problems properly relating to the fuze itself should not confuse the issue. This procedure was fully justified by the production of a type of gaine which has since required very little alteration. Examination of later "blinds" has shown that practically without exception the fault lay in the ignitory system and that ignition of the C.E. in the ignition chamber was followed by satisfactory detonation of the gaine. (O.C.Memo."B" 7221, 7972).

The earlier types, Patterns 12, 20, 21, were not strong enough to withstand the shock of oblique impact in heavy shell and a suggestion was made to strengthen the gaine by means of a steel liner, but the design was not adopted, a stronger form of gaine being designed instead

* References of this type refer to files in the Armament Research Department.

(Pattern 22-1925).

In the same year, for the first time, shellite and T.N.T. filled shell fitted with base fuze and R.D. gaine were fired at a ship target. The so-called "Monarch" trials confirmed the rest trials and proved beyond dispute that the fragments produced by detonation of a shell filling though smaller were, because of their greater number and velocity, superior in effect to those produced by explosion only. (O.C./C.427).

3.9 Early in 1925, a suggestion was made that in order to avoid distortion on impact, the gaines should be made of high grade steel. Both this question and that of adapter design were, however, held over until the results of trials with DD/L/1000A were available, when D.N.O. decided to abandon the R.D. gaine in the 8-inch shell and revert to a flat adapter suited to receive either fuze DD/L/110 (without gaine) or DD/L/1000 (O.C.Memo."B" 8437, 8901, 9346).

Pattern 22, R.D.2724 (Figure 4.e)

The new design, in addition to being much stronger, was provided with a gaine transit plug to obviate any risk of foreign matter entering the touch-hole, "blinds" having been traced to this cause. DD/L/1931, DD/L/Sk.77 and DD/L/1173 are all based on R.D.2724 which proved very satisfactory (O.C.Memos."B" 8927 II, 8980).

Aggregated C.E.

An important discovery was also made in 1925, namely that C.E. could be produced in crystalline aggregates which had the free-flowing properties required for easy stemming and which could, by careful control, be produced in a grain size to give the required density. An account of this important aspect of the work is given in Appendix 2.

Stemming Machines

The first designs of stemming machines, based on the methods used in the laboratory were produced during 1925. Appendix 3 gives a brief outline of the development up to the present time.

In October 1925, the Ordnance Committee decided to suspend all further trials on the R.D. gaine on the grounds that a perfect fuze to design DD/L/1000 was a more useful article than a combination of a fuze such as DD/L/110 with a perfect gaine. (O.C.Memo."B" 9568, 9723, 9802).

A summary of R.D. gaine trials reproduced from O.C.Memo."B" 9723 is given in Appendix 4.

SECTION 4 APPLICATIONS OF THE R.D. GAINE PRINCIPLE

4.1 In 1925, C.S.R.D. submitted to the Ordnance Committee a comprehensive report on the R.D. Gaine (O.C.Memos."B" 8921, 12613, 12614, 18281) with the suggestion that "consideration might well be given to the application of the principle established for the purpose of bringing about the complete detonation of H.E. generally in the various types of Service stores". The reasons for advocating this general application of the R.D. gaine principle were:-

a. Safety in handling stores both during manufacture and as completed ammunition;

b. economy in inspection and maintenance;

c. enhanced efficiency;

d. greater durability and hence reliability under varying conditions of climate.

The following stores were then suggested as being suitable for the application of the gaine principle:

I. Land Service

(a) Gaines containing fulminate detonators, e.g. No.2 or No.8 type.

(b) Trench Mortars - safety in handling and against hostile fire would be the chief advantage.

(c) Land mines - greater durability of the R.D. gaine would be an advantage.

(d) Tank shell - the R.D. gaine principle is especially suited to A.P. ammunition.

II. Naval Service

(a) Projectiles - the great advantage of detonation of the shell filling over explosion has been clearly established. The insensitiveness to impact of the R.D. gaine makes it peculiarly suited to A.P. projectiles.

(b) Mines - adoption of the R.D. gaine principle would lead to greater safety, increased efficiency, economy in cost and upkeep and practically unlimited durability during all conditions of Service storage.

(c) Torpedoes - the chief feature would be greater safety against hostile fire, the only sensitive part of the impulse system being the small igniting cap.

III. Air Service

(a) Bombs - again there would be much greater safety in handling, in forced landings or crashes and against hostile fire.

(b) Anti-personnel bombs - a smaller impulse system could be designed than is possible with mercury fulminate or composite detonators.

Certain objections to this programme were raised by S. of D who considered that while the principle might in due course be applied to all stores in which some slight delay in detonation could be accepted, for the time being its use should be limited to fuzes for A.P. shell for which its insensitiveness to shock rendered it particularly suitable. The Ordnance Committee concurred in this view with the result that for some years the development of the R.D. gaine was confined almost entirely to its embodiment in the base fuze for A.P. shell. Its success in this field led to later development in the directions suggested by C.S.R.D. but as yet no other designs have been accepted for Service use.

4.2. Up to the present time the R.D. gaine principle has been applied in the following stores:-

1. Base fuzes of the Naval type for coast defence and the attack of armoured structures and concrete shelters, e.g. Fuzes No.185, No.158A, 159, 500, 345, 345A, 346, 501, 479, 479A, 480.

2. Gaine for small piercing shell (3-pr., 2-pr., etc.) for attack of tanks, DD/L/8390 (modified from R.D.5403).

3. Gaine to replace No.2 Mk.III for use with fuzes of the No.101 type DD/L/3350.

4. Gaine for 6-pr. H.E. shell for attack of CMBs.

5. Fuzes for aircraft bombs DD/L/3280, DD/L/3300.

6. Triple purpose shell DD/L/2050, DD/L/2404.

7. Mine DD/L/6658.

8. Signal, under-water, exploding, DD/L/2018, DD/L/7567.

9. Azide sleeve, DD/L/7370.

10. Apparatus for testing explosives.

11. Bomb, Incendiary, 20 lb. "J".

4.2.1 Fuze Percussion Base Detonating

The most important application of the R.D. gaine was to base fuzes of the Naval type and in particular to those for the attack of heavy armour. This section of the subject is dealt with in Part II.

4.2.2. Fuze, Percussion, Base, Detonating, Small. DD/L/8390

For anti-tank work, C.S.R.D. in 1938 designed a small base detonating fuze to design R.D.5403. Because of earlier trouble with the medium base fuze caused by the seeping of mineral jelly through the threads of the side closing plug, the ignition chamber was put inside the fuze. S. of D., however, having overcome the seepage trouble by the application of a sealing composition, modified the design to DD/L/8390 which retained the side closing plug.

Trials with this design, slighly modified by C.S.R.D., had shown that the fuze was quite reliable in its detonative functioning at rest when war broke out and the investigation was suspended.

(Earlier trials with a small base fuze for the Q.F. 2-pr. A.P. shell had proved unsatisfactory. O.C.Memos."B" 33309, 33689, 35048).

4.2.3 Fuze, Percussion Nose No.101 DD/L/3350 type of gaine, DD/L/Sk. 1684

In 1929, in consequence of the number of prematures with the No.101 fuze and No.2 gaine, S.of D. was asked to collaborate with C.S.R.D. in the preparation of a design of gaine for use with the No.101 fuze. A design DD/L/3350 was produced embodying R.D. gaine pattern 60 (R.D.3254). Various modifications in the design were incorporated in the following amendments:-

A. improved closing plug, (?)

B, C, D. proposed incorporation of Baffle and Ignition unit,

E. replacement of gaine to design R.D.3254 by R.D.3956,

G, H, J, K. improvements in ignition,

L. incorporation of delay unit.

DD/L/3350K with non-delay filling passed through a series of trials successfully and was recommended by the Ordnance Committee for use under the No.101E fuzes.

DD/L/3350L gave unsatisfactory results and C.S.R.D. suggested the incorporation of a B and I unit.

DD/L/Sk.1684 introduced a proposed modification to give improved functioning when fuzed delay.

In 1937 however, the Ordnance Committee pronounced the gaine unsuitable for filling under war conditions and for Service use and the investigation was closed.

(O.C.Memos."B" 16325, 17897, 20425, 21525, 22222, 22498, 22827, 24008, 25131, 25596, 25689, 25808, 26054, 26267, 26643, 27312, 28318, 28835, 29072, 30873, 33671. R.D.C.2779/28, 7586/36).

4.2.4. Shell for Q.F. 6-pr. S.A. gun in twin mounting (Coast Defence)

Shell to design DD/L/2845 fuzes (1) DD/L/1980 (A.A.), (2) No. 132 (Anti C.M.B.), and fitted with R.D. gaine, 1928.

The first trials were carried out with R.D. gaine No.3203 which was replaced as improvements were made to the gaine by R.D.3254 and later R.D.3956 with Baffle and Ignition unit R.D.3927. Success was very nearly achieved when further trials were cancelled. (O.C.Memos."B" 12614, 15208, 17237, 19662, 20673, 20707, 23315, 23412, R.D.C.92/28.
Shell to design DD/L/5477 with fuze No.51 in place of No.132 and R.D. gaine No.4496, 1932.

Trials were carried out with a new design of fuze and gaine assembly replacing No.51, DD/L/4760, but although the fragmentation obtained was good, the wide variations in time of functioning were disappointing. A new design of gaine R.D.Sk.No.4786 (Figure 4.i) followed shortly, by an addition in the form of a modified Baffle and Ignition unit R.D.No.4883, was brought out. This was followed by a further modification, a universal Baffle and Ignition unit, R.D.F. 5810, but though good results were obtained in the rest trials, the gun trials remained obstinately unsuccessful. The failure was attributed to a possible loss of tamping resulting from break-up of the fuze on the target. (O.C.Memos. "B" 26633, 27439, 27835, 30307, 30545, 32122, 32537, 33425).

4.2.5 Fuzes for Aircraft Bomb

In 1928, S. of D., in answer to a request from A.D.(R.D.Arm.) submitted to the Ordnance Committee several designs of fuzes for aircraft bombs, three of which made use of the R.D. gaine principle.

(a) DD/L/3300 tail fuze for the 50 lb. and 120 lb. bombs;

(b) DD/L/3260 tail fuze for the 250 lb. and 500 lb. bombs;

(c) DD/L/3280 with fuze DD/L/3270 for the 1000 lb. bomb.

After a considerable amount of work on these designs, the investigation was suspended.

(a) DD/L/3300 (with R.D. gaine No.3254) was used with fuze to design DD/L/226 as alternative to fuze to design DD/L/3240 for the 50 lb. G.P. bomb. It had four stemmed channels with strengthened closing plugs for the ignition chambers. In order to make the system inter-changeable with DD/L/3240 the external contour below the shoulder of the gaine was altered to design DD/L/3300C (A and B introduced other modifications suggested by C.S.R.D.). A Baffle and Ignition unit to design R.D.3927 was added in DD/L/3300D and after several modifications to this unit the gaine reached its **final** form in DD/L/3300 J/1.

The results of the trials of this design were sufficiently promising for the ignition unit to be considered as a standard form but the design as a whole was not adopted. (O.C.Memos.B. 15736, 17267, 17839, 18816, 19065, 21495, 21778, 22022, 22534, 23698).

(b) DD/L/3260 was criticised by the Air Ministry as too complicated and was not developed. (O.C.Memos. "B" 16202, 17267).

(c) DD/L/3280, like DD/L/3300, had four stemmed channels and four separate ignition chambers. It also passed through a series of modifications:- A, in which the diameter was reduced from 1.4 inches to 1.2 inches in conformity with DD/L/3240;
B, which had one common plug for the four ignition chambers instead of one each;
C, in which an annular groove joined the touch holes on the ignition chambers face of the plug;
D, with 2-piece plug;
E, with Baffle and Ignition unit incorporated to give an ignition system similar to that in DD/L/3300 J;
F, with three stemmed channels and separate closing plugs.

The performance of DD/L/3280 was judged sufficiently promising for trials simulating conditions at high altitudes. From the results, it was considered that the gaine had given a satisfactory performance though the length of delay was 30 per cent. greater than under normal atmospheric conditions.

At this stage, owing to a change of policy with regard to G.P. bombs, the Ordnance Committee on the advice of A.D.(R.D. Arm.) suspended the investigation.

(O.C.Memos. "B" 16202, 17267, 17659, 19152, 20458, 21498, 22022, 22560, 22584, 23646, 23698, 24823, 24857).

4.2.6 Triple Purpose Shell DD/L/2050, DD/L/2404

In 1925, S.of D. was asked to prepare, in collaboration with C.S.R.D., a design of shell showing a method of filling suitable for the following fuzes used with an R.D. gaine in the nose of the shell.

A. Anti-ship No.45P

B. Anti-aircraft No.202 or No.198

C. Bombardment No.106E.

C.S.R.D. at that time, was unwilling to endanger the secrecy of a principle so eminently suited to A.P. projectiles and the project lapsed (O.C.Memos. "B" 8534, 8921, 10097, 10525).

4.2.7. Mine DD/L/6658 C/1

In 1937, a design of exploder unit was prepared by S.of D. utilising an electric ignitor to design DD/L/6723 A/1 and R.D. gaine to design DD/L/6858 C/1 but was discarded in favour of a design using an electric detonator.
(R.D.H.4502/37, C.6391/39).

4.2.8 Signal, Under-water, exploding DD/L/Sk.1953B, R.D.Sk.F. 5778, DD/L/2018A, DD/L/7567, DD/L/7567A.

In 1936, in answer to a request from C.I.N.O., S.of D. submitted a design of detonating signal using the principle of the R.D. gaine (DD/L/Q.1953B) to which C.S.R.D. added a modification R.D.Sk.F.5778 incorporating the new small gaine then in course of development.

The results were unsatisfactory and a new design DD/L/7567 of R.D. gaine and Baffle and Ignition unit, based on R.D.Design No.4786A was tried in a mock-up to design DD/L/2018A, but again with unsatisfactory ignition.

In view of these results, S.of D. concluded that the margin of certainty of functioning would never be sufficiently large to make the combination suitable for issue to the Service and the investigation was abandoned. (R.D.C.2700/37, N.O.5449/36.*

4.2.9 Lead Azide Sleeve DD/L/7370

Early in 1940, Vickers-Armstrong, Dartford, who had the contract for filling the Base Fuzes, submitted to C.S.R.D. a simplified design based on the principle of the R.D. Gaine, viz. V/A Design No.27258 G.L., Drawing No.27266 G.L. A shortened form of this modification known as the lead azide sleeve, was used by the Department in the short delay fuze.
(R.D.C.4595/39, 3017/40, 9319/40, 592/42, X.A.614).**

4.2.10 Apparatus for Testing Explosives

In 1941, a simple form of R.D. gaine, R.D.No.3753, was applied to small-scale testing to determine whether an explosive is safe against burning to detonation under U.P. conditions.
(Phys./Ex.128, R.D.C.2321/42.

* A file of D.N.O.
** This file is in the Armament Research Department.

4.2.11 Bomb, Incendiary, 20 lb. "J"

In 1944, tha application of the R.D. gaine to avoid the use of an aside sleeve in the window-breaking charge of the above bomb, was suggested by M.D.1.

C.S.A.R. expressed the opinion that in the present state of our knowledge of the principles involved in the operation of the R.D. gaine, it was not possible to apply it to a device required for large scale production.
(O.B.Proc."Q" 2810, 2991).

PART II

SECTION 5 FUZE, PERCUSSION, BASE, DETONATING, LARGE AND MEDIUM - DESIGN

5.1 Fuze, Percussion, Base, Detonating, Large - DD/L/1000 Type

The application of the R.D. gaine principle to the base fuze was one of a series of investigations, some of which had been in progress for years with the No.16D fuze. Within a few years, the action of the R.D. gaine section of the fuze was brought to a high pitch of perfection, but it is to be regretted that, although the percentage of failures has been very greatly reduced, the same perfection has not been reached with the ignitory system even yet. In order to understand the development of the various sections of the fuze, it is advisable first of all to make a brief survey of the general action. (See Figure 6).

The acceleration of the projectile in the gun withdraws the long-stroke detent, the free end of its articulated stem being carried over to one side by the centrifugal force generated by the spin of the shell. The detent is thus locked in the 'armed' position. The upper centrifugal bolt now freed moves out, thus arming the fuze, as soon as the centrifugal force is able to overcome the frictional resistance of the bolt. This resistance is greatly increased temporarily during acceleration of the projectile in the gun but falls off as the acceleration diminishes towards the muzzle. The stroke of the detent is made as long as possible in the hope of delaying the liberation of the centrifugal bolt and the complete arming of the fuze till the shell is outside the muzzle. The precise arming point is, however, not known. The lower centrifugal bolt spring is compressed on rotation of the shell and the lower centrifugal bolt moves out leaving a free passage for the flash from the detonator, which slides forward with the inertia pellet on retardation of the shell and strikes the needle. The strength of the creep spring, the mass of the inertia pellet and the sensitiveness of the detonator must be so adjusted that the detonator does not function until the required shock is delivered, thus enabling the shell to pass through slight obstruction without detonating. A further safety device is in the form of a pea-ball below the inertia pellet. When the inertia pellet moves forward due to the retardation of the shell in the plate, the pea-ball by centrifugal action, moves outwards allowing the passage of the flash from the detonator into the lower part of the fuze.

From here there is a two-way path for the flash, through either the delay or the non-delay channel. The copper stem of a pressure plate closes the entrance to the non-delay side sending the ignitory flash via the delay when the round has been prepared so that a valve in the base of the shell is left open to allow the chamber pressure of the gun to bulge the pressure plate inwards. For non-delay, the valve in the base of the shell is closed by hand before loading the shell into the gun and the chamber pressure is prevented from bulging the pressure plate. The non-delay side of the fuze is thus open to the ignitory flash when the detonator is fired on impact at the target. The flash then passes through the touch-hole and ignites the C.E. in the ignition chamber. The rest of the action is as in the R.D. gaine, where ignition is raised to explosion in the ignition chamber and explosion to detonation at a point usually rather less than one inch along the fire-channel. The lateral confinement of the fire-channel must be sufficiently great to force the detonative impulse upwards into the magazine where it is enhanced by exploders and subsequently initiates the shell filling.

5.1.1 DD/L/990, 1924

In July, 1923, a preliminary experiment on the embodiment of the principle of the R.D. gaine in a base fuze of the No.16 type was carried out in the Research Department. A longitudinal fire-channel was drilled parallel to the major axis of a No.16 fuze, one end entering the magazine cavity and the other terminating in an ignition chamber on the lines of the standard R.D. gaine. The filling of the ignition chamber and fire-channel was carried out in the usual manner and the magazine of the fuze was filled with hand-stemmed C.E. With the fuze fired at rest, good detonation of the magazine was obtained, although the walls of the ignition chamber gave way slightly.

At that time, the final design of the No.16 fuze was uncertain, designs R.L.28490A and DD/L/10 being under trial and the regularity of delay under investigation. C.S.R.D. considered that an attempt to re-design the fuze to incorporate the gaine would not only substantially delay the production of a satisfactory fuze, but also render more difficult the evolution of a reliable gaine. Attention was for the time being, therefore, focussed on the development of the gaine. (O.C.Memo "B" 7180, R.D.C.5604).

S.of D., while in agreement with C.S.R.D. as to the desirability of perfecting the gaine as a separate unit, thought that it would be found eventually both convenient and desirable to include the principle of the R.D. gaine in the fuze itself. On the basis of dimensions supplied by C.S.R.D., S.of D. at the end of 1924 brought out a design of base fuze, DD/L/990, similar to DD/L/110A but with an R.D. gaine and without optional delay. This design was followed shortly by an improved design DD/L/1000.

5.1.2.a DD/L/1000, 1924

The dimensions were based on R.D. gaine, pattern 20,

Fire-channel: Length 2 inches; diameter 0.1 inch
Thickness of annulus 0.2 inch (possibly 0.15 inch)
Filling: C.E. stemmed within density limits, 1.30-1.40 gms./c.c.

Ignition Chamber: Volume not less than 0.3 c.c.
Filling, C.E. density 1.5 gms./c.c.
(O.C.Memos. "B" 7325, 7972, R.D.C.5604).

5.1.2.b DD/L/1000(1) which was the original DD/L/1000 design with an optional delay incorporated, appeared in August 1924. This fuze gave complete detonation with a shell filled T.N.T. and fitted with T.N.T. exploder, but it was thought that the magazine could be improved so as to provide continuity with the exploder system in the event of set forward effects being produced.

For the clearer understanding of the evolution of the DD/L/1000 type of fuze, it has been decided to deal with the development of each of the various parts of the fuze, rather than the fuze as a whole, in chronological order. The following broad subdivisions may be made:

A. R.D. Gaine System - Magazine
Fire-channel
Ignition Chamber

B. <u>Ignitory System</u> - Delay and non-delay systems; Detonating system — Cross channel fillings, Delay Pellet, Creep springs, Inertia Pellet, Needle, Detonator

B. Ignitory System -	Delay and non-delay systems	Cross channel fillings
	Detonating system	Delay Pellet
		Creep springs
		Inertia Pellet
		Needle
		Detonator

A. R.D. Gaine System

5.1.3 Magazine

a. DD/L/1000A, 1925, is the same as DD/L/1000(1) with the suggested modification to the magazine incorporated in it. Pellet exploders were also adopted for use in the exploder cavity in place of exploders of the bag type which some times showed set-up effects.

Since DD/L/1000A is substantially the same as DD/L/110A with the powder magazine replaced by a detonating magazine, no alteration of existing adapters was required. The experimental trials were sufficiently successful for the Ordnance Committee to arrange for the manufacture of 100 fuzes, fitted with E.O.Co. delay fitments.
(O.C.Memos. "B" 8431, 8529, 8618, 8665, 8779).

b. DD/L/1000C, 1925. It was suggested that blinds which had occurred in the trials might be due to the disintegration of the connecting C.E. pellet in the exploder due to the shock of impact. To overcome this defect a modification to DD/L/1000B was proposed by C.S.R.D. in design R.D.No.2724 in which the hollow needle plug of the fuze was prolonged to form a thimble in which an easy-fitting C.E. pellet could be accommodated. This modification entailed a slight deepening of the exploder cavity, thus enabling a more robust pellet to be used for adjustment of depth.

DD/L/1000C, based on R.D.2724, differs from it chiefly in having a screwed cap which C.S.R.D. considered unnecessary.

An alternative method of combatting the effects of disintegration of the pellets was simply a paper wrapping, which proved successful in impact trials and was favoured by the Ordnance Committee rather than any alteration to the design.
(O.C.Memos. "B" 9033, 9156, 9239, 9265, 9381).

c. DD/L/1000G (1925) Picric powder in central magazine. This design is based on R.D.No.2832, a method of fuzing which makes use of a picric powder exploder for use with shellite fillings, which are more difficult to detonate than T.N.T. In order to avoid prematures in the gun due to the formation of sensitive mixtures, the C.E. pellet in the central magazine which was used with T.N.T. fillings, was replaced by a picric powder pellet whenever it was necessary to use the picric powder exploder. The letter A after the fuze number, e.g. No.158A, designates a picric powder exploder and a picric powder pellet in the central magazine.
(O.C.Memo. "B" 9641).

d. DD/L/1000P Increased power of magazine - flat ended magazine cover. It was shown in rest trials by I.N.O. that the picric powder central magazine pellets did not pick up from the magazine ring as well as the C.E. central magazine pellets did, possibly because of the steel wall between the magazine ring and the central pellet. Also there was a weakness in the design in that the central pellet was unprotected from moisture. It was therefore decided to replace the central pellet by an enlarged magazine to design DD/L/1000P. This design has the disadvantage that the magazine filling cannot set forward with the exploder, but it was thought that the size and lateral effect of the magazine should be sufficient to step over any gap which might occur.

(O.C.Memos. "B" 13806).

e. DD/L/1000T Dome shaped magazine cover. Trials confirmed the suspicion that there was a lack of continuity of the explosive in the new system and a dome-shaped magazine cover was introduced in place of the flat-ended magazine cover of DD/L/1000P.
(O.C.Memos. "B" 15022, 15054, 17112, 17255, 17303).

5.1.4 Fire-channel

a. DD/L/1000H 1925. Brass liner for fire-channel. (DD/L/Sk.449). Examination of recovered fuzes showed that impact on heavy armour caused distortion of the fire-channel of the gaine, the consequent alteration in density of the stemmed C.E. giving rise to blinds. Several methods of overcoming this defect were suggested, among them the insertion of a brass liner to design DD/L/1000H into the fire-channel. A simpler suggestion, namely the use of high-grade steel for gaines, having proved successful, the design DD/L/1000H was not adopted.
(O.C.Memos. "B" 16138, 16775).

b. DD/L/1000J 1925. Transverse channel. Blinds with DD/L/1000 type fuzes had been traced to the failure to detonate of the C.E. in the stemmed vertical channel owing to the increase in density of portions of the C.E. on heavy impact. To obviate this defect, a screwed-channel was suggested by S.of D. but in addition to filling difficulties it met with little success in the trials.

In answer to C.S.R.D's suggestion that in addition to a vertical channel, a transverse channel might be included in the fuze so that the change over from ignition to detonation could take place where the C.E. filling was less affected by gun and plate stress, S.of D. produced design DD/L/1000J. There was, however, some doubt on all sides as to its success and in view of the greatly improved results with the vertical channel obtained in the meantime, the latter was adopted for Service fuzes.
(O.C.Memos. "B" 9329, 9522, 9603 III, 9711, 11237).

c. DD/L/1000 S and S* 1926. Stopper at top of stemmed channel. Branched channel. It was suggested that a stopper at the top of the fire-channel might provide a better safeguard to the filling than the Service design when a succession of plates are met with before the delay expires. Two designs were submitted, DD/L/1000S based on R.D.No.2905 and DD/L/1000S*, S.of D's design. DD/L/1000S was finally adopted in certain fuzes.
(O.C.Memos. "B" 9709, 10319, 11736, 13868, 14065, 14177, 15084, 15312, 15313, 17035, 17227).

5.1.5.a Ignition Chamber

DD/L/1000, K, L, M, N Ignition Chamber Closing Plug. Failures in trials had drawn attention to the rate of burning of the C.E. in the ignition chamber and its dependence on the confinement provided. Experimental evidence obtained in the Research Department had shown that the margin of strength for maintaining this confinement in DD//L1000A was much too small and the statement was made by C.S.R.D. that 100 per cent. of detonations could not be achieved without a new design of closing plug.

Three designs of closing plug were submitted by S.of D., DD/L/1000K and DD/L/1000L with side closing plugs and DD/L/1000M with a two-piece base closing plug as suggested by C.S.R.D. in R.D.No.2945, which had been evolved for the R.D. gaine and had never failed in hundreds of gaines.

DD/L/1000M, though based on R.D.2945, differed from it in important items which C.S.R.D. thought essential and a modified design was brought out by S.of D. as DD/L/1000N which was used in subsequent trials. Additional features of DD/L/1000N were

a. Abolition of locking pin and guide screw

b. Improved exploder system of shell filling

The arguments against the base closing plug put forward by S.of D. were:-

1. Its incorporation would entail extensive disturbances to the existing design, viz. increasing the overall length and adopting a different design of keyhole thus entailing alterations to the design of cover-plate.

2. It was not advisable to have powder pellets separated from the propellant gases only by the gas-check and a somewhat short closing plug.

3. The base plug was entirely dependent on its own strength for immovability instead of being backed by the adapter as the side-plug was.

C.S.R.D.'s view was that

1.a The additional expense entailed by change of design was justified if 100 per cent. of detonations were achieved, and experience had shown that the gaine to this design was very successful as a separate unit.

2.a The metal available allowed of ample sealing and with the additional protection of the gas-check no anxiety was felt on the score of safety.

3.a The small thickness of metal available on the side of the fuze body was a weakness in the side-closing plug. It was preferable not to rely on assistance from the adapter since the tolerance of the fuze in the adapter might operate adversely.

S.of D. suggested comparative trials of the two types of closure, but in the meantime developments were taking place in the Research Department which resulted in the production of a much improved design with base closing plug which became the basis of all future development in this type of fuze.
(O.C.Memos. "B" 10271, 10670, 10748, 10858, 12130, 13868, 14635).

5.1.5.b. DD/L/1000R (renumbered as DD/L/3000)

Experiments had shown that in order to provide a margin of safety should gun and plate stresses affect the fuze adversely, it was desirable for detonation to be attained in the stemmed channel at the earliest stage possible. In all the fuzes of the DD/L1000 type, this turnover to detonation took place unduly late. Three factors were thought to contribute to this effect:

1. a leaky closing plug in the ignition chamber;

2. short-circuit of the flash direct to the stemmed channel;

3. excessive pressure produced by too large an amount of gunpowder in the flash pellet.

The modifications suggested by C.S.R.D. to overcome these defects were:-

1.a prevention of leakage past the closing plug of the ignition chamber by the use of the N modification of closing plug;

2.a use of a pressed filling with a short flash cavity for the ignition chamber;

3.a reduction in size of the gunpowder pellets;

4. improvements in the magazine (See Section 5.1.3).

In support of his suggestions, C.S.R.D. brought forward the chart shown in R.D.No.3324 (Figure 20) which shows the variation from round to round of fuzes tested in this connection by the Research Department. In particular, he stressed the great improvement in performance obtained by the introduction of the short gaine R.D.3254 in which the suggested modifications were applied.

In view of the great improvement brought about by the stemmed filling in the ignition chamber, which was rendered possible by base closure, S.of D. withdrew his objections to the base closing plug, and incorporated it, together with the other suggested modifications, in the new design, DD/L/1000R, which showed such promise that it was renumbered as DD/L/3000 and ultimately became the basis of all future development of the large base fuze (See Section 5.2).

Since the DD/L/1000 type fuzes could not be converted to the DD/L/3000 type, priority was at first given to efforts to improve the existing design but these were not successful.
(O.C.Memos. "B" 14635, 14636, 14927, 15055, 15239, 15596)

5.1.5.c DD/L/1000Y 1928. Proposed baffle in ignition chamber. One of the suggestions for improvement of the ignition of the C.E. was the introduction of a baffle into the ignition chamber. The design was not adopted.

B. Ignitory System

5.1.6 Delay and non-delay systems

Cross-channel fillings

a. DD/L/1000Q, 1928, shows the reduced cross-channel pellet suggested by C.S.R.D. for use in fuzes of the DD/L/1000N type under conditions of high shock of discharge. It had been suggested by C.S.R.D. that excessive pressure produced by too large an amount of gunpowder in the flash pellet was responsible for the short circuiting of the flash through the ignition chamber.
(O.C.Memos. "B" 14635, 16099).

DD/L/1000R (see also Section 5.1.5.b)

The reduced cross-channel filling was also incorporated in DD/L/1000R with base closing plug which was re-numbered as DD/L/3000. (For further account see Section 5.2).
(O.C.Memos. "B" 14635, 15596, 16099, 16196, 17390, 18080)

Delay Fitment

b. DD/L/1000U (DD/L/Sk.449), 1928, Spring liner to protect delay fitment.

Break-up of the components of the delay fitment was suggested as a possible cause of irregular delays. One method of overcoming this, suggested by S. of D. was the incorporation of a spring liner to minimise the shock on the delay fitting of impact on heavy targets. Numerous trials were carried out but without much success and it was finally shown by recovery trials that the risk of the delay pellet breaking up was small and that break-up of the perforated pellet did not cause long delays if a paper disc was used. The investigation was therefore suspended.
(O.C.Memos. "B" 13868, 15054, 15129, 15218, 16138, 16193, 16775, 17584, 17847).

c. DD/L/1000V, 1928. Perforated powder pellet omitted. An alternative method for counteracting the effect of break-up of the perforated powder pellet was by omitting it altogether. Although some advantage might have been expected from the application of the principle underlying the DD/L/1000V design, the conditions were evidently too difficult for success and the trials were inconclusive. Moreover, since Trial ID 14 confirmed the rest trials that the break-up of the perforated pellet had no adverse effect on the delay, this investigation was also suspended.
(O.C.Memos. "B" 15563, 15809, 16562, 17076, 17372, 17818, 18280).

5.1.7 Detonating System

Creep Springs (see Table 3)

a. DD/L/1000B, 1925. The results of trials suggested that two fuzes had functioned by air resistance to the shell when it left the muzzle. Investigation of the shape of the head of the shell used in the trial, viz. 6-inch C.P.C. Mk.XV/AQ, disclosed that, although the head was struck with a radius of approximately 4 calibres, its length was only that of one struck with 2.1. calibres. For the calculations on which the strength of creep spring was based, the conditions assumed, viz. 6-inch shell 4 c.r.h., were therefore erroneous in that the shell used must be regarded as a 2 c.r.h. shell for purposes of estimating retardation by air. In order to avoid prematures, the creep springs were therefore strengthened according to design DD/L/1000B to give an ample margin of safety.
(O.C.Memos. "B" 8915, 9352)

b. DD/L/1000 D, E, F, 1925. Prematures in DD/L/1000 type fuzes were found to be due to the weakeness of the creep sping. Different strengths of spring had, therefore, to be calculated for each particular type of fuze in which the spring was used (Table 3).

D	-	creep spring,		86 oz.	in Fuze		No.260
E	-	"	"	100 "	"	"	No.345
F	-	"	"	114 "			

(O.C.Memos. "B" 9352, 9574, 9627, 9712, 9934, 10235)

c. DD/L/1000 GG, HH, JJ, KK, LL, 1928, are designs of special creep springs.

GG	creep spring		120 oz.	
HH	"	"	140 "	
JJ	"	"	160 "	in fuze No.479
KK	"	"	180 "	
LL	"	"	200 "	

(O.C.Memos. "B" 15759, 17390, 21377)

5.1.8.a. DD/L/1000W, 1928. "Waisted" Inertia Pellet. For the reduction of friction between the inertia pellet and the fuze body, various devices were suggested. DD/L/Sk.446 of ball bearing pellet was suggested by S.of D. but considered by the Ordnance Committee as not likely to prove successful. Another suggestion was the "waisted" inertia pellet which was not regarded favourably on account of the limited margin of sealing provided for a prematurely fired detonator. The design was not adopted.
(O.C.Memos. "B" 15379, 15854, 16238, 17578).

b. DD/L/1000X, 1928. Lengthened needle, and modified inertia pellet. In order to improve the sensitiveness of the fuze, various modifications to the inertia pellet, detonator and needle were suggested by S.of D. (DD/L/Sks.628, 631, 632). The suggestion chosen by the Ordnance Committee was that of a modified inertia pellet and lengthened needle, reducing the length of travel of the pellet (DD/L/Sk.628). The lengthened needle was also adopted later in the DD/L/3000 and 4000 designs.
(O.C.Memos. "B" 15853, 16038, 17573, 17578, 18385, 18431, 19238, 21377, 22741).

5.1.9 DD/L/1000 Z, Z*, Z** D.N.O. on 13.8.25 signified his approval for the adoption of fuzes to designs DD/L/1000 and DD/L/110 in place of No.16D in all existing shellite filled shell from 1.5-inch to 5.2-inch, provided that the fuzes could be made air-tight.

Trials for air-tightness carried out at first with copal varnish were suspended in favour of S.of D's suggested modification to the design, consisting of an expanding disc, the grooves of which were coated with R.D. cement before insertion. This modification proved successful and was finally adopted in three forms:

DD/L/1000Z	for new fuzes;
DD/L/1000Z*	for fuzes under manufacture;
DD/L/1000Z**	for fuzes modified from screwed closing plugs (DD/L/1000C)

(O.C.Memos. "B" 9151, 9204, 9296, 9311, 9331, 9564, 9603, 9822, 9844, 9988, 10306).

5.1.10 DD/L/1500 In 1925 the suggestion was made that the sensitivity of DD/L/1000A might be increased by the incorporation of a spring frame. In order to do this the fuze would have had to be modified closely on the lines of DD/L/800. It was judged simpler to add a detonating system to DD/L/800 rather than a spring frame to DD/L/1000A. DD/L/1500 shows the suggested arrangement.

In 1926 the suggestion was again put forward that a frame system should be applied to fuzes of the DD/L/1000 and 110 types. The Ordnance Committee however suspended action on DD/L/1500 type of fuze pending further trials for sensitivity of DD/L/1000 type and the development of the base detonating fuze for smaller natures of shell.
(O.C.Memos. "B" 8665, 8779, 9933, 10426, 11233).

5.2 Fuze, Percussion, Base, Large, Detonating - DD/L/3000 Type

5.2.1 DD/L/3000, 1928, re-numbered from DD/L/1000R.

The decision to carry out trials with the DD/L/1000R type of fuze necessitated the introduction of special designs of gas-check plate, keyhole plugs and fuzing keys. The number DD/L/3000 was therefore assigned to DD/L/1000R to differentiate it from the DD/L/1000 type with side closing plug. The special features of DD/L/3000 are:

1. the base closing plug;

2. the reduced volume of powder in the cross channels;

3. the "S" design, with a metal stopper at the top of the fire-channel and branched channels to the magazine;

4. the "T" magazine;

5. the omission of the locking pellet and guide screw.
(O.C.Memos. "B" 14635, 14927, 15343, 20779).

A. R.D. Gaine System

5.2.2 Magazine

(a) DD/L/3000C, 1929. Special magazine with gaine extension.

In order to overcome the drawbacks of the T magazine, viz. the difficulty of accommodating the domed end and the possible lack of continuity in the impulse system, C.S.R.D. suggested a special form of magazine to design DD/L/3000C, but in view of D.N.O.'s decision to adopt the T magazine and the DD/L/3000S design, it was not required.
(O.C.Memos. "B" 17255, 17429, 18188).

(b) DD/L/3000T, 1928. Dome-shaped magazine cover.

The T magazine was designed originally for the DD/L/1000 type fuzes and applied to DD/L/3000. Its final adoption was due to ease of manufacture rather than to any superiority in performance.
(O.C.Memos. "B" 17429, 18107, 18188, 18246, 19422, 19691).

5.2.3 Fire Channel

(a) DD/L/1000S and 3000S, DD/L/Sk.759, 1928. Branched C.E. channels.

The design DD/L/1000S with screwed plug at the top of the C.E. channel was combined with DD/L/3000 according to design R.D.No.3416 which also introduced a new feature, viz. a branched or Y channel leading to the magazine.

Filling troubles were experienced with this design in that, owing to difficulties in drilling, a ridge was formed at the junction of each branch channel with the vertical channel. To overcome this defect, S.of D. proposed a modification (DD/L/Sk.759) which allowed the drill to travel down the branch channel and remove any ridge but controlled the ultimate reach. A special machine was also devised by C.S.R.D. for stemming the branch channels (Appendix 3) but manufacturing and filling difficulties still persisted and the design was ultimately abandoned in favour of a design with the single vertical channel, DD/L/3000U.
(O.C.Memos. "B" 15121, 15313, 17035, 17227, 17507, 19422, 19850, 20120, 21830, 22069).

(b) DD/L/3000 U, V, W, DD/L/3000U, 1931. Pressed C.E. pellet at forward end of stemmed channel; branch channels omitted.

In order to avoid manufacturing difficulties, D.N.O. suggested that with the T magazine an unbranched channel provided with a C.E. stopper such as had proved successful in Fuze No.501 might be used in place of the branched channels and screwed-in plug of DD/L/3000S.

Three designs were submitted by S.of D.: DD/L/3000U had a pellet of 5.2 grains at the top of the channel as in Fuze No.501, DD/L/3000V and W had pellets 20 per cent. and 18 per cent. larger, respectively. In view of possible manufacturing troubles envisaged with V and W and the satisfactory performance of Fuze No.501, DD/L/3000U was adopted. (O.C.Memos. "B" 22069, 22268, 22411, 24328, 26094, 26172).

5.2.4 Ignition Chamber

(a) DD/L/3000X, DD/L/Sks.893, 893A and B, 894, 894A, 1931. Modified ignition chamber.

In order to overcome manufacturing difficulties in the production of a beehive ignition chamber of volume constant within the close limits required by the specification, S.of D. submitted designs DD/L/Sks.893 and 894 with a cylindrical ignition chamber. From the manufacturing point of view these were much simpler, but did not appear sufficiently strong. Amended designs DD/L/893A and B and 894A were brought forward. Of these, DD/L/893B, suggested by I.N.O.Woolwich, was the most promising, but the cylindrical design, though simpler for production, was less efficient for its purpose of raising the combustion rate of the C.E. to explosion point. The development by C.S.R.D. of a new method of filling the ignition chamber with a pressed-in filling, particularly suited to ignition chambers of irregular volume, rendered further trials with DD/L/Sk.893B unnecessary.
(O.C.Memos. "B" 21684, 22230, 22569, 23380)

DD/L/3000X, 1931. Modified ignition system.

The results obtained, however, indicated the necessity for improving the means of approach of the flash from the cross channels to the ignition chamber and a design DD/L/3000X was brought out with an additional flash-hole in the closing plug of the ignition chamber at right angles to the exisiting one. This design was chosen with the slight modification that the horizontal flash -holes were increased in diameter from 0.04-inch to 0.06-inch.
(O.C.Memos. "B" 22945, 22793, 23003).

DD/L/3000X (a), (b), (c), (d), N.X.(d)

Trials of fuzes with modified cross channel fillings and ignition chamber closing plugs to design DD/L/3000 N X (see Section 5.2.5.a) showed that the X modification was not effective enough to secure quick ignition with non-delay setting. It was proposed to try the effect of restricting the blow-back of gases from the cross-channel filling on the non-delay side in the same way as on the delay side by replacing the fibre sleeve at the outer end of the cross channel by a brass fitment with a 0.04-inch taper hole. These modifications were incorporated in DD/L/3000X (a). This was again modified to DD/L/3000X (b), a three-piece closing plug incorporating a booster gunpowder pellet close to the C.E. filling. During the filling of fuzes to this design, a slight modification was found necessary to obviate the risk of C.E. being nipped by the threads of the closing plug. This modification was incorporated in DD/L/3000X (c) to which, as the result of further experience, slight dimensional alterations were made to facilitate assembly, the final design DD/L/3000X (d) being used in conjunction with the N modification in the series of trials mentioned in Section 5.2.5.a.

Although design DD/L/3000NX(d) was the best compromise to apply to fuzes already manufactured, it had certain disadvantages:

(i) the performance when set non-delay was not satisfactory in that a burst could not be achieved within 10 feet of the plate and the specification had to be amended accordingly;

(ii) the design of closure of the ignition chamber - the 3-piece plug - was too complicated;

(iii) the process of filling was lengthy and required careful supervision and inspection.

The Ordnance Committee, while concurring in DD/L/3000NX(a) for existing stocks of fuzes, were in favour of a complete re-design of the ignition chamber and cross-channel arrangements. DD/L/3000Z(a) and (b) were produced by S. of D. in answer to their request. For further developments from DD/L/3000NX(d) see Section 5.2.5.a.
(O.C.Memos. "B" 23396, 23485, 23907, 24299, 24541, 25253, 25320, 25354, 25696, 25953, 26629, 26870, 26939, 27724, 27725)

(b) DD/L/3000Y Single flash hole in line with cross channel.

A modification to DD/L/3000X was proposed by I.N.O.Woolwich, who thought that some of the variation in the results with the fuze set non-delay might have been due to the varying position of the entry flash holes in the plug relative to the cross channel. This would be obviated by a single flash hole in line with the cross channel. DD/L/3000Y was rejected in favour of DD/L/3000X.
(O.C.Memos."B" 23003, 23485).

(c) DD/L/3000Z (a) and (b), 1931. Proposed new design of cross channels and ignition chamber similar to those in Fuze No.501 (DD/L/4000 Type).

The success of fuze No.501 led to the suggestion that a similar type of ignition system should be adopted in the large base fuze in place of the complicated design DD/L/3000NX (d). The chief features of the design submitted by S. of D., DD/L/3000Z (a) and (b), are:-

(i) It has a direct lead from the cross channels to the ignition chamber obviating the present tortuous passage through the ignition chamber closing plugs.

(ii) The angle between the main flash channel and the non-delay cross channel is less acute.

(iii) There is an increase of approximately 100 per cent. in the igniting surface of the C.E. filling in the ignition chamber.

The designs differed in the shape of the ignition chamber (a) being beehive-shaped (b) cylindrical.

The Ordnance Committee proposed trials of design DD/L/3000Z (a) because of the anticipated simplicity in manufacture and filling. C.S.R.D.,however, who filled the fuzes, found that they could not be filled by the usual methods and that individual assembly would be required for each fuze, a defect which condemned the design at the outset. Also, the delays obtained were about 12 feet so that no superiority in performance was achieved by its use.

(O.C. Memos "B" 25696I, 25903, 26870)

B. Ignitory System

Delay and non-delay systems

5.2.5 Cross channel fillings

(a) DD/L/3000M, 3000N, 1931. Increased powder filling in cross channels.

In 1927, failures with DD/L/1000 type fuzes had been ascribed to excess pressure on the C.E. pellet in the ignition chamber from the gun-powder in the cross channels. The quantity of gunpowder was therefore reduced in designs DD/L/1000Q and DD/L/1000R (DD/L/3000).

As a result of subsequent trials, the view was taken that this reduction in the gunpowder content of the cross-channels had at last been overdone and that it was sound policy to use a cross channel filling of the maximum possible size without upsetting the ignition chamber filling. The greatest filling possible without further machining represents a 48 per cent. increase, shown in DD/L/3000M, while DD/L/3000N gives an increase of 105 per cent., achieved by deepening the cross channels.

Of these two designs, DD/L/3000N proved the more satisfactory and was combined with the X modification in a series of trials which finally culminated in the production of design DD/L/3000NX (d) (see Section 5.2.4).

(b) DD/L/3000NN is identical with DD/L/3000N except for a small choke pellet in the cross channel on the detonator side of the gunpowder pellet.

Trials of No.480 fuzes modified to DD/L/3000MX (c) with the delay pellet perforated and the non-delay side closed, gave a delay of 6 feet, showing that where blow-back was prevented, sufficient rapidity of action could be obtained. It was therefore suggested that the same principle might be successfully applied to the non-delay side, and trials were carried out with fuzes No.480 and 159 modified to DD/L/3000NX (d) with perforated powder pellet and diaphragm on the non-delay side. No improvement was achieved, the mean delay being 15.8 feet.

It was then thought that the rapidity of action of the perforated delay pellet might have been due to the quick pick-up of the grain powder compared with that of a perforated pellet. Substitution of grain powder and a diaphragm for the pellet gave a mean delay of 11 feet.
(O.C.Memos."B" 21862, 22019, 22392, 23907, 24299, 25696II, 25953, 26151)

R.D.No.4614, 1933. Grain powder and capsule in cross channel.

The success of the first trials with grain powder led to the proposal that the whole of the non-delay side should be filled with grain powder in place of the perforated pellet, a capsule being fitted to prevent the seating of the pressure plate from being contaminated. With this arrangement, a mean delay of 6.4 feet was obtained. Drastic trials were suggested in order to test whether this modification should be generally applied for Service use and were carried out with 13.5-inch shell against 1-inch plate at 1500 f.s., non-delay setting. The results were not satisfactory, delays varying from 55 feet to 7 feet being recorded.
(O.C.Memos. "B" 26151, 26629, 26747, 26939, 27724, 28130).

I.N.O.Sk.No.126, 1933. Perforated screw plug and grain powder on non-delay side of fuze.

Because of manufacturing difficulties with R.D.No.4614, I.N.O. submitted a sketch of a proposed assembly. It was, however, felt that too much care was required in the assembly of this fitment and that, moreover, the grain powder was not completely successful. Apart from the possibility of its escape from the cross channel, it formed a stronger backing for the paper disc than the perforated pellet and would be more difficult to blow away. No further trials were carried out with the grain filling.
(O.C.Memos. "B" 27725, 28130)

R.D.No.4699, 1933.

R.D.Sk.No.F.5770, 1936.

Improved designs embodying later modifications to the cross channel system are described in full in Section 5.8.

Detonating System

5.2.6 Creep Springs

DD/L/3000 A, B, D, E, E, F, GG, HH, JJ

The creep spring strength is the same as for corresponding DD/L/1000 numbers.

5.2.7 Inertia Pellet - Detonator - Needle

(a) DD/L/3000 P, Q, and R, 1929, DD/L/Sks.372 and 606. Enlargement of flash hole and provision of debris trap in inertia pellet.

Trials carried out to establish the cause of irregular delays had established that constriction of the flash channel just below the detonator and accumulation of debris from the detonator, due possibly to insufficient tamping above, could bring about lengthened delays. S.of D.'s design DD/L/3000 P,Q and R is based on DD/L/Sk.No.372 (P modification) and DD/L/Sk.No.606 (Q modification) the former giving an enlarged entry to the flash hole and increased tamping and the latter embodying a debris trap. The combination of the two modifications is DD/L/3000R, which was approved for inclusion in Service fuzes.
(O.C.Memos. "B" 16196, 17635, 18669, 19422, 20505).

(b) DD/L/3000R (a) Proposed modification to flash channel.

In consequence of a blind in which the debris from the detonator appeared to have obstructed the flash channel in spite of the debris trap, C.S.R.D. suggested that the design should be modified so that the inclined portion of the flash channel should enter the masking bolt recess and not the debris trap. DD/L/3000R (a) was accordingly brought out by S.of D. who pointed out, however, that the new design reduced the efficiency of the masking bolt as a safety device. The design was not adopted.
(O.C.Memos. "B" 25097, 25341).

(c) DD/L/3000G and H, 1932. Modification to Inertia Pellet to take large detonators.

Although success had been obtained with the No.159 fuze when set delay, frequent failures occurred with the non-delay setting.

A possible cause for these failures was sought in the long and tortuous passage through which the detonator flash had to ignite the C.E. pellet in the ignition chamber, assisted on the way only by a perforated gunpowder pellet as opposed to the delay pellet on the delay side. Trials with larger detonators had been carried out under delay conditions with a view to shortening and regularising the length of delay, without success, but trials with a non-delay setting had never been carried out. C.S.R.D. argued that the provision of a larger detonator would not, according to these earlier trials, upset the existing delay conditions, but might supply the extra necessary impulse to improve the results at non-delay setting. DD/L/3000G and H show the modifications to the inertia pellet to take a 3.5 grain detonator to design DD/L/5527 (G) and a 4.0 grain detonator to design DD/L/5528 (H). The improvements hoped for not being realised in trials carried out with fuzes to design DD/L/3000 NGX and NHX, it was decided to try C.S.R.D's earlier suggestion of a booster pellet close to the touch-hole of the ignition chamber. This modification, DD/L/3000 X (b), is dealt with in Section 5.2.4.a.
(O.C.Memos. "B" 17964, 18388, 19340, 24397, 24488, 24968)

(d) DD/L/3000K, 1936. Two flash channels in inertia pellet and no debris trap.

The occurrence of one blind was traced to the possibility of the pea-ball having blocked the exit to the flash channel in consequence of the similarity in dimensions between the pea-ball and the annulus round the base of the inertia pellet into which the flash channel emerged. In order to overcome any such possible blockage, a design was tried with two flash channels, so that if one should be blocked, there would still be an alternative route. The debris trap was considered unnecessary since the chance of both channels being blocked was extremely small and for ease of manufacture its omission was advantageous.

The incorporation of the double flash channel reduced the distance when set 'non-delay' to about 9 feet, a satisfactory result. As anticipated, the distance when set 'delay' was also reduced by about 20 per cent. The thickness of the pressed gunpowder delay is not specified and the filler is expected to adjust it by experiment to give the delay required. This loss of 20 per cent. was therefore readily restored.

In the meantime other improvements to the detonating system had produced such good results with fuzes No.159 and No.480 at non-delay setting, that the committee, in 1938, decided to suspend action with the K design for the time being.
(O.C.Memos. "B" 31821 II, 32126, 32186, 32856, 34007). (O.C.Memo.1424)

(e) R.D.No.4699 (Figure 18)

In the new design of fuze No.159 proposed by C.S.R.D. in 1934, a single-hole base detonator was introduced in place of the four-hole base detonator of the Service fuze to give an easier escape for the detonator gases through the flash-hole in the inertia pellet. This detonator was of the lugless type without a washer and with a thinner shell than the Service type. In trials with Service fuzes the modified detonator, filled with Service "C" composition gave a satisfactory performance.
(O.C.Memos. 27724, 30304, see also Section 8.1).

(f) R.D.Sk.F.5452 (Figure 23(a))

In order to provide extra tamping for the detonator, a modified detonator plug of the type shown in R.D.Sk.F.5452 was suggested, but

not approved on account of the danger of crushing the needle cap by bringing the inertia pellet to a dead stop.
(O.C.Memos. "B" 30048, 30227).

(g) R.D.Sk.F.5498 (Figure 23 (b))

A modified form of detonator plug was next designed to direct the detonator gases through the inertia pellet. Precautions were also taken to render it impossible for the needle to over-penetrate the detonator and cause blinds by partially or wholly sealing the flash hole through the inertia pellet. This improvement was subsequently embodied in the new design of fuze R.D.Sk.F.5770.
(O.C.Memos. "B" 30304, 31821 II; see also Section 8.2)

(h) DD/L/Sk.1989

Difficulty of filling and the necessity for new gauges were brought forward by S.of D. in criticism of C.S.R.D.'s design of lugless detonator (Item e). He proposed a new design on more orthodox lines, using a Service 5-grain lead azide detonator shell with a single hole punched in the base and filled with 4 grains of Service "C" composition. Adjustment was made by varying the thickness of the closing washer. The Ordnance Committee favoured the lugless detonator if it was decided to adopt the larger form.
(O.C.Memos. "B" 31820, 32983)

5.3 Fuze, Percussion, Base, Medium, Detonating, DD/L/2000 Type

In view of the success attendant on the application of the R.D. gaine principle to the large base fuze, D.N.O. asked that it should also be applied to the smaller natures of shell in a fuze on the lines of DD/L/1000, non-delay setting, and with the same gauge as service medium base fuzes. It was required to function in 3-inch and 4.7-inch S.A.P. shell giving a delay of 4-6 feet.
(O.C.Memos "B" 9867 II, 10026, 10579).

5.3.1 Ignition Chamber

a. DD/L/2000, DD/L/2000A, 1926.

Both designs followed the general lines of DD/L/1000 except for the magazine cover which in the new design was of a simpler type.

DD/L/2000: The special feature of this design was a base closing plug in the ignition chamber and the placing of the fire-channel central in the section of the fuze body wall, theoretically not the best place for strength but necessary in order to separate the upper end of the ignition chamber from the central bore hole of the fuze.

DD/L/2000A: This design had the side-closing plug, preferred by S.of D., which enabled a stronger position to be chosen for the vertical channel and a longer vertical channel to be incorporated. Although this design was not favoured by C.S.R.D., it proved more sensitive than the later design DD/L/2000C, and in general more satisfactory in trials. It was eventually adopted for Service as Fuze No.500 (N.O.D.3300).
(O.C.Memos. "B" 11035, 13001, 14443, 14636, 14951, 15378, 16162, 18671, 19838. Table 1)

b. DD/L/2000B, R.D.No.2945, 1926. Modified side closing plug. Neither of the designs DD/L/2000 or 2000A met with C.S.R.D.'s approval and a stronger design with a type of horizontal plug based on R.D.No.2945 was suggested.

DD/L/2000A was modified accordingly to DD/L/2000B, further slight modifications being added subsequently in DD/L/2000B(i), but the design still suffered from several defects.

(a) There were considerable difficulties of manufacture and filling.

(b) The channel through which the ignition flash had to pass was not only tortuous but variable in that the cross channel in the closing plug was sometimes in line with the communicating flash channel and sometimes not. This could hardly fail to give rise to irregularity of delay.

(c) The design offered a passage for C.E. dust into the interior of the fuze.

(d) The side-closing plug of the ignition chamber did not give air-tight closure over its threads, an objection which C.S.R.D. had brought forward against DD/L/2000A.

DD/L/2000B was replaced by DD/L/2000C.
(O.C.Memos. "B" 11682, 12121, 13081)

e. DD/L/2000C, 1927. Modified ignition chamber plug.

This design overcame most of the defects of DD/L/2000B, in particular the possibility of entry of C.E. dust into the interior of the fuze. Another advantage was its ability to make use of the pressed-in filling. There were still, however, the weakness in the position of the ignition chamber and the coarse thread on a closing plug of small diameter. For some time this modification appeared to be the best and fuzes were ordered to this design, but finally in a series of trials with DD/L/2000A, DD/L/2000C and DD/L/2000C modified to DD/L/2000H, A gave the most consistent results and was in consequence adopted for Service use.
(O.C. Memos "B" 12323, 13001, 13081, 14636, 15688, 16162).

5.3.2 Cross Channels

a. DD/L/2000G, DD/L/2000H, 1927. Reduced powder filling in cross channel. (1 sheet)

This modification was introduced at the same time into fuzes of the DD/L/1000 and 2000 types because of the supposed adverse effect of the pressure of an excess of gunpowder on the C.E. in the ignition chamber. Much work was carried out on various types of cross channel filling in the DD/L/1000 type and in DD/L/3000 the cross channel filling was increased again. In DD/L/2000 type, the results did not justify the decrease and a return was made to the original type A.

(DD/L/2000G is DD/L/2000A modified to take a 3.7 grain powder pellet)
(DD/L/2000H is DD/L/2000C modified to take a 3.7 grain powder pellet)
(O.C.Memos. "B" 14636, 14951, 15378, 15688, 15855, 16162)

b. DD/L/2000H, 1928. In this later design of DD/L/2000H the locking pellet and guide screws are omitted. This type was later incorporated in the new design DD/L/4000.
(O.C.Memo. "B" 16052).

5.3.3 Creep Springs

DD/L/2000D, E, F DD/L/2000A with weaker creep springs (Table 3)

A	creep	spring	58 oz.
D	"	"	44 "
E	"	"	29 "
F	"	"	14.5 oz.

(O.C.Memos. "B" 19460, 19975, 20183, 20924)

5.3.4 Needle

DD/L/2000J, 1930. Lengthened Needle.

Trials similar to those with DD/L/1000 and DD/L/3000 were carried out with a lengthened needle reducing the inertia pellet travel from 0.26-inch to 0.14-inch. Improved sensitiveness was the result.
(O.C.Memos. "B" 19460, 19679, 19823, 19839, 20091, 20445, 21139)

5.3.5 Magazine

DD/L/2000T, 1928. Domed magazine cover.

The new design of slightly domed magazine cover caused an increase in overall length of fuze of 0.03-inch but gave an actual reduction in volume of 6 per cent. It was adopted for the new design DD/L/4000 but not for DD/L/2000 on account of the filling alterations which would have been entailed.
(O.C.Memos. "B" 14636, 15856, 18246)

5.4 Fuze, Percussion, Base, Medium, Detonating, DD/L/4000 Type

Although the general performance of the DD/L/2000 type fuzes was good, they were not entirely satisfactory. In particular, they appeared to lack sensitiveness in consequence of their greater velocity, both rotational and axial. Although it was discovered later that some of this insensitiveness was due to the use of unsatisfactory ammunition in trials, it was decided to carry out certain improvements to the fuze,notably an increase in the weight of the inertia pellet. Since this involved a considerable departure from the original design in that the new fuze was not interchangeable with fuze to DD/L/2000, a new number was given to the heavier pellet types.

5.4.1 Inertia Pellet

a. DD/L/4000, 1928. Heavier inertia pellet.

In order to get the extra mass required, the length of the inertia pellet was increased by $\frac{1}{4}$-inch and the bore very slightly.

The DD/L/2000H design, with the locking pellet and guide screw omitted, was incorporated in the new design.
(O.C.Memos. "B" 14636, 15116, 15347, 15688, 17805)

b. DD/L/4000B, 1930. Lengthened needle and modified pellet.

Trials with lengthened needle gave increased sensitiveness. This modification was therefore adopted, together with the necessary alteration to inertia pellet and creep spring (DD/L/4000C). (O.C.Memos. "B" 21139)

c. DD/L/4000D, 4000E, 1930. Improved inertia pellet.

DD/L/4000D In order to reduce friction by limiting the travel of the masking bolt a design DD/L/4000D with a retaining screw was proposed by S. of D. It was not approved of by the Ordnance Committee on the grounds that some form of stabbing would be necessary to secure the retaining screw.

DD/L/4000E was a simpler form in which a small lip of metal prevented the masking bolt from projecting beyond the line of the inertia pellet. The results of the trials with this design, did not, in the Committee's opinion, justify the additional complexity of manufacture entailed.
(O.C.Memos. "B" 20672, 22643).

5.4.2 Creep Spring

DD/L/4000C, 1930. Creep Spring 152 oz. (Table 2)

Since the frictional hold on the inertia pellet was held to be a quantity variable not only from round to round, but even at different periods in the same round, it was decided to use a creep spring of sufficient strength, unaided by friction, to prevent the creep of the inertia pellet under the most severe conditions of retardation of the shell.
(O.C.Memos. "B" 19975, 20183, 20924)

5.4.3 DD/L/4000A, 1929. Modified magazine.

At C.S.R.D.'s suggestion, the magazine was made much more powerful. A magazine cover similar to that of DD/L/3000T was adopted, together with a C.E. pellet twice as thick as in DD/L/2000A. The increased size of pellet involved an increase of overall length of 0.6-inch over that of fuze No.500. By shortening the exploder, it could be accommodated in a shell cavity designed to take No.500 but not No.12.

In order to reduce friction to a minimum, the inertia pellets were made of Monel metal and passed through a sizing die.

At the beginning of 1930, this design was adopted as fuze No.501 for both Naval and Land service in the 4.7-inch S.A.P. shell (N.O.D.3328). (O.C.Memos. "B" 18246, 18994, 19780, 19838; Table 1)

5.5 Fuze, Percussion, Base, Large, Detonating, DD/L/5000 Type

This fuze was designed to replace Fuze No.16D in old stocks of 9.2-inch A.P.C. shell, which it was considered unsound to refuze with the new base detonating fuze No.346 (DD/L/3000 type) recommended for use with the new type of 9.2-inch A.P.C. shell. The new fuze gave a delay of 30-40 feet, i.e. too long for the performance of the old shell, which could not be guaranteed to penetrate further than the first obstruction. The best chance of success with such shell would be obtained by the use of a fuze giving only sufficient delay to ensure this initial perforation, for instance a fuze like No.501 giving 4.7 feet delay at 1500 f.s. Since fuze No.501 itself was too small for the 9.2-inch shell, S.of D. was asked to design a fuze with the external contour of DD/L/3000 type fuzes and the internal arrangement of fuze No.501 (DD/L/4000 type) with the necessary adjustments to suit the 9.2-inch shell.

5.5.1 Two designs were brought out:-

a. DD/L/5000, 1932. Internal system of DD/L/4000 type embodied in DD/L/3000 type contour.

In connection with this design, S.of D. pointed out that the detent system required at least 4.4 tons/sq.inch to arm in the 9.2-inch gun, thus allowing no factor of certainty and presenting a serious handicap if it should be desirable to use the fuze in any larger gun. An alternative design was suggested.

b. DD/L/5000A, 1932. DD/L/3000 type fuze with DD/L/4000 type fire-channel system.

Except for the fire-channel, this design is identical with DD/L/3000, an advantage for manufacture and inspection. The design was approved for trial by the Ordnance Committee and gave satisfactory results in the preliminary rounds against 1-inch M.S. plate.

Before carrying out large scale trials, a small-scale comparative trial was staged with 9.2-inch shell, fuzed No.16D, against 3-inch and 1-inch plate. In view of the results, viz. 75 per cent. of detonations, it was regarded as better economy to buy modern shell rather than to spend money on developing a new fuze for use with old shell.

DD/L/5000A was again brought forward by S.of D. at a time when the difficulties of combining delay and non-delay systems in one fuze appeared almost insurmountable; but D.N.O. was averse to the consideration of separate delay and non-delay types for the large base fuze.
(O.C.Memos. "B" 24738, 24840, 25582, 25627, 32056)

5.6 Fuze, Percussion, Base, Large, Detonating, DD/L/6000 Type

The development of design DD/L/6000 was an attempt to combine the best feature of the DD/L/1000 and 3000 types in order to secure detonative efficiency combined with ease of manufacture and filling. The purpose of the ignition chamber filling in the R.D. gaine system is twofold,

(i) to develop the necessary heat and pressure to cause detonation of the C.E. within one inch of the beginning of the fire channel, and

(ii) to seal this end of the fire-channel until such pressure has been developed.

The main defect of the DD/L/1000 type was that the manufacturing tolerances enabled the flash upon occasion to by-pass the C.E. pellet in the ignition chamber and ignite the stemmed filling in the fire-channel before sufficient pressure had arisen in the ignition chamber, with the result that the C.E. in the fire-channel burned without ever achieving detonation.

Two methods were suggested for improving design DD/L/1000:-

(a) A plug of stemmed C.E. (density 1.5 gm./c.c., length 0.13-inch) consolidated into position at the end of the channel next the ignition chamber.

(b) A brass septum 0.01-inch thick covering the ignition chamber end of the stemmed channel.

5.6.1 Trials of No.158 fuzes fitted with these modifications having proved satisfactory, S.of D. was asked to design a new type of fuze along the same lines.

a. DD/L/6000, 1934; R.D.Sks.5452, 5498; DD/L/Sk.1818, 1935.

The new design followed the lines of Fuze No.158 with the modifications suggested and with a debris trap in the inertia pellet as in Fuze No.159. The preliminary trials gave a shorter and more regular delay of approximately 10 feet at the non-delay setting, but in later trials trouble was experienced as a result of over-penetration of the detonator by the needle which tended to block the flash channel into the inertia pellet.

R.D.Sk.No.5498, Figure 23b, shows a proposed means of limiting the travel of the needle.

DD/L/Sk.1818 is the modification proposed by S.of D. in which a thinner needle is used. The results of trials showed that whereas the fuzes with the thin needle when set non-delay gave good results against thick plates, it was doubtful whether there was sufficient tamping of the detonator gases when they were used against thin plates.
R.D.Sk.5452, Figure 23a, with a tamping ring on the detonator holder was suggested for use with thin needles to improve the results against thin plates.

Trials of DD/L/6000 type fuzes, modified to DD/L/Sk.1818, in 13.5-inch shell proved very disappointing, probably as a result of insufficient tamping. Trials in the 6-inch shell were satisfactory but not as good as those with the No.479 fuze.

In 1936, in view of the Admiralty's decision not to proceed in the meantime with new designs of fuzes, development ceased. (O.C.Memos. "B" 26978, 28436, 30228, 30650, 31375, 31821, 32004, 32097, 34736).

5.7 Fuze, Percussion, Base, Large, Detonating, DD/L/7000 Type

The difficulty of obtaining satisfactory results with the fuze set non-delay without upsetting the delay side led to the production of a design DD/L/7000 with two separate detonating systems.

5.7.1.a DD/L/7000, 1936. Optional delay with separate detonating systems.

Many of the improvements suggested by C.S.R.D. in R.D.No.4914 (Section 6.2.1) were incorporated, also the following features:-

(a) side-closing ignition chamber (similar to DD/L/1000 type)

(b) a thin needle and increased tamping of detonator (DD/L/1818 and 1818A)

(c) two flash channels and no debris trap (DD/L/3000K)

(d) C.E. ignition system of fuze to design DD/L/6000

(e) central pressure plate.

b. DD/L/7000A and B, 1936. This design is similar to DD/L/7000 except for the ignition chamber on the non-delay side which is similar to that of fuze No.501. It is therefore an attempted combination of the large and medium base fuzes in the large type. In DD/L/7000, however, the detonator flash has a considerably longer travel before reaching gunpowder than in the medium base fuze.

As a result of the decision of the meeting held at the Admiralty on the 16th September, 1936, that no new design of fuze should be considered in the meantime, no trials of this fuze have ever been carried out.
(O.C.Memos. "B" 32056, 34736)

5.8 Proposed New Designs

5.8.1 R.D.No.4699

In 1934 suggestions for an improved design of fuze No.159 were submitted by C.S.R.D. to the Ordnance Committee for consideration. The new features were:-

(a) A more powerful detonator - the existing 3-grain 4-hole base detonator filled with "A" composition was replaced by a single-hole base filled with Service "C" composition which produces more hot particles than the 6.6.4 composition in use.

(b) Sinking of the detonator deeper in the inertia pellet so that greater tamping of the mouth of the detonator was obtained.

(c) A longer needle to compensate for (b)

(d) an empty "dead-head" contiguous to the ignition face of the gunpowder to assist in the ready dispersal of air between the detonator and the gunpowder.

(e) A filter of low density gunpowder with a flash cavity to trap incandescent particles.

(f) A one-piece closing plug of bronze in place of the 3-piece steel closing plug of NX(d).

At first, there was a certain amount of opposition to the single-hole base detonator on the grounds of difficulty in manufacture and inspection, but it was not sustained in the face of C.S.O.F.'s willingness to undertake the work. The trials carried out with the various types of detonator are described in Sections 5.2.7 and 6.2.2.

The design was not adopted in its entirety, but several of the features were investigated separately with varying success. The results of the various trials led C.S.R.D. to submit to the Ordnance Committee an entirely new design of the fuze R.D.Sk.F.5770.
(O.C.Memos. "B" 27724, 27970, 28465, 28882, 30048).

5.8.2 R.D.Sk.F.5770 (Figure 19)

The difficulties experienced with both No.158 and No.159 fuzes are in large measure due to the initial necessity of making the fuzes conform, as far as possible, to existing fuzes. Had S.of D. and C.S.R.D. in the first instance been given a free hand to design the best possible fuze for the purpose, much time, money and labour would have been saved and a more satisfactory fuze produced.

In order to overcome the many difficulties inherent in the existing design, C.S.R.D. in 1936 produced a completely new design of fuze, R.D.Sk.F.5770. The R.D. gaine system, which had reached a high stage of perfection, was retained, together with the C.B. method of filling the ignition chamber.* The chief alterations lay in the very considerable simplifications from a manufacturing point of view, the incorporation of a non-delay system as similar as possible to the pierced delay which had produced such good results, and in the moving of the optional delay setting device on to the fuze axis, thus making it possible to envisage an automatic delay or non-delay setting mechanism in the loading rammer, a desirable feature in at least the 8-inch gun cruisers with their semi-automatic loading gear. The new fuze would be cheaper to manufacture because it is through-drilled on the axis and the safety mechanism is considerably simpler.

The main features of the design are:-

R.D. Gaine System - This part of the fuze remains substantially as in the DD/L/3000 type. As far as is known in the Department, no failure was ever traced to the gaine system after the C.B. method of filling the ignition chamber was introduced. The best features of the DD/L/3000 NX(d) design are embodied in the closing plug.

Ignitory System -

(a) Cross Channels - Diagonal flash holes are introduced sloping at the ignition chamber end and opening into a flash gallery cut in the screw threads of the body cavity of the ignition chamber.

(b) Delay and non-delay - The delay fitting is unchanged, and on the non-delay side the "pierced delay" principle which gave very good results in the trials, has been incorporated.

A central pressure plate of reduced diameter replaces the former eccentric plate which caused difficulty in manufacture and assembly. There are four reasons for centralising the pressure plate:

1. It makes possible the retention of the proved delay ignition system and allows the application of the "pierced delay" principle to the non-delay side.

2. It enables the gas-check to be a flat disc with a central pocket which would rotate and seat itself as the cover plate is screwed home.

3. The axial position of the optional delay mechanism makes it possible to envisage automatic delay and non-delay setting.

4. The cost of production would be less.

(c) Inertia Pellet, Needle and Detonator -

1. The flash holes in the inertia pellet are simplified and the debris trap omitted.

2. The masking bolt cannot be blown out by blast from the detonator.

3. The pea-ball cannot block the exit from the flash-hole.

4. Precautions are taken against over-penetration of the detonator by the needle.

5. The detonator plug is designed to take a more powerful detonator and to provide heavier tamping, thus directing a more powerful flash through the inertia pellet.

* See p.37

Although C.S.R.D.'s design was warmly supported by S.of D. who recommended its adoption with only slight amendments, the Admiralty decided against the development of any new fuze in the meantime. The wisdom of this step may be questioned in view of two recent reports published by I.N.O., New York, in 1943 and 1944 respectively, in which the same defects of the ignitory detonating system are pointed out as were pointed out by C.S.R.D. in 1936 and almost identical remedies suggested.
(O.C.Memos. "B" 32117, 34736 (and Appendix),36377)
(O.B.Procs.29089, 29096; Appendix 5 to this report).

SECTION 6 FUZE, PERCUSSION, BASE, DETONATING - FILLING

In the early stages of the work, the fuzes were sent to the Research Department for the R.D. gaine filling, but with increased development, this procedure became impossible and filling was handed over to the Royal Ordnance Factory, Woolwich, and to the Thames Ammunition Works, the methods being carefully laid down in the appropriate specifications. With the outbreak of war, the operations previously carried out at Woolwich were transferred to Bridgend, where trouble was experienced in 1942 with unsatisfactory fillings (Appendix 2). The question of a new stemming machine, more efficient and less dependent upon the personal factor, was raised, and the Research Department produced a type of multiple head stemming machine designed to meet requests for production on a large scale. It was not thought advisable, however, to make any major alterations during the war to the methods used. Minor alterations were made to the existing machines to improve their functioning and a better product resulted.

The details of the various fillings are given in the appropriate specifications and DD/L/ method of filling designs. In this section a brief survey is given of the development of these methods.

6.1. A. R.D. Gaine System

6.1.1 Magazine

The original DD/L/1000 magazine in the form of a ring containing compressed C.E. was not sufficiently powerful and made no allowance for set forward of the exploder pellets upon impact. An additional central pellet of C.E. was therefore introduced in DD/L1000A. Owing to its tendency to break-up on impact, the pellet was wrapped in paper. In fuzes of the "A" type which were used with a shellite filling and picric powder exploder, the C.E. pellets were suspected of giving rise to prematures through the formation of sensitive mixtures and were replaced in DD/L/1000G by picric powder pellets. The latter, however, proved less sensitive than C.E. and in the end the whole design of magazine was altered, the final form being a single domed cavity filled with a pellet of C.E. pressed in a floating mould to a density of 1.5 gm./c.c. (DD/L/1000T). This arrangement had the additional advantage of being water-tight. (O.C.Memos."B" 8431, 8529, 9641, 13806, 14395, 14938).

6.1.2 Fire-channel

One of the major problems faced by the Research Department was the production of a suitable filling for the fire-channel. Experimental work on the R.D. gaine had shown the extreme importance of the density of this filling in enabling the rate of reaction to rise from explosion to detonation values within a certain limited distance. There were in addition the requirements necessitated by mechanical filling and impact stresses in the gun and on the target; that is to say, the required filling must be of a free-flowing type, with a density varying within narrow limits, capable of being compressed, within even narrower limits, to the density required for the fire-channel, and able to remain in this condition until detonation took place.

In the first instance, a screwed channel was suggested by S. of D. (DD/L/1880) but filling difficulties proved too great and trials were discontinued.

Three methods of filling the vertical channel in such a way as to overcome the impact stresses were suggested by C.S.R.D. :-

1. Uniform density (E method using corned C.E.)

   Filling was completed in about 30 stemmings to a practically uniform density of 1.3 gm./c.c.

2. Screw-filling (H method using corned C.E.)

   The average density obtained was 1.3 gm./c.c., the explosive in the channel being in the form of a relatively soft core with a harder exterior.

3. Alternating densities (J method using aggregated C.E.)

   The increments were adjusted so that alternate layers of relatively hard and soft material were obtained, an average density of 1.3 gm./c.c. being used in the first instance (limits 1.32-1.28 gm./c.c.).

The results of trials led to the adoption of the J method with a slight amendment in the density limits, viz. 1.25-1.19 gms./c.c.

Two important developments were responsible for the solution of this difficult problem; first, the discovery that C.E. could be precipitated, under carefully controlled conditions, in the form of crystal aggregates which possessed the required characteristics for easy stemming and the correct densities in both the free-flowing and compressed states, and second, the development of a method of mechanical stemming which rendered the stemmed filling impervious to gun or plate stresses. Although improvements could still be made to this method to enable quick and accurate manufacture on a large scale, the fact remains that since the application of these two improvements, no shell failure has ever been traced to the failure of the stemmed filling in the fire channel provided the C.E. in the ignition chamber was properly ignited. (Appendices 2 and 3).

Although no further failures to detonate were recorded, once the ignition chamber filling was ignited, it was suggested that improved performance might be obtained if the last part of the fire-channel was stemmed to a slightly higher density, e.g. about 1.33 gm./c.c. Since the adoption of this suggestion at that time would have necessitated the use of two stemming machines,* C.S.R.D. made the alternative suggestion that, (1) a pressed pellet of C.E. should be inserted into the top of the channel, or (2) design DD/L/1000S, with branched channels and a screwed stopper at the top of the fire channel, should be adopted. The second suggestion was investigated and for a time adopted in fuzes of the DD/L/3000 type, but in the meantime experiments on the filling of the vertical channel were sufficiently successful to enable the additional complication of branched channels to be avoided, and a return was made to the single vertical channel with a pellet of compressed C.E. at the magazine end, (DD/L/3000 U), this form being adopted for Service use. Details of the present fillings are given in the Specifications (Table 1.g).

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* The subsequently designed Direct Type Stemming Machine, R.D. No.6251 (Appendix 3) embodies the capability of stemming the channel with the density increasing increment by increment if necessary.

(O.C.Memos."B" 9329, 9489, 9522, 9603 III, 9352, 9677, 9709, 9711, 9950,11514, 12130, 14635, 22069, 22268, 22411).

6.1.3 Ignition Chamber

In the DD/L/1000 and 2000 type fuzes, a separately pressed pellet of C.E. was used in the ignition chamber. The occurrence of prematures with DD/L/1000 type fuzes led to the suggestion that manufacturing tolerances could allow the igniting flash from the cross channel to pass directly to the base of the stemmed channel, thus igniting the explosive in it before the pressure in the ignition chamber had risen to the value necessary to produce detonation at the required distance along the fire-channel. That the separately pressed filling has not given rise to any difficulties in the medium base fuzes is ascribed to the slight differences in design of ignition chamber from the DD/L/1000 design.

The pressed-in filling, rendered possible by the introduction of the base closing plug in DD/L/3000, obviated this difficulty, but another arose in that the volume of the beehive ignition chamber could not without considerable manufacturing difficulties be kept within the ve y close limits required for sufficiently regular results. In 1931, C.S.R.D. overcame this final difficulty by the introduction of a new method of filling which proved so successful that it was adopted almost immediately for the DD/L/3000 type fuzes and is still in use.

C.B. Method

The C.B. or "cut-back" method of filling was particularly suitable for the beehive ignition chamber, in that it rendered unnecessary both the accurate gauging of the ignition chamber and the manufacture of C.E. pellets within fine limits.

The ignition chamber was over-filled with C.E. pressed in at a pre-determined load. The excess of filling was then removed and a second pressing to a stop produced the flash cavity and brought the C.E. to the required level. The immediate success of this method led to the adoption of DD/L/3000 in place of DD/L/1000 as the Service design of large base fuze.

Full working details are included in the specifications. (Table 1.D).

In connection with this work, the Research Department had to work out a special method of measuring the volume of the filling space in the ignition chamber. The apparatus then devised has been used throughout the war to calibrate the test blocks used by C.I.N.O. in filling all the Navy's large base fuzes.

The Research Department also devised a special gauge for determining how many washers were required to fill the space in which the tolerances accumulated between the filling and the end of the ignition chamber plug when the plug was in one piece with its head. This was a very critical gauging because too many washers crushed the filling and gave blinds, whereas too few washers allowed set-back and subsequent short-circuit by the ignition flash.

O.C.Memos. "B" 14635, 15860, 16363, 21684, 22580, 23128, 23781, 23970, 24397, 25253, 26871).

6.2 Ignitory System

6.2.1 Cross Channels (Figures 16A and B – See also Section 5.1.6)

Another suggestion for lessening the risk of prematures due to the short-circuiting of the flash through the ignition chamber, was that the pressure of the ignitory flash should be decreased by reducing the amount of gunpowder in the cross-channel filling (DD/L/1000Q and R). Later experience showed that while the amount of this filling could undoubtedly be too large, it was advisable to have it as large as possible without causing excessive pressure in the ignition chamber (DD/L/3000M, N).

Non-delay side

A very comprehensive series of experiments was carried out by the Research Department on the effect of altering the quantity and nature of the gunpowder used on the non-delay side, control experiments being carried out at the same time to test the effect on the delay of changes on the non-delay side. These modifications, together with the results obtained from each are illustrated in R.D.No.4914 (47 sheets), extracts from which are shown in Figure 16B.

The main lines of investigation were:-

(1) the reduction in amount of gunpowder in the perforated pellet on the non-delay side;

(2) the use of fine-grained gunpowder either partly or wholly replacing the perforated pellet.

(1) In addition to varying amounts of gunpowder used in the perforated pellets, varying sizes of distance pieces were used to test the effect of the position of the pellet in the cross-channel. Better effects were obtained with a smaller pellet placed near the ignition chamber than with a larger amount farther away.

(2) In view of the very good results for non-delay performance obtained with an ordinary delay pellet perforated, the suggestion was made that the fine-grained powder of the delay pellet might act as a trap for the incandescent particles, thus providing a more efficient means of ignition than the compressed perforated pellet. Because of the possibility of escape from the cross-channel to other parts of the fuze, the powder had to be enclosed in a capsule, thus adding to the complexity of manufacture. The initial results with only a small capsule were so good that it was proposed that the whole of the non-delay side should be filled with fine-grained powder. Very good results were obtained experimentally, but in the drastic firing trials arranged to test its use for Service, erratic delays, varying from 7 to 55 feet, were obtained.

These disappointing results, together with additional complexity of manufacture, entailed by the use of fine-grained powder, led to the decision to retain the perforated gunpowder pellet in the meantime on the non-delay side and to concentrate on improving the flash from the detonator instead. It was later discovered that the fuzes used for this trial were defective, other fuzes from the same lot giving blinds with delays pierced (a condition most favourable to good performance) in testing the efficiency of R.D.X. fillings for A.P. shell. The Research Department has, therefore, in the proposed new design of fuze

R.D.Sk.5770, returned to the idea of fine-grained powder on the non-delay side, the manufacturing difficulty being overcome by the use of a fitment similar to the delay fitment, thus obviating additional inspection and the installation of new plant. (O.C.Memos."B" 14635, 15596, 15631, 18080, 21862, 24328, 24524, 25382, 25696 II, 25953, 26151, 26629, 26871, 27724, 32117, 34736).

Delay Side (Figure 16)

The delay fitment is in two sections, a small perforated gunpowder pellet in a metal fitment closed by a baffle plate being screwed on to another metal fitment containing the delay pellet and fine-grained powder. A perforated pellet in the cross channel transmits the flash from the fine-grained powder to the ignition chamber. There is therefore much more assistance to the original flash from the detonator on the delay than on the non-delay side; also it is thought that the resistance to blow-back might be advantageous in securing ignition on the delay side. Herein lies the main cause of difficulty in securing a completely satisfactory optional delay fuze. The provision of a detonator suitable for both delay and non-delay sides is a problem not yet solved. Until such a detonator can be provided, it would seem that the only solution lies in providing a non-delay fitment as similar as possible to the delay fitment, as C.S.R.D. has suggested in R.D.Sk.F.5770.

The chief difficulties met with on the delay side were:-

1. Break-up of the perforated powder pellets and delay pellets.

2. Blockage of the hole in the baffle-plate.

3. Varnish from the baffle-plate on the delay pellet.

1. In DD/L/1000V the perforated powder pellet was omitted, but the results of trials were inconclusive. In the meantime other trials established the fact that break-up of the perforated pellet in itself did not produce adverse results provided that the touch-hole in the baffle plate was not blocked. Break-up of the delay pellet upon impact was unlikely and break-up on assembly could be avoided by regulating the torque applied in screwing together the two parts of the fitment.

2, The use of excessive cement proved to be the most likely cause of blockage of the touch-hole. The omission of shellac and cement, together with the introduction of a paper disc, overcame this difficulty and also prevented the hole from being blocked with powder.

3. The presence of varnish on the delay pellet was also due to the application of too great a torque in assembling part I and II of the delay fitment. It was overcome by the regulation of the torque applied. (O.C.Memos."B" 15563, 16947, 16992, 17372, 17390, 17573,19641, 19794, 19892, 19910, 24308).

6.2.2 Detonator

The original design DI/L/1000 made use of the 3-grain "A" detonator. Experiments carried out to investigate the pressure and velocity of the gases from these detonators revealed that a 30 per cent. variation could take place without any apparent effect on the functioning of the detonator a result scarcely in accordance with the view then held that it was the pressure and velocity of the flash which controlled the burning of a powder system ignited by means of the flash. Moreover, this wide variation in performance led to considerable doubt as to the adequacy of the standard test when applied to detonators required for DD/L/1000 type fuzes; later a more stringent test was designed. (O.C.Memo."B" 31905).

Trials were carried out with 4-grain "A" detonators to determine their effect on the length of delay and on the delay pellet. There was a slight shortening of the delay and the regularity was unaffected, so no change was made in the existing system. Later, however, it was pointed out by C.S.R.D. that this very fact might be made use of to improve the non-delay side, in that the more powerful 4-grain detonator would have more chance of igniting the filling in the ignition chamber, any slight decrease in the delay times being compensated for by an increase in size of the delay pellet.

Trials were carried out with 3.5-grain and 4-grain detonators filled with "A" composition (DD/L/3000G and H, section 5.2.7.c) but did not produce the hoped-for results. Long delays and blinds still occurred at the non-delay setting.

Experiments carried out in the Research Department on detonators under the conditions present in the fuze led to the conclusion that improvement would be obtained by altering the arrangement and filling of the existing Service detonator (R.D.No. 4698, Figure 22, indicates the various experimental arrangements).

The following modifications were embodied in an improved design suggested for Fuze No.159, R.D.No.4699, Figure 18.

(1) The 3-grain 4-hole base detonator filled with Service "A" composition was replaced by a 4-grain single-hole base detonator filled with Service "C" composition, which produces a greater number of hot particles than the 3-grain 6.6.4 composition.

(2) The detonator was sunk deeper in the inertia pellet so that greater tamping of the mouth of the detonator is obtained. (See Section 5.2.7.e.f.g).

The Ordnance Committee was, however, unwilling to recommend any major alteration to the fuze such as that entailed by the proposed modifications to the detonator, on the grounds that under the existing system the delay results, which were the most important, were eminently satisfactory and very extensive trials under all conditions would be necessary to ensure that they were not upset by the proposed alterations.

(C.C.Memos."B" 14435, 17372, <u>17390</u>, <u>17635</u>, 17964, 18388, 18669, 19340, <u>24397</u>, <u>24488</u>, 24642, <u>24968</u>, <u>27283</u>, <u>27724</u>, 28465, 28882, 30048, <u>30227</u>, <u>30304</u>, 31905).

In 1935, C.S.O.F. submitted to I.N.O. a report on the effect of antimony sulphide and potassium chlorate dusts on the functioning of 2.5 grain igniferous detonators. It was stated that the presence of dust had a marked effect on the performance of the detonator at flash test, but the effect on the violence of the explosion was comparatively small and the sensitivity scarcely affected.

As a result of this investigation, the specifications for "A", "B" and "C" compositions were amended to include a greater proportion of dust, viz:

1. <u>Antimony sulphide</u>: all to pass a No.120 B.S. sieve and approximately 20 per cent. to be retained on a No.170 B.S. sieve.

2. <u>Potassium chlorate:</u> all to pass a No.120 B.S. sieve and approximately 75 per cent. to be retained on a No.170 B.S. sieve.

(<u>Note</u>: In C.S.O.F.'s experiemnts nearly 80 per cent. of the antimony sulphide dust passed a No.360 B.S. sieve).

Trials with the revised "A" composition carried out in 3-grain detonators did not substantiate the claim to greater regularity and ignitory power and were discontinued.

(O.C.Memos. "B" 33040, 33325, 36377; O.C.Memos.1852, <u>1932</u>).

SECTION 7 ADDITIONAL INVESTIGATIONS

7.1 Fuze Body and Inertia Pellet - Metals used

7.1.1. R.D. Gaine System

When the gaine was a separate unit, the material used was a type of brass which proved unable to withstand the impact stresses when the fuze was used against heavy armour. Various types of metal were investigated, high-grade steel being finally chosen as the most resistant. With the embodiment of the R.D. gaine principle in the base fuze, the question of material became one with that of the fuze body itself.
(O.C.Memos. "B" 7325, 7972, 8791, 8927, 8980, 8993, 9042, 9723).

Fuze Body

The material finally recommended by C.S.R.D. for the fuze body was high tensile brass of the following composition and strength:-

Cu	Zn	Pb	Fe	Mn	Al	Other substances
59/62	Rem.	0.1	0.8/1.3	1.5/2.2	2.8/3.2	0.1

20 tons yield, 40 tons break and 15 per cent. elongation.

Since it was essential that the material should be perfectly sound and homogeneous, rolled bar and bar produced by the inverted extrusion process were recommended as being inherently superior to bar extruded by the old process. Hot stamping of the blanks was excluded from the specification on the grounds that it did not overcome faults but merely disguised them.
(O.C.Memos. "B" 17465, 19732, 20060, 22081, 22167, 26238, 26354, 33420, O.B. Procs. 4020, 5095, 6677).

7.1.2. Inertia Pellet

Various methods were suggested for reducing friction between the inertia pellet and the fuze body.

(a) Ball-bearing pellet (Section 5.1.8.a)

(b) Plating either of the inertia pellet or of the interior of the fuze body.

(c) Use of a lubricant, preferably dry.

(d) Reduction of area in contact by means of a "waisted" inertia pellet (Section 5.1.8.a)

(e) Improvement in balance of inertia pellet (Section 5.4.1.c.)

(f) Use of a material which could be burnished to a high polish.

Of these the two last were the most fruitful suggestions. In the first instance, rustless steel was suggested, but in addition to being twice as expensive as brass, it would have altered the weight by $6\frac{1}{2}$ per cent., thus necessitating a complete series of trials in all the guns to re-determine the creep spring values. Corronil and Monel metal were without this disadvantage in that the inertia pellet would be only slightly heavier and no further trials would be necessary.

Monel metal, an alloy of nickel and copper, was finally chosen for the inertia pellet. Manufacturing difficulties led to an enquiry as to other metals suitable for the purpose and the following metals were suggested by C.S.R.D. :-

Kunial copper, phosphor bronze, nickel silver and Tungum metal.

On further consideration, the Ordnance Committee decided that the satisfactory performance of the monel metal pellet outweighed the difficulties of manufacture.
(O.C.Memos."B" 15065, 15119, 15379, 17573, 17578, 25175, 25591, 29269, 29561).

7.2 Needle, Material and Shape

7.2.1 Material

In the earliest types of fuzes the Ordnance Factory used hardened and tempered steel for the needles. Needles made by E.C.Co., however, were made from steel in the machinable condition, the result being a distinct lack of sensitiveness giving rise to blinds. This defect was overcome by amending the specification to provide for the hardening and tempering of the needles. The specification has since been amended to provide for the manufacture of rustless steel needles.
(O.C. Memos. "B" 12730, 13011).

7.2.2 Shape

(a) Point

During the last war the shape of the needle point was the subject of several trials, the results of which pointed to the superiority of an extremely fine point for sensitiveness. These very sharply pointed needles being difficult to manufacture, a compromise was arrived at in the DD/L/1000 and 2000 type needles.

In 1927 as a result of D.N.O.'s suggestion that the investigation should be opened again, trials were carried out with:-

(a) a chisel shaped needle (DD/L/Sk.403);

(b) a sharp but unpolished needle;

(c) a sharp needle with a slightly blunter point.

The final shape decided upon was a fine needle (cone angle 23°) with a slightly blunter point (cone angle 35°).

In 1943, a report was published by S.R.1.(F.R.G.) on "The Influence of Needle Point Contour on the Initiation of Detonators", in which it was shown that a 23° point with a 35°, 0.05-inch termination acted in the same way as a 35° point and was less efficient than a 30° point with a 0.008-inch flat.

The Board, however, recommended that for base fuzes "the bluntest needle consistent with satisfactory operation" should be adopted. In their opinion, the use of sharp needle strikers in base fuzes constituted a definite risk of premature in flight.
(O.C.Mins. 6077, 10,000, 13484, 15482, 21502, 31,164)
(O.C.Memos."B" 14185, 14301, 14489, 14709, 14829, 14982)
(O.C.Memos.1921; O.C.Procs.364, 8251, 28668).

(b) Length (see also Sections 5.1.8.a, 5.3.4, 5.4.1.b)

One of the measures advocated by C.S.R.D. for increased sensitiveness was the use of a lengthened needle. The arguments brought forward against this modification were:-

(1) the smaller travel required might require a stronger creep spring, necessitating a series of further trials;

(2) the possibility of prematures in flight;

(3) the longer needle will enter the flash-hole a greater distance and might have some effect on the delay times: trials would again be necessary to settle this point;

(4) the longer needle is more difficult to assemble axially and any slight departure from accuracy might result in jamming of the needle in the inertia pellet.

The lengthened needle was, however, adopted in DD/L/3000 and 4000 (Section 5.4.1.b) where it appears to have given complete satisfaction. (O.C.Memos."B" 16038, 17578, 18385, 19238, 19460, 20183, 20445, 20924, 21139, 21881, 22741).

(c) Diameter

In the trials of DD/L/6000 in 6-inch C.P.B.C. shell against 160-inch N.C.plate, the fuzes failed because the delay fitments had not ignited, owing to the jamming of the needle in the flash-hole of the inertia pellet. Two suggestions were brought forward to overcome this defect:-

(i) S.of D.'s design DD/L/Sk.1818 with thinner needle and modification to detonator plug.

(ii) C.S.R.D.'s design R.D.Sk.5498 for controlling the travel of the needle.

Trials were carried out with various fuzes modified to DD/L/Sk.1818 in 6-inch and 13.5-inch shell. Satisfactory results were obtained against thick plates but for success against thin plates, either increased tamping or an improved detonator was required.
(O.C.Memos."B" 30228, 30650 II, 31375, 31821, 32004, 32097, 32186, 32364).

7.3 Locking pellet and guide screw

Trials carried out in 6-inch C.P.B.C. shell with the No.345 fuze minus locking pellet and guide screw showed no adverse results. It was therefore decided to increase the sensitiveness and simplify manufacture by omitting them from the design. DD/L/1000N was the first design submitted without them, then came DD/L/1000R and all the subsequent DD/L/3000 designs. It was also decided to omit them from design DD/L/2000.

The occurrence of irregular delays and blinds has upon more than one occasion caused the wisdom of this step to be questioned but, so far, comparative trials with and without locking pellet and guide screw have failed to establish a case for their re-introduction. Whether the number of rounds fired in these trials is sufficient to determine this point is doubtful. The probability of blinds or long delays from this cause would need to be fairly high to be established by the firing of only a few rounds of each. (O.C.Memos."B" 13717, 13868, 14636, 15852, 16252, 16506, 17299, 17635, 17737, 17762, 17964, 18107, 19422, 32097).

7.4 Baffle and ignition Unit (Figure 21)

In order to safeguard the gaine from undue blast effect when used as a separate unit with an unvented fuze, a combined Baffle and Ignition Unit was designed to form an integral part of the gaine adapter. It consisted of a baffle plate and a perforated gunpowder pellet the face contiguous to the C.E. pellet in the ignition chamber being ignited. The unit was designed for use with various fuzes, e.g. Nos.51, 132, 106E. One type, R.D.No.3927 is shown in Figure 21. (O.C.Memo."B" 20626).

When difficulty arose with the ignition system of the DD/L/3000 type fuze, it was suggested that the introduction into the ignition chamber of a Baffle and Ignition unit would render the ignition system more similar to that of the very satisfactory DD/L/2000 type in which also the fuze of the powder pellet contiguous to the C.E. was the one ignited whereas in the DD/L/3000 type, ignition starts at the end farthest away. In view of other improvements in the cross channel filling and in the detonator, the suggestion was not adopted. (O.C.Memos."B" 20463, 20626, 20673, 20707, 30307, 30545).

7.5 Effect of Rotational Velocity

In one series of trials it was found that the results for the No.480 fuze were very much better than those for the No. 159 fuze. Since the fuzes are similar except for the creep spring, which is stronger in No.480, it was suggested that the reason for the different behaviour of the two fuzes lay in the different rotational velocities of the two shell. Since, in order to escape from the cross channel the gases from the powder pellet must move against centrifugal force towards the centre of the fuze, the rotational velocity might be expected to exert some influence on the rate of rise of pressure within the cross channel and correspondingly on the ignition of the C.E. filling in the ignition chamber. The magnitude of the resistance offered to the cross-channel gases at a radius of 0.8-inch from the centre of the fuze in Fuze No.480 is 6½ times as great as in Fuze No.159. Although the forces are small in comparison with the maximum pressure of the gas from the powder pellet, it was suggested that they were sufficient to affect the ignition of the C.E.

Trials were carried out with 6-inch shell, some fired with about the same spin as at non-delay proof of No.159 in the 13.5-inch gun and others with reduced spin. No abnormally long delays were recorded.

In the absence of any evidence as to the harmful effect of low rotational velocity, the investigation was suspended. (O.C.Memos."B" 27283, 27256, 27970, 29402)

7.6 Sensitivity - Creep Springs (Tables 3 and 4)

The large base fuzes Nos.159, 346, 480, differ from each other only in the creep spring, the strength of which is calculated from various factors including the diameter of the projectile and the shape of its head. When the early DD/L/1000 designs were brought to gun-trial it was found that certain of the creep spring values had been wrongly calculated in that, according to the radius of the head (approximately 4 calibres), they were made suitable for a 4 c.r.h. shell, whereas the shell actually had the retardation of a 2 c.r.h. shell because its length was that of a shell struck with 2.1 calibres. In order to bring the safety factor to 2, which was then considered sufficient, design DD/L/1000B was brought out. DD/L/1000D, E and F gave the values for stronger creep springs required in the smaller natures of shell. Another series DD/L/1000 GG, HH, JJ, KK, LL, MM was designed, JJ only being adopted for use in service fuzes. The safety factor was also raised from 2 to 4.

The occurrence of blinds in both large and medium base fuzes at gun-proof led to the suggestion in 1942 that the creep springs were too strong and that the sensitivity would be increased if their strength was considerably reduced. Table 4 show C.E.A.D.'s table, factor of safety against creep force.

The important factors necessitating strong creep springs to the detriment of sensitivity against their plate are:-

(a) the possibility of the caps coming off at the muzzle

(b) the factor of safety of 5 which experience now indicates as necessary.

Although there is no doubt that weakening of the creep spring increases sensitivity, it is not certain that it is the primary factor in producing blinds on a thin target. Experiments carried out by I.N.O. (New York) showed that blinds could be produced under these conditions by the tendency of the inertia pellet to seal off the detonating flash by being blown back on to its rear seating if its forward momentum on impact is insufficient.

The Ordnance Board decided that only two alterations were called for at present:-

(1) Substitution of a 44 oz. spring for the existing 57 oz. one in Fuze No.159 to increase its sensitivity.

(2) Substitution of an $18\frac{1}{2}$ oz. spring for the existing 14 oz. one in Fuze No.551 in order to bring the factor of safety to the prescribed value.

In connection with the problem of Sensitivity, S.R.1. (F.R.G.) is at present* carrying out investigations on

(i) Measurement by means of special gauges of shell decelerations (a) in the air and (b) passing through targets.

(ii) Firing of detonators by blunt strikers.

The second investigation has been undertaken to determine the effect of using a blunt striker and thicker detonator covering, such as is used by the Germans instead of a creep spring. (O.C.Memos."B" 8915, 15651, 15759, 15762, 15923, 17390; O.B. Procs.18956, 19762, 26002, 27769, 28668, 28699, 29603, 29096, 29256, 29483).

* at the time when this was written

SECTION 8 POLICY

8.1 R.D. Gaine Principle

In the first instance the R.D. gaine was developed as a separate unit, those responsible for the work being of the opinion that the base fuze was itself beset by so many problems that the gaine could not be developed satisfactorily as part of the fuze system. When it became obvious that the gaine would have to be incorporated in the fuze, development work was continued on the gaine itself and the improvements transferred to the fuze. In this way a much better R.D. Gaine system was evolved than would otherwise have been possible.

In view of the excellence of the principle for application to A.P. projectiles its use was restricted to the base fuzes, large and medium, for A.P. shell. Since, even in wartime, the demand for these fuzes was not too great to be met by individual filling, the development of a multiple-head stemming machine, suggested by the Research Department, was not proceeded with. Nor, since the trial and error method had succeeded in producing a fuze that worked fairly satisfactorily, was there any detailed investigation into the fundamental principles underlying the action of the gaine. In consequence of this policy the development and application of one of the Research Department's most interesting discoveries have, of necessity, been neglected for over twenty years. Results of far reaching importance to the theory of detonation would almost certainly be obtained from an investigation into the behaviour of explosives in general under the conditions of the R.D. gaine.

8.2 Base Fuze

In asking for a detonating base fuze for naval shell, D.N.O. made the following additional stipulations:-

1. An optional delay system was to be incorporated in the large base fuze.

2. In the interests of economy the new fuze should be based on the No.16D fuze then in use.

The second of these two stipulations is the factor which, more than any other, has militated against the production of a completely successful base fuze. There can be no possible doubt that, from the naval point of view, the optional delay fuze is the goal to be aimed at. There is not only the all-important question of storage; it is also desirable that shell already in the gun should be readily alterable from one setting to another to meet altered conditions. The No.16D fuze, however, did not lend itself to the adoption of the R.D. gaine principle together with an optional delay. In order to conform to existing contours, the path of the detonator flash had to be made extremely tortuous. Moreover, there is on the delay side both more assistance to the flash from the detonator and more resistance to "blow-back" of the gases from the gunpowder pellet in the cross channel than on the non-delay side. Not only does this "blow-back" weaken the chances of good ignition of the filling in the ignition chamber; it seems probable that it may assist in the jamming of the inertia pellet into the needle cap before the C.E. is satisfactorily alight. In addition, the eccentricity of the inertia pellet and the pressure plate, besides complicating manufacture, render impossible any automatic setting from delay to non-delay or vice versa. From every point of view except that of temporary economy, it was a mistake to graft the R.D. gaine principle on to the No16D fuze, which had throughout its history been subject to long and unaccountable delays. It would have been truer economy to have concentrated on making a perfect fuze and adjusting the shell filling to suit.

8.2.1 DD/L/1000 was in 1927 adopted for use in Naval Service base-fuzed piercing shell, 5.2-inch and above, in place of the No. 16D igniferous fuze
(O.C.Memo."B" 12461).

(i) No.158 fuze ("B" type of creep spring, 57 oz.) in 16-inch and 13.5-inch shell.

(ii) No.260 fuze ("D" type of creep spring, 86 oz.) in 8-inch and 7.5-inch shell.

(iii) No.345 fuze ("E" type of creep spring, 100 oz.) in 6-inch, 5.5-inch and 5.2-inch shell.

Later, in consequence of the occurrence of prematures, certain alterations were made. (O.C.Memo."B" 16091).

(a) No.260 fuze was replaced by No.345 in 8-inch shell.
No.260A fuze was replaced by No.345A in 7.5-inch shell.

(b) Nos.345 and 345A were replaced by No.479 in 6-inch to 5.2-inch shell.
(No.479 had a JJ type of creep spring, 180 oz.)

(c) Nos.158 and 158A remained in use for shell above 8-inch.
(See also Section 5.2 and Table 1.g)

The DD/L/1000 type gave on the whole a fairly good performance, but especially in the No.158 fuze it was subject to long delays and to prematures which gave rise to partial detonations. The weakness of the design lay in the fact that, owing to manufacturing tolerances, the flash from the touch-hole could bye-pass the pellet filling in the ignition chamber and ignite the C.E. in the stemmed channel directly. The weakness of the side-closure was also blamed for reducing the confinement necessary in the ignition chamber. The actual break-down in Service, however, was shown to be due to the contamination of the ignition chamber filling by mineral jelly from the screw-thread luting, another weakness of the DD/L/1000 ignition chamber closure. DD/L/2000, with a somewhat different type of closing plug, seems to have been free from the former defects but did give some trouble, also from contamination by luting. C.S.R.D. had consistently advocated a base-closing plug for the ignition chamber and a design DD/L/1000R with this modification was finally adopted as DD/L/3000.

8.2.2 DD/L/3000 was in 1929 adopted into Naval Service in the following fuzes:-

	Design	Fuze	corresponds to and supersedes
(i)	DD/L/3000 BRST*	No.159	No.158
(ii)	DD/L/3000 ERST	No.346	No.345
(iii)	DD/L/3000 JJRST	No.480	No.479

* The letter indicates the modification to the original DD/L/3000 design.

The "U" modification later replaced the "S" branched channel design.
(O.C.Memo."B" 20779 - See also Section 5.2 and Table 1.g).

The DD/L/300 type was free from the defects of the DD/L/1000 type but introduced new ones. It was more costly to make and more difficult to gauge but, even more important, it gave a less satisfactory performance at non-delay setting. The chief reason for its adoption was that it gave a higher percentage of detonations than the DD/L/1000 type; but the argument brought forward was that the features chiefly responsible for its improved performance in that direction might also be applied to DD/L/1000.

8.2.3 DD/L/6000 (Section 5.6) was designed to combine the best features of the two designs, but in practice it did not produce the expected results. D.N.O., in discussing the failure of DD/L/6000 to provide the required solution, pointed out that there were two aspects of the problem of obtaining a simpler and more reliable base fuze for heavy shell:-

(a) The immediate one of obtaining a design to which current manufacture should proceed, and

(b) a general investigation to obtain an improved fuze of a design more simple than the No.159 type.

He regarded (b) as a matter of no great urgency and, concentrating upon (a) as the "prime need", brought forward the suggestion that the No.159 (DD/L/3000) type should be abandoned in favour of the No.158 (DD/L/1000) type with the following improvements:-

(i) a No. 159 type of C.E. magazine

(ii) a pre-pressed pellet in a side ignition chamber and the lower end of the vertical C.E. chamber specially stemmed.

In support of this view, he cited the superiority of fuze No.479 (modified to take a thinner needle) to fuze No.480 in 6-inch shell against 4-inch N.S. plate at normal, suggesting, among other causes, the greater liability of crushing a Monel metal inertia pellet by severe impact than one of Metal Class A. Also No.479 has a locking pellet and guide screw, whereas No. 480 has none. Although the results of trial have never established any case for the re-introduction of the locking pellet and guide-screw, the state of complete crush-up exhibited by many of the sectioned blinds has given rise to considerable doubt as to the wisdom of the omission. A meeting of all the Departments interested was suggested in order to arrive at a definite policy

(a) for immediate production

(b) for the future.

8.2.4 At the conference called by D.N.O. on September 16th, 1936, to review the situation, C.S.R.D. urged the following policy:-

1. Fuze for immediate production

Fuze body to design DD/L/3000 NX(d) with certain modifications, including a one-piece bronze ignition chamber closing plug with three touch-holes, a Y channel in the inertia pellet and an improved detonator system.

2. Fuze for the near future

Fuze as for (1) but with a 4-grain "C" detonator in place of the 3-grain "A" detonator.

3. Fuze for future development

A fuze embodying the delay system of the DD/L/3000 type, which had reached satisfactory performance, but with various alterations to the detonator and safety arrangements to bring the non-delay performance up to the same level.

The two alternative suggestions for a new fuze were designs DD/L/7000 and R.D.Sk.F.5770. DD/L/7000 (section 5.7) attempted to combine the good points of the large and medium base fuzes by having two separate detonating systems. Even in this design, however, the detonator flash had a considerably longer travel before reaching the gunpowder on the non-delay side than on the delay side. R.D.Sk.F.5770 (Section 5.8.2) was an entirely new design of fuze with an axial arrangement of inertia pellet and pressure plate (the latter enabling automatic setting to delay or non-delay) and with the ignitory system altered to embody the results of many years' research.

The Admiralty decided that, in the circumstances, it was a safer policy to retain the existing fuze, which gave a very good performance at delay setting, rather than to risk upsetting these results for a possible improvement in the less important functioning at non-delay setting. As events turned out, the Admiralty's decision was justified in that it is doubtful whether the trials of a new fuze could have been successfully completed before the outbreak of war, but the occurrence of blinds and long delays reported by I.N.O., New York, show that the performance of the fuze is still at fault under certain conditions and the conclusions arrived at there support these of the Design and Research Departments that complete satisfaction will not be achieved until a new fuze is designed. (Appendix 5)
(O.C.Memos. "B" 9603, 10319, 13868, 14284, 15596, 16367, 17390, 17465, 18107, 20779, 26871, 27724, 32097, 34736).
(O.B.Procs. 29089, 29096).

SECTION 9 SUMMARY AND CONCLUSIONS

Summary

The discovery in the Research Department, Woolwich, that under certain conditions C.E. could be brought to detonation from ignition, provided the long-sought-for answer to the Admiralty's request for a detonating gaine for naval shell. C.E. is not sensitive to impact and is therefore free from the defects attendent on the use of sensitive detonators. Moreover, it does not deteriorate on storage even under tropical conditions, thus simplifying problems of maintenance and inspection.

In the first instance the R.D. gaine was developed as a separate unit, many experiments being carried out to determine the optimum conditions of density and confinement of the explosive. It soon became apparant, however, that the incorporation of the gaine in the fuze itself was desirable, and attention was focussed upon the development of an optional delay fuze based on the No.16D fuze and incorporating the principle of the R.D. gaine. Although the gaine lent itself to numerous other applications, its pre-eminent suitability for A.P. munitions led to the policy, for security reasons, of confining its use to the base fuze for naval shell. Other applications were investigated but none passed into the Service.

In the experimental field, however, work was continued on the R.D. gaine as a separate unit, in order that problems relating to the fuze itself should not confuse the result. The outcome of these investigations was a highly efficient R.D. gaine system incorporated in a mediocre fuze. In the large base fuze, adapted from 16D, the ignitory detonator is called upon to ignite the C.E. in the gaine under very different conditions according as the fuze is set delay or non-delay. Although, on the whole, the performance when set delay has been highly satisfactory, erratic results and, not infrequently, blinds have been recorded at non-delay setting. Much time and labour have been spent on improving the ignitory system of this fuze, but it has for some years been realised that the fault is inherent in the design, and although some improvement in performance may be achieved by the incorporation of a more powerful detonator, it is extremely doubtful whether the present design of fuze can ever be brought, as a whole, to the state of perfection achieved many years ago in the R.D. gaine.

In the medium base fuze the problem of optional delay does not arise. This factor, together with the freedom given to the two departments in the choice of a design, have resulted in the production of a highly efficient fuze. An attempt to combine the two designs in a more efficient type of large base fuze was interrupted by the approach of war. A new design of large base fuze put forward by the Research Department was not considered for the same reason.

Conclusions:

1. The R.D. gaine principle has proved highly successful in base fuzes for A.P. shell, and has very greatly increased their detonative violence.

2. There is still room for investigation into the best type of detonator for the ignitory system of the fuze.

3. One criticism levelled against the R.D. gaine is that the ignition is too critical. The basic difficulty is that in approaching the R.D. gaine system an ignitory flash carries in front of it a quantity (variable according to design) of dead air. This air, blowing in through the 0.04-inch diameter touch-hole, cuts a short-circuiting channel through the C.E. The more air the deeper the cut and the longer the length of the channel necessary to reach detonation. Exigencies of space forbid the lengthening of this channel beyond a certain limit so that the problem must be tackled on the ignitory side of the gaine system.

4. In the development of the lead azide sleeve, a transition has been made from an insensitive explosive with heavy tamping to a very sensitive explosive with little tamping. It is suggested that an intermediate form with PETN as the explosive might prove of more value than either of the previous forms.

5. It is believed that fundamental research into the underlying principles of detonation of the R.D. gaine which have, for lack of facilities, never been fully investigated, would not only yield results of great importance to the theory of detonation in general, but would also reduce the difficulties of manufacture on a large scale and so enable this safe and ingenious device to be widely used in the Service.

ACKNOWLEDGMENTS

The development of the R.D. gaine was carried out in the High Explosives Section of the Research Department, Woolwich, in collaboration with the Explosives Section, which was responsible for the discovery of aggregated C.E.; the automatic stemming machine was developed in the High Explosives Section, and the choice of a suitable metal for the gaine lay with the Metallurgical Section.

The incorporation of the R.D. gaine principle into the large and medium base fuzes was the work mainly of the High Explosives Section in collaboration with the Design Department, the experimental work being carried out in the Research Department and the final gun trials by the Admiralty.

In conclusion, the author wishes to express her gratitude to the staff of the Ordnance Board, in particular the Records Section, the Drawing Office of the Armament Design Department and the following sections of the Armament Research Department, Fuze Section, Explosives Section, Information Section, Metallurgical Branch, and Drawing Office, without whose generous assistance the completion of the monograph would not have been possible.

a. Fuze, Percussion, Base, Large, Detonating - DD/L/1000 Type

Item	DD/L/No.	Date	Title and Comments	O.C.Memos "B"
5.1.1.a	990	15.7.24	Fuze,Percussion, Base, Large, Detonating, incorporating the R.D. gaine. (Fuze otherwise the same as DD/L/100A but without optional delay)	7325
5.1.2.a	1000	20.7.24	Fuze, Percussion, Base, Large, Detonating with optional delay incorporating R.D. gaine.(Without central magazine pellet)	7325 7972
b	1000 (1)	12.8.24 8.11.24 13.2.25 22.9.25		8341
5.1.3.a	1000 A 1000 A(1)	2.12.24 20.10.25 5.2. 25 25.2.25 18.6.25 22.9.25	Modified magazine. Deeper C.E.magazine ring and addition of central pellet. Creep spring strength 37 oz. Fuze otherwise same as DD/I/1000(1) (sealed).	8655 8779
5.1.7.b	1000 B 1000 B(1)	18.6.25	DD/L/1000A with stronger creep spring, 57 oz. (sealed)	8915
5.1.3.b	1000 C	2. 9.25	Modified Cap - to overcome effect of possible disintegration of central pellet.	9156
5.1.7.b	1000 D E F	24.10.25	DD/L/1000A type with special creep springs D 86 oz. E 100 oz. F 114 oz.	9325
5.1.7.c	1000 GG HH JJ KK LL	2. 8.28	DD/L/1000 type Special Creep Springs (see Table 2) GG 120 oz. HH 140 oz. JJ 160 oz. KK 180 oz. LL 200 oz.	15759
5.1.3.c	1000 G	3.11.25	DD/L/1000 type - Addition of Powder Magazine (central) - in place of central magazine pellet.	9641

Item	DD/L/No.	Date	Title and Comments	D.C.Memos "B"
5.1.4.a	1000 H	19.11.25	DD/L/1000A type. Proposed brass liner for vertical C.E.channel.	16138
b	1000 J	26.11.25 8. 2.26	DD/L/1000A type with horizontal C.E. channel.	9603 III
5.1.5.a	1000 K	9. 3.26	Proposed closing plug for ignition chamber (S. of D.'s auto-sealing type).	10670 IV
	L	9. 3.26	Proposed closing plug for ignition chamber (S. of D.'s gas-check type)	
	M	22.4.26	Modified ignition chamber and closing plugs.	13868
	N	25.6.26) 30.7.26)	(Two part ignition chamber base closing plug based on Design R.D. 2945-locking pellet and guide screw omitted)	
5.1.3.d	1000 P	4.11.27	DD/L/1000 type. Modified Magazine (totally enclosed magazine with flat-ended magazine cover).	13806
5.1.6.a	1000 Q	15.12.27 5. 3.28	DD/L/1000 type. Reduced filling cross channels.	14635
5.1.5.b	1000 R	15.12.27	DD/L/1000 type with (one-piece) base closing plug to ignition chamber and reduced filling in cross channels. (Re-numbered as DD/L/3000)	14635
5.1.4.c	1000 S	21.1.26	DD/L/1000A type fitted with stopper at top of stemmed channel (Based on R.D.No.2905 with Y channel leading to magazine).	11736
	1000 S*	22.1.26	DD/L/1000A type fitted with stopper at top of stemmed channel (S.of D.'s design)	
5.1.3.e	1000 T	24.2.28 19.3.28	DD/L/1000 and 3000 types. Proposed magazine (Similar to P but with domeshaped magazine cover)	13806
5.1.6.b	1000 U	26.3.28	Spring liner to minimise shock on delay fitting, based on DD/L/Sk.449	13868
5.1.6.c	1000 V	23.4.28 24.5.28	DD/L/1000 and 3000 types. Special delay fitting. (Powder pellet in front of delay omitted)	15563
5.1.8.a	1000 W	12.5.28 13.9.28 19.7.28	DD/L/1000 and 3000 types "Waisted" Inertia Pellet.	15379
b	1000 X	19.6.28	DD/L/1000 type -Lengthened needle and modified inertia pellet to test the effect of short pellet travel (Travel reduced from 0.27-in. to 0.14-in.)	15853

Item	DD/L/No.	Date	Title and Comments	O.C.Memo. "B"
5.1.5.c	1000 Y	13.9.28	Proposed baffle in ignition chamber.	
5.1.9.	1000 Z Z^{*} Z^{**}	12.1.26 19.1.26	DD/L/1000 type - Modified Delay Hole.(addition of airtight closing plugs) Z for new work Z^{*} for Fuzes already under manufacture. $Z^{**}$for Fuzes modified from design with screwed closing plugs.	9151

Table 1.

b. Fuze, Percussion, Base, Large, Detonating - DD/L/3000 Type

Item	DD/L/No.	Date	Title and Comments	O.C.Memos. "B"
5.2.1.a	3000	14.2.28 9.3.28	Fuze, Percussion, Base, Detonating, with R.D.Gaine System and Optional Delay. (Base closing plug to Ignition Chamber-supersedes DD/L/1000R)	14635 14927
5.2.2.a	3000 C	4.3.29	DD/L/3000 type - Special magazine proposed by C.S.R.D.	17255 18188
5.2.7.c	3000 G and H	8.6.32	No.159 type Deepening of Detonator Recess in Inertia Pellet. 3000 G takes 3.5 Gr.Detonator to DD/L/5527. 3000 H takes 4.0 Gr. Detonator to DD/L/5528	24397
d	3000 K	17.9.36	No.159 type Inertia Pellet with two Flash Channels. Debris Trap omitted.	32186
5.2.5.a	3000 M 3000 N	15.1.31 10.2.31	No. 159 type Increased powder filling in cross channels. M.48% increase-no alteration to empty fuze. N.105% " - cross channels deepened.	21862
b	3000 NN	7.5.32	No.159 type Increased powder filling and choke pellet in cross channels.	
5.2.7.a	3000 P, Q and R	25.4.29	DD/L/3000 type. Enlargement of flash hole and provision of debris trap in inertia pellet.	17993
b	3000 R(a)	3.12.32	No.159 type. Proposed modified flash channels.	25097

Item	DD/L/No.	Date	Title and Comments	O.C.Memos "B"
5.2.3.a	1000 S 3000 S	9.3.28 28.12.28	DD/L/1000 and 3000 types. Branches C.E. channels - based on R.D.3416.	15121
5.2.2.b	3000 T	14.3.28 18.12.28 28.12.28	DD/L/3000 type - Special magazine.	17134 17429
5.2.3.b	3000 U, V and W	2. 3.31	DD/L/3000 type - with C.E. pellet at forward end of stemmed channel. Branch channels omitted.	22069
	3000 U	27.4.31	DD/L/3000 type - with C.E. pellet at forward end of stemmed channel. Branch channels omitted (dimensioned drawing)	22069
5. 2.4.a	3000 X (a) (b) (c) (d)	24.6.31 21.10.31 20.10.32 1. 12.32 11. 1.33	No.159 type. Modified ignition arrangement for gaine system.	24968
b	3000 Y	25.6.31	DD/L/3000 type - Proposals to provide easier passage between horizontal cross channels and ignition chamber.	22793
c	3000 Z a and b	19.10.31 3. 4.33	DD/L/3000 type incorporating similar gaine ignition system to that in Fuze No.501. Modified ignition chamber and cross channels.	25696 I
5.2.6.	3000 A B D E F GG HH JJ		Creep springs as in corresponding DD/L/1000 numbers.	

Table 1

c. Fuze, Percussion, Base, Medium, Detonating - DD/L/2000 Type

Item	DD/L/No.	Date	Title and Comments	O.C.Memos. "B"
5.3.1.a	2000 2000 A	12.5.26	Fuze, Percussion, Base, Medium, Detonating embodying R.D. gaine.	9867 II
b	2000 B 2000B(1)	14.7.26 6.9.26	DD/L/2000 type with modified side closing plug for ignition chamber.	11035
c	2000 C 2000 C(i)	16.2.27 10.7.28 5.3.27 2.9.27	DD/L/2000 type with modified ignition chamber plug, etc.	12121
5.3.3	2000 D E F	15.10.27	DD/L/2000 A and C with weaker creep springs. D E F	
5.3.2.a	2000 G) H)	15.12.27	DD/L/2000 type with reduced filling in the cross channels.	14636
b	H H(1)	30.1.28 10.7.28	DD/L/2000C type with reduced filling in the cross channels. Sealed.	16052
5.3.4	2000 J	20.1.30	DD/L/2000 type with lengthened needle.	19020
5.3.5	2000 T	20.3.28	DD/L/2000 and 4000 types special magazine.	15856

Table 1

d. Fuze, Percussion, Base, Medium, Detonating - DD/L/4000 Type

Item	DD/L/No.	Date	Title and Comments	O.C.Memos. "B"
5.4.1.a	4000	7.1.28	Fuze, Percussion, Base, Medium, Detonating (heavy pellet type) with R.D. gaine system DD/L/2000 modified.	14636
5.4.3	4000 A 4000 A(1)	7.5.29	DD/L/4000 type modified magazine.	18246

Item	DD/L/No.	Date	Title and Comments	O.C.Memos. "B"
5.4.1.b	4000 B	12.11.29 28.2.30	DD/L/4000 A type - lengthened needle and modified pellet.	21139
5.4.2	4000 C	3.3.30	DD/L/4000 B type with 152 oz. creep spring.	19975
5.4.1.c	4000 D	3.3.30	DD/L/4000 type. Proposals to improve balance of inertia pellet.	19975
	4000 E	15.5.30	" " "	20672

Table 1

e. Fuze, Percussion, Base, Large, Detonating - DD/L/5000, 6000, 7000 Types

Item	DD/L/No.	Date	Title and Comments	O.C.Memos. "B"
5.5.1.a	5000	6.9.32	Fuze, Percussion, Base, Large, Detonating Non-delay. (Externally as DD/L/3000, internally as DD/L/4000)	24840
b	5000 A	6.9.32 10.10.33	As above with internal components of No.159 type fuze.	24840
5.6.1.	6000	12.12.34 7.2.35	Fuze, Percussion, Base, Large, Detonating, Optional delay	28436
5.7.1.a	7000	7.11.36	Fuze, Percussion, Base, Large, Detonating, Optional delay with separate detonating systems on delay and non-delay sides.	32056
b	7000 A) 7000 B)	26.11.36	Fuze, Percussion, Base, DD/L/7000 type, non-delay - on lines of Fuze No.501.	32056

Table 1

f. Additional Designs of Base Fuze

Item	DD/L/No.	Date	Description	O.C. Memos. "B"
5.1.10	1500	1925	DD/L/1000A with spring frame (not adopted)	8655
	2460	1928	DD/L/2000A modified to fire electrically	
	4700	1930	No.500 fuze modified to use up existing stocks of shell (not used)	21139
	Sk.1818	1935	Modification to DD/L/6000 - thinner needle.	30228
	8390	1938	Base fuze detonating, small, modified from R.D.5403.	

Table 1

g. Fuzes, Percussion, Base, Detonating - Large and Medium

Size	Type	DD/L/No.	Date	Fuze No.	N.O.D.	Specification
Large	DD/L/1000	1000 BZ (1)*	12.1.26	158 Mk.I) 158A Mk.I)	2384	I. 415 X 19.9.35
		1000 DZ (1)	14.8.26	260 Mk.I) 260A Mk.I)	2385	I. 418 G 20.6.35
		1000 EZ (1)	14.8.26	345 Mk.I) 345A Mk.I)	2386	I. 419 Q 4.11.36
	DD/L/3000	3000 BPST 3000 B.U.	27.6.29 24.9.34	159 Mk.I) 159 Mk.II) 159 Mk.II/L	3314 3376	I. 432 AF 10.10.42 L.11658
		3000 EPST 3000 EU	2.9.29 21.11.33 4.3.34 4.5.37 -.8.38	346 Mk.I) 346 Mk.II) 346 Mk.II/L	3315	I. 434 Z 10.10.42 L.8030 GG (L.16332) 7.5.43
		3300 JJPST 3300 JJRUTX(d)	11.3.32 3.8.32 24.2.33 24.10.33	480 Mk.I))) 480 Mk.II) 480 Mk.II/L	3316	I.435 AA 10.10.42 L.8006 II (L.16332) 7.5.43

Size	Type	DD/L/No.	Date	Fuze No.	N.O.D.	Specification
Medium	DD/L/2000	2000 A 2000 A(1)	14.4.31 31.1.27 15.8.28 1.9.31	500 Mk.I 500 Mk.I/L	3300	I.428 AA 10.10.42 L.7949 JJ 18.9.44
	DD/L/4000	4000 A(1) 4000 BC	30.7.29 29.11.29	501 Mk.I 501 Mk.I/L 501 Mk.II/L	3328	I.433 AE 22.11.43 L.7984 GG 19.8.44 L.7984 GG 18.8.44
				502 Mk.I 502 Mk.I/L		I. 433 AE 22.11.43 L. 7984 GG 19.8.44
	DD/L/4000	DD/L/10890		551 Mk.I)) 551 Mk.II)	4182	I. 433 AE 22.11.43

* For system of marking experimental fuzes see O.C. Memo. "B" 10319

Fuzes with "A" after the number were used with Shellite fillings and a picric powder exploder.

TABLE 2.

Measurement of Pressue in gaine prior to bursting

Round No.	Wall thickness of gaine (inches)	*Static pressure to produce same impression as explosion pressure (tons/sq.inch)
1	0.08	23.8
2	0.08	22.9
3	0.08	23.2
4	0.08	23.2
5	0.08	23.5
6	0.08	22.9
7	0.10	28.9
8	0.10	27.4
9	0.05	21.2
10	0.05	17.0

* For the measurements a Brinell type of apparatus was used in which nickel-chrome discs were used for taking the impression caused by the blow. All the discs were standardised for static load before use. The equation used for determining the equivalent static load was :-

$$L = H \frac{\Pi D}{2} (D - \sqrt{D^2 - d^2})$$

where L = load in kilogrammes

D = diameter of ball in millimetres

d = diameter of impression in millimetres

H = Brinell hardness number

TABLE 3

CREEP SPRINGS

(a) DD/L/1000 and 3000 Types

DD/L/1000 and 3000	A	B	D	E	F	GG	HH	JJ	KK	LL	MM
Diameter of wire (inches)		.046	.048	.048	.053	.053	.053	.057	.057	.061	.061
Number of coils		7	7½	6	6½	6	6	6	6½	6	6¼
Length free (inches)		1.22	1.4	1.35	1.3	1.25	1.35	1.25	1.35	1.3	1.4
Weight(in oz.) to compress spring to 0.68 ± 0.02 inch.	37	57	86	100	114	120	140	160	180	200	220
Length coil to coil not to exceed (inches)						.4	.4	.4	.4	.4	.4
Fuze		158 159	260	345 346				479 480			

(b) DD/L/2000 and 4000 types

DD/L/2000	A	D	E	F	DD/L/4000	C
Diameter of wire (inches)		.029	.026	.022		.045
Number of coils		7	6¼	7		6½
Length free (inches)		1.0	.95	.95		.95
Weight (in oz.) to compress spring to 0.35 ± 0.025 inch	58	44	29	14.5	Weight (in oz.) to compress spring to 0.52 ± 0.025 inch.	152
Length coil to coil not to exceed (inches)		.22	.22	.22		
Fuze	500					501

FUZES, PERCUSSION, BASE.

FACTOR OF SAFETY AGAINST CREEP FORCE. Q.P. No. 29927/F/11/15. O.B.90B/501/8

$$c = \frac{pd^2 wk}{W} \times \frac{16}{7000}$$

c = CREEP FORCE IN OZS.
p = LB. PRESSURE ON 1 INCH DIA. PROJ., OF 2 C.R.H. OBTAINED FROM TABLES. RELATED TO M.V.
d = DIA. OF PROJ., IN INCHES.
w = WT. OF PELLET + ½ SPRING IN GRAINS.
W = WT. OF PROJ., IN LB.
k = FACTOR OF SHAPE OF HEAD OF PROJ., OBTAINED FROM TABLES.

ARMAMENT DESIGN ESTBT.

CALIBRE	TYPE	MARK	DRG. No. EMPTY.	DRG. No. FILLED.	DRG. No. DRIVING BAND.	DIA. BORE	WT. SHELL LB.	M.V. F.S.	p	k	FUZE.	WT. PELLET + ½ SPRING.	CREEPFORCE OZS.	SPRING TEST LOAD	FACTOR
16 INCH	A.P.C.	IV B.N.T.	N.O.D. 4431	N.O.D. 4473	D.D. (L) 2479	16·0 INCHES	2049·125	2475	22·44	0·47	159	1338·05 GRNS	4·04	57 OZS.	14
15 —"—	—"—	XI A.N.T., XII A.N.T.	N.O.D. 4444	N.O.D. 4473	R.L.T. 20076	15·0 —"—	1917·562	2475	22·44	0·71	159	1338·05 —"—	5·75	57 —"—	9·9
15 —"—	—"—	XVIII B.N.T. XIX., XX.	N.O.D. 4443	N.O.D. 4473	R.L.T. 20076	15·0 —"—	1938·000	2475	22·44	0·47	159	1338·05 —"—	3·75	57 —"—	15·2
15 —"—	—"—	XXI A.N.T.	N.O.D. 4453	N.O.D. 4473	R.L.T. 20076	15·0 —"—	1917·062	2475	22·44	0·71	159	1338·05 —"—	5·73	57 —"—	9·94
15 —"—	—"—	XXII B.N.T. - SHELLITE.	N.O.D. 4454	N.O.D. 4473	R.L.T. 20076	15·0 —"—	1938·000	2475	22·44	0·47	159	1338·05 —"—	3·75	57 —"—	15·2
15 —"—	C.P.C.	II ** A.	N.O.D. 5772	N.O.D. 5777	R.L.T. 20076	15·0 —"—	1942·562	2475	22·44	0·71	159	1338·05 —"—	5·64	57 —"—	10·10
15 —"—	A.P.C.	XXII B.N.T. - T.N.T.	N.O.D. 4454	N.O.D. 5779	R.L.T. 20076	15·0 —"—	1933·062	2475	22·44	0·47	159	1338·05 —"—	3·76	57 —"—	15·15
14 —"—	—"—	VIII B.N.T.	N.O.D. 4442	N.O.D. 4473	D.D.(L)6713/1	14·0 —"—	1589·625	2475	22·44	0·47	159	1338·05 —"—	4·00	57 —"—	14·25
9·2 —"—	—"—	XIII B.	D.D.(L) 11275	N.O.D. 6269	R.L. 14093A	9·2 —"—	380·000	2880	28·58	0·47	346	1340·00 —"—	9·18	100 —"—	10·87
8 —"—	S.A.P.C.	IV B.N.T.-SHELLITE.	N.O.D. 4457	N.O.D. 4473	D.D.(L)2243A	8·0 —"—	256·000	2800	27·26	0·47	346	1340·00 —"—	9·80	100 —"—	10·20
8 —"—	S.A.P.C.	IV B.N.T. - T.N.T.	N.O.D. 4457	N.O.D. 5739	D.D.(L)2243A	8·0 —"—	254·750	2800	27·26	0·47	346	1340·00 —"—	9·89	100 —"—	10·10
7·5 —"—	S.A.P.C.	I A	N.O.D. 2695	N.O.D. 2698A	R.L.T. 13557A	7·5 —"—	200·000	2770	26·75	0·83	345	1340·00 —"—	19·10	100 —"—	5·24
6·0 —"—	C.P.B.C.	XXX/VIII, XXX/XIV, A.Q.N.T.	N.O.D. 4448	N.O.D. 4478	R.L.T. 11909A	6·0 —"—	102·875	2960	29·92	0·71	480	1345·00 —"—	22·90	160 —"—	7·00
6·0 —"—	C.P.B.C.	XXXIII A.Q.N.T.	N.O.D. 5709	N.O.D. 4478	R.L.T. 11909A	6·0 —"—	100·000	2960	29·92	0·71	480	1345·00 —"—	23·50	160 —"—	6·81
5·5 —"—	C.P.C.	V/IA, V/IIA, V/IIIA, V/I ** A.	N.O.D. 2650	N.O.D. 3407	N.O.D. 2650	5·5 —"—	83·437	2725	26·00	0·71	480	1345·00 —"—	20·60	160 —"—	7·75
5·25 —"—	S.A.P.	IC, II C. N.T. III C. N.T.	N.O.D. 4051, 4436, 4465.	N.O.D. 4039	D.D.(L)T 7025/3	5·25 —"—	80·000	2690	25·50	0·50	501	1070·00 —"—	10·74	152 —"—	14·16
4·7 —"—	S.A.P.	IB, II B.N.T.	N.O.D. 4050, 4437	N.O.D. 4039	D.D.(L)T 6643/2	4·724 —"—	62·000	2500	22·71	0·58	501	1070·00 —"—	11·48	152 —"—	13·24
4·7 —"—	S.A.P.	III A.N.T. IV A.N.T. IIA, VA, IVA.N.T. VIA.N.T.	N.O.D. 2639, 2663, 2299, 2693, 4012, 4438	N.O.D. 3404	D.D.(L)T416A, R.L.24559	4·724 —"—	50·312	2650	24·87	0·71	501	1070·00 —"—	19·10	152 —"—	7·97
4·5 —"—	S.A.P.	IC, IIC, N.T. III C. N.T.	N.O.D. 4033, 4411, 4421	N.O.D. 4039	D.D.(L)T 6659/2	4·45 —"—	55·250	2500	22·71	0·50	501	1070·00 —"—	10·16	152 —"—	14·95
4·0 —"—	S.A.P.	II, II N.T., III, III N.T., V, VI N.T.	N.O.D. 1184, 2640, 2692, 2289/4426/7	N.O.D. 3404	R.L. 22866/3	4·0 —"—	31·375	2475	22·44	1·00	501	1070·00 —"—	28·00	152 —"—	5·43
12 PDR.	S.A.P.	III, IV.	C.I.N.O. 498A.	N.O.D. 3404	R.L. 11357	3·0 —"—	12·687	2000	16·25	1·00	501	1070·00 —"—	28·25	152 —"—	5·38
4·0 INCH	S.A.P.	I B, III B, N.T.	N.O.D. 4025, 4093	N.O.D. 4039	D.D.(L)T 6574A.	4·0 —"—	35·750	2475	22·44	0·50	501	1070·00 —"—	12·30	152 —"—	12·35
15 —"—	H.E.B.N.F.	VII B.	N.O.D. 5737	N.O.D. 5746	R.L. 20076	15·0 —"—	1938·000	2457	22·17	0·58	551	1041·00 —"—	3·55	14 —"—	3·94
6·0 —"—	C.P.B.C.	III B.N.T.	N.O.D. 4440	N.O.D. 3437	R.L. 28938D.	6·0 —"—	112·000	2760	26·62	0·58	480	1345·00 —"—	15·30	160 —"—	10·46
6·0 —"—	C.P.B.C.	XXXV B.Q.	N.O.D. 5761	N.O.D. 5738	R.L.T. 11909A.	6·0 —"—	110·000	2800	27·26	0·58	480	1345·00 —"—	17·50	160 —"—	9·14

APPENDIX I

THE BABY BOMB

Experiments carried out with a view to obtaining a small anti-personnel bomb which would detonate with gunpowder ignition, had led in 1921 to the detonation, by means of a single chambered gaine (Figure 2a), of a bomb filled with C.E. A series of experiments was therefore designed to determine the best type of gaine for the purpose.

Double-chambered Gaines (Figure 2b)

In the first instance, presumably on the analogy of the C.O.W. gaine, an attempt was made to achieve detonation with a double-chambered gaine. Two types were tried, A, with a closed diaphragm between the chambers and B, with a thicker diaphragm having a hole 0.02-inch diameter through the centre. Detonation with good fragmentation was obtained with one bomb only, with a gaine of type B, but since it was the upper chamber of the gaine that burst, the conclusion was drawn that a single chambered gaine was sufficient to produce detonation of the C.E.

Single-chambered Gaines (Figure 2c)

Detonation was obtained with a type A similar to the original successful gaine, but the design was weak in that the body was too easily sheared from the head. A stronger design which also simplified filling was therefore introduced.

A lengthy series of experiments was next carried out to investigate the effects of:-

1. the nature and thickness of the steel in (a) the gaine, (b) the bomb;

2. the diameter of the touch-hole;

3. the nature of the black powder pellets.

The experiments confirmed the view that detonation depended upon the density of the explosives concerned and the nature of the confinement. Certain conditions were necessary before the velocity of the reaction reached the minimum required to produce detonation, but if the density was too high or the confinement too strong, the bombs did not break up. Within the range investigated, the pressure increased with the confinement. (Table 2)

Bomb as Detonating Gaine (Figure 3)

Although the fragmentation effect produced by these experimental bombs was not suitable for anti-personnel purposes, the increasing demand for a detonating gaine caused C.S.R.D. to submit to the Ordnance Committee a design of modified baby bomb as a possible answer to the problem. The weight, 2$\frac{1}{2}$oz., was considered too great by the Committee, but in view of the promising performance of the gaine in the 18-pr. shell, further development on these lines was given first priority.

In the course of development, it was observed that in one experiment, although "very good detonation one inch down the core" was obtained, "the black powder container did not appear as if it had been split open. It seemed as if the heat from the burning black powder had set the C.E. going." In the next round the gunpowder container was omitted and the C.E. ignited directly by a flash from the touch-hole above which was a black powder pellet and an igniter. "Very good detonation one inch down the core" was again obtained. The experiment was repeated this time without any black powder pellet, ignition being effected in the ordinary way with an igniter.

Again the result was "very good detonation one inch down the core". Proof of the ability to bring C.E. to detonation from ignition having thus been obtained, the next line of development was to determine the optimum conditions for detonation and in particular the best form of C.E. for stemming the fire-channel. This aspect of the work is dealt with in Appendix 2.

APPENDIX 2

One of the greatest difficulties confronting the successful application of the R.D. Gaine principle was the extreme sensitiveness of this method of producing detonation to the physical state of the explosive in the fire channel. Not only within the confines of this small space, but almost at a given point along it, explosion must be converted to detonation, a requirement imposing very strict limits upon variations in the physical structure of the explosive concerned.

In the stemming of base fuzes the problem was to find a free-flowing C.E. with the necessary crystalline structure in the unpressed condition to give in the pressed state the required building-up of energy to secure detonation. In 1925 the discovery was made in the Research Department that C.E. in the form of small aggregates of minute crystals answered the purpose and much experimental work has since been carried out (a) to find the optimum conditions for detonation and (b) to render the laboratory process suitable for manufacture on a large scale.

Even when the optimum conditions for detonation are established, the difficulty of obtaining in the laboratory consistent batches of C.E. with aggregates of the required size, shape, structure and density, is considerable and is enhanced when production on a large scale is carried out. No essentially new factor has been introduced into the method since 1925, but considerable improvements have been effected in the control of the many variable factors involved in the process of aggregation. In particular, the introduction in 1938 of a continuous process has led to much more consistent results; with some modifications, this process is the one in use to-day.

Aggregated C.E. - Summary of development of process of manufacture

References: Aggregated C.E. Part I (1938); A.R.D. Explosives Report No.263/42 (See also Figure 31, this monograph)

1925-30

The essential feature of the discovery made in 1925 was that a type of C.E. suitable for the stemming of gaine channels could be produced by the addition of a solution of Grade I C.E. in acetone to water in a state of continual agitation. The C.E., which is precipitated in large granules, was filtered off, dried and sieved. The difficulty lay, however, in obtaining a product with a density within the narrow limits permitted by the specification, which were:-

1. The grain size should be 20-50 I.M.M. (approximately 40 per cent. of 20-30 I.M.M. and 60 per cent. of 30-50 I.M.M.)

2. The bucket delivery (or increment) in the filling machine should be between 42 and 47 mgms., corresponding to a bulk density of about 0.8 gms./c.c.

3. The pressed density in the channel should be between 1.19 and 1.26 gms./c.c. (preferably between 1.22 and 1.24 gms./c.c.). The average length of a pressed increment and the reduction in length on pressing are also considered.

4. It should pass the chemical and stability tests of Grade I C.E.

In an endeavour to meet these stringent conditions, numerous experiments were carried out to test the effect of the following variables:-

1. pH of the dilution water;

2. method of mixing the acetone/C.E. solution;

3. variations in the speed of the stirrer;

4. variations in temperature;

5. addition to acetone of various substances (e.g. B.P. Paraffin, Gum Dammar);

6. method of mixing acetone/C.E. solution with the water.

Detailed conclusions are not given in the report but the general conclusion drawn from the series of experiments was that a warm concentrated solution of C.E. in acetone should be added to cold water with rapid stirring.

From the results quoted, distilled water appears to give the highest bulk density.

1930-32

The next advance lay in the development of a procedure for making batches of about 20 lb. of aggregated C.E. R.D.Drawing No.4414 indicates the lay-out of the plant used. (Figure 31a)

C.E. dissolved in warm acetone (54° - 56°C.) was run into distilled water, continuously agitated, at a rate controlled by the size of three glass jets, the most suitable size delivering 150-160 c.c. of solution per minute. The solution consisted of 45.5 litres (10 gallons) of distilled water with 12.8 kilos of Grade I C.E. dissolved in 16 litres of pure acetone. The diluting water was warmed to 35°C., whereas in the original method the best results had been obtained with water at 0°C.

Considerable difficulty was found in satisfying the stability test as laid down in the specification, even though the C.E. was of the grade specified and had also been partially purified. Failures to pass the test were invariably traced to inadequate grinding and drying in the preparation of the sample.

1933-34

The chief difficulty with the process, however, was low bucket delivery. A detailed investigation of the variables involved showed that while large changes could be made without appreciably raising the bucket delivery, it could be raised to within specification limits by a rumbling or polishing treatment of the aggregated C.E. after drying.

The general conclusions drawn from the investigation were:-

1. Increased stirring speed in range 120-300 r.p.m. gave smaller particles and a slightly higher bulk density.

2. The temperature of the water between 35° and 50°C. and the method of heating were not important.

3. The time for complete addition of the C.E. solution was immaterial.

4. Decreasing the temperature of the C.E. solution from 52° to 42°C. gave a pulverant and sticky product but the bulk density was little changed.

5. The number, size and material of the jets had no important influence.

6. The size, type and position of the acetone tank were without effect.

7. Changes in the concentration of the C.E. solution caused slight inverse changes in bulk density.

8. Decrease in the proportion of water to C.E. solutions showed a slight advantage.

9. The position and type of stirrer were not important.

10. Change in the time between precipitation and filtration had no effects.

11. There was no advantage in increasing the time and temperature of drying beyond the limits at present specified.

12. Unavoidable variations in the height of free fall from jets to water were not sufficient to cause appreciable variation in the physical properties of the product.

No strict correlation was found between bulk density and bucket delivery, nor did microscopic investigation of the crystals reveal any deviation of importanoe from standard C.E. N.12. The variations obtained in bulk density were, therefore, chiefly due to differences in closeness of packing, dependent on particle shape and surface conditions. Smoothing the grains by means of a polishing or rumbling treatment was found to have the required effect in raising the bucket delivery to the specified value.

Three different methods of rumbling were tried:

1. Kneading - Dry unsieved aggregated C.E. was enclosed in a rubber fabric bag and kneaded between the hands for some time.

2. Tumbling - C.E. enclosed in a rubber-fabric bag was tumbled in a rectangular box mill rotating at about 50 r.p.m.

3. Drum milling - 10 lb. of dry aggregated C.E. was introduced into a drum mill rotated at about 120 r.p.m. The mill consisted of a cylindrical drum 18 inches long and 10 inches in diameter containing either a beechwood ball or 4 rubber-covered wooden rollers 17 inches long and 1 inch in diameter.

In 1934 acceptable batches were produced by the 1930 process and rumbling the dried product in a drum mill before sieving.

1936

In 1936 an alternative process was put forward in which a solution of 100 gms. of C.E. in 199 c.c. of acetone at 60°C. was added by means of a fine jet to water kept violently agitated by a stream of compressed air issuing from a tube reaching to the bottom of the cylinder. Some of the C.E. was precipitated but much remained in suspension until the air was turned off. At the conclusion of the run the product was filtered, washed, dried and sieved, the over-size material being crushed until the whole passed through a 20 I.M.M. Sieve. The crushed and uncrushed products were then tested separately. The results show that the two products have almost identical pressed densities but uncrushed samples have lower bucket deliveries than crushed samples.

Tests were carried out on the effect of variations in

1. the size of the jet

2. the diameter of the water container

3. the distribution of the air

4. the method of introducing the acetone/C.E. solution into the water (e.g. by spraying).

This method did not prove any more satisfactory than previous ones; of 10 batches only 4 were acceptable, the pressed densities of the others being too high.

1935-37

Continuous Process

In December, 1935, an apparatus was developed for the continuous mixing of a solution of C.E. in acetone with water. It consisted of a tall U-tube filled with aqueous acetone. The liquids were run in and mixed at the top of one limb, aggregated C.E. collected in the flask connecting the two limbs and aqueous acetone overflowed from the other. R.D. No.5414 Sheet 1 shows the apparatus used. (Figure 31b)

Results show that within the limits investigated the position of the stirrer blades with respect to the surface of the liquid and the slope of the stirrer shaft are the most critical variables, the speed of the stirrer and ratio of acetone to water are less critical and the temperature and concentration of the C.E. solution and the rate of flow have hardly any effect. The effect of the temperature of the water was not systematically examined but such observations as were made indicated that a temperature above 25°C. was not desirable.

A plant was set up in the factory in November, 1936, and in the ensuing 12 months, 59 batches were made, about 450 lb. of aggregated C.E. being passed for issue. No batch was rejected on account of incorrect pressed density or bucket delivery though in some instances sieving or blending was necessary to even out small variations.

1938

In 1938 the continuous process was adapted to factory output. R.D. Drawing No.5413, Sheets 1 and 2, show the lay-out used. Sufficient acetone/C.E. solution for a 5-hour run was made from 20 lb. of Grade I C.E. and 15.2 litres of warm acetone. After drying, the C.E. was sieved to collect the 20-50 I.M.M. portion which was about 60 per cent. The dust and oversize, the latter comprising from 5-10 per cent. of the whole yield, were used in making up the solution for the next run. (Figure 31c)

This method yielded about 30 lb. of aggregated C.E. per day and gave more consistent results than any of the previous ones; but difficulty was still encountered, especially after an interval between runs, in re-establishing the exact conditions for the production of material which would pass the specification tests for pressed density and bucket delivery.

At this stage, the only source of supply of Aggregated C.E. was the Research Department Experimental Plant which could not be expected to cope with the increased demand expected in view of the development of other fuzes requiring aggregated C.E. Also D.N.O. had demanded, for tactical reasons, that other sources of supply should be made available. It therefore became a matter of urgency to evolve a procedure which could be manipulated successfully on a large scale.

1942

In 1942, A.R.D. Explosives Report No.263/42 was published on "The Manufacture of Aggregated C.E.". This report described the process and the plant in sufficient detail to enable the production of Aggregated C.E. to be carried out under factory conditions, provided that careful control is maintained. (Figure 31d)

1944

At the present time, (1944) this process is being carried out successfully at R.O.F. No.53.

The following extract from the report gives a summary of the procedure followed.

"Manufacturing procedure

(a) Aggregating conditions Aggregated C.E. is prepared by the addition of a hot concentrated solution of C.E. in acetone to violently agitated water. The flow of C.E. solution and water is by controlled jets and the agitation is maintained by a small paddle stirrer. The main variables to be controlled are:-

1. C.E. solution - concentration and temperature.

2. Stirrer - design, slope and speed.

3. Jets for C.E. solution and water - design, arrangement and flow.

(b) Preparation of batches and yield The input for each batch consists of 20 lb. Grade I C.E. which may include C.E. for reworking. The time of aggregation is 90 minutes and during this period the C.E. is transferred to a mechanical wet sieve. The cycle of operations from preparing the C.E. solution to completing wet sieving, washing and filtering and loading into trays takes 3-$3\frac{1}{2}$ hours. The C.E. is dried in the trays for 24 hours in a current of air at 100°-120°F., allowed to cool for at least 12 hours, and dry-sieved to select aggregates passing 25 B.S.S. and retained on 60 B.S.S. The output is approximately 14 lb. or 70 per cent. of input. The remainder consists of fines and oversize which are reworked.

The theoretical maximum output of the aggregating plant is thus about 80 lb. per 24 hours, but practical limitations in drying, sieving and testing are likely to reduce this figure considerably, and the demand for aggregated C.E. has not so far justified a high rate of production. The limited physical tolerance does not permit high output without continuous and careful testing of the product. It is likely, however, that for many purposes where the good handling and pelleting properties of Aggregated C.E. would be an advantage, the very close limits on density could be relaxed, and the problem of large scale production thus simplified.

(c) Testing and blending of batches Each batch is physically tested and when a number of batches have been examined three or four are selected for blending according to the test results in order to form a blended lot with pressed density near the middle of the range and with good bucket delivery compared with a standard sample. Any batches outside the limits are rejected and are available for reworking. A convenient size of lot is 50 lb.

(d) Testing of lots and preparation for issue After blending a lot is tested for the inspecting authority in the order (1) Sieve test (2) other physical tests (3) chemical tests. The chemical tests are described in Specification No.A.177F. A point to be noted is that for the vacuum stability test the aggregated C.E. must be prepared by ball milling.

Aggregated C.E. failing in the sieve test may be re-sieved and re-tested and the results of other physical tests may require the material to be incorporated in another blend or re-worked.

Accepted lots are packed in rubber bags in quantities not exceeding 10 lb. The filled bags are then packed in boxes in which they should not be a loose fit; rough handling should be avioded. Aggregated C.E. is hard enough to withstand normal handling, but if the aggregates were harder they would not break up sufficiently under stemming load."

The following appendices to the report give further details:-

I. Description of plant and flow sheet

II. Process instructions for the manufacture of aggregated C.E.

III. Notes on manufacture. Typical work sheet

IV. Process instructions for testing aggregated C.E.

V. Notes on testing. Typical test sheet

VI. Suggested form of General Safety Directions

VII. Drawings of plant and lay-out.

APPENDIX 3

STEMMING MACHINES

In the experimental stage, the filling of the R.D. gaine was carried out by hand, a method which gave good results in the hands of a skilled operator, but which was obviously unsuited to production for Service use. Various designs of machine were, therefore, developed with a view to rendering the filling process as mechanical as possible and less dependent on the skill of the operator.

Type 1. R.D.No.2826. 16.10.45 (Figure 25)

The first stemming machine was based directly on a simpler apparatus for the uniform filling of narrow tubes (R.D.No.2269, 1925)*. In this machine the increments were alternately fed into the fire-channel and pressed by a stemming pin with a constant load on top. Raising the stemming pin automatically opened the exit from the hopper containing the C.E. and lowering the stemming pin automatically closed it. A ratchet device was used to adjust the level of the fuze to correspond to the added increments.

* not reproduced.

Type 2. R.D.No.2842. 10.11.25 (Figure 26)

In this type, a rotating bucket tipped the C.E. into a hopper from which it escaped, in amounts regulated by means of a feed tappet, down a chute into a funnel designed to fit the particular fuze (or other Service component being filled) and so into the fire-channel of the fuze. Here it was compressed by the raising of the fuze against a fixed stemming pin, the position of the fuze for each increment being controlled by the hand lever. Although this method represented a considerable advance, too much still depended on the operator.

Type 3. R.D.No.2852. 18.11.25 (Figure 27)

In this type the fuze, instead of being movable, is in a fixed position on the base-plate of the machine and the stemming needle is brought down to it, the movement being controlled by means of a variable load. This type did not prove satisfactory and was soon replaced by a very much improved machine.

Type 4. R.D.No.2927; 1926, 1929 (Figure 28, M.I.L. Secret Patent No.164. 1926)

The original design of Type 4, which was brought out in February 1926, was amended in May 1926 and again in May 1929. It introduces several new and important mechanical features, and though modified in certain directions to suit individual factories, has remained the standard stemming machine ever since. The method is, very briefly, as follows:-

Into a supply of aggregated C.E. a small "bucket" is mechanically dipped, retracted, wiped and tipped over the funnel leading to the fire-channel. The levelling of the C.E. in the bucket by means of a mechanical felt wiper serves to control the volume of the C.E. but not the density, unless the grain size is standardised within fairly narrow limits. The difficulty of obtaining a form of C.E. which would give the correct density, not only for bucket delivery but also when stemmed, has been dealt with in Appendix 1. A weakness of the previous design had been the necessity for altering the pressing load for each new increment. In the new design a retreating table was introduced in order to lower the fuze, after the addition of each increment, by the amount required to keep the pressing load constant.

The main difficulties of this type of machine are:-

1. The retreating table is difficult to maintain in good mechanical order. Any slackness or stiffness interferes with the regularity of production and may cause somplete jamming.

2. The method of measuring the C.E. still calls for more skill from the operator than may be easily available.

3. There is no mechanical check on the accuracy of the stemmed increments.

4. Certain readjustments have to be made to the counterpoise, if the machine is used for filling fuzes of different weights. Experiments have shown that the inertia of the retreating table system is an important factor in governing the density obtained, hence the necessity for careful inspection to ensure correct working under all circumstances.

Direct Type, R.D.No.6251, 1930 (Ref. Fuze Section Report No.53) (Figure 30)

In 1930, the large-scale production of the R.D. gaine in anti-aircraft shell was envisaged and a new type of machine capable of being used in a multiple head form was designed to meet it. At the same time the design aimed at overcoming the difficulties attached to the use of Type 4.

The improvements introduced in R.D.6251 are:-

(i) It fits the filling guide and funnel automatically in proper alignment to the fuze at once, thus eliminating one of the chief sources of difficulty of the present design.

(ii) It does away with the disadvantage of bucket delivery adjustment and testing the stemming load.

(iii) It easily furnishes a written record of the length of every increment in every channel. With the present machine C.I.N.O. has an inspector to watch and count every increment but that gives no control of the density.

Production on the expected scale was, however, not needed, and the somewhat complicated design No.6251 never came into use except in the laboratory, where a hand-operated single-head mock-up has been successfully in use since 1930 for most of the experimental fillings carried out in the Research Department.

The defects of the present type, although reduced by later improvements, are still considerable and in 1942 some difficulty was experienced in this direction in the Bridgend filling factory.

Stemming Machine for Branch Channels R.D.No.4060A, 1931 (Figure 29)

The development of a fuze to design DD/L/3000S, in which the fire-channel branched at the top into a Y-form, called for a special apparatus for stemming these branch channels. The general arrangement is shown in Figure 29.

APPENDIX 4

R.D. GAINE TRIALS

A. Impact trials (for details see Appendix to O.C.Memo."B" 9723)

Item	Trial to test gaine for	Shell	Filling	Target	Angle of attack	S.V. f.s.	CC.B	Remarks
1.	Insensitive-ness and set-up on impact	Two 6" APC	Weighted	5"C.	N (normal)	1986 1997	6833	Perforation and subsequent detonation for both.
2.	"	"	"	4"C.	20°	2000	"	"
3.	"	Two 12" APC	"	9"C.	N	1959 1955	"	"
4.	"	"	"	5"C.	20°	1494 1498	"	"
5.	Ability to withstand shock of oblique impact.	One 15" APC	Shellite 70/30	10"C.	20°	1600	7565	N.C.D. 45 ft. in rear.
6.	"	Two 15" APC	"	6"C.	20°	1498 1503	8460 8604	Perforation and subsequent detonation.
7.	"	One 15" APC	"	8"C.	20°	2005	7547 8495 8604	"
8.	"	Two 15" APC	Weighted	8" "Erin"	30°	1714 1702	8437 8668	Perforation One gaine subsequently detonated.
9.	"	One 16" APC	TNT block plugged	12"C.	30°	1762	8437 8910	Perforation Distortion
10.	Ability to withstand heavy shock.	"	Weighted (gaine also weighted)	15"C.	N	1842	8437 8516 8922	Perforation No distortion.

B. Delay and Position of Burst (for details see Appendix to O.C.Memo.9723)

Item	Trial to test gaine	Shell	Filling	Target	Angle of attack	S.V. f.s.	OC.B	Remarks
1 a.	With fuze RL.28490B	Three 6" CPC	Shellite 80/20	1" MS	N	1500	7065	Mean delay 42.7 ft.
b.	With fuze 16D converted to non-delay	"	"	"	N	"	7136	Mean delay 3.3 ft.
2.	With fuze RL.28490C	Two 15" APC	Shellite 70/30	12"C.	N	1885 1917	7317 "	V.E. (shell failure) N.C.D. at 52 ft. in rear.
3.	With fuze 16D converted to non-delay	One 15" APC	"	"	N	1900	7439	N.C.D. in plate
4.a.	R.D. gaine (Robust pattern-No.22)	One 16" APC	TNT cast block	10"C.	30°	1601	8437	E.O.
b	Repeat	"	"	"	"	1711	9368	V.E. at 34ft.
5 a.	With existing type of powder filled fuze.	One 15" APC	Shellite	Armour 8"	N	1550		Delay 49 ft.
b.	"	"	TNT	9"	N	"		40 ft.
c.	"	"	Shellite	8"	N	"		40 ft.
d.	"	"	TNT	11"	N	"		37 ft.
e.	"	"	TNT	11"	N	"		32 ft.
f.	"	One 15" SAPC	Shellite	4"	N	"		50 ft.
g.	"	"	TNT	6"	N	"		40 ft.
h.	"	"	TNT	8"	N	"		34 ft. All apparently N.C.D.

C. Fragmentation Trials (for details see Appendix to O.C.Memo."B" 9723)

Item	Trial to test	Shell	Filling	Conditions	OC.B	Remarks
1 a.	Gaine in 7.5 inch APC shell of different capacities	One 7.5" APC 4%	TNT pressed block	Under water	6169 7980	Satisfactory. Good order of detonation.
b.	"	One 7.5" APC 5%	"	"	7980	
c.	"	"	"	"	"	Satisfactory, superior to 1.a
d.	"	One 7.5" APC 3%	TNT cast block	"	8959	Completely unsatisfactory.
4 a.	Whether gaine would function if broken away from adapter*	One 15" APC	TNT	At rest	8437 8642	Gaine did not function.
b.	"	"	Shellite	"	"	"

* For adapter trials see Appendix to O.C.Memo."B" 9723.

APPENDIX 5

U.S.A. MANUFACTURE AND FILLING

Large and medium base fuzes have, during the present war, been also manufactured and filled in the United States of America. With one exception, the types of fuze supplied have given excellent results at gun proof in Great Britain. The one failure occurred with the large base fuze which gave blinds in Fuze No. 480 when used in 6-inch shell against 4-inch plate.

Proof trials carried out in the United States showed that in every instance where the ignition chamber filling was properly ignited, high order detonation took place. This result is especially interesting since aggregated C.E. is unprocurable in the United States and C.E. crystalline, dense was used instead.

An examination of recovered blinds showed that in every instance the delay pellet had failed to ignite. It was concluded that since the failures occurred in a relatively light shell fired at a relatively thick plate, the heavy impact caused the inertia pellet to jam in the needle cap, thus preventing the detonator from exerting its full power through the flash-hole.

As a result of these investigations, the following changes in design, resembling very closely the suggestion made by C.S.R.D. in 1936, were introduced:-

(a) a strengthened detonator closing plug,

(b) a chamfered lead into the flash channel in the inertia pellet,

(c) a slight increase in the weight of the detonator,

(d) roughening of the lighting-up surface of the delay fitment.

Although some improvement resulted, failures at thick plate proof persisted, indicating that the source of the trouble had not been located. Examination of recovered blinds led to the conclusion that the C.E. filling in the ignition chamber had not been properly ignited.

The trials established the point that the failures were due to extreme deceleration on impact, their frequency increasing with increase in deceleration. Sectioned fuzes showed such a violent crushing of the ignitory system that the needle completely choked the flash channel in the inertia pellet. It was suggested that when the inertia pellet is forward, the delay backfires into the space below the inertia pellet, whereas, if it is back on its rear seating, it tamps the delay and concentrates all the delay flash towards the ignition chamber. Experiments showed that the flash from the delay to the beehive was strong if the inertia pellet was in the rear, and weak if it was jammed forward. A similar action is suggested from the gunpowder pellets in the cross-channel.

As a result of these experiments, I.N.O.(New York) suggested the following modification to the existing fuze:-

(a) a much wider opening to the flash channel

(b) a self-sealing delay fitment

(c) a booster pellet for the delay

(d) a strengthened needle cap.

That he regards these measures as merely makeshift, however, is indicated by his final conclusion that "it is thought probable that beford long the design of our large base fuzes will have to be reviewed".
(Ref.ANI/96/291 (1943), ANI/96/778 (1944*); O.B.Procs.29089, 29256).

* Report by I.N.O. (New York)

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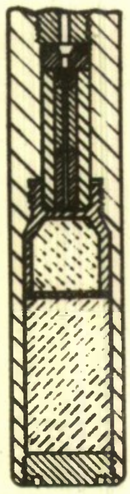
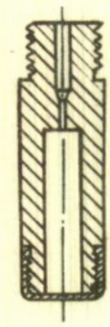
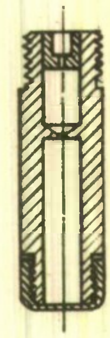


(a)
C. O. W. GAINE.

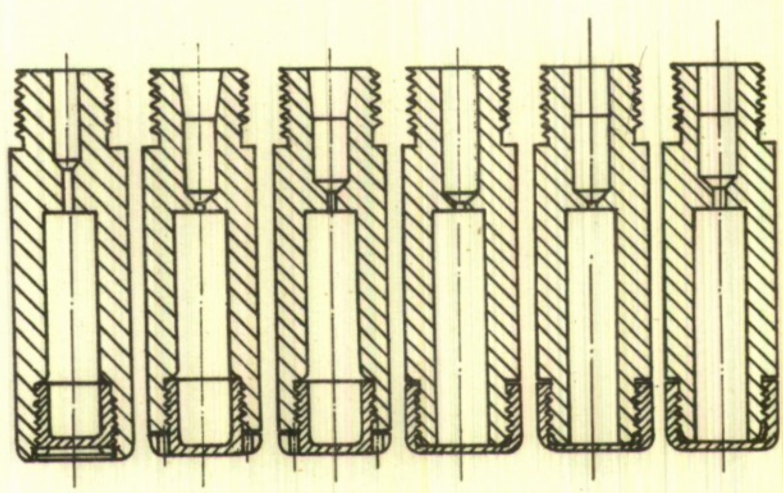
(b)
Nº 1 GAINE.



(c)
Nº 2 MARK I
(R. D. PATTERN)



(d)
MAGAZINE GAINE
(R.D. PATTERN)



MARK I | MARK I* | MARK I** | MARK II (ORIGINAL) | MARK II (ALTERED) | MARK III

(e) Nº 2 GAINE.

FIGURE 1.

REQN. Nº: D.110	TRACED BY: P. FENNER.	APPROVED BY: T.C. ROBERTS	
DRAWN BY:	CHECKED BY:	PASSED BY:	FOR C.S.A.R.

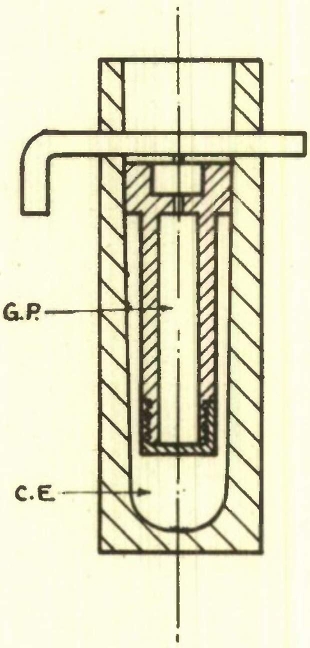
DEVELOPMENT OF DETONATING GAINES (EARLY TYPES).

DRG Nº ARD. 6742

SHEET 1. 4 SHEETS.

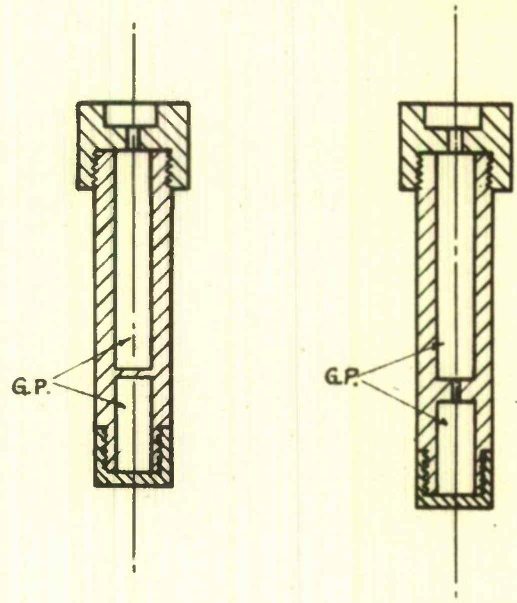
4. 1. 45.

FIG. 2. CONFIDENTIAL - DISCREET



BABY BOMB.
(FIRST SUCCESSFUL ROUND)
1921.

FIG. 2 a.

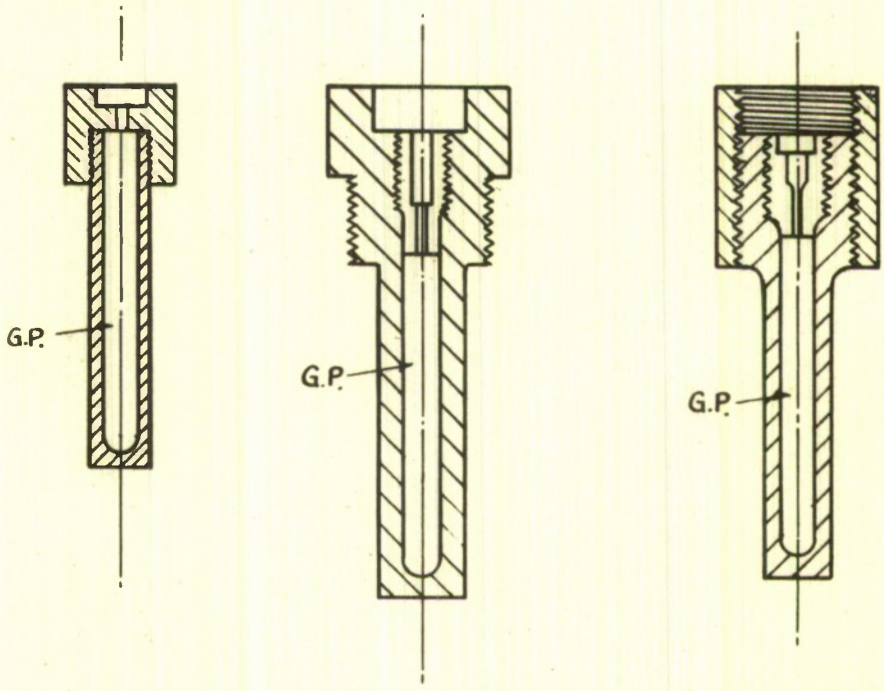


A. 1921.

B. 1921.

DOUBLE CHAMBERED GAINES.

FIG. 2 b.



A. 1921.

B. 1921.

C. 1922.

SINGLE CHAMBERED GAINES.

FIGURE 2c.

THE BABY BOMB.

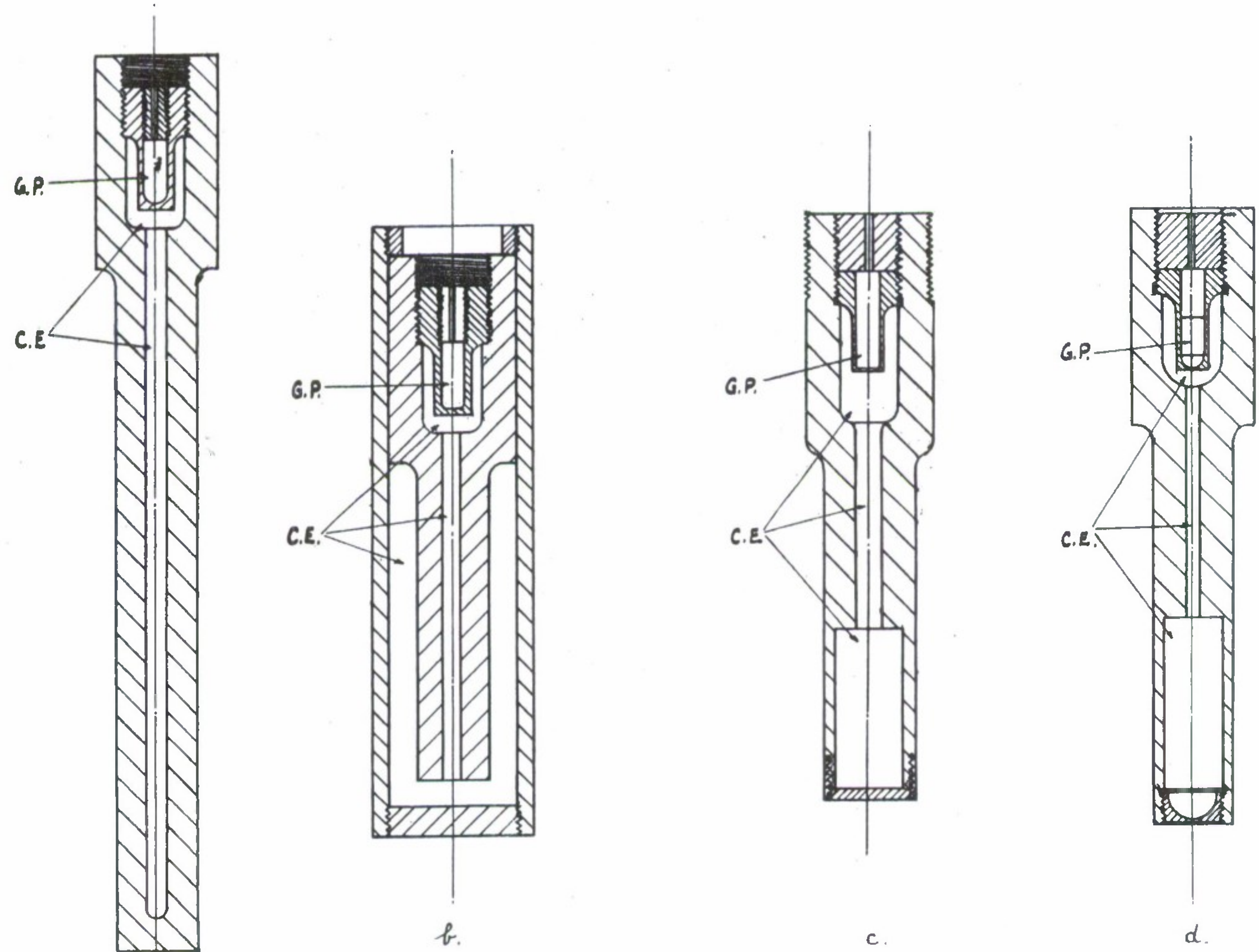
REQN. Nº: D118	TRACED BY: P. FENNER	APPROVED BY: T.C. ROBERTS	P. W. W. [illegible]
DRAWN BY:	CHECKED BY:	PASSED BY: [signature]	FOR C.S.A.R.

DEVELOPMENT OF DETONATING GAINES (EARLY TYPES.)

DRG Nº ARD. 6742.

SHEET 2 4 SHEETS.

4. 1. 45.



a. 1922.

b. 1922.

c. 1923.

d. 1923. TYPE 10.

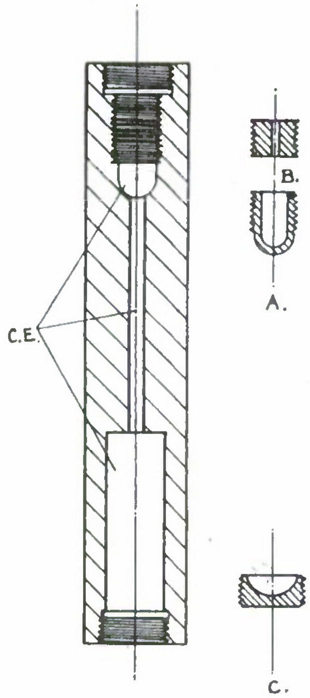
FIG. 3.

R.D. DETONATING GAINES — BABY BOMB TYPE

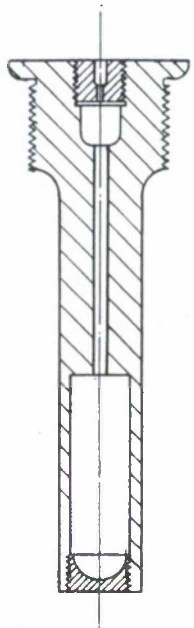
REQN. Nº: D.118	TRACED BY: P. FENNER.	APPROVED BY: T.C. ROBERTS	[signature]	
DRAWN BY:	CHECKED BY:	PASSED BY: [signature]	FOR C.S.A.R.	

DEVELOPMENT OF DETONATING GAINES. (EARLY TYPES.)

DRG. Nº. ARD. 6742.	
SHEET 3	4 SHEETS.
4. 1. 45.	



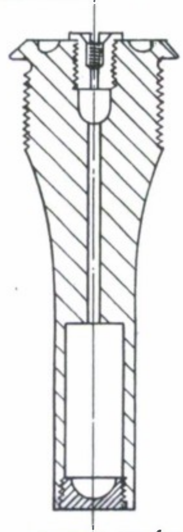
a. (1923).
FIRST GAINE IN WHICH C.E. WAS DETONATED FROM IGNITION.
(G.P. HOLDER (A) OMITTED IN TRIAL.)



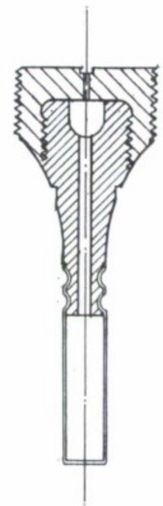
b. PATTERN 12 (1923).

c. PATTERN 20 (1924)

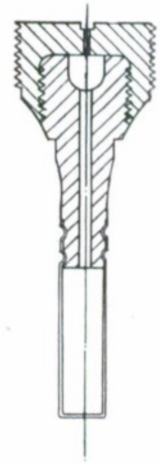
d. PATTERN 21 (1924)



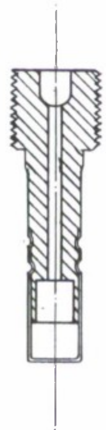
e. PATTERN 22 (1925)
R.D. Nº 2724.



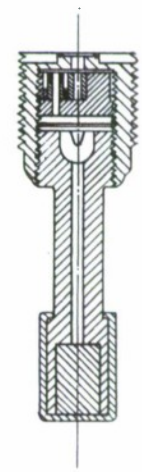
f. PATTERN 50 (1927).
R.D. Nº 3203.A



g. PATTERN 60 (1927).
R.D. Nº 3254.



h. PATTERN 70 (1930)
R.D. Nº 3956



i. GAINE FOR 6 PDR. H.E. SHELL (1936)
R.D. Nº 4786 A.

FIG. 4.
R.D. GAINES — NEW PRINCIPLE.

REQN. Nº: DJ18	TRACED BY: P. FENNER.	APPROVED BY: T.C. ROBERTS.	E.W.W. [signature]
DRAWN BY:	CHECKED BY:	PASSED BY: [signature]	FOR C.S.A.R.

DEVELOPMENT OF DETONATING GAINES. (EARLY TYPES.)

DRG. Nº ARD. 6742.
SHEET 4 — 4 SHEETS.
4. 1. 45.

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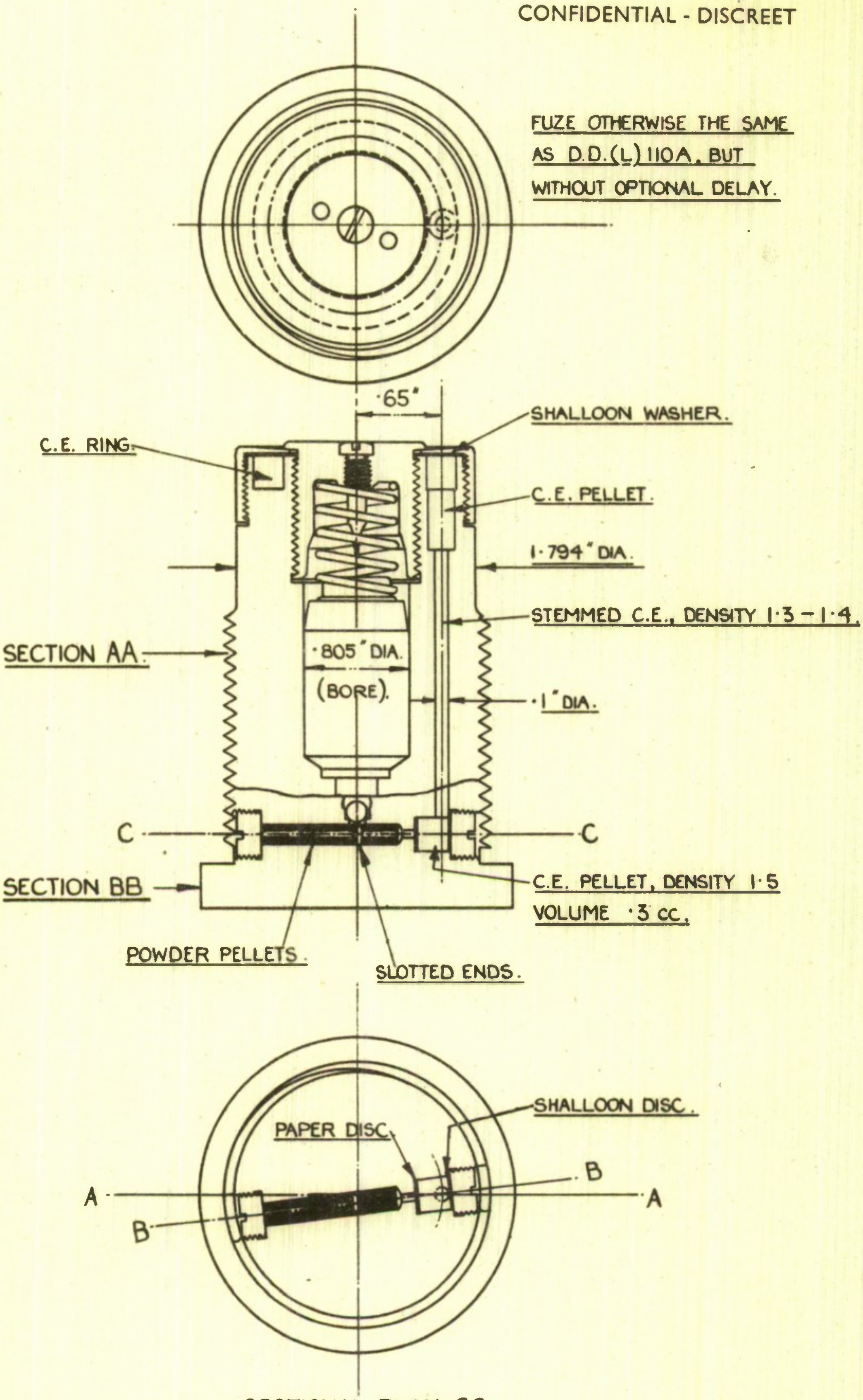
FUZE OTHERWISE THE SAME AS D.D.(L) 110A, BUT WITHOUT OPTIONAL DELAY.



SECTIONAL PLAN CC.

FIG. 5.

TRACED FROM D.D.(L) 990.

DD/L/990 FUZE, PERC. BASE, LARGE, DETONATING WITH R.D. CAINE SYSTEM.

DRG. NO. ARD. 6879.

27.6.45.

CONFIDENTIAL - DISCREET

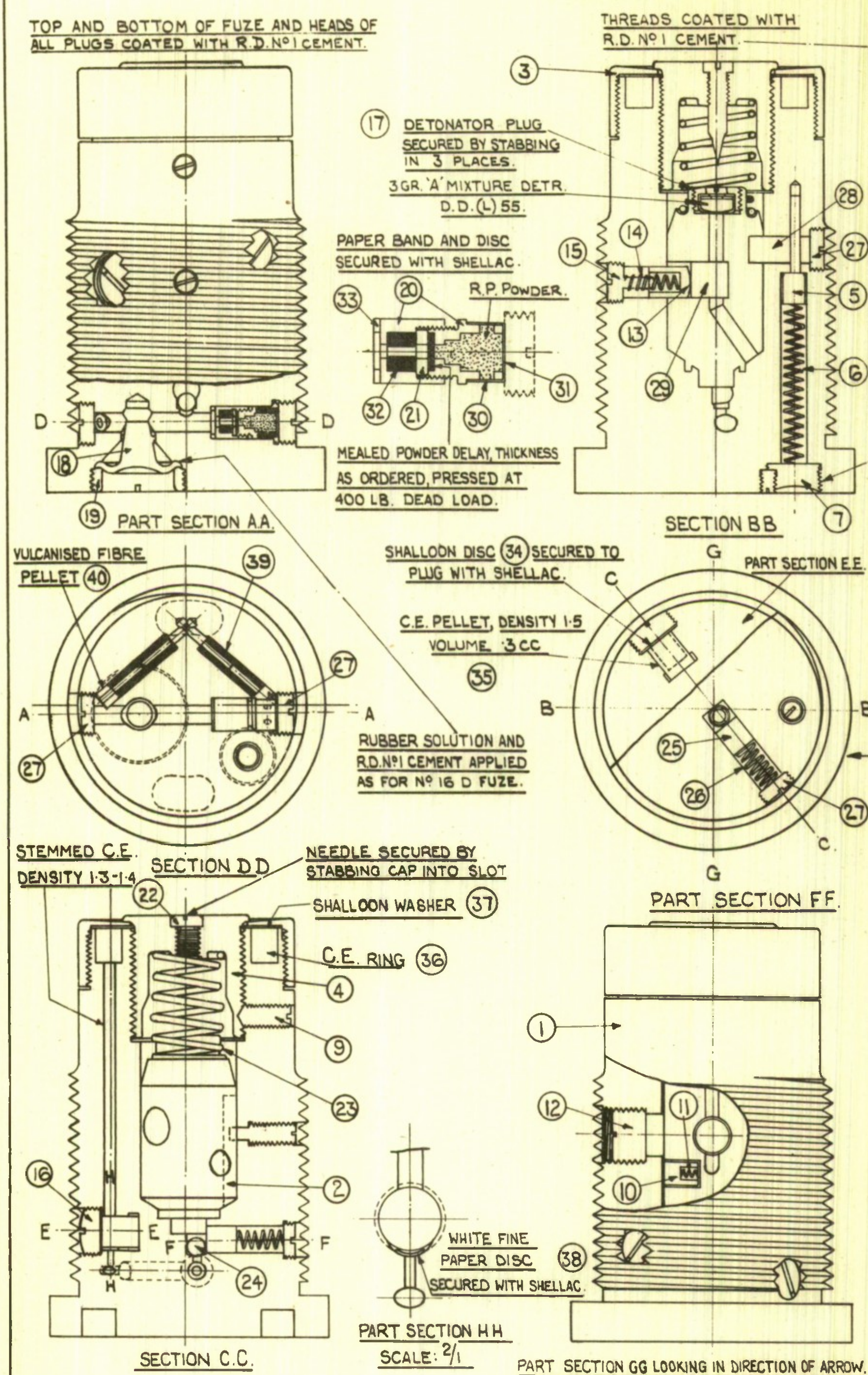
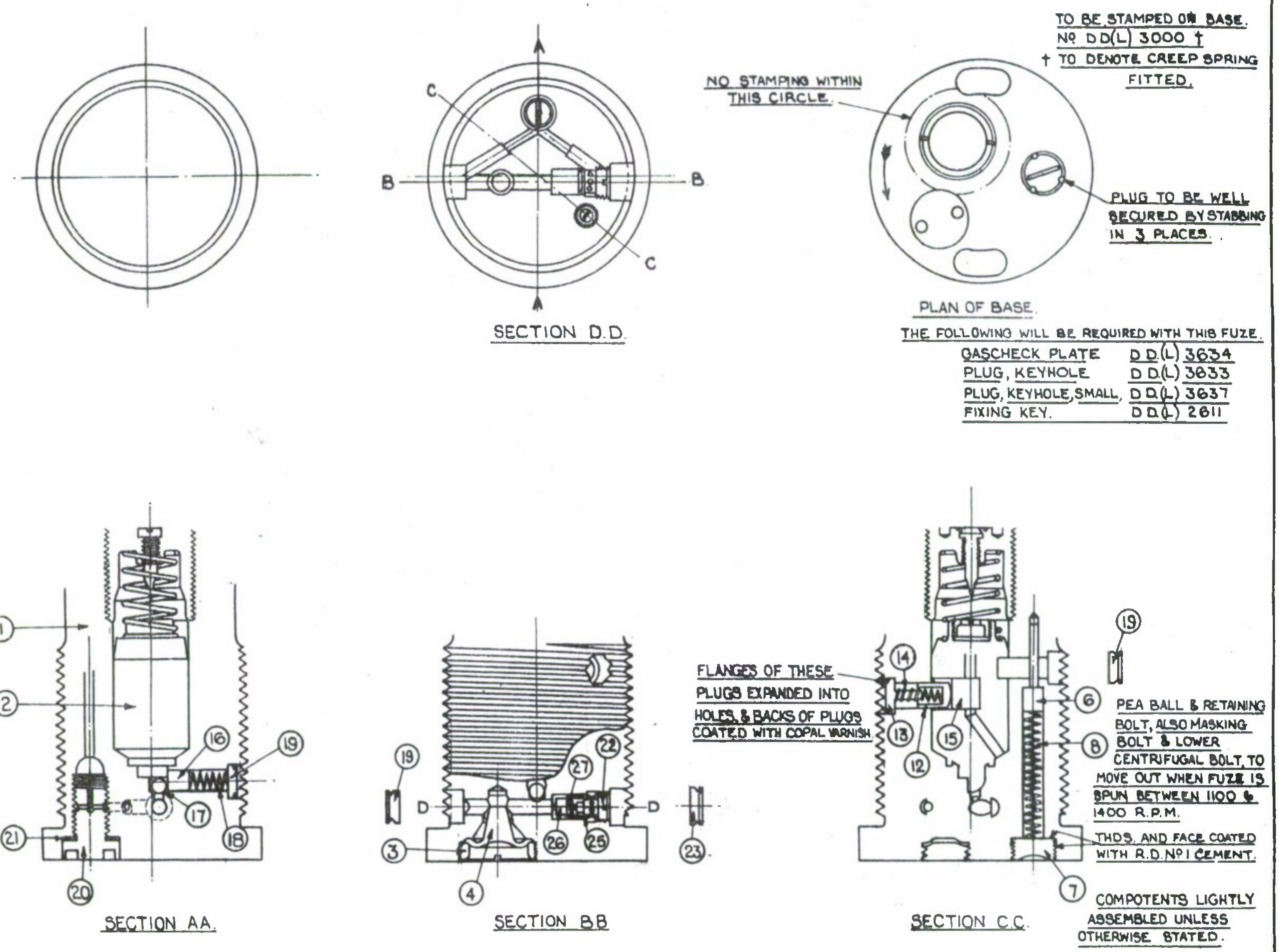


FIG. 6.

TRACED FROM D.D.(L) 1000

DD/L/1000 FUZE, PERC. BASE, LARGE, DETONATING WITH R.D. CAINE SYSTEM AND OPTIONAL DELAY.	DRG. Nº ARD 6884.
	27. 6. 45

CONFIDENTIAL - DISCREET



GENERAL ARRANGEMENT.

FIG. 7.

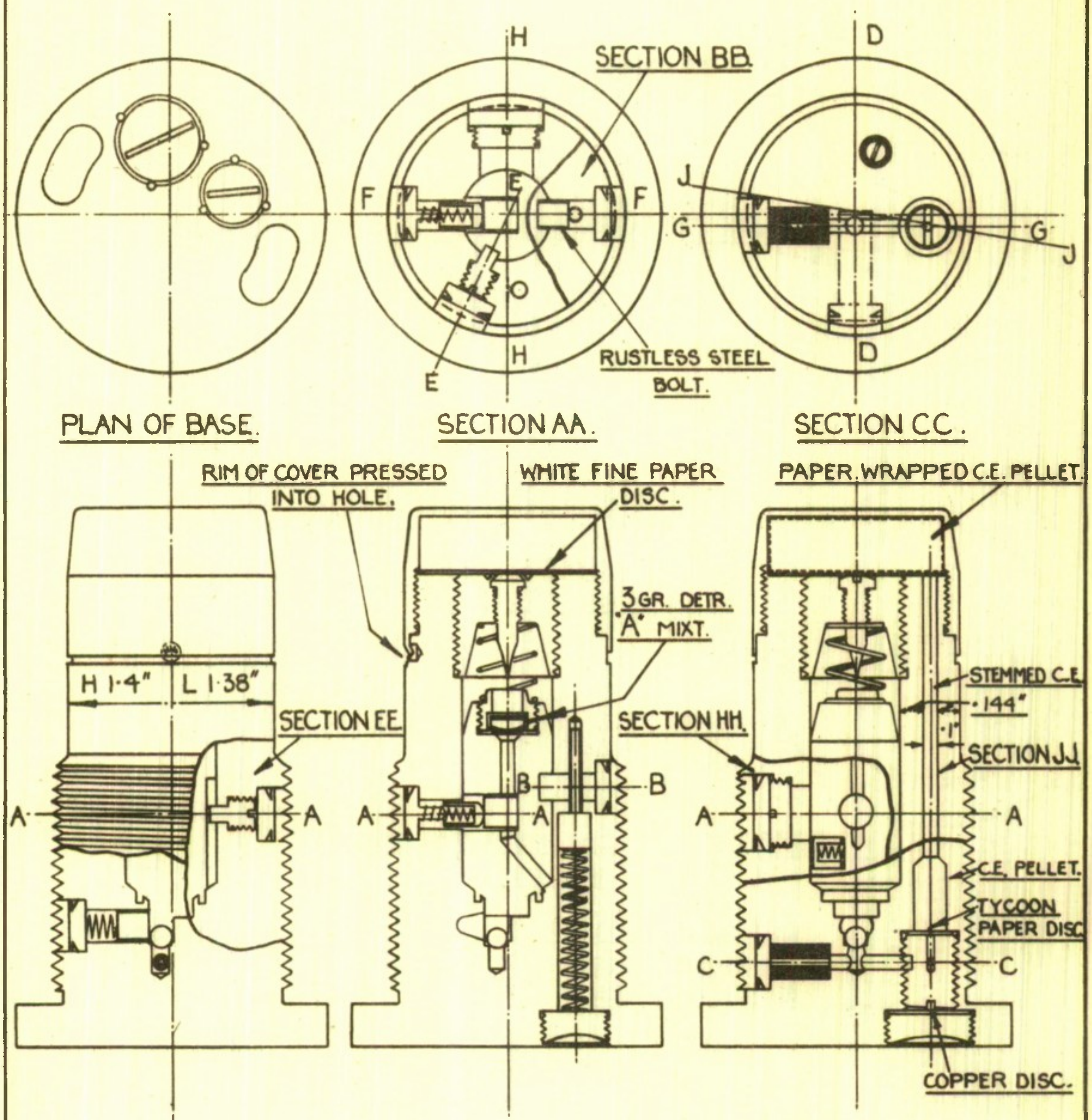
TRACED FROM D.D.|L|3000|1

Nº D.D.|L|3000, FUZE, PERCUSSION, BASE, LARGE, DETONATING.
WITH THE R.D. GAINE SYSTEM & OPTIONAL DELAY.

DRG Nº A.R.D. 6899

9.7.45.

CONFIDENTIAL - DISCREET



SECTION DD. SECTION FF. SECTION GG.

FIG. 8.

TRACED FROM D.D. (L). 2000A.

DD/L/2000 FUZE, PERC., BASE, MEDIUM, DETONATING.

DRG NO ARD. 6883.

27. 6. 45.

CONFIDENTIAL - DISCREET

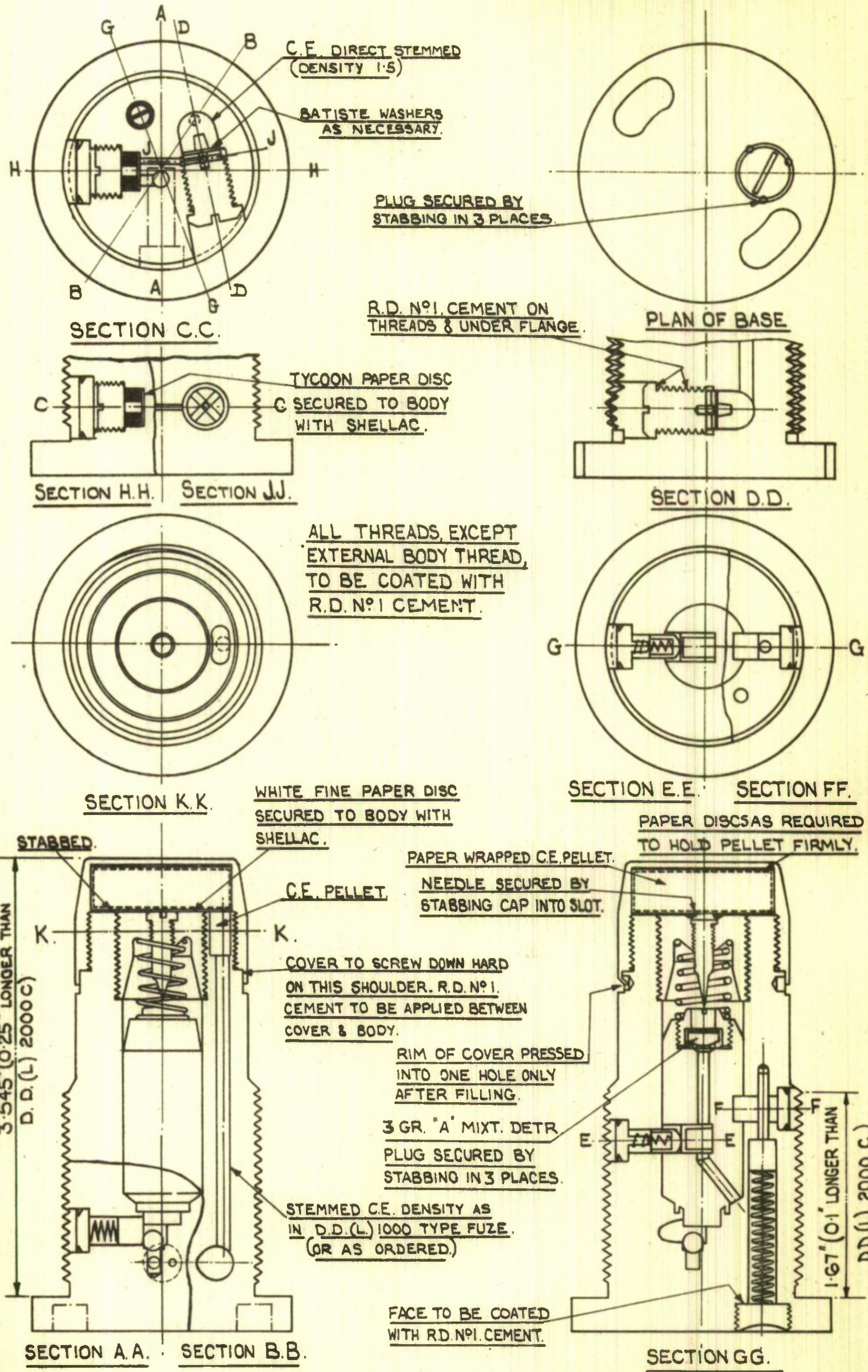


FIG. 9.

TRACED FROM D.D.(L) 4000

DD/L/4000 FUZE, PERC., BASE, MEDIUM, DETONATING (HEAVY PELLET TYPE).

DRG Nº ARD.6882.

27. 6. 45.

CONFIDENTIAL - DISCREET

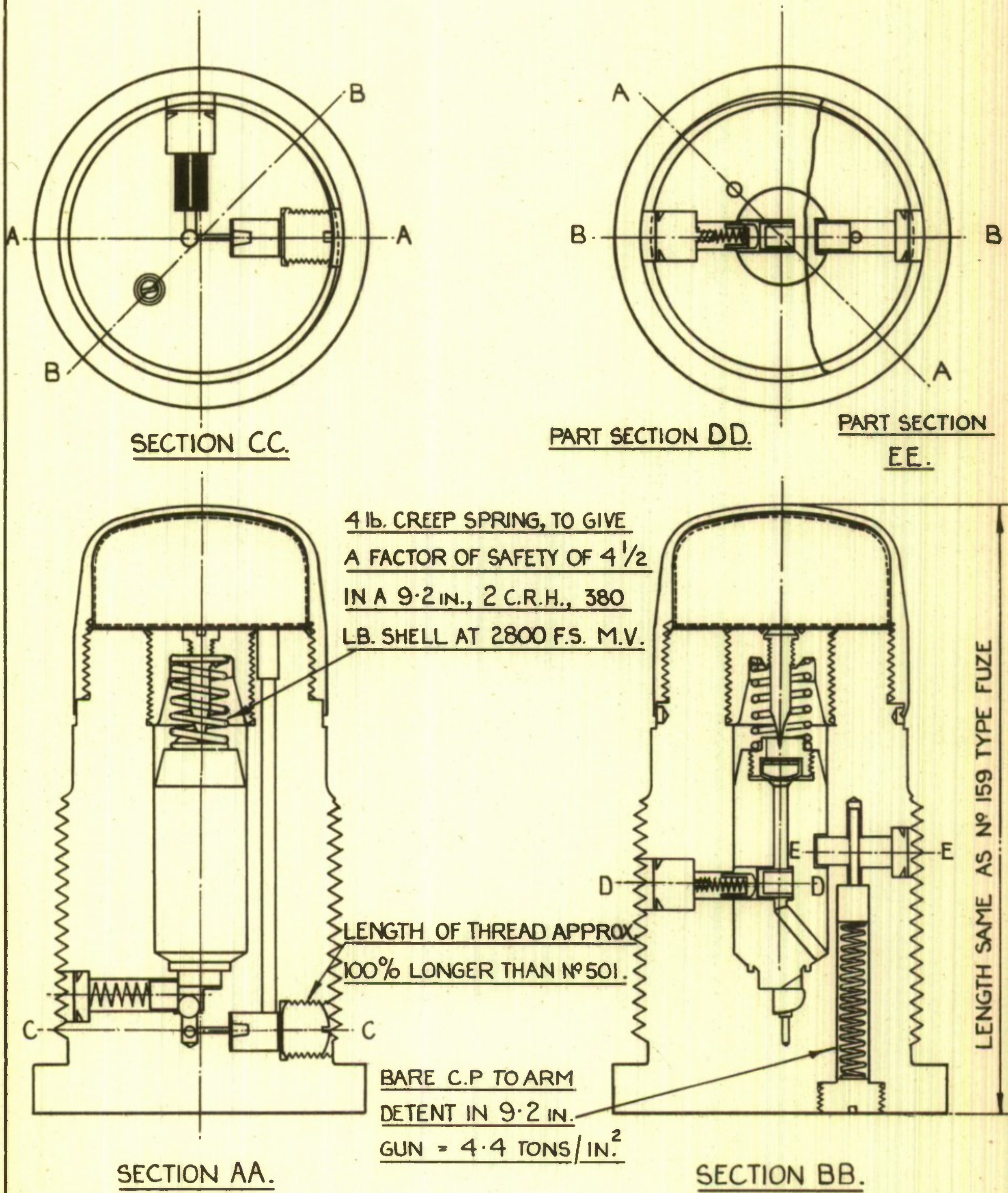


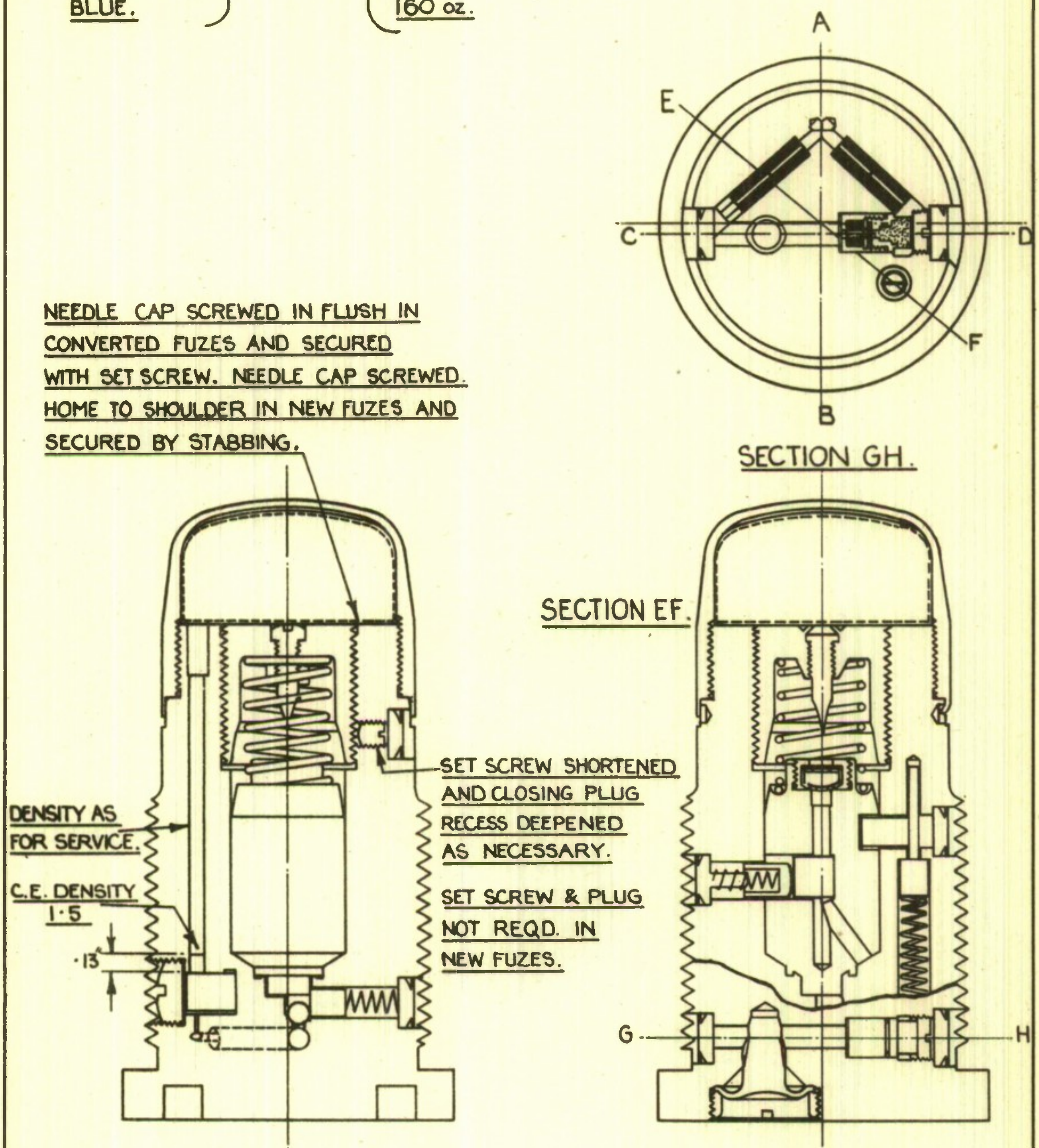
FIG. 10.

TRACED FROM D.D.(L) 5000.

DD/L/5000 FUZE, PERC., BASE, LARGE, NON-DELAY, DETONATING WITH INTERNAL COMPONENTS AS IN FUZE NO.501.	DRG. NO. ARD. 6881.
	27.6.45.

CONFIDENTIAL - DISCREET

BASE OF FUZE COLOURED;	WHEN FITTED WITH	CREEP SPRING.
WHITE.		57 oz.
YELLOW.		100 oz.
BLUE.		160 oz.



SECTION AB.

SECTION CD.

NOTE: WHEN ASSEMBLED TO SHELL, THIS FUZE TAKES PLUGS, KEYHOLE Nº 2, AND PLATE, GASCHECK, Nº 3.

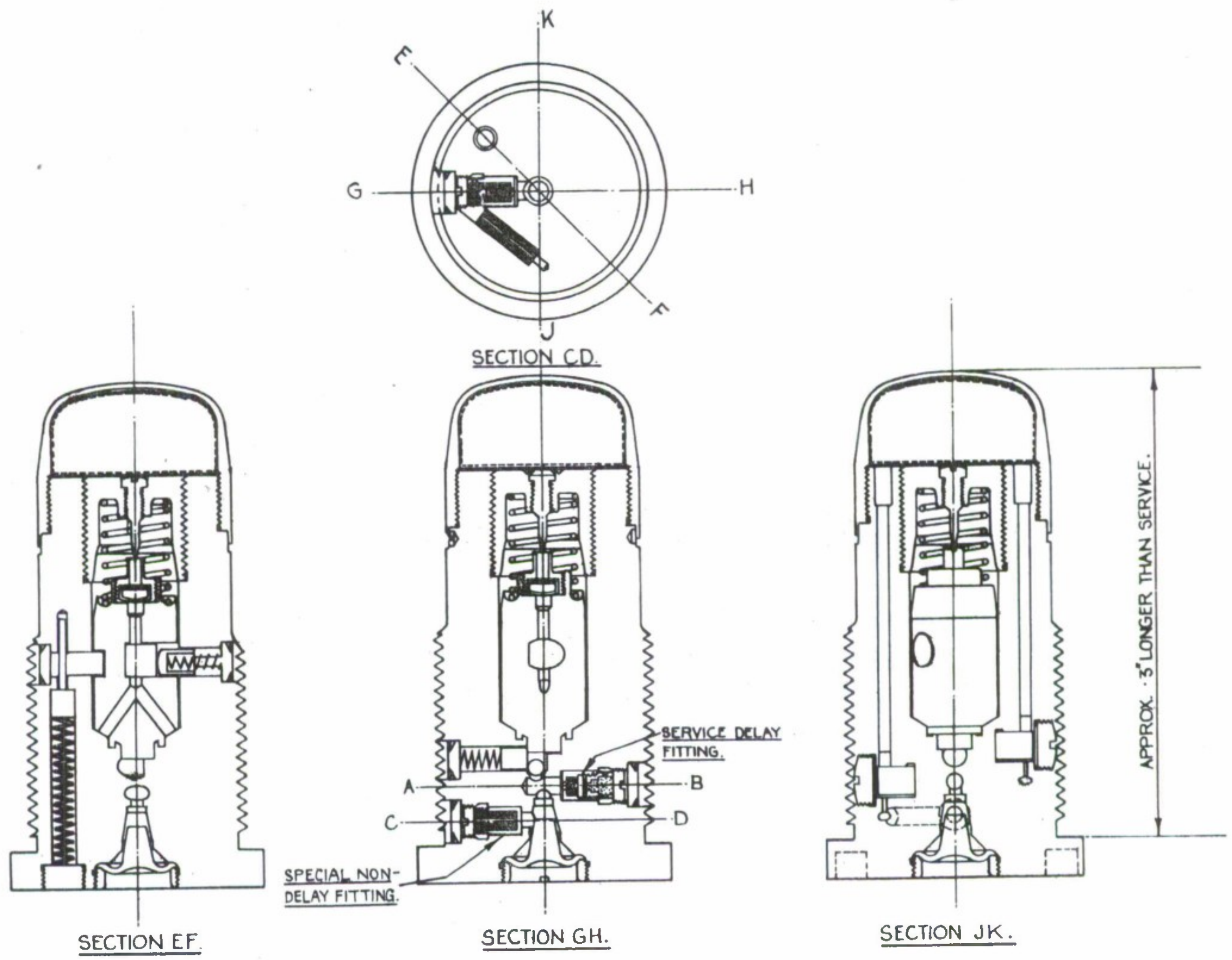
FIG. 11.

TRACED FROM D.D.(L)6000.

DD/L/6000 FUZE, PERC., BASE, LARGE, DETG., OPTIONAL DELAY. BASED ON DD/L/1000 (FUZE Nº 158) TYPE WITH MAGAZINE ON LINES OF DD/L/3000 (FUZE Nº 159) TYPE.

DRG. Nº A.R.D. 6880.

27.6.45.



STEMMED CHANNELS AND IGNITION CHAMBERS FILLED AS IN D.D.(L)6000.

FIG. 12.

TRACED FROM D.D.(L) 7000.

DD/L/7000 FUZE, PERC., BASE, LARGE, DETONATING, WITH SEPARATE R.D. GAINE SYSTEMS FOR DELAY AND NON-DELAY.

DRG. NO. ARD 6885.

27. 6. 45.

CONFIDENTIAL - DISCREET

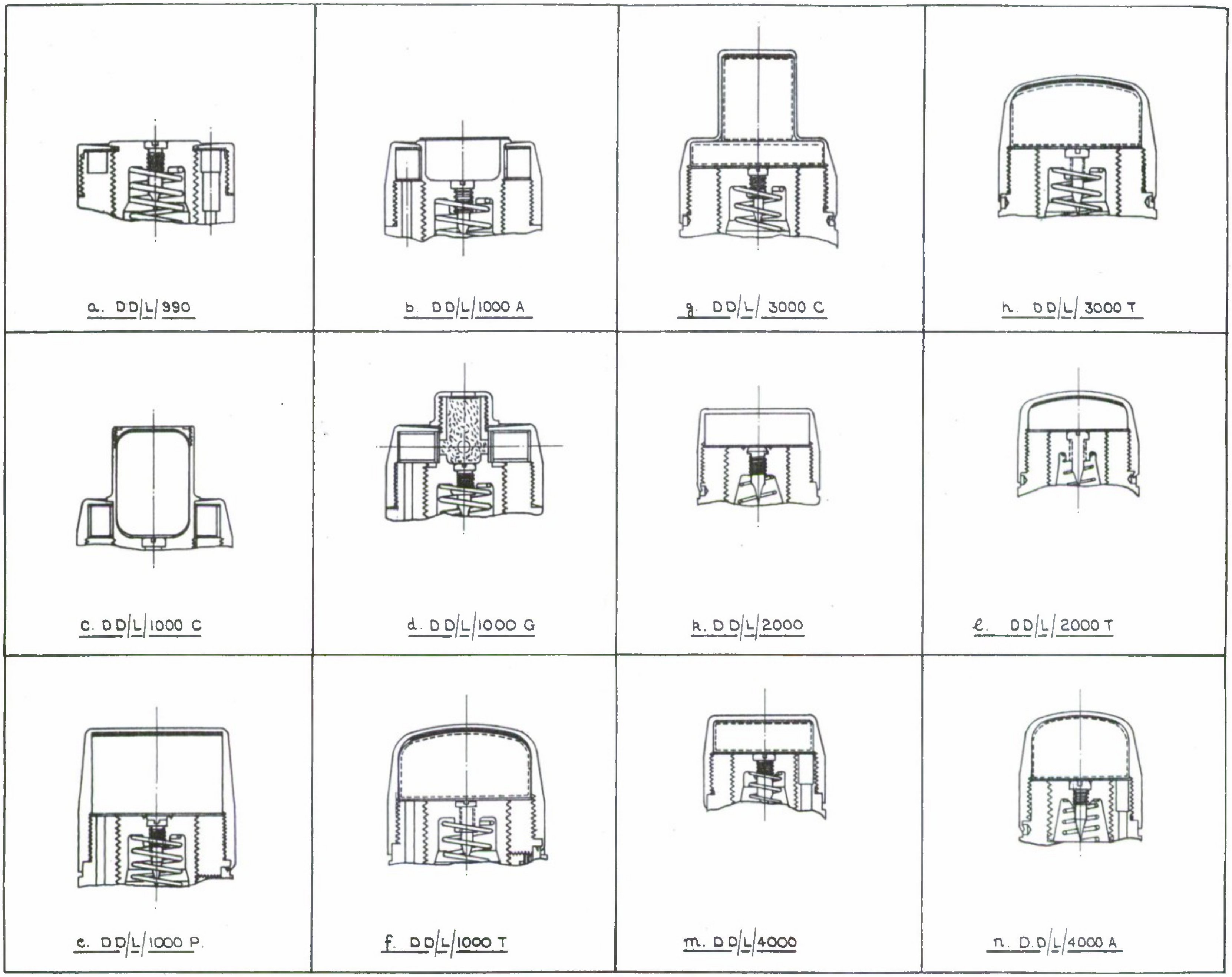
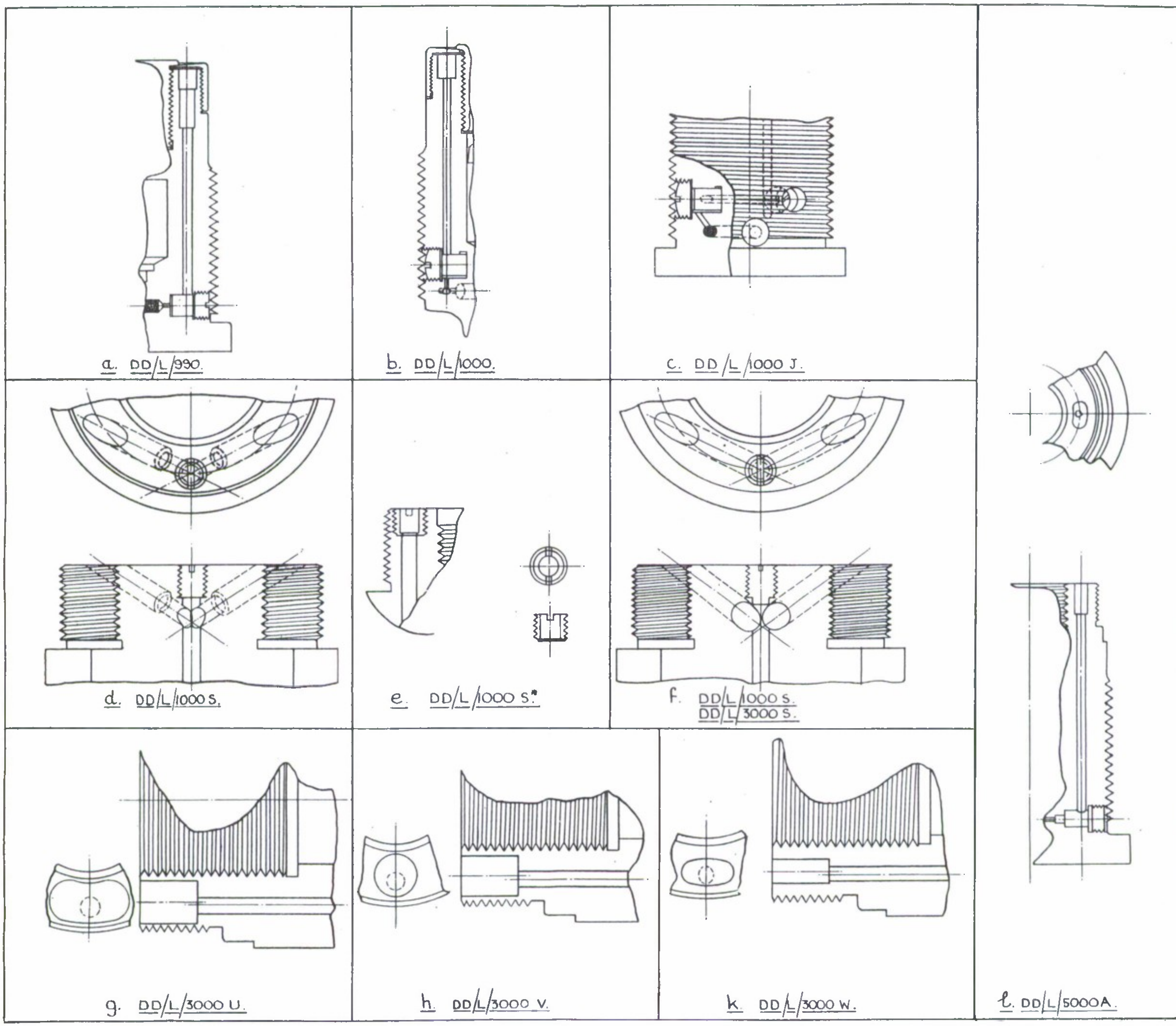


FIG. 13.

MAGAZINE – DIFFERENT TYPES.

DRG No A.R.D.6888

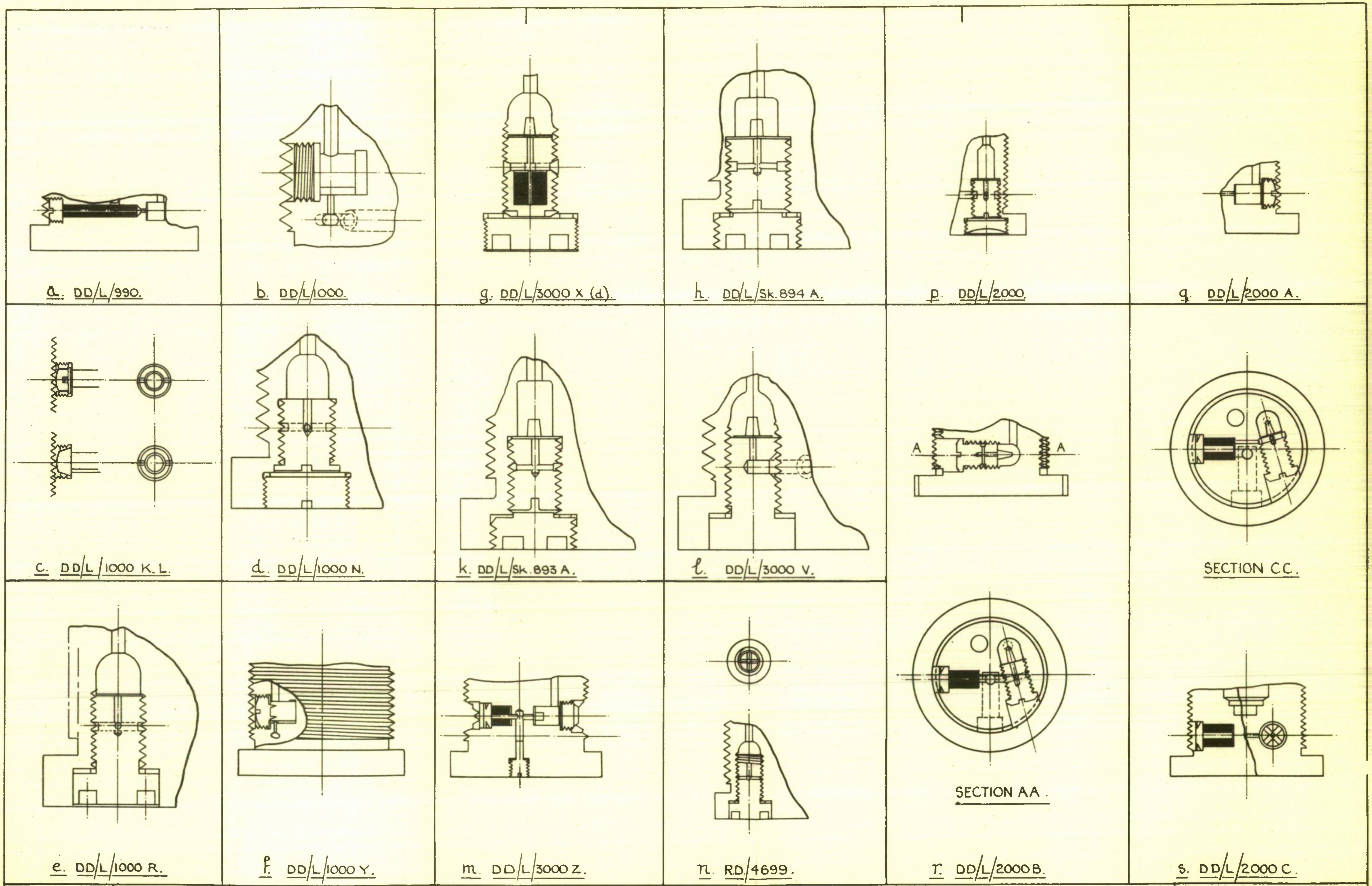
2-7-45



FIRE - CHANNEL - ALL TYPES. FIG. 14.

DRG No. ARD6886.

27.6.45.

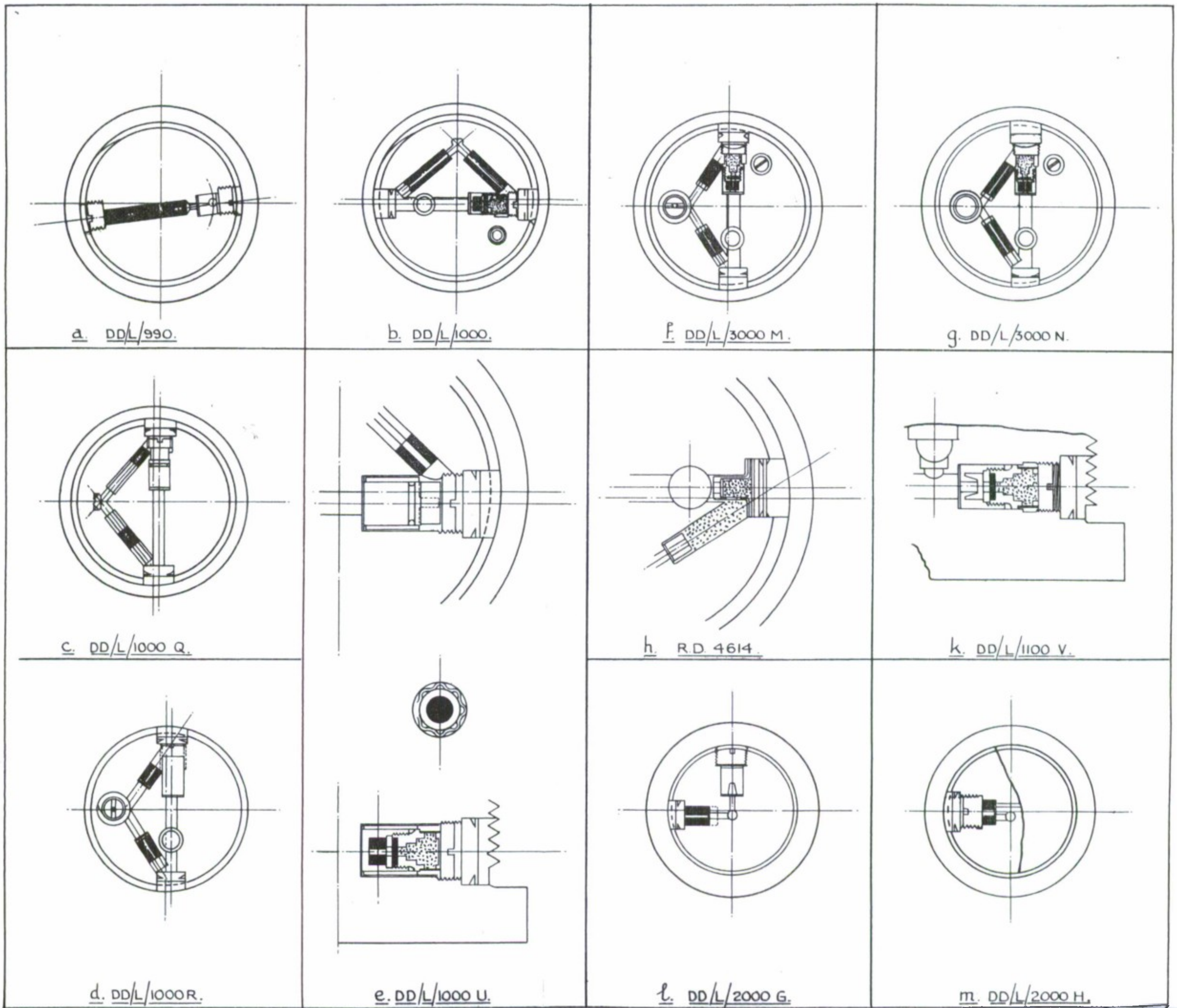


REQN. NO: T.185	CHECKED BY: [signature]	[signature] FOR C.S.A.R.
DRAWN BY:	APPROVED BY: T.C. ROBERTS	
TRACED BY: P. FENNER.	PASSED BY: [signature]	

IGNITION CHAMBER. FIG. 15.

DRG NO. ARD. 6890.

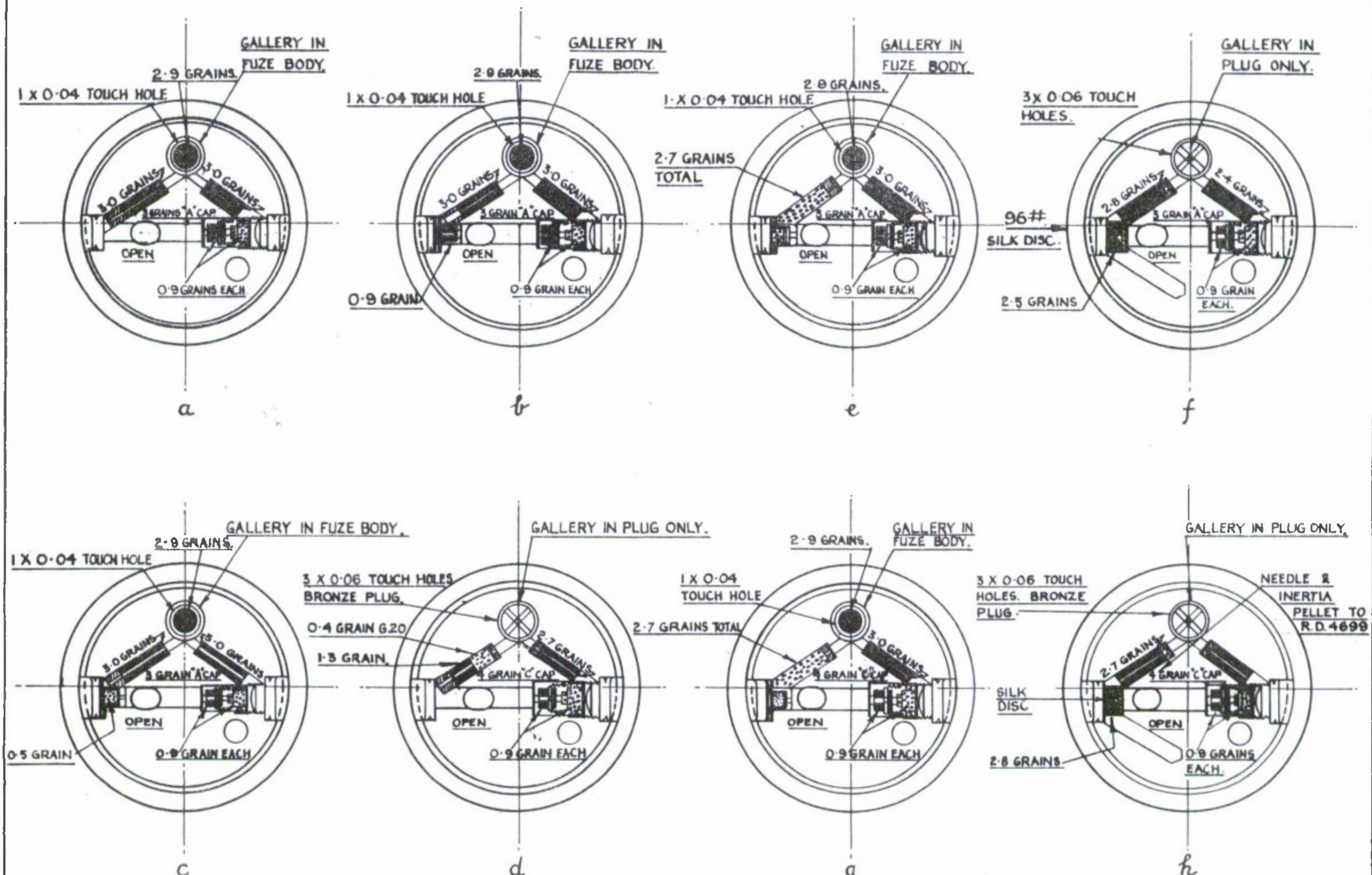
2. 7. 45.



CROSS CHANNEL FILLINGS. FIG. 16 A.

DRG NO ARD 6887.

29.6.45



	a	b	c	d		e		f	g	h
DELAY (FEET)	18·6	15·8	11·0		8	10				
DELAY (SECONDS)				0·0066			0·0055	0·0073	0·0045	0·0055
S.V. F/S	1700	1700	1700	FIRED AT	1700	1560	FIRED AT	FIRED AT	FIRED AT	FIRED AT
REV/SEC.	113·3	113·3	113·3	REST	113·3	46·2	REST	REST	REST	REST
T.O. LENGTH (INCHES)				0·61			0·875	0·67	0·97	0·60

PRESSED GUNPOWDER.

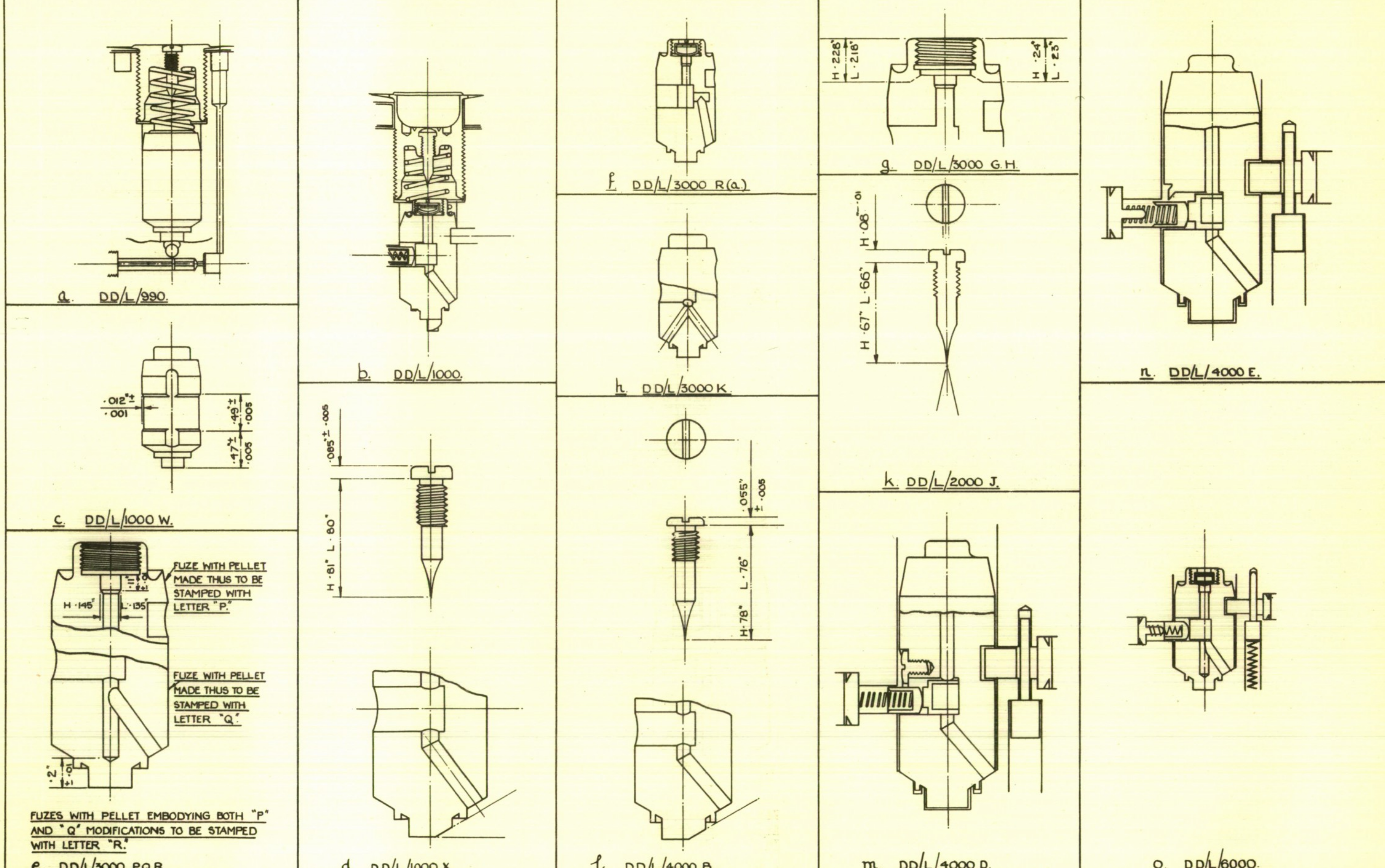
GRAIN POWDER.

FIG 16 b

TRACED FROM R.D. Nº 4914 1, 2, 3, 5, 30, 32, 36, 47.

REQN. Nº: D.146	CHECKED BY: A. Field	E. G. W. [illegible]	CROSS CHANNEL FILLINGS. (EXPERIMENTAL.)
DRAWN BY: A. Field	APPROVED BY: T.C. ROBERTS		DRG NO ARD 6822.
TRACED BY: P. FENNER	PASSED BY: [illegible]	FOR C.S.A.R.	2. 5. 45.

CONFIDENTIAL - DISCREET



REQN. Nº. T. 185	CHECKED BY: [signature]
DRAWN BY:	APPROVED BY: T.C. ROBERTS
TRACED BY: P. FENNER	PASSED BY: [signature]

[signature]
FOR C.S.A.R.

INERTIA PELLET AND NEEDLE. FIG. 17.

DRG NO. A.R.D. 6892.

5. 7. 45.

R.D. ref. 1619/29 (42)(43)

CONFIDENTIAL - DISCREET

EX.

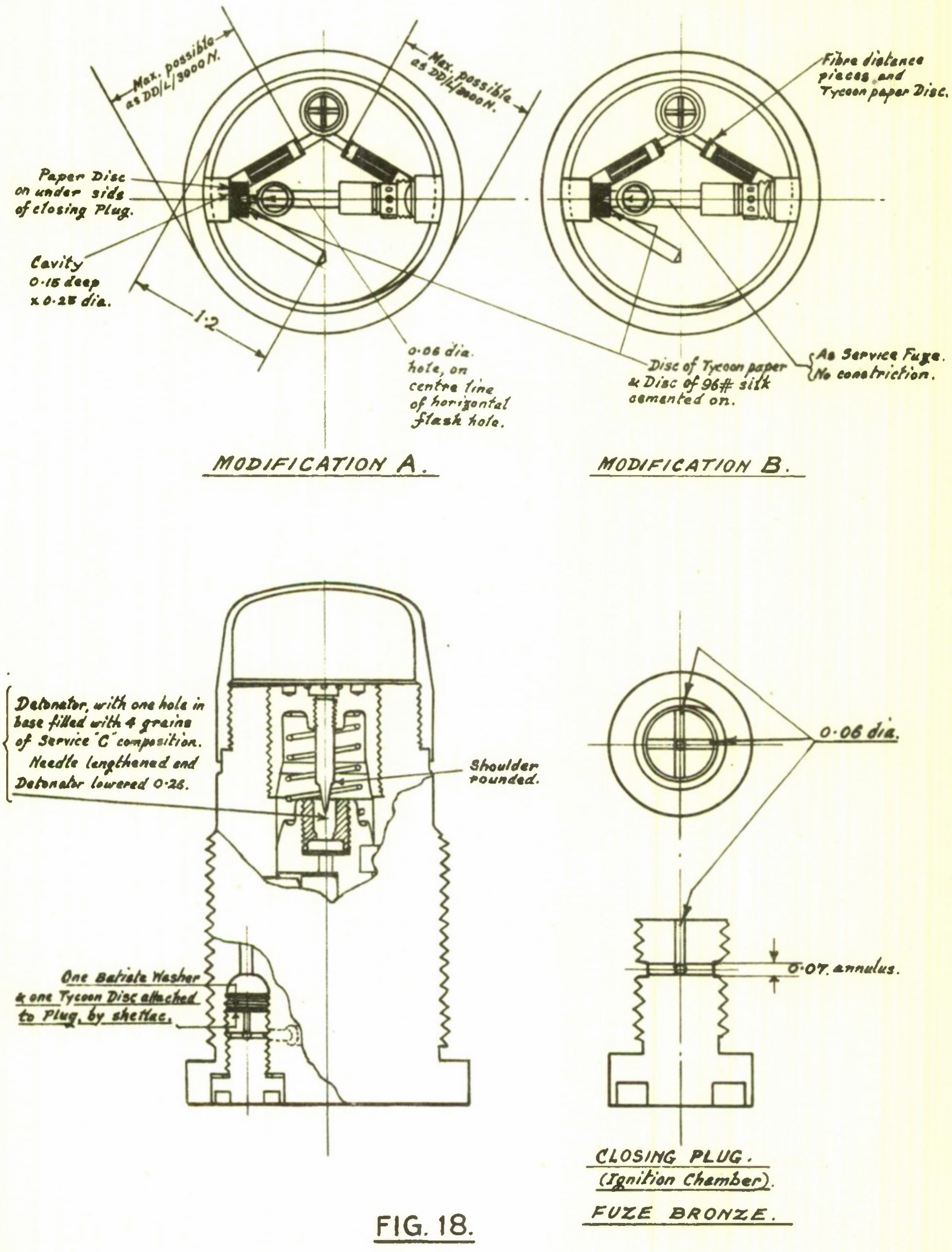


FIG. 18.

ROUGH SKETCH.

REQ. Nº F.4824.		
DRAWN BY:-	CHECKED BY:-	C. H. Awood. FOR C.S.R.D.
TRACED BY:- H.Y.	PASSED BY:- DIMENSIONS IN INCHES.	DATE:- 17.5.34.

AN EXPERIMENTAL TREATMENT OF Nº 159 TYPE FUZE.

R.D. Nº 4699.

11-5-34.

CONFIDENTIAL - DISCREET

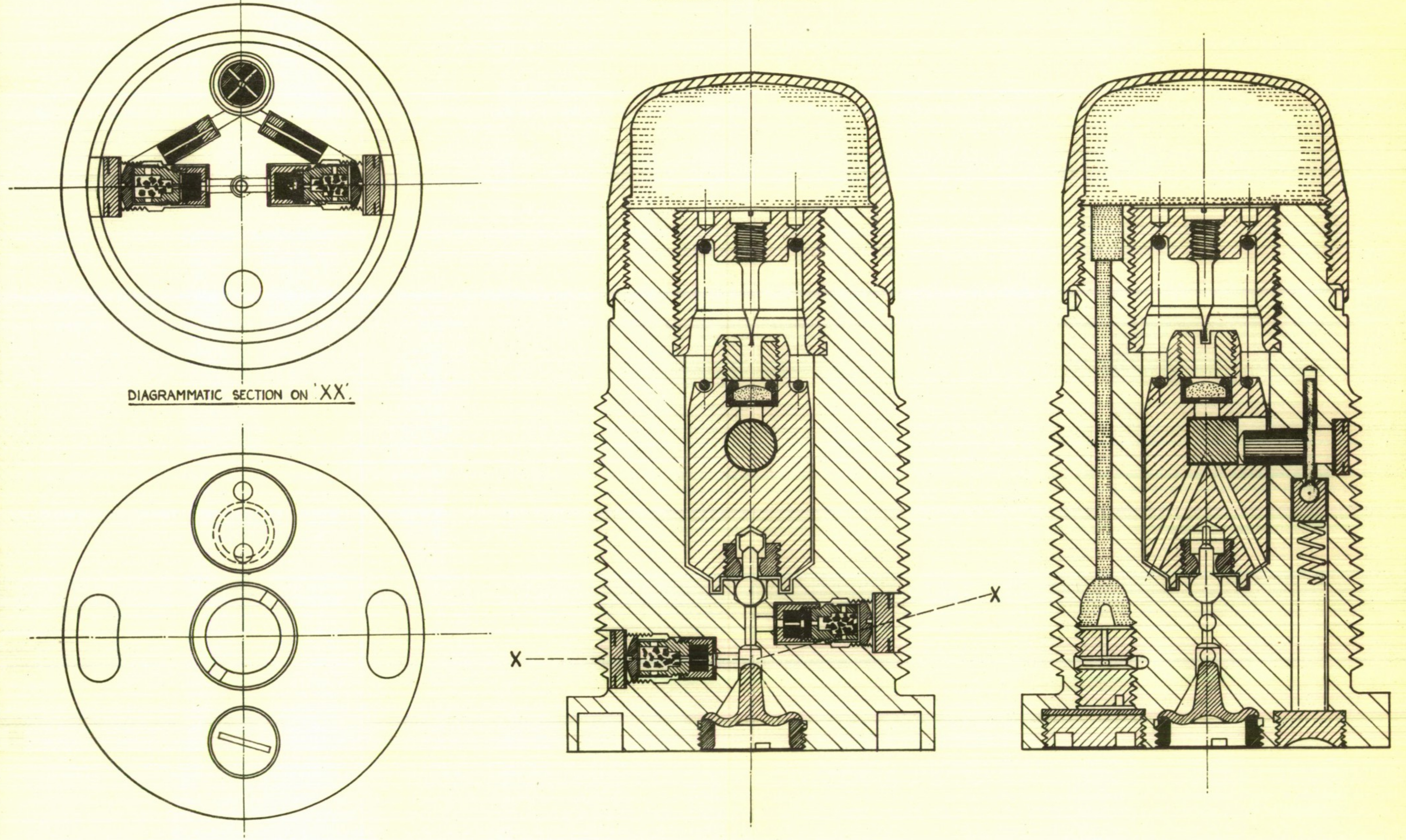


FIG. 19

TRACED FROM A.R.D. SKETCH Nº F.5770/1, 2 & 3.

REQN. Nº:- T. 131.	CHECKED BY:-		FUZE BASE LARGE
DRAWN BY:-	APPROVED BY:- T.C. ROBERTS		PROPOSED SIMPLIFICATION & IMPROVEMENT.
TRACED BY:- P. FENNER.	PASSED BY:-	FOR C.S.A.R.	

DRG Nº ARD. 6815.

19. 4. 45.

R.D. NO. 3324.

OCT. 20 TH. 1927.

CONFIDENTIAL - DISCREET

CHART SHOWING POSITION OF TURNOVER TO DETONATION IN FUZES & GAINES.

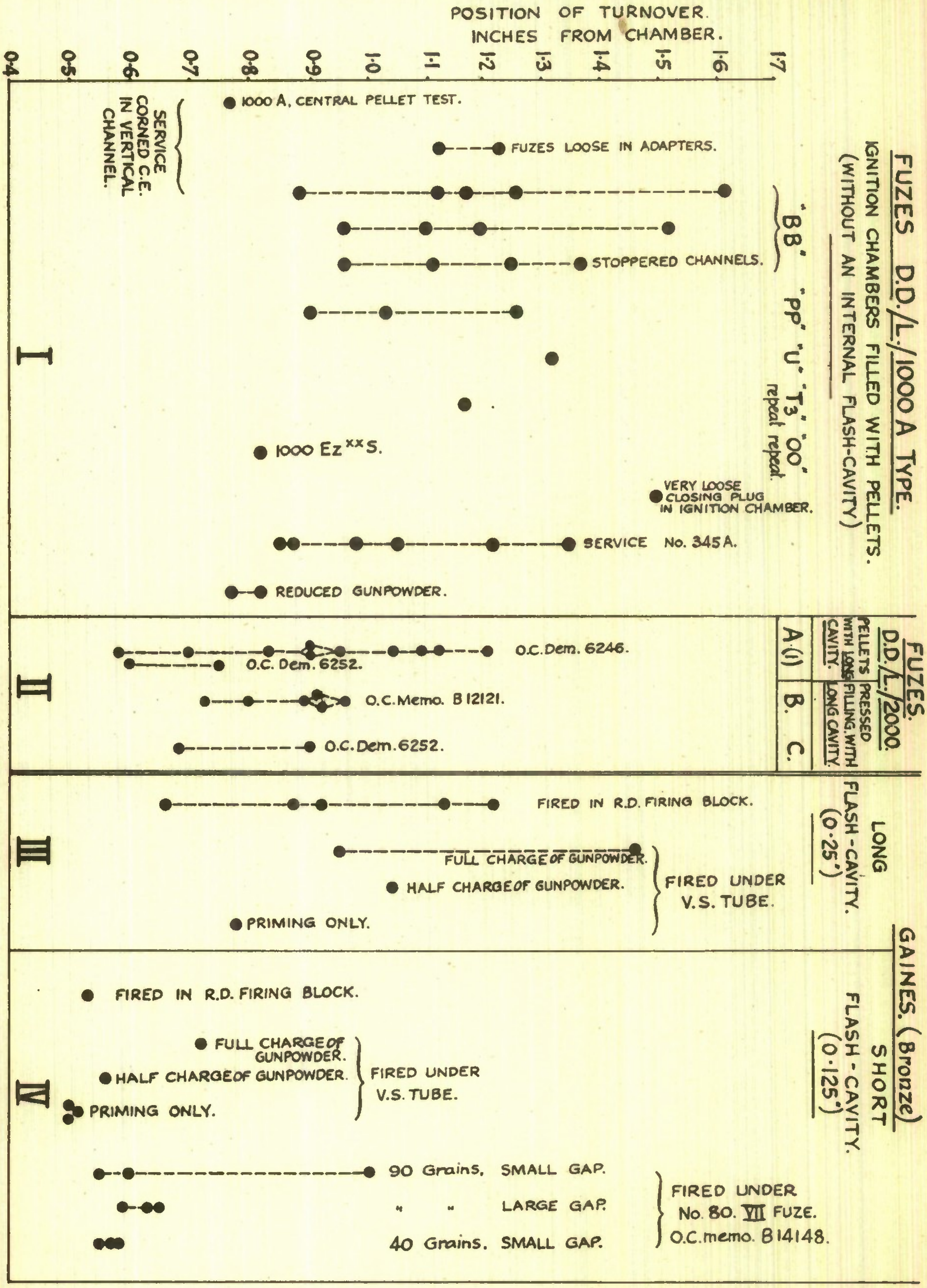


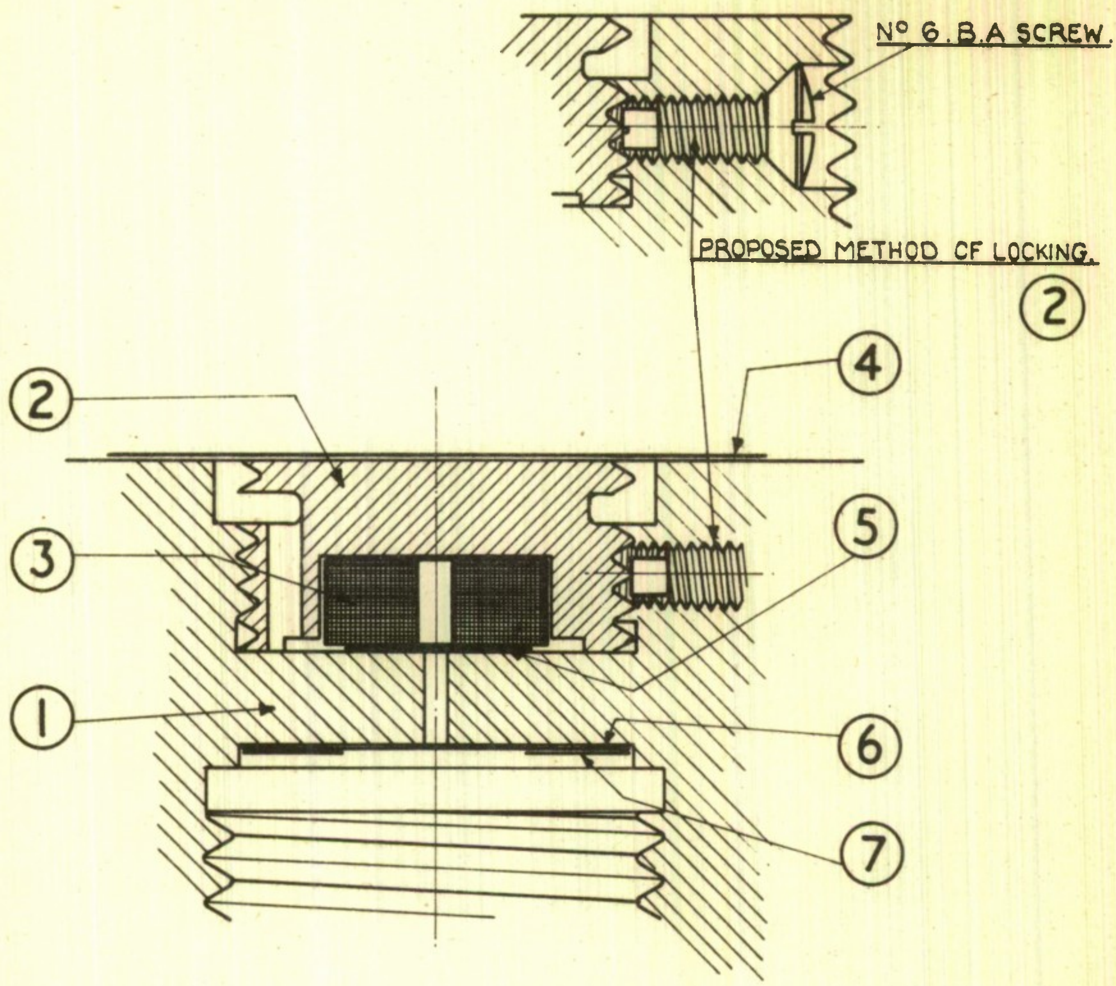
FIG. 20.

[signature] FOR C.S.R.D.

Date:- 21-X-27.

F.1421.

CONFIDENTIAL - DISCREET



ASSEMBLY.

FIG. 21.

LIST OF COMPONENTS.		
ITEM Nº	Nº OFF.	DESCRIPTION.
1	1	ADAPTER BODY.
2	1	BAFFLE PLUG.
3	1	GUNPOWDER PELLET.
4	1	TYCOON PAPER PROTECTING DISC.
5	1	TYCOON PAPER DISC.
6	1	TYCOON PAPER DISC.
7	1	BATISTE WASHER.

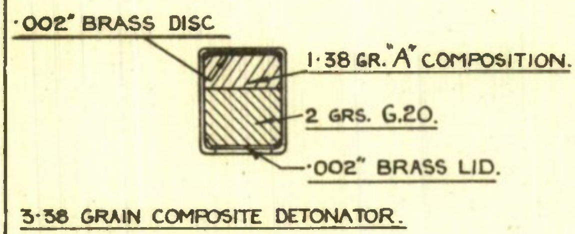
REQN Nº T. 168	TRACED BY: P.JONES.	APPROVED BY: T.C. ROBERTS.	P. W. W. Ling. FOR C.S.A.R.
DRAWN BY:	CHECKED BY:	PASSED BY: [signature]	

BAFFLE AND IGNITION UNIT.

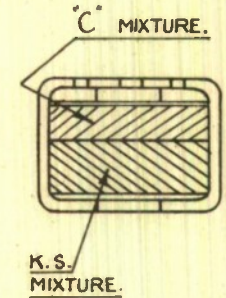
DRG Nº A.R.D.6834.

23-5-45

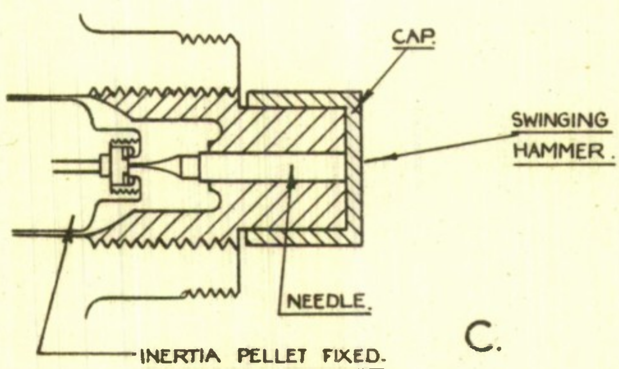
CONFIDENTIAL - DISCREET



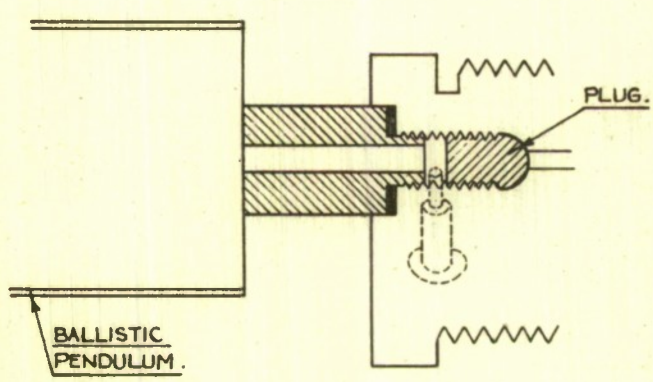
A.



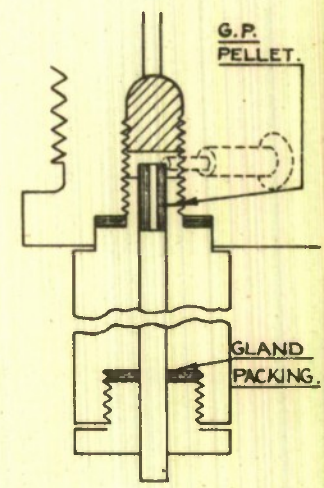
B.



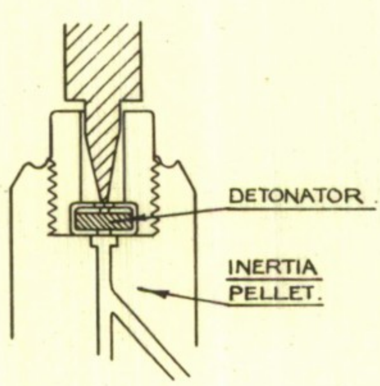
C.



D.



E.



F.

NOT TO SCALE.

FIGURE 22.

TRACED FROM R.D. Nº 4698.

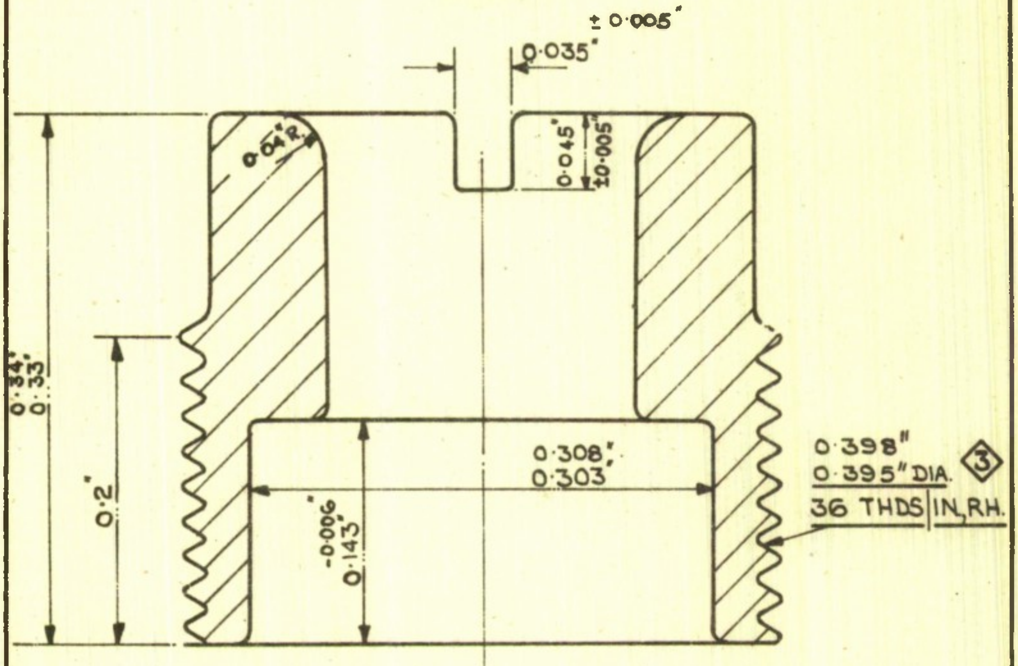
DETONATOR - MODIFICATIONS.

DRG. Nº ARD 6835.

23.5.45.

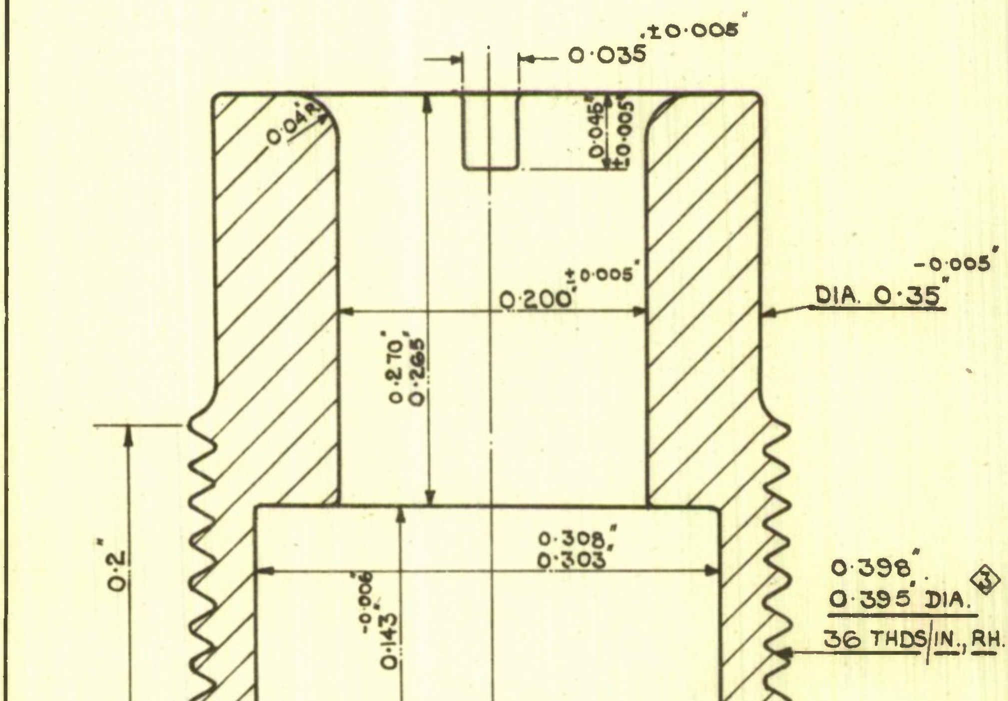
CONFIDENTIAL - DISCREET

FIG. 23.



(a) F. 5452.

BRONZE.



(b) F. 5498.

REQN. NO. T.142	TRACED BY: P. JONES	APPROVED BY: T.C. ROBERTS	E. W. W. Ling (signature) FOR C.S.A.R.
DRAWN BY:	CHECKED BY:	PASSED BY: (signature)	

PROPOSED DETONATOR PLUGS	DRG. NO. A.R.D. 6800
TO IMPROVE TAMPING AND TO CHECK EXCESSIVE PENETRATION BY NEEDLE.	23·3·45

CONFIDENTIAL - DISCREET

REF:- C 3411/29 (3) R.D.1619/29 (27)

O.C.B. 20059.

EX.

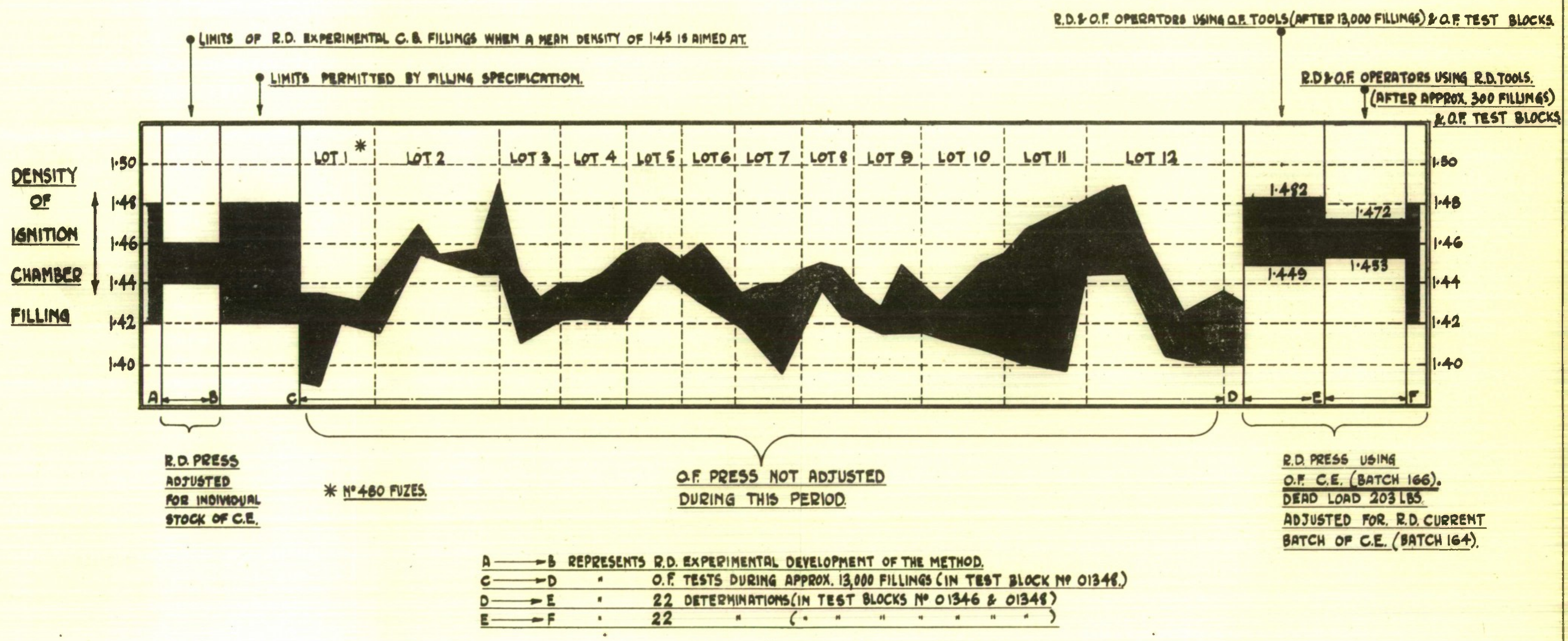
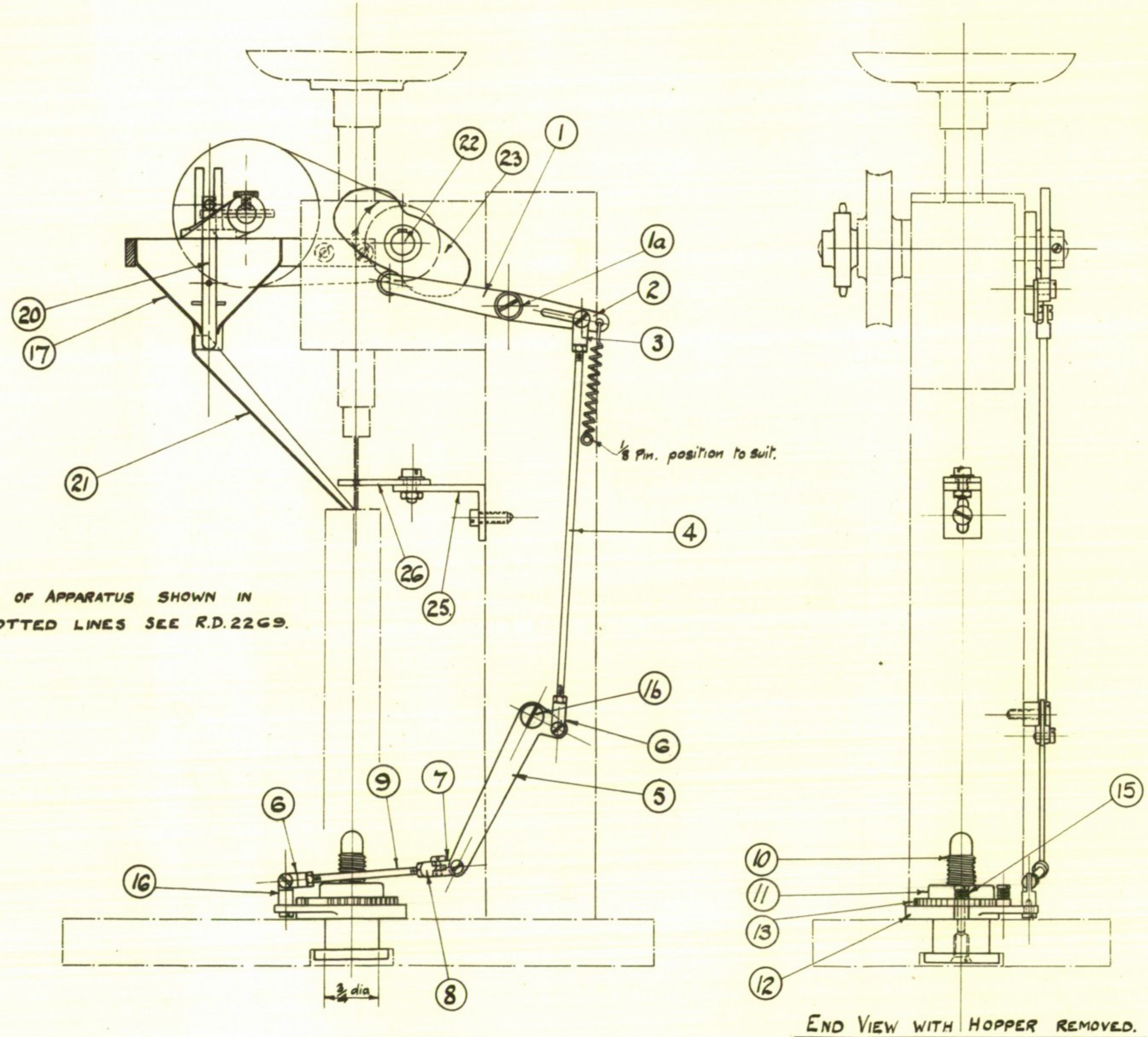


FIG. 24.

REGⁿ Nº F 4749.			
DRAWN BY:	C.H. Awcock. FOR C.S.R.D.	DIAGRAM SHOWING RESULTS OF FILLING OF TEST BLOCKS FOR CONTROL OF FILLING OF THE IGNITION CHAMBER OF Nº 159 TYPE FUZE. C.B. METHOD.	R.D. Nº 4678.
TRACED BY: W.L.			
CHECKED BY: [signature]			
PASSED BY: [signature]	DATE:- 14.3.34.		13-3-34

R.D. N° 2826.
OCTOBER 16TH 1925.

CONFIDENTIAL - DISCREET



FOR DETAILS OF APPARATUS SHOWN IN CHAIN DOTTED LINES SEE R.D. 2269.

END VIEW WITH HOPPER REMOVED.

SUMMARY OF PARTS.

Part No	No off	Description	Mat'l	Remarks.
1a	1	Cam Lever pivot screw.	M.St.	
1b	1	Bell Crank ″ ″	″ ″	
1	1	Cam Lever	″ ″	
2	1	Pivot Screw for (3)	″ ″	
3	1	Eye for vertical Conn. Rod.	″ ″	
4	1	Connecting rod (vertical)	″ ″	
5	1	Bell Crank Lever	″ ″	
6	2	Female connecting eyes.	″ ″	
7	1	Two-way swivel eye.	″ ″	
8	1	Male connecting eye	″ ″	
9	1	Connecting rod (horizontal)	″ ″	
10	1	Turntable	″ ″	
11	1	Collar for (10)	″ ″	
12	1	Crank	″ ″	
13	1	Ratchet	″ ″	
14	1	Moving Pawl.	″ ″	
15	1	Check pawl.	″ ″	
16	1	Swivel pin for (12)	″ ″	
17	1	Feed hopper	Br.&Copper.	
18	1	Sprocket Wheel 2" dia		Meccano Sprocket Wheel No 95.
19	1	Sprocket Wheel 1" dia		″ ″ ″ No 96.
20	1	Feed pin	M. St.	
21	1	Chute from hopper.	Br.& Copper.	
22	1	Cam & Worm Wheel Spindle	M.St.	
23	1	Cam.	M.St.	
24	1	Sprocket Chain.		Meccano Sprocket Chain No 94.
25	1	Bracket.	M.St.	
26	1	Guide Plate.	M.St.	
27	1	Feed Operating Spindle	M.St.	

FIG. 25

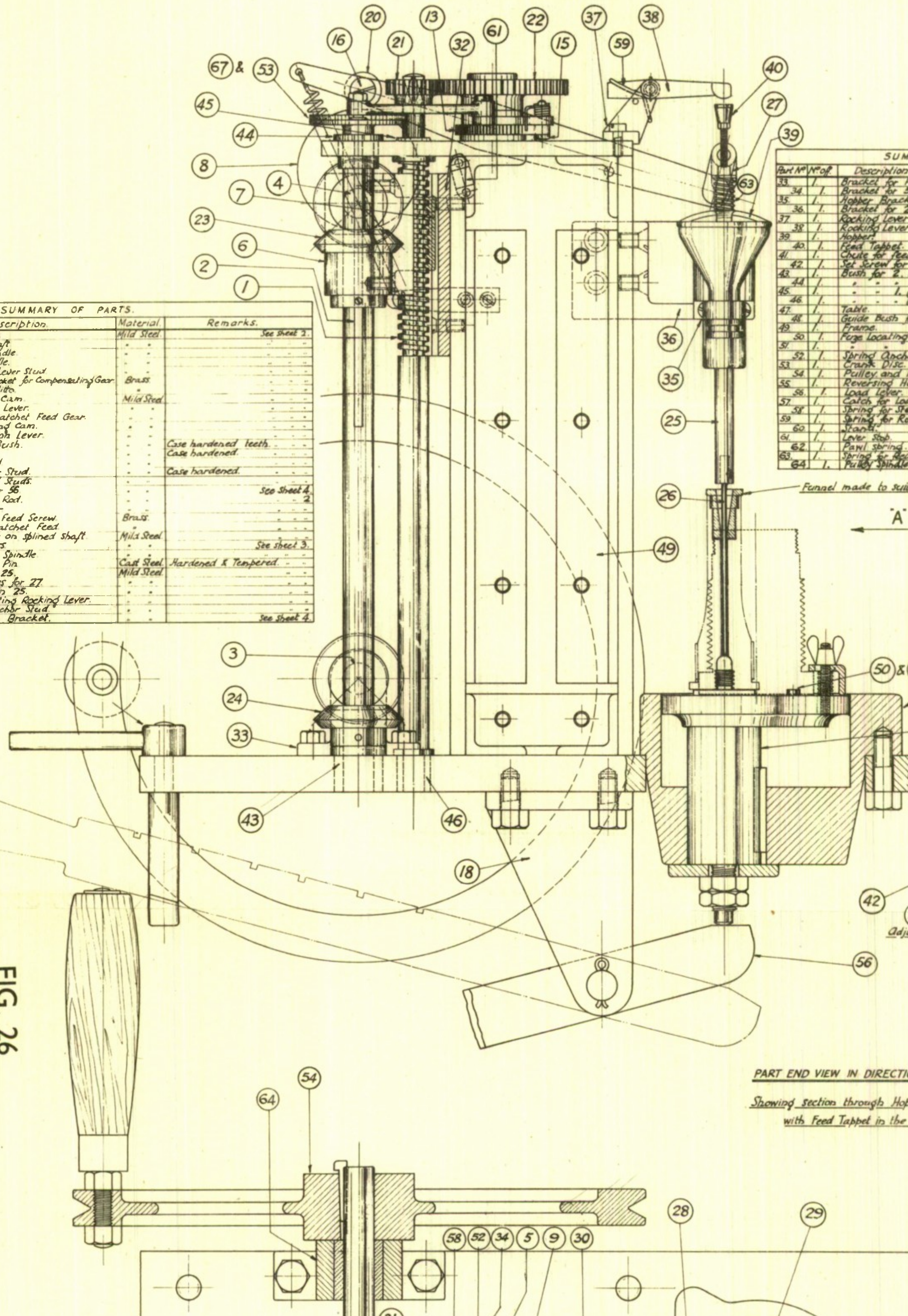
MODIFIED APPARATUS FOR UNIFORM FILLING OF NARROW TUBES.

R.D. No. 2842.

November 10th 1925.

STEMMING MACHINE. TYPE No. 2.

GENERAL ARRANGEMENT.



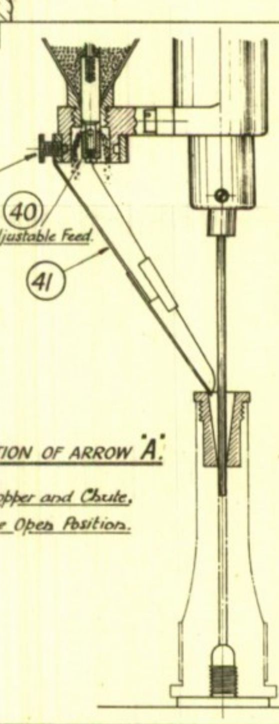
SUMMARY OF PARTS.

Part No	No off	Description	Material	Remarks
1.	1.	Feed Screw	Mild Steel	See Sheet 2.
2	1.	Splined Shaft	" "	" "
3	1.	Pulley Spindle	" "	" " "
4	1	Cam Spindle.	" "	" " "
5	1	Stemming Lever Stud	" "	" " "
6	1.	Bearing Bracket for Compensating Gear	Brass	" " "
7	1	Nut for ditto	"	" " "
8	1	Eccentric Cam	Mild Steel	" "
9	1	Stemming Lever.	" "	" " "
10	1	Stud for Ratchet Feed Gear.	" "	" " "
11	1	Pawl Riding Cam.	" "	" " "
12	1	Pawl Motion Lever	" "	" " "
13.	1	Ratchet Bush.	" "	Case hardened teeth. " " "
14	1	Pawl.	" "	Case hardened. " " "
15.	1	Pawl Stud	" "	" " "
16	1	Cam Roller Stud.	" "	Case hardened. " " "
17	2.	Conn. Rod Studs.	" "	" " "
18	1	Bracket for 56	" "	See Sheet 4.
19	1	Connecting Rod.	" "	" " 2
20	1	Cam Roller	" "	" " "
21	1.	Pinion for Feed Screw	Brass	" " "
22	1.	Gear for Ratchet Feed	"	" " "
23	1.	Mitre Gear on splined shaft	Mild Steel	" " "
24	3.	Mitre Gears	" "	See sheet 3.
25	1.	Stemming Spindle	" "	" " "
26	1.	Stemming Pin	Cast Steel	Hardened & Tempered. " "
27	2	Links for 25.	Mild Steel	" "
28	2.	Pivot Screws for 27	" "	" "
29	1	Pivot pin in 25.	" "	" "
30.	1.	Pin operating Rocking Lever.	" "	" "
31.	1.	Spring Anchor Stud.	" "	" "
32.	1.	Vee Slide Bracket.	" "	See Sheet 4.

SUMMARY OF PARTS.

Part No	No off	Description	Material	Remarks
33.	1.	Bracket for Pulley Spindle.	Mild Steel	and Brass. See Sheet 4.
34.	1.	Bracket for 5	" "	" " "
35.	1.	Hopper Bracket.	" "	" " "
36.	1.	Bracket for 25.	" "	and Brass " " "
37	1.	Rocking Lever Bracket.	" "	" " "
38	1.	Rocking Lever.	" "	" " "
39	1.	Hopper.	Brass &	Copper. " " 3.
40.	1.	Feed Tappet.	Brass &	Fibre. " " "
41.	1.	Chute for Feed.	Brass &	Copper. " " "
42.	1.	Set Screw for 41.	Brass.	" " "
43.	1.	Bush for 2. (bottom)	"	" " "
44	1.	" " " (top)	"	" " "
45	1.	" " 1. (top)	"	" " "
46	1.	" " " (bottom).	"	" " "
47	1.	Table.	Mild Steel	" " "
48	1.	Guide Bush for 47.	" "	" " "
49	1.	Frame.	M.S. plate	and Angle Iron. " " "
50.	1.	Fuze Locating Pin (large)	Mild Steel.	" " "
51.	1.	" " " (small).	" "	" " "
52.	1.	Spring Anchor Bracket.	" "	See sheet 4.
53	1.	Crank Disc.	" "	" " "
54	1.	Pulley and handle.	Cast Iron	From Stock. " " "
55	1.	Reversing Handle	Mild Steel	" " "
56.	1.	Load Lever.	" "	" " "
57	1.	Catch for Load Lever.	" "	" " "
58	1.	Spring for Stemming Lever	Sp. Steel.	Size to suit. See Sheet 1.
59.	1.	Spring for Rocking Lever.	" "	" " " " " "
60	1.	Stand.		See Sheet 5.
61.	1.	Lever Stop.	Mild Steel	See Sheet 4.
62.	1.	Pawl spring.	Sp. Steel.	
63.	1.	Spring for Feed tappet.	" "	Size to suit.
64.	1.	Pulley Spindle Bracket. (Outer)	M.S. & Brass	See sheet 4.

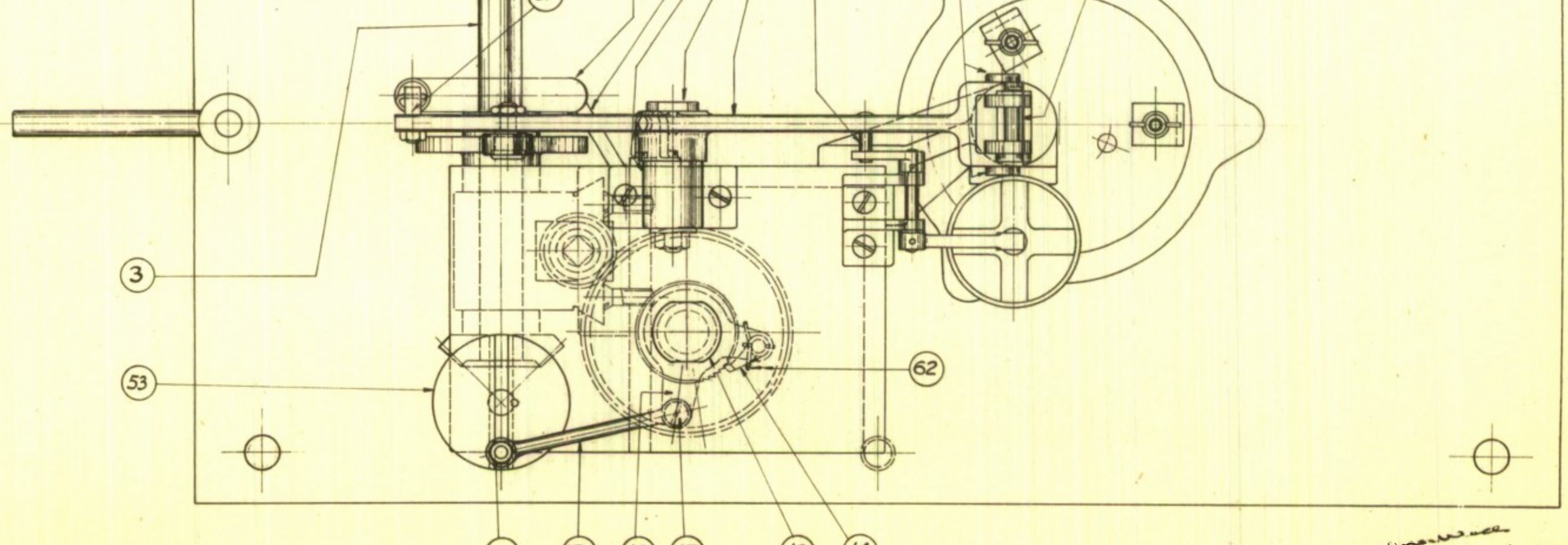
FIG. 26



PART END VIEW IN DIRECTION OF ARROW "A".

Showing section through Hopper and Chute, with Feed Tappet in the Open Position.

CONFIDENTIAL - DISCREET



Posted by:-

Date:-

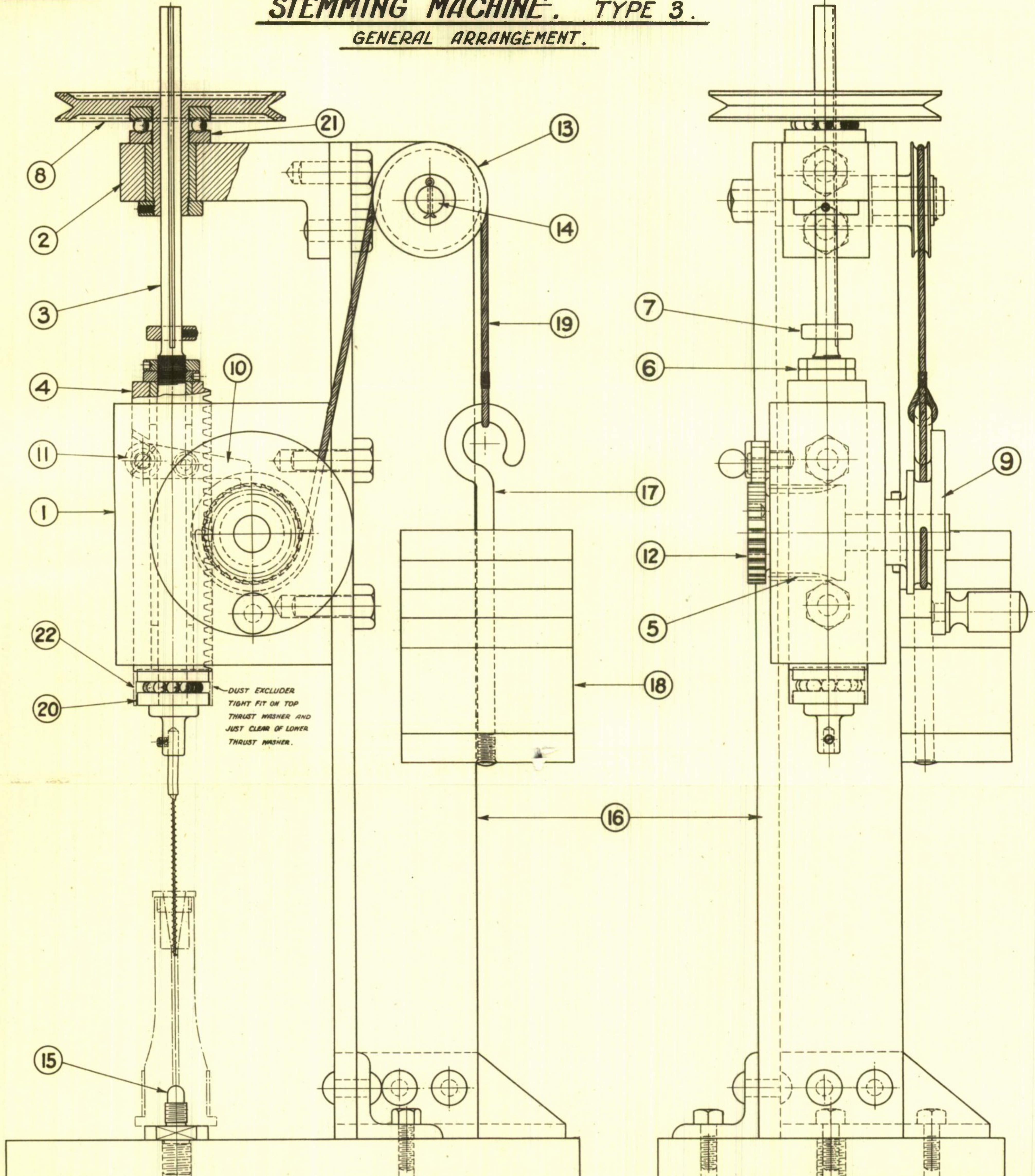
for C.S.R.D.

Date:- 2-12-25

R.D. Nº 2852.
Nov: 18th. 1925.

STEMMING MACHINE. TYPE 3.

GENERAL ARRANGEMENT.



SUMMARY OF PARTS.

Part Nº	Nº Off.	Description.	Material.	Remarks.
1	1	Main Bearing Block.	Brass	
2	1	Top Bearing Bracket.	Mild Steel.	Fitted with brass bush.
3	1	Driving Spindle.	" "	
4	1	Rack Sleeve.	" "	Fitted with brass bushes.
5	1	Feed Pinion.	" "	
6	2	Nuts for (3)	" "	
7	1	Stop Collar.	" "	
8	1	Driving Pulley.	" "	Fitted with screwed collar.
9	1	Feed Pulley.	" "	
10	1	Check Pawl.	" "	
11	1	Screw for (10)	" "	
12	1	Check Ratchet	" "	
13	1	Idler Pulley.	" "	
14	1	Stud for Idler Pulley.	Mild Steel.	
15	1	Seating Screw for Gaine.	Brass.	
16	1	Frame and Base Plate.	Mild Steel.	Built up from plate and angles.
17	1	Hanger for Feed Weights	" "	
18	5	Feed Weights.	" "	4 off ½" thick. 1 off 1½" thick.
19	—	Wire rope ⅛ diameter.	" "	Sufficient length as in General Arrang^t
20	1	Hoffmann Single Thrust Washer.	—	Size Nº W ½
21	1	Hoffmann Single Thrust Washer.	—	Size Nº W ⅝.
22	1	Dust Excluder	Brass.	Made from any suitable size tube.

FIG. 27

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Drawn By
Traced By
Checked By
Passed By
Date

for C.S.R.D.
Date 7-12-25

R.D.No 2927.

STEMMING MACHINE, — TYPE No 4.

GENERAL ARRANGEMENT OF COMPLETE MACHINE.

May 8th 1929

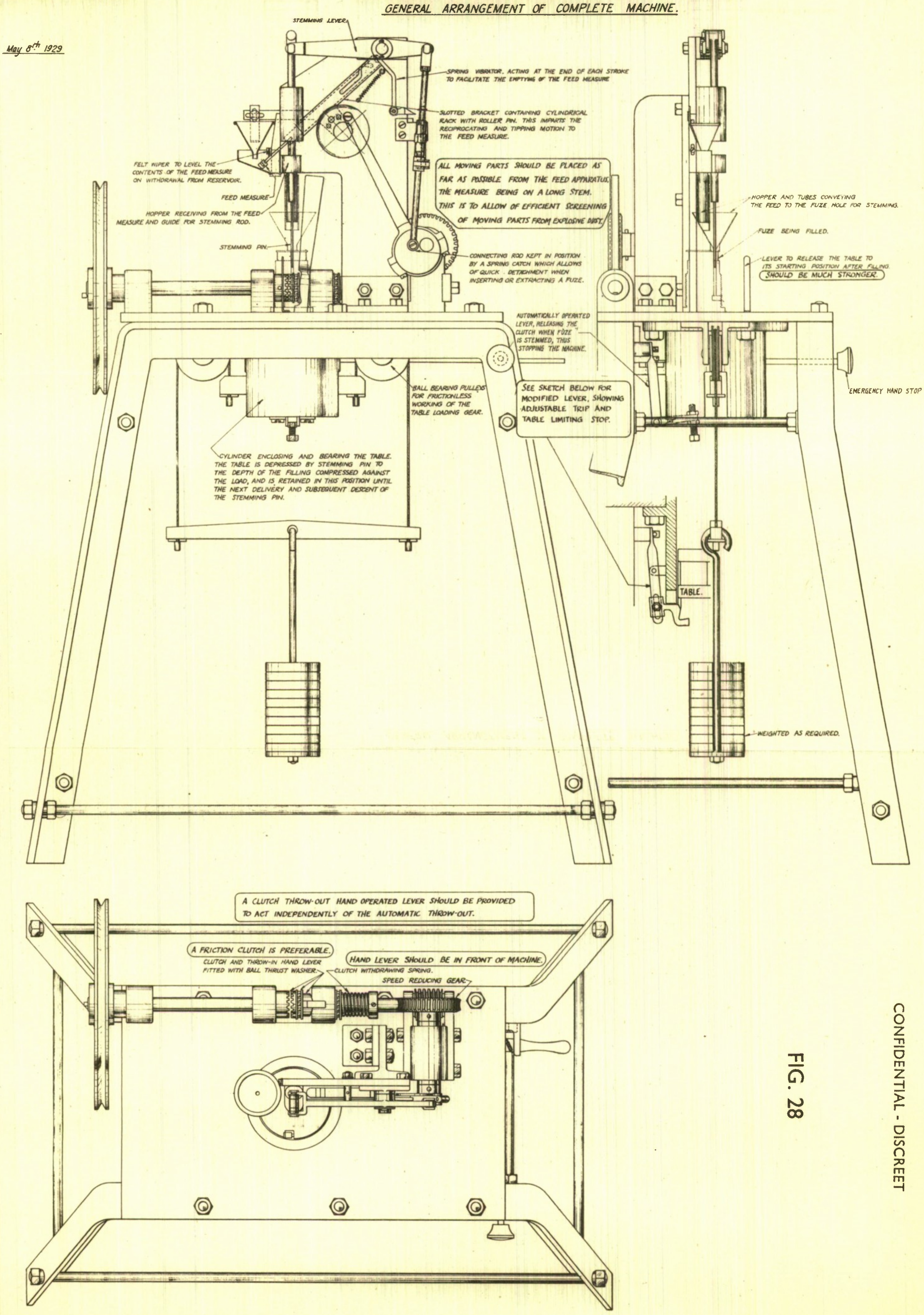

FIG. 28

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for C.S.R.D.

Date:- 12-7-32

EX

REF. C.1619/29.④

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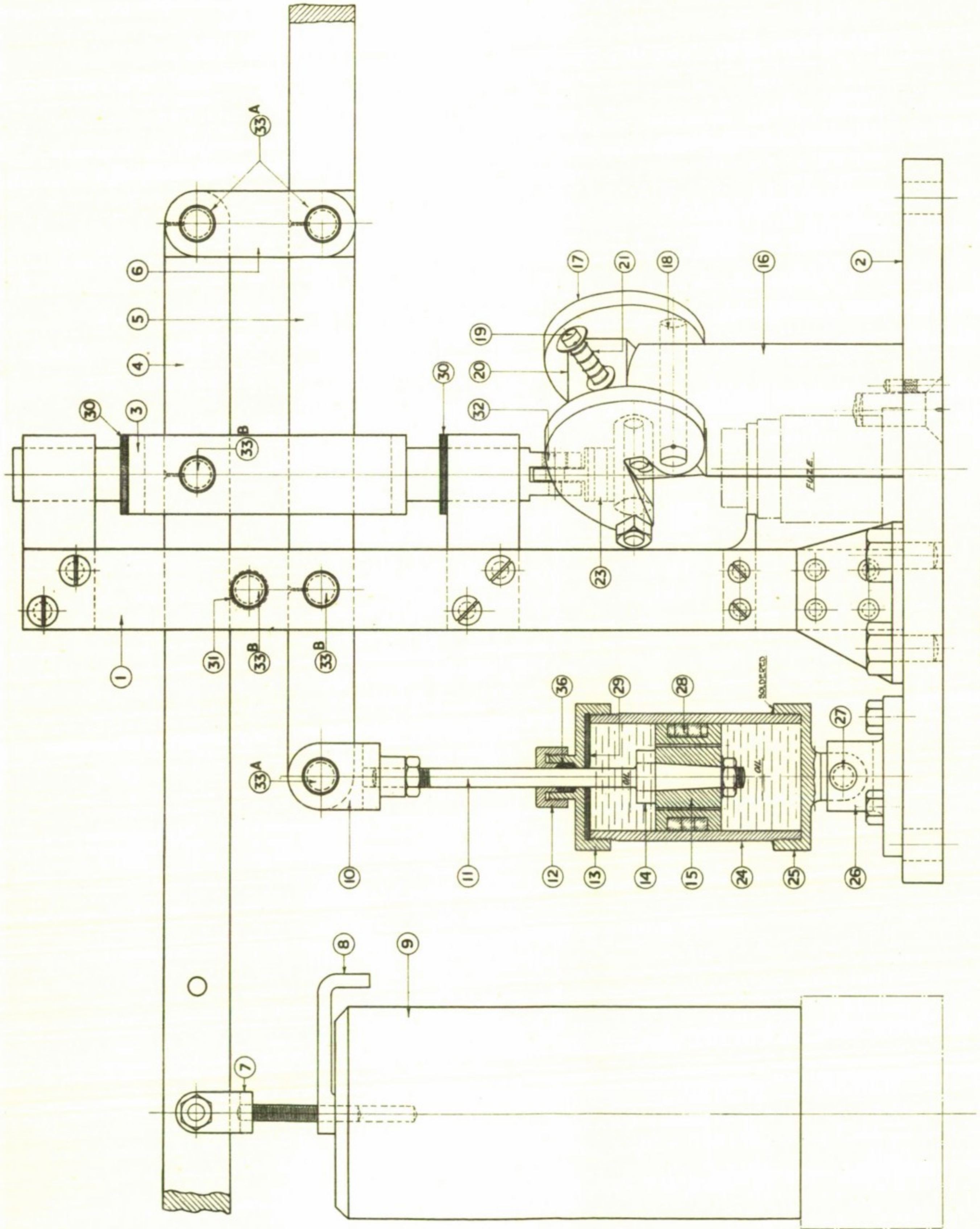
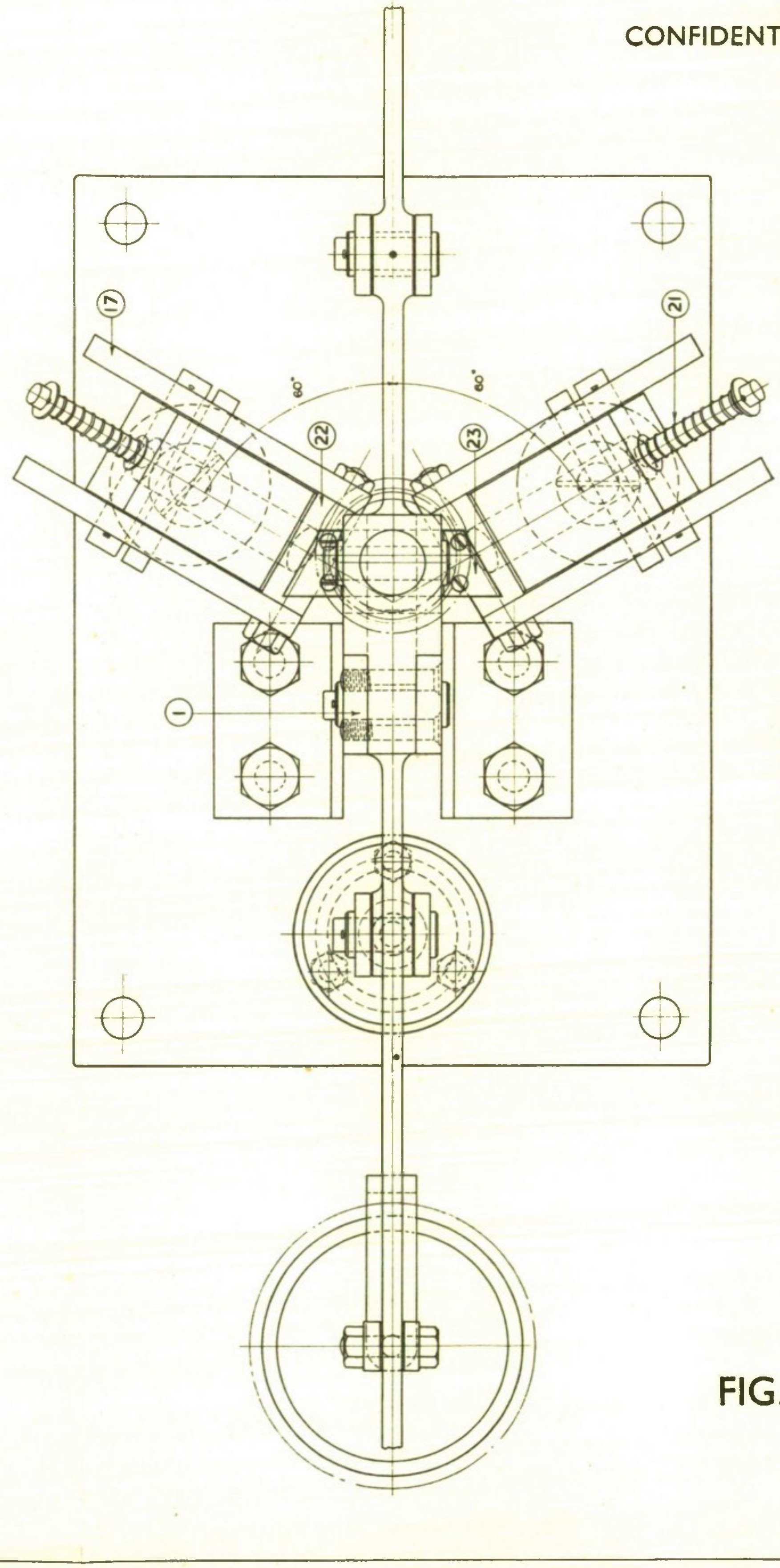


ELEVATION.



PLAN.

FIG. 29

SUMMARY OF PARTS.

PART Nº	Nº OFF.	DESCRIPTION.	MATERIAL.	SHEET Nº	REMARKS.	PART Nº	Nº OFF.	DESCRIPTION.	MATERIAL.	SHEET Nº	REMARKS.
1	1	Piller.	M.S. & BRASS.	2.		19	2	Plungers for Stemming Mechanism	M.S.	2.	
2	1	Base Plate.	M.S.	3.		20	2	Plunger Holder.	"	"	
3	1	Plunger.	"	2.		21	2	Return Spring.	SPRING STEEL	"	
4	1	Load Arm.	"	3.		22	2	Cross Bars.	M.S.	"	
5	1	Handle.	"	"		23	1	Bridge piece.	M.S. & LEATHER	"	
6	2	Shackles.	"	"		24	1	Cylinder body.	BRASS.	3.	
7	1	Adjusting Pin.	"	"		25	1	" base	M.S.	"	
8	1	Locking Lever.	"	"		26	1	" holder.	M.S.	"	
9	1	Loading Weight.	"	2.		27	1	Pin.	"	"	
10	1	Forked end.	"	3.		28	1	Chrome Leather packing.		1.	¼ Sq. 20" long ends scarfed.
11	1	Piston Rod.	"	"		29	1	" " washer.		"	2⅝ outside dia. ⅛ thick. hole ⅞ dia
12	1	Gland Nut.	BRASS.	"		30	2	" " washers.		"	1⅝ dia. 3/16 thick. hole 1⅛.
13	1	Cylinder Cover.	"	"		31	1	Roller.	CAST STEEL.	2.	
14	1	Distance piece.	M.S.	"		32	1	Pin for Bridge piece.	M.S.	"	
15	1	Piston.	"	"		33A&B	6	Shackle Pins.	"	"	
16	2	Pillers for Stemming Mechanism.	"	2.		34	1	Balance Weight for Handle.	"	3.	
17	4	Cams. - - -	"	"		35	2	Drifts.	"	2.	
18	2	Spindles. - .	"	"		36	1	Asbestos cord packing.	"	1.	

REGᴰ IN F. 3240.

DRAWN BY- W.L.

TRACED BY- [illegible]

CHECKED BY- [illegible]

PASSED BY- [illegible]

[signature] FOR C.S.R.D.

DATE- 5.2.31.

APPARATUS FOR STEMMING BRANCH CHANNELS OF 3000 S TYPE FUZES.

R.D. Nº 4060A

SHEET 1. 3 SHEETS.

23-9-30. 24-1-31.

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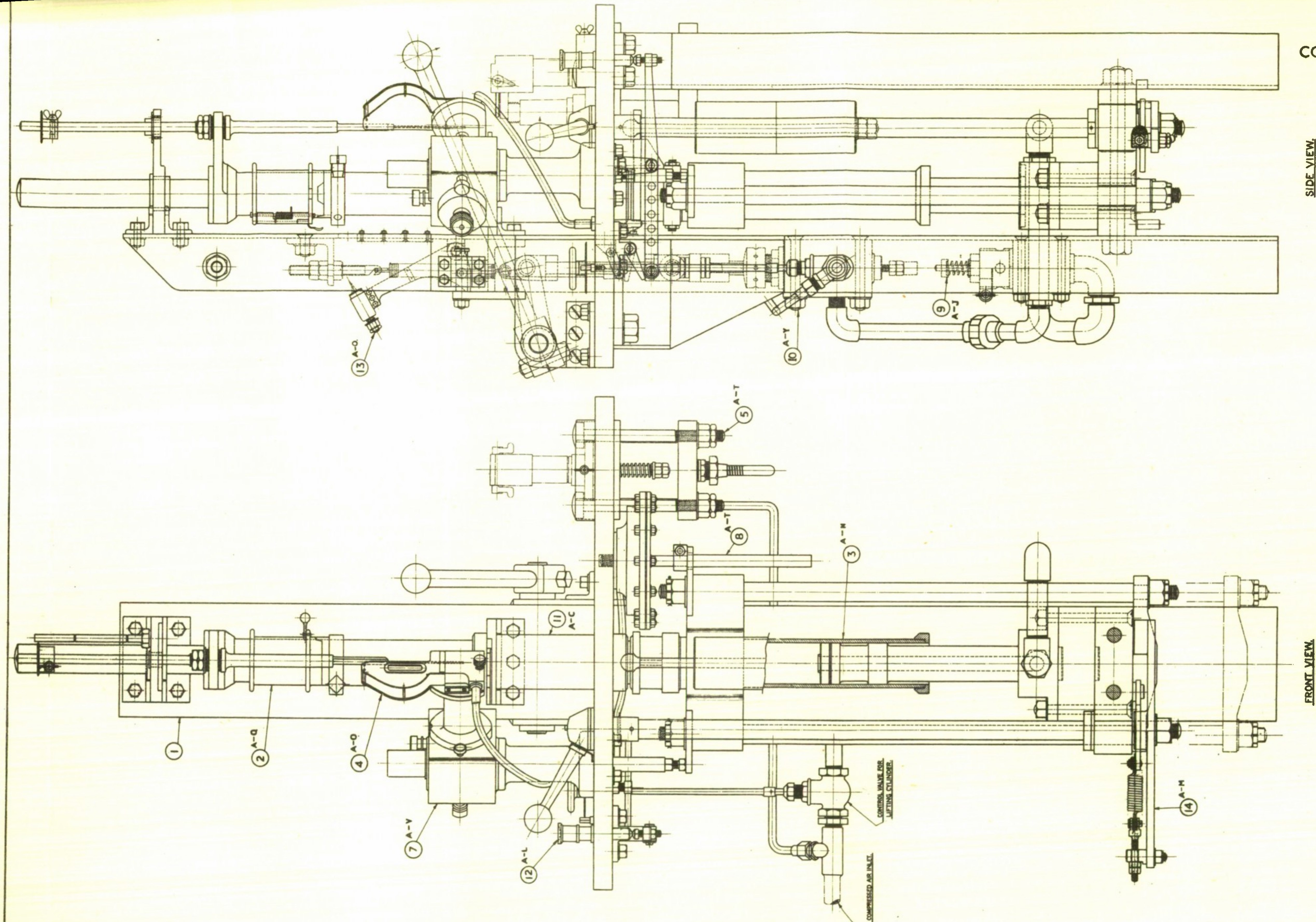


FIG. 30A

REQN No E11,093.		
DRAWN BY:- W.L.		
TRACED BY:-		
CHECKED BY:-		
PASSED BY:-	FOR C.S.R.D.	

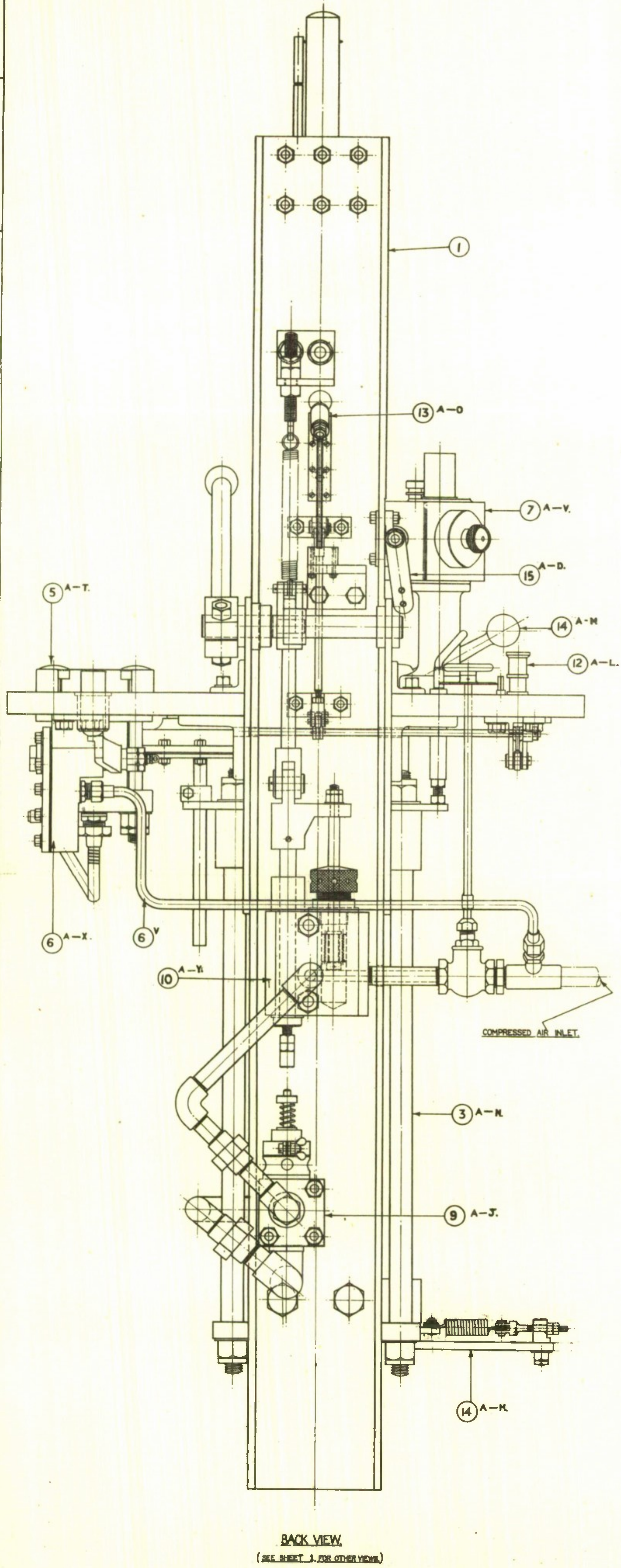
DIRECT STEMMING MACHINE.

R.D. No 6251.

SHEET 1. 17 SHEETS.

1-6-42

CONFIDENTIAL - DISCREET



BACK VIEW.
(SEE SHEET 1, FOR OTHER VIEWS.)

SUMMARY OF PARTS.

PART Nº	SHEET Nº	DESCRIPTION.	REMARKS.
1	3	FRAMEWORK & TABLE.	
2 A-Q	4	ASSEMBLY OF STEMMING HEAD WITH DETAILS.	
3 A-N	5	" " LIFTING CYLINDER " "	
4 A-O	10	" " HOPPER " "	
5 A-T	6	" " AIR CYLINDER & VALVE GEAR.	
6 A-X			
	7	DETAILS OF AIR CYLINDER & VALVE GEAR.	
	8		
7 A-V	10	ASSEMBLY OF METERING HEAD WITH DETAILS.	
	11	DETAILS OF " "	
8 A-T	9	ASSEMBLY OF DIAPHRAGM PUMP WITH DETAILS.	
9 A-J	14	" " INLET & EXHAUST VALVE WITH DETAILS.	
10 A-Y			
	15	DETAILS OF INLET & EXHAUST VALVE.	
11 A-C	17	CENTRING GAUGE FOR FUZE VICE.	
12 A-L	12	ASSEMBLY OF RECORDING MECHANISM.	
13 A-O			
	13	DETAILS " " "	
14 A-M	16	DELIVERY & NON-DELIVERY MECHANISM WITH DETAILS.	
15 A-D	8	GAUGE FOR POSITIONING OF METERING HEAD WITH DETAILS.	

MATERIAL TO BE ORDERED FROM TRADE.

Nº OFF.	DESCRIPTION.	FIRM.
4	MORGANITE BRONZE-GRAPHITE BEARINGS.	THE MORGAN CRUCIBLE Cº LTD
	TYPE L.B. 181, ·3135 BORE, ·3725 LONG.	BATTERSEA CHURCH ROAD
1	" L.B. 170, ·375 BORE, ·4375 LONG.	LONDON, S.W. 11.
1	COMPRESSION COCK 1/8 GAS.	
	BUCK & HICKMAN, FIG. 9582.	BUCK & HICKMAN,
		2 WHITECHAPEL ROAD,
		LONDON E. 1.
1	CLUPET COMPRESSION RING 65·5 MM.	THE CLEWS PETERSEN PISTON RING Cº LTD,
1	" " " 56 MM.	MILL LANE,
1	" " " 43 MM.	WEST HAMPSTEAD,
	WIDTH & DEPTH OF GROOVES FOR RINGS WILL	LONDON,
	BE MADE TO SUIT.	N.W. 6.
1	NEEDLE VALVE 1/2" BORE.	
1	LENGTH OF STEEL FLEXIBLE TUBING 12" LONG,	
	1/4" BORE, WORKING PRESSURE 80 LB/SQ INCH.	
32	3/16 DIA. HARDENED STEEL BALLS.	
1	TECALEMIT NIPPLE - 1/4 B.S.F.	TECALEMIT, BRENTFORD, MIDDLESEX.
	(TYPE TO SUIT GREASE GUN AT FACTORY.)	

FIG. 30B

DIRECT STEMMING MACHINE.

FOR C.S.R.D.

R.D. Nº 6251.

SHEET 2. 17 SHEETS.

1. 6. 42.

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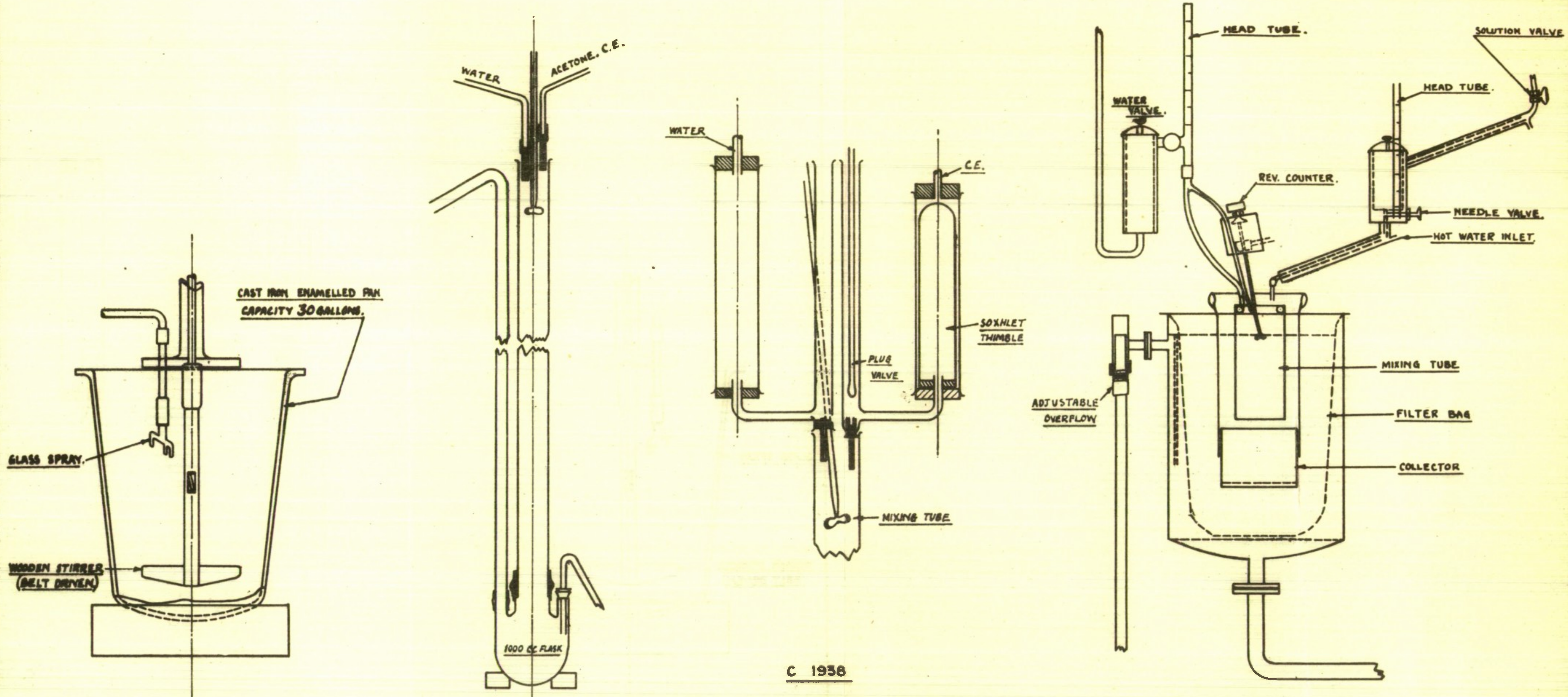

a 1932

TRACED FROM R.D. Nº 4414.

b 1935

TRACED FROM R.D. Nº 5414/1

C 1938

TRACED FROM R.D. Nº 5413/2

d 1942.

TRACED FROM R.D. Nº S. 1090/3.

FIG. 31.

REQN. Nº: D.118	CHECKED BY:	P.G.W. Ley.	AGGREGATED C.E.	DRG NO ARD.6778
DRAWN BY: A. Field	APPROVED BY: T.C. ROBERTS.		DEVELOPMENT OF MIXING APPARATUS.	1 SHEET.
TRACED BY: P. FENNER.	PASSED BY: [signature]	FOR C.S.A.R.		3. 2. 45.

[dstl]

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