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ROYAL ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

EXPLOSIVES DIVISION

R.A.R.D.E. MEMORANDUM (X) 9/63

Laboratory assessment of Service lead azide and the alternative forms RD1343 and RD1352

F. E. Ball
S. V. Peyton

Fort Halstead, Kent.

February, 1963

R.A.R.D.E.
Printing Section

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F.E. Ball (X2)

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Summary

This memorandum records the laboratory assessments of mechanical sensitiveness and safety in handling, together with filling and functioning characteristics in selected detonators, which have been determined for representative samples of Service lead azide and the lead azides RD.1343 and RD.1352. The work forms part of the comprehensive joint trials programme sponsored by D/RARDE, D/ERDE, DOF/F and the Ordnance Board, to evaluate alternative forms of lead azide for Service use.

The safety in handling assessment places the azides in the preferred order of RD.1352, RD.1343 and Service lead azide. In other respects, however, the dextrinated form RD.1352 is inferior to RD.1343 and Service lead azide. Differentiation between RD.1343 and Service material appears to be marginal, and requires further full scale production trials for final resolution. The possibility of introducing RD.1352 to Service in future depends on acceptability of re-design of stores to incorporate slightly larger detonators.

Approved for issue:

S. W. Coppock, Principal Superintendent, 'X' Division

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1. INTRODUCTION

Service lead azide is a very sensitive material, needing careful handling and liable to accidental ignition in filling operations. A less sensitive form of lead azide would have many advantages, and D/E.R.D.E. has proposed two types for investigation; (1) RD.1343, lead azide precipitated with carboxy methyl cellulose, and (2) RD.1352, lead azide precipitated in the presence of dextrin.

A programme of comprehensive trials was proposed in order to assess the properties of these materials in comparison with Service azide, from the stand-points of safety in handling, ease of filling, efficiency in present Service detonators and suitability for future designs. The programme was discussed with D/E.R.D.E. and D.O.F./F. and finally was presented by D/A.R.D.E. at the Eighteenth Meeting of the Sensitive Azides Working Party of the Ordnance Board. (Proceeding Q.8629 (Special)). The meeting adopted the programme, which required investigations appropriate to each of the Departments concerned. Those undertaken by this Establishment are the subject of this Report.

The programme was designed around the anticipated introduction of the 'new family' of small detonators, and called for the use of aluminium alloy shells where practicable. Incompatibility of mercury fulminate with aluminium necessarily implied substitution of the Service 'A' and 'B' ignitory mixtures by 'L' mixture (RD.1651 composition), then recently developed. It was intended also to exploit the value of the inverse loading technique where this appeared to offer advantages to the fillers.

The types of detonator chosen for laboratory evaluation and subsequent filling and firing trials represented those for which continuing requirements were foreseen or anticipated, and which fitted into the rationalised detonator scheme then under consideration. The types were as follows:-

Proposed		Replacing	Method of Filling
American type M22	LZY	U.S. fillings	Inverse
6.7 grain (approx.)	LZY	Service 6.7 grain AZY	Inverse
2.8 " (")	LZ	" 2.8 grain AZ	Direct
2.0 " (")	LZ (new family)	____	Direct
2.3 " (")	LZY(new family)	____	Inverse
1.8 " (")	ZY	Service 1.8 grain ZY	Inverse or direct as practicable.

2. SCOPE OF INVESTIGATION

The programme was divided broadly into four phases:-

(i) Manufacture and supply of selected representative batches of the lead azides, by R.O.F. Chorley, under supervision of D/E.R.D.E.

(ii) Preliminary laboratory assessment trials by D/A.R.D.E. at Fort Halstead.

(iii) Filling trials by D.O.F. at R.O.F. Chorley.

(iv) Functioning trials by D.I.Arm. and D/A.R.D.E. in association.

The work done under (ii) and (iv) was as follows:-

(1) Evaluation of the comparative sensitivity to impact of the three azides on the Rotter Machine, and to friction by the grit friction test.

(2) Determination of the filling conditions, using weighed charges in the selected detonators, for optimum functioning of each type of azide.

(3) Measurement of initial peak pressures given by the detonators on the pressure bar.

(4) Assessment of detonative efficiency by a 'gap' test.

(5) Determination of the comparative ignitability of the pressed azides when ignited by 1.7 gr. 'L' mixture detonators.

(6) Climatic trials on the bare detonators.

3. EXPERIMENTAL

3.1 Materials

3.1.1 Azides

Several batches of RD.1343 and RD.1352 were made at R.O.F. Chorley under the supervision of D/E.R.D.E. Samples from two batches of each were supplied for the laboratory trials, together with samples from two current lots of Service azide. The lot numbers were as follows:-

Service azide	Lots 4394A and 4404A
R.D.1343	Lots Cy 2/57 and 7/57
R.D.1352	Lots Cy 2/57 and 7/57

Preliminary filling and functioning tests in detonators showed that with each type of azide the properties of the two lots were identical. The main trials were therefore done with one or other of the two lots of each azide.

3.1.2 'L' Mixture

This was as formulated in A.R.D.E. Report (S) 30/57.

3.1.3 Tetryl

The tetryl was CE Class 1, granulated, to Specification L10108.

3.1.4 Detonator Cups

Examination of various alloys of aluminium with magnesium and manganese to assess suitability for use as material for detonator shells had reached an advanced stage prior to commencement of the lead azides investigation. Aluminium A3 appeared to be suitable for use with the larger shell, but it was necessary to select an alloy with mechanical properties more closely akin to those of detonator copper to achieve satisfactory filling and closure with the smaller types. The alloys of the 'Birmabright' Aluminium/magnesium series BB2 and BB3 were chosen for final evaluation. With some adjustment of shell wall thickness, good filling and closure was finally obtained with the BB2 alloy.

The new detonator intended to replace the Service 1.8 grain ZY was at first designed to be inverse loaded, and sample cups were manufactured. It was found, however, that ignitability through the paper base disc was poor, and it was realised that considerable investigation would be necessary to produce a satisfactory inverse loaded detonator. For the purposes of the present trials it was decided to use direct loading, with a thin paper disc on the azide and a one hole washer.

The design numbers of the cups finally adopted are shown below, together with the amended nomenclature used throughout this Report.

The filling weights cited eliminate anomalies and may be considered reasonably representative of the charge weights found to be practicable:-

Detonator	Loading	Design No.	Material
M22 LZY	Inverse	73/2/183	Aluminium Alloy A3 ≁
6.7 gr. LZY	"	D3/L/4894	" " "
2.3 gr. LZY	"	L5/8792	" " BB2 ∅
2.4 gr. LZ	Direct	L5/9108	" " "
1.6 gr. ZY	"	L5/9432	" " "
2.0 gr. LZ	"	S5/7747/F.83	" " "

3.2 Impact tests on Rotter Machine

Samples of the selected batches were tested on the Rotter Machine, using the 'up and down' technique with a 2 Kg. weight, as described in A.R.D.E. Memorandum (MX)41/58. Lead 2:4 dinitroresorcinate (RD.1337) was used as the standard for comparison, with a Figure of Insensitiveness of 11.

The original tests were made in 1957: these were repeated (1962) immediately before publication of this Memorandum.

A summary of the results is as follows:-

Material	Figure of Insensitiveness	
	1957 tests	1962 tests
LDNR RD.1337	11	11
Service Lead Azide 4404A	18	20
" " " 4394A	-	21
Dextrinated Lead Azide RD.1352 CY2/57	21	16
" " " RD.1352 CY7/57	19	20
Lead Azide RD.1343 CY2/57	21	20
" " RD.1343 CY7/57	21	16

The Figures of Insensitiveness vary for each sample, but all are within the range 16 - 21. From this it is considered that the limited reproducibility of results when tested under these conditions does not allow firm conclusions on the differences, if any, in sensitiveness to impact of the three lead azides.

3.3 Grit friction test

The pendulum friction apparatus, similar to that described in R.D. Exptl. Report No. 236/42, was modified for the tests, a mild steel shim, 0.002 inch thick, replacing the emery paper normally used. The grit, consisting of finely divided carborundum, to the amount of 50 per cen by volume, was mixed with the azides before testing. The method used was to determine the number of firings obtained out of 25 at three different striking velocities of the pendulum. The results are summarised in the following table.

≁ Equivalent to S1.B in "O" condition.

∅ " " NS.4 in "O" "

Azide	Lot No.	Percentage firing at velocities in feet/sec. of		
		3	5	7
Service	488/54	60	92	
	4394 A	52	88	100
	4404 A	80	92	100
RD.1343	2/57	20	64	
	7/57	24	48	84
RD.1352	2/57	0	8	28
	7/57	0	0	28

The table shows that by this method of test RD.1343 is somewhat less sensitive to friction than Service azide and RD.1352 is appreciably less sensitive. Service azide Lot 488/54 was an old sample included for comparison.

3.4 Filling of detonators

3.4.1 Pressing

The detonators were filled singly with weighed charges on a dead load press, the column lengths of the fillings being measured. The present Service pressing loads were used for Service azide and RD.1343 in all British detonators containing tetryl, and for all three azides in the 2.4 gr. LZ type. British detonators filled with RD.1352 and tetryl were pressed at half the Service loads. Some 6.7 gr. detonators with Service azide were also pressed at half the Service load for comparison in pressure bar tests with RD.1352 detonators.

3.4.2 Behaviour of azides in filling operations

The three azides all had good flowing and pressing properties, and there were no fires during pressing. Filling details are given in Tables I to V from which it is seen that the pressed densities of Service azide, RD.1343 and RD.1352 decrease in that order.

3.5 Determination of charge weights and pressure bar tests

3.5.1 6.7 gr. LZY

This detonator was investigated in some detail, preliminary trials being done in inverse loaded A3 aluminium cups using the present Service weights of fillings for all three azides. Ten detonators of each type were fired on the 0.7 inch pressure bar and the degree of detonation assessed by a chemical method. In this test the detonator holders after firing were immersed in acetone, the extract poured off and a few drops of sodium hydroxide solution added. The appearance of a pink or red colour showed that detonation was incomplete, the intensity of colour increasing with incompleteness of detonation. Absence of colour denoted complete detonation. The test is critical, and it is probable that detonators which gave a faint pink colouration would have initiated a following tetryl channel; however, the indication is that the column length of azide in such a detonator is near the minimum for consistent functioning.

The results of the pressure bar firings given in Table VI show that with Service charge weights, Service azide and RD.1343 gave complete detonations, whereas with RD.1352 two detonators gave incomplete detonations and the pressure was low, with high C.V. A repeat test gave ten incomplete detonations. The weight of RD.1352 was then increased to (1) 3.25 and (2) 3.45 grains, keeping the weight of tetryl constant. Only the 3.45 grain filling gave ten complete detonations. Reduction of RD.1352 from 3 to 2 grains with slight increase in weight of tetryl gave partial explosions of the tetryl, some being unconsumed, and low pressures on the bar.

When the weights of Service azide and RD.1343 were reduced from 3 to 1.2 grains, with increase in weight of tetryl, complete detonations were obtained with both azides.

Trials with RD.1352 in other types of cup confirmed that the minimum weight for complete detonation of the tetryl is just about 3 grains. Both inverse loaded BB2 and direct loaded tinned copper cups gave ten complete detonations, whereas direct loaded BB2 and A3 cups gave some incomplete detonations, with low pressures. In direct loaded tinned copper cups reduction of RD.1352 from 3 to 2.46 grains gave five explosions of the tetryl.

Referring to Table I, it is concluded that the minimum column lengths of Service azide and RD.1343 for consistent functioning are not greater than 0.021 and 0.023 inch respectively, but RD.1352 requires a length of about 0.08 inch. The present cup will not accommodate this length of RD.1352, and it was decided to suggest a filling of 3 grains, since in the gap tests described below, this filling initiated tetryl pellets, though with reduced efficiency compared with the other two azides. It was found by D.O.F./F. that with a filling of 2 grains of 'L' mixture the closed detonators were over-length, and it was agreed to reduce the weight of 'L' mixture to 1.54 grains and to press it at the Service load.

With Service azide and RD.1343 the Service charge weights were proposed, since an increase in weight of tetryl from 1.7 to 2.5 grains had little effect on the pressure bar results.

3.5.2 <u>2.4 gr. LZ</u>

The charge weights of the azides were governed by the necessity to allow sufficient column length for a thickness of 'L' mixture which would ensure consistent sensitivity to stab. The minimum length was fixed at 0.046 inch, and the charge weights found for the azides are given in Table II. The detonators were fired on the 0.4 inch pressure bar, instead of the specified 0.7 inch bar, giving higher pressures and a better standard of comparison. The results are shown in Table VII.

3.5.3 <u>1.6 gr. ZY</u>

With Service azide and RD.1343 the same column lengths were proposed as in the 1.8 gr. ZY tinned copper detonator. Although the column lengths of the azides are much above the minimum, it was thought that any increase in weight of tetryl might introduce sealing difficulties in fuzes.

The column length of RD.1352 was made approximately 0.08 inch, following on the experience with 6.7 gr. detonators. It was then necessary to reduce the weight of tetryl in compensation. The filling details are given in Table III and the pressure bar results in Table VIII. The RD.1352 detonators gave lower pressures than the other two types, but detonation was complete.

3.5.4 <u>M22 LZY</u>

This detonator was designed to have adequate column length when used with U.S. dextrinated azide. The column lengths of the three fillings were made approximately the same as those in the U.S. detonator, the weights of 'L' mixture and tetryl being constant for the three azides, the weights of which were adjusted to fill the remaining volume. Table IV shows the filling details and Table IX the pressure bar results. It is seen that the pressures given by the three types of detonator are not significantly different.

3.5.5 2.3 gr. LZY

The charge weights of azide and tetryl were arranged to be approximately the same as those in the 1.6 gr. ZY, with the addition of an increment of 'L' mixture. The filling details are shown in Table V and the pressure bar results in Table X. As with the 1.6 gr. ZY, the RD.1352 detonators gave lower pressures than detonators containing the other two azides, but all types detonated completely.

3.5.6 2.0 gr. LZ

To obtain the minimum column length necessary for the 'L' mixture filling to give reliable stab sensitivity, 0.6 grain of the mixture was found to be required, thus allowing a maximum of 1.4 grains for the charge weight of the lead azide increment. Detonators containing Service lead azide filled to this optimum design (Drawing L5/8467/F/83, not reproduced) were tested on both the 0.4 inch and 0.7 inch pressure bar, with results summarised in Table XI. In comparison with the 2.4 grain LZ (Section 3.5.2) the reduction in mean pressure was feared to be significant and a brief firing trial was therefore arranged before proceeding with tests on detonators filled RD.1343 and RD.1352.

The trial vehicle chosen was mortar bomb fuze No. 162, for which the 2.0 gr. LZ detonator was envisaged to have a potential application. Firings at ambient temperatures resulted in 3/18 failures to initiate the stemmed channel. Gap tests then in progress also qualitatively confirmed the reduced efficiency of this 'new family' detonator in transmission through aluminium septa, particularly in comparison with the alternative 2.4 grain LZ. The effect appeared to be due to the reduction in charge weight, and it was considered that restriction of diameter to 0.169 inch had prejudiced the usefulness of the detonator.

Since no Service application could be foreseen, further trials with this design were abandoned. The Working Party progressing the trials confirmed a recommendation to withdraw this item from the trials programme.

3.6 Gap tests

A measure of the relative detonative efficiency of detonators is obtained by firing them with aluminium septa of various thicknesses, which constitute the gap, between detonator base and tetryl charge. Either a stemmed tetryl channel, of density 1.2-1.3 gms. per cc. or a tetryl pellet of density 1.50-1.55 was used. The stemmed channels were 0.125 inch diameter and 0.25 inch long, contained in 0.75 inch diameter aluminium alloy. In order to give reasonable pressures on the 0.7 inch bar, tetryl pellets were assembled between the stemmed channels and the protective asbestos pellets. The tetryl pellets were unconfined. The 2.4 gr., 1.6 gr. and 2.3 gr. detonators were fired with stemmed channels followed by tetryl pellets, and the 1.6 gr., 2.3 gr., M22 and 6.7 gr. with pellets alone. The method of test was to find the maximum septum thickness which would allow five successive complete detonations of the tetryl pellet.

3.6.1 Detonators with septa, stemmed channels and tetryl pellets

The complete pressure bar results are given in Tables XII, XIII and XIV, from which the maximum septa thicknesses through which the detonators initiated the stemmed channel and pellet are as follows:-

Detonator	Azide		
	Service	RD.1343	RD.1352
2.4 gr. LZ	0.04 inch	0.04 inch	3/5 failed at 0 inch
1.6 gr. ZY	0.07 "	0.07 "	0.03 inch
2.3 gr. LZY	0.07 "	0.07 "	0.05 inch

The results show that Service azide and RD.1343 are equally efficient in all three detonators, whereas RD.1352 is appreciably less efficient in 1.6 gr. and 2.3 gr. detonators, and gives failures to detonate in 2.4 gr. detonators even without a septum.

3.6.2 Detonators with aluminium septa and tetryl pellets

All detonators in this group contain tetryl. The complete pressure bar results are shown in Tables XV to XVIII inclusive, and include those for 6.7 grain LZY directly loaded in tinned copper shells, for comparison. The maximum septum thicknesses obtained are given in the following table:-

Detonator	Azide		
	Service	RD.1343	RD.1352
1.6 gr. ZY	0.04	0.04	1/5 failed at 0 inch
2.3 gr. LZY	0.07	0.06	0.06 inch
M22 LZY	0.125	0.125	0.125 inch
6.7 gr. LZY Inverse, A3 cups	0.157	0.157	0.100 "
6.7 gr. LZY Direct, tinned copper cups	0.020	Not done	1 failed at 0 inch

The results show that Service azide and RD.1343 are equally efficient in all the detonators tested, whereas RD.1352 is as efficient as the other two azides only in 2.3 gr. and M22 detonators.

The superiority of the 2.3 gr. over the 1.6 gr. is thought to be due to (1) the effect of inverse loading and (2) the method of initiation by stab. The small air gap inherent in the closure of inverse loaded detonators probably gives a fragment initiation effect, and it has previously been shown that with stab-initiation a detonator develops a greater impulse than with flash initiation.

In 6.7 gr. detonators the superiority of inverse loading is even more marked. Besides the absence of air-gap, the direct loaded tinned copper detonator has a thick base, which degrades the impulse more than the thin aluminium alloy disc of the inverse loaded detonator.

This gap test, though giving a comparison of the efficiencies of the three azides, is somewhat severe, the tetryl pellet being unconfined. It is considered that the efficiency of the detonators would be greater in Service stores, in which the tetryl is confined.

3.7 Ignitability of pressed azides

The azides were pressed into 1.6 gr. inverse loaded cups without base discs, the exposed filling being varnished with cellulose ester varnish. The detonators were tested in the A.R.D.E. ignitability apparatus, in which a 1.7 gr. 'L' mixture detonator flashes down straight tubes of various lengths on to the 1.6 gr. detonator. The method of test was to find the maximum distance between the detonators which gave ten successive firings of the 1.6 gr. detonator. The results are given in Table XIX, and show that the ignitability of the three azides is of the same order, Service azide being slightly more ignitable than the other two azides.

4. APPLICATION TO FACTORY FILLING TRIALS

The charge weights suggested for the various detonators were communicated to D.O.F./F., who arranged preliminary factory filling trials. As a result of these, slight modifications to some of the weights were found to be necessary due to differences between hand filled laboratory samples and those from the factory production line. The laboratory trials were repeated with the slightly modified weights of charge. The results given in the Tables are those obtained with the charge weights agreed with D.O.F./F.

About 25,000 of each type of detonator were then filled under production conditions with each type of azide, and 5,000 of each type were selected for trials from those which had passed inspection. Details of the observations made at R.O.F. Chorley during this programme and the Conclusions drawn are given in CROF Filling Group Report No. 76 dated December 1961.

5. GAP TESTS WITH PRODUCTION FILLED DETONATORS

The detonator/aluminium septum/tetryl pellet tests were repeated with samples taken from the 5,000 selected detonators. In these trials the maximum septum thickness was determined through which twenty successive complete detonations of the tetryl pellets were obtained. The detailed pressure bar results are shown in Tables XX to XXIV inclusive, and the maximum septum thicknesses are given in the table below.

Detonator	Azide		
	Service	RD.1343	RD.1352
1.6 gr. ZY	0.03	0.03	0.01 inch
2.3 gr. LZY	0.03	0.04	0.03
M22 LZY	0.125	0.125	0.125
6.7 gr. LZY	0.10	0.125	0.125
2.4 gr. LZ	0.02	0.01	Failed at 0 inch

The maximum thicknesses of the septa penetrated by corresponding detonators of each type show some variation in comparison with the laboratory-filled items. In general, the thickness of septum penetrated is less, but the order of relative efficiency of the azides is maintained. An exception appears to be the 6.7 grain LZY types, with which the Service azide filling of the production detonators was slightly less effective than RD.1343 or RD.1352; the reason for this is not clear.

6. CLIMATIC TRIALS

The programme of climatic trials arranged in collaboration with the Ordnance Board is published as Appendix II to the Board Proceeding Q.8814 (Special).

Samples from the 5,000 detonators selected from the production lots were submitted to ISAT/B storage in this Establishment, withdrawals being made at intervals up to 2 years. Twenty detonators were fired by D.I.Arm. at each withdrawal, using 0.4 inch or 0.7 inch pressure bar as appropriate. The full results of the firings have been reported by D.I.Arm. to the Ordnance Board, to D.O.F./F. and to this Establishment.

The mean pressures and coefficients of variation calculated from the individual results are given in Tables XXV to XXIX.

The poorest performance is that recorded for detonator M22 LZY, which gave a total of 23 misfires, and low pressure rounds at various intervals in the trial. All azide fillings were affected, RD.1352 being marginally the worst. It is noted with interest that M22 is one of the two detonators in the trial not sealed with varnish RD.1177.

The other detonator not sealed with RD.1177 is the 1.6 grain ZY type. This also shows considerable variation in the range of pressures developed, and with RD.1352 filling the coefficient of variation reaches 15.5%.

All other types withstood the two year trial without significant deterioration, but the RD.1352 filling appears to show a marginally inferior performance. All would be acceptable for Service usage.

7. CONCLUSIONS

7.1 Safety in handling

7.1.1 No significant difference in sensitiveness to impact of the three types of lead azide is detected when tested in the Rotter Apparatus. This may be due to the limitations of the method when applied to testing of primary explosives.

7.1.2 On Grit friction pendulum tests RD.1352 is significantly less sensitive than Service lead azide or RD.1343. The latter is slightly less sensitive than Service lead azide.

7.1.3 Safety in handling assessment therefore places the azides in the preferred order of RD.1352, RD.1343, Service lead azide.

7.2 Efficiency in Service detonator designs

7.2.1 The detonators tested were filled to the following basic designs:-

M22, LZY	L5/9378	Inverse loading
6.7 grain LZY	L5/9456	" "
2.3 grain LZY	L5/8791	" "
2.4 grain LZ	L5/9565	Direct "
1.6 grain ZY	L5/9434	" "

In all these the performance of Service azide and RD.1343 is satisfactory and the azides are equivalent to each other.

7.2.2 Performance of RD.1352 in the 2.4 grain LZ detonator is not satisfactory, as indicated by the Gap test. Under the same test, RD.1352 also fails in the 1.6 grain ZY and 6.7 grain LZY (direct loaded, tinned copper cup) detonators.

7.2.3 There appears to be no significant difference in susceptibility to ignition by flash from 'L' mixture.

7.2.4 The results of climatic storage trials indicate that the performance by RD.1352 is marginally inferior under ISAT/B conditions. With the exception of detonators M22, LZY and 1.6 grain ZY (neither of which was varnished with RD.1177) however, the performance of all three types would be acceptable for Service use.

7.2.5 It is concluded that in present Service detonator designs Service lead azide and RD.1343 are interchangeable without change in efficiency. However, RD.1352 would not be acceptable for use with small detonators of either LZ or ZY type.

7.3 Suitability for future designs

7.3.1 On the results of this investigation it appears that Service lead azide and RD.1343 will show equal efficiency, but RD.1343 may offer some small improvement on safety aspects, particularly during filling operations. It is considered that relevant evidence will be obtained only by larger scale filling trials arranged to cover lengthened periods, batch-to-batch variation, requirements of automatic loading, and other details.

7.3.2 Potential use of RD.1352 is attractive in relation to safety in handling, but acceptability for future designs will depend on re-design of stores to allow introduction of slightly larger detonators. A minimum requirement would be a column length of RD.1352 not less than 0.1 inch.

ACKNOWLEDGEMENTS

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TABLE I

Filling details - 6.7 gr. LZY detonators

Type of azide	Method of filling and shell	Dead Load lb.	Charge weight grains			Filling length inch		
			L	Z	Y	L	Z	Y
Service	Inverse A3	1,000 "	2.0 1.8	3.0 1.2	1.7 2.5	0.055 0.050	0.054 0.021	0.070 0.107
	"	500	2.0	3.0	1.7	0.060	0.058	0.075
	Direct Tinned Copper	500	2.0	3.0	1.7	0.059	0.062	0.083
RD.1343	Inverse A3	1,000 "	2.0 1.8	3.0 1.2	1.7 2.5	0.055 0.050	0.057 0.023	0.070 0.107
RD.1352	Inverse A3 " "	500 " " "	1.54 1.23 1.10 1.10	3.0 2.0 3.25 3.45	1.7 2.0 1.7 1.7	0.046 0.036 0.032 0.032	0.072 0.048 0.076 0.085	0.075 0.088 0.075 0.075
	Inverse BB2	500	1.54	3.0	1.7	0.047	0.073	0.077
	Direct A3	500	1.54	3.0	1.7	0.044	0.071	0.078
	Direct BB2	500	1.54	3.0	1.7	0.044	0.071	0.080
	Direct Tinned Copper	500 "	1.54 1.90	3.0 2.46	1.7 1.7	0.045 0.056	0.074 0.063	0.084 0.084

TABLE II

Filling details - 2.4 gr. LZ detonators

Type of azide	Dead load lb.	Charge weight grain		Filling length inch	
		L	Z	L	Z
Service	500	0.70	1.70	0.046	0.079
RD.1343	500	0.70	1.62	0.047	0.079
RD.1352	500	0.70	1.49	0.046	0.080

TABLE III

Filling details - 1.6 gr. ZY detonators

Type of azide	Dead load lb.	Charge weight grains		Filling length inch	
		Z	Y	Z	Y
Service	325	1.30	0.30	0.076	0.045
RD.1343	325	1.22	0.30	0.077	0.045
RD.1352	160	1.10	0.25	0.083	0.039

TABLE IV

Filling details - M22 LZY detonators. 175 lb. dead load

Type of azide	Charge weights grains			Filling length inch		
	L	Z	Y	L	Z	Y
Service	0.74	2.7	1.05	0.062	0.152	0.132
RD.1343	0.74	2.4	1.05	0.062	0.152	0.132
RD.1352	0.74	2.2	1.05	0.062	0.152	0.132

TABLE V

Filling details - 2.3 gr. LZY detonators

Type of azide	Dead load lb.	Charge weight grains			Filling length inch		
		L	Z	Y	L	Z	Y
Service	350	0.50	1.40	0.35	0.041	0.080	0.046
RD.1343	350	0.50	1.30	0.35	0.040	0.080	0.046
RD.1352	175	0.47	1.27	0.25	0.040	0.088	0.038

TABLE VI

Pressure bar and chemical test results - 6.7 gr. LZY detonators
(0.7 inch bar)

Method of filling	Type of azide	Dead Load lb.	Charge weight		Mean pressure tons/ sq.in.	C.V. %	Chemical test Degree of detonation
			Z	Y			
Inverse A3	Service	1,000	3.0	1.7	9.4	1.6	10/10 D
"	"	"	1.2	2.5	10.0	2.1	10/10 D
"	"	500	3.0	1.7	9.0	1.1	10/10 D
Direct Tinned Copper	"	500	3.0	1.7	9.3	1.9	10/10 D
Inverse A3	RD.1343	1,000	3.0	1.7	9.6	2.9	10/10 D
"	"	"	1.2	2.5	10.0	3.3	10/10 D
Inverse	RD.1352	500	3.0	1.7	7.8	5.0	8 D, 2 D-
A3	"	"	3.0	1.7	7.2	3.0	10/10 D-
"	"	"	2.0	2.0	4.1	9.7	10/10 E
"	"	"	3.25	1.7	8.3	4.9	9 D, 1 D-
"	"	"	3.45	1.7	8.7	2.9	10/10 D
Inverse BB2	"	"	3.0	1.7	7.8	3.1	10/10 D
Direct BB2	"	"	3.0	1.7	6.3	2.1	10/10 D-
Direct A3	"	"	3.0	1.7	6.9	3.9	3 D, 7 D-
Direct Tinned Copper	"	"	3.0	1.7	9.5	4.3	10/10 D
			3.0	1.7	9.1	2.9	10/10 D
"	"	"	2.46	1.7	7.4	9.3	5 D, 5 P

D = complete detonation of tetryl in detonator
D- = nearly complete detonation
P = partial detonation of tetryl in detonator
E = explosion of tetryl in detonator

TABLE VII

Pressure bar results - 2.4 gr. LZ detonators

(0.4 inch bar)

Type of azide	Charge weight grains		Mean pressure tons/sq.in.	C.V. %
	L	Z		
Service	0.70	1.70	11.7	2.4
RD.1343	0.70	1.62	11.6	3.5
RD.1352	0.70	1.49	10.3	2.5

TABLE VIII

Pressure bar and chemical test results - 1.6 gr. ZY detonators

(0.4 inch bar)

Type of azide	Dead Load lb.	Charge weight grains		Mean pressure tons/sq.in.	C.V. %	Chemical test Degree of detonation
		Z	Y			
Service	325	1.30	0.30	12.3	1.3	10/10 D
RD.1343	325	1.22	0.30	12.2	2.3	10/10 D
RD.1352	160	1.10	0.25	9.1	5.0	10/10 D

D = complete detonation

TABLE IX

Pressure bar and chemical test results - M22 LZY detonators

(0.4 inch bar)

Type of azide	Charge weight grains		Mean pressure tons/sq.in.	C.V. %	Chemical test Degree of detonation
	Z	Y			
Service	2.7	1.05	11.6	4.4	10/10 D
RD.1343	2.4	1.05	11.3	6.2	10/10 D
RD.1352	2.2	1.05	11.0	3.5	10/10 D

TABLE X

Pressure bar and chemical test results - 2.3 gr. LZY detonators

(0.4 inch bar)

Type of azide	Charge weight grains		Mean pressure tons/sq.in.	C.V. %	Chemical test Degree of detonation
	Z	Y			
Service	1.40	0.35	13.0	1.8	10/10 D
RD.1343	1.30	0.35	13.5	2.9	10/10 D
RD.1352	1.17	0.25	10.3	4.4	10/10 D

D = complete detonation

TABLE XI

Pressure bar result - 2.0 gr. LZ detonators. Service lead azide - (0.4 inch and 0.7 inch bars)

	0.4 inch bar	0.7 inch bar
	Pressure tons/sq. in.	Pressure tons/sq. in.
High	11.0	4.2
Low	9.5	3.7
Mean	10.0+	3.9*
C.V.%	4.0	3.2

+cf Table VII
*Mean Pressure 2.4 gr. LZ detonator = 4.6 tons/sq.in.

TABLE XII

Pressure Bar results - 2.4 gr. LZ detonators/aluminium septa/tetryl channels/tetryl pellets. Fillings as Table II

Thickness septum inch	Individual pressure, tons/sq.in. (0.7 inch bar)		
	Service azide	RD.1343	RD.1352
0.05	1.4	1.5	1.4
0.04	6.7, 6.5, 6.5, 6.4, 6.2	6.5, 6.4, 6.3, 6.3, 6.0	
0.03			5.9
0.00	6.7, 6.7, 6.6, 6.6, 6.5		6.2, 6.2, 1.6, 1.5, 1.3

TABLE XIII

Pressure Bar results - 1.6 gr. ZY detonators/aluminium septa/tetryl channels/tetryl pellets. Fillings as Table III

Thickness septum inch	Individual pressures, tons/sq.in. (0.7 inch bar)		
	Service azide	RD.1343	RD.1352
0.08	1.4	1.5	
0.07	6.5, 6.5, 6.4, 6.4, 6.0	6.4, 6.4, 6.4, 6.3, 6.1	
0.04			6.5, 1.5
0.03			6.7, 6.7, 6.6, 6.4, 6.3

TABLE XIV

Pressure Bar results - 2.3 gr. LZY detonators/aluminium septa/tetryl channels/tetryl pellets. Fillings as Table V

Thickness septum inch	Individual pressures, tons/sq.in. (0.7 inch bar)		
	Service azide	RD.1343	RD.1352
0.08	1.6	1.7	
0.07	6.7, 6.6, 6.5, 6.4, 6.0	6.6, 6.4, 6.2, 6.1, 6.1	1.8
0.06			6.1, 6.1, 1.7
0.05			6.6, 6.5, 6.4, 6.2, 6.2

TABLE XV

Pressure Bar results - 1.6 gr. ZY detonators/aluminium septa/tetryl pellets

Thickness septum inch	Individual pressures, tons/sq.in. (0.7 inch bar)		
	Service azide	RD.1343	RD.1352
0.050	6.4, 6.3, 6.0, 5.7, 1.3	6.4, 1.6	
0.040	6.8, 6.7, 6.6, 6.6, 6.4	6.8, 6.7, 6.7, 6.3, 6.3	
0.005			6.7, 6.3, 1.3
0.000			6.5, 6.5, 6.0, 1.7

TABLE XVI

Pressure Bar results - 2.3 gr. LZY detonators/aluminium septa/tetryl pellets

Thickness septum inch	Individual pressures, tons/sq.in. (0.7 inch bar)		
	Service azide	RD.1343	RD.1352
0.08	6.5, 6.4, 6.2, 1.7		
0.07	6.7, 6.6, 6.5, 6.4, 6.3	6.5, 6.3, 6.1, 1.8	6.6, 1.5
0.06		6.7, 6.7, 6.5, 6.5, 6.5	6.7, 6.5, 6.4, 6.4, 6.1

TABLE XVII

Pressure Bar results - M22 LZY detonators/aluminium septa/tetryl pellets.
Fillings as Table IV

Thickness septum inch	Individual pressures, tons/sq.in. (0.7 inch bar)		
	Service azide	RD.1343	RD.1352
0.187	1.4	0.9	0.8
0.157	6.3, 1.6	6.4, 6.3, 6.0, 1.4	6.3, 1.4
0.125	6.7, 6.7, 6.7, 6.6, 6.5	6.7, 6.7, 6.6, 6.3, 6.2	6.8, 6.7, 6.7, 6.5, 6.5

TABLE XVIII

Pressure Bar results - 6.7 gr. LZY detonators/aluminium septa/tetryl pellets

(1) Inverse loaded A3 shells
Azide 3 grains
Tetryl 1.7 grains

Thickness septum inch	Individual pressures, tons/sq.in. (0.7 inch bar)		
	Service azide	RD.1343	RD.1352
0.187	6.5, 6.4, 2.3	6.5, 6.4, 6.0, 2.7	
0.157	6.5, 6.5, 6.3, 6.3, 6.3	6.6, 6.5, 6.4, 6.3, 6.1	
0.125			3.7
0.100			6.5, 6.5, 6.5, 6.3, 6.2

(2) Direct loaded
Filling as (1)

0.03	6.5, 6.5, 6.2, 5.7, E	Not done	E
0.02	6.3, 6.3, 6.3, 6.2, 6.1		E
0.01			E
0.00			E

E = explosion

IGNITABILITY TESTS

TABLE XIX

1.6 gr. inverse loaded detonators
ignited by 1.7 gr. "L" mixture detonators

Azide	Maximum distance between detonators for 10 successive ignitions of 1.6 gr.
	inches
Service	11
RD.1343	8
RD.1352	9

GAP TESTS ON PRODUCTION FILLED DETONATORS

Pressure Bar results - Detonators/Aluminium septa/tetryl pellets 0.7 inch bar.

1.6 gr. ZY

TABLE XX

Thickness septum inch	Pressures in tons/sq.in.		
	Service azide	RD.1343	RD.1352
0.04	9.2,4.7	9.3,3.5	
0.03	9.3,9.3,8.3,9.1,9.3, 9.2,9.2,9.2,9.3,9.7, 8.8,9.2,9.7,9.3,9.2, 9.3,9.4,9.4,9.2,8.3 Mean 9.2 C.V. 3.8%	8.9,9.3,9.6,9.3,9.3, 9.0,9.5,9.1,9.4,9.7, 9.3,9.2,9.3,9.5,9.4, 8.9,9.2,9.5,9.4,9.5 Mean 9.3 C.V. 2.3%	8.8,9.0,2.1
0.02			9.9,9.8,9.7,9.5,9.7, 9.9,9.5,9.4,9.3,9.7, 9.4,9.3,9.2,5.2
0.01			9.6,9.7,9.8,9.8,9.2, 9.6,9.6,9.7,9.3,9.9, 9.8,9.9,9.7,9.3,9.8, 10.1,9.4,9.7,9.8,9.7 Mean 9.7 C.V. 2.3%

GAP TESTS ON PRODUCTION FILLED DETONATORS

TABLE XXI

2.3 gr. LZY

Thickness septum inch	Pressures in tons/sq.in.		
	Service azide	RD.1343	RD.1352
0.05		9.0,9.5,9.4,2.2	
0.04	9.5,9.3,9.1,9.2,9.3, 9.3,3.1	9.5,9.4,9.5,9.6,9.5, 9.6,9.8,9.8,9.7,9.6, 9.7,9.8,9.5,9.6,9.6, 9.7,9.3,9.4,9.3,9.7 Mean 9.6 C.V. 1.6%	9.1,9.2,9.2,3.5
0.03	9.6,9.7,9.7,9.6,9.7, 9.3,9.7.9.8,9.5,9.7, 9.8,9.6,9.4,9.8,9.7, 9.5,9.6,9.7,9.2,9.6 Mean 9.6 C.V. 1.7%		9.2,9.6,9.1,9.3,9.5, 9.2,9.5,9.4,9.0,9.3, 9.2,8.8,9.2,9.0,9.0, 9.0,9.3,9.2,9.5,9.2, 9.4 Mean 9.2 C.V. 2.2%

TABLE XXII

M22 LZY

Thickness septum inch	Pressures in tons/sq.in.		
	Service azide	RD.1343	RD.1352
0.157	9.8, 1.9	1.9	1.8
0.125	10.8,10.2,10.6,10.5, 10.5,10.3,10.2,10.5, 10.3,10.7,10.4,10.6, 10.6,10.5,10.5,10.6, 10.4,10.5,10.5,10.4 Mean 10.5 C.V. 1.4%	10.6,10.4,10.5,10.2, 10.2,10.2,10.4,10.5, 10.3,10.5,10.5,10.3, 10.5,10.3,10.5,10.1, 10.5,10.3,10.5,10.5 Mean 10.4 C.V. 1.3%	10.6,10.5,10.4,10.5, 10.3,10.4,10.3,10.2, 10.5,10.3,10.4,10.4, 10.5,10.4,10.3,10.2, 10.4,10.2,10.2 Mean 10.4 C.V. 1.2%

GAP TESTS ON PRODUCTION FILLED DETONATORS

TABLE XXIII

6.7 gr. LZY

Thickness septum inch	Pressures in tons/sq.in.		
	Service azide	RD.1343	RD.1352
0.157	4.8	4.5	9.5,9.8,9.9,9.9,10.0, 9.9,9.7,9.5,9.5,9.7, 9.7,10.2,9.9,9.7,9.8, 10.0,3.0
0.125	9.9,9.5,9.5,9.6,9.5, 10.2,9.3,9.6,7.5, 9.8,9.8,5.8	10.4,9.9,10.0,10.3, 10.2,9.8,9.7,9.5,9.8, 9.6,9.8,9.6,10.2, 9.7,9.7,10.2,9.8,9.2 Mean 9.9 C.V. 3.1%	9.7,10.2,10.0,10.2, 9.8,10.3,10.0,10.2, 10.2,9.9,10.0,10.2, 10.0,9.8,9.8,9.7,9.9, 9.7,9.7 Mean 10.0 C.V. 2.2%
0.10	10.2,9.9,10.4,9.9, 9.8,9.6,10.2,9.7, 10.2,9.5,10.1,9.8, 9.9,10.2,10.1,9.9, 10.0,9.8,9.9,10.0 Mean 10.0 C.V. 2.2%		

TABLE XXIV

2.4 gr. LZ

Thickness septum inch	Pressures in tons/sq.in.		
	Service azide	RD.1343	RD.1352
0.03	9.5,9.7,E	6.9, 5.8	
0.02	10.3,10.2,10.6,10.2, 10.1,9.4,9.1,9.2,9.0, 9.1,9.7,8.8,9.1,9.0, 9.0,9.2,9.8,9.0,9.3 Mean 9.4 C.V. 6.7%	9.4,10.3,9.8,9.1,9.6, 9.8,9.3,10.1,9.9, 9.7,9.6,9.6,9.0, 9.7,6.7	
0.01		9.8,9.6,10.0,9.5, 9.7,9.5,9.7,9.5,9.3, 9.5,9.5,9.8,9.4,9.5, 9.5,9.7,9.6,9.6,9.6, 9.4 Mean 9.6 C.V. 1.7%	
0.00			3.2

E = explosion

CLIMATIC TRIALS: PRESSURE BAR RESULTS BY D.I. ARM.

ISAT (B) CONDITIONS
TABLE XXV

1.6 gr. ZY 0.4" Bar Pressures in tons/sq.in.

	Service azide		RD.1343		RD.1352	
	Mean	C.V.%	Mean	C.V.%	Mean	C.V.%
Controls(1)	13.6	5.3	13.1	8.4	9.6	8.1
" (2)	13.7	4.0	13.2	3.2	9.8	6.5
1 month	14.0	4.5	13.6	4.3	10.1	4.8
3 months	13.8	4.8	13.4	9.4	10.2	12.6
6 "	13.2	7.4	13.3	7.3	9.7	9.1
12 "	13.1	4.2	12.2	5.1	8.1	13.2
15 "	13.8	5.7	12.3	10.5	8.4	14.6
18 "	13.6	6.4	13.0	7.9	8.7	15.5
21 "	13.7	5.1	12.3	9.1	7.8	15.2
24 "	12.8	6.5	12.1	6.4	7.2	14.8
24 normal storage	14.5	8.0	13.9	8.4	10.3	13.4

TABLE XXVI

2.3 gr. LZY 0.4" Bar Pressures in tons/sq.in.

	Service azide		RD.1343		RD.1352	
	Mean	C.V.%	Mean	C.V.%	Mean	C.V.%
Controls(1)	12.6	4.9	12.8	5.4	11.3	5.1
" (2)	13.1	4.0	12.2	6.2	10.2	6.2
1 month	12.1	10.2	12.0	7.1	10.4	7.3
3 months	12.9	7.6	12.8	6.9	10.6	6.2
6 "	12.9	7.4	12.7	7.7	10.6	7.8
12 "	12.2	5.5	12.1	6.4	10.7	13.0
15 "	12.5	6.2	12.7	7.1	10.9	8.3
18 "	12.2	9.1	12.1	6.6	10.4	6.4
21 "	12.7	4.1	13.4	4.0	11.8	7.2
24 "	13.2	4.7	12.9	3.7	11.1	4.5
24 normal storage	13.4	4.0	13.5	6.2	11.4	7.2

CLIMATIC TRIALS: PRESSURE BAR RESULTS BY D.I. ARM.

ISAT (B) CONDITIONS
TABLE XXVII

M22 LZY 0.4" Bar Pressure in tons/sq.in.

	Service azide		RD.1343		RD.1352	
	Mean	C.V.%	Mean	C.V.%	Mean	C.V.%
Controls(1)	12.0	6.3	11.2	6.2	10.9	4.7
" (2)	12.1	3.9	11.6	2.1	11.3	2.6
1 month	11.5	6.6	10.8*	5.1	10.5*	5.0
3 months	11.9	6.5	11.2	6.0	11.4	4.8
6 "	11.1*	3.4	10.6ø	3.9	10.3*	3.1
12 "	11.8+	5.9	11.0+	6.3	10.9+	4.8
15 "	11.3	5.5	10.5	4.2	10.0	10.0
18 "	11.1	6.7	10.2	9.1	9.8*	11.0
21 "	11.2	7.5	10.9	5.6	10.3"/	6.6
24 "	11.9+	4.7	11.2	6.3	11.0/	4.0
24 normal storage	11.8	6.0	11.1	6.5	10.9	7.5

* 1 misfire: mean of 19 rounds
ø 6 misfires: " " 14 "
+ 2 misfires: " " 18 "
"/ 4 misfires: " " 16 "
/ 3 misfires: " " 17 "

TABLE XXVIII

6.7 gr. LZY 0.7" Bar Pressures in tons/sq. in.

	Service azide		RD.1343		RD.1352	
	Mean	C.V.%	Mean	C.V.%	Mean	C.V.%
Controls(1)	8.5	2.3	8.4	3.7	7.6	6.6
" (2)	8.6	3.9	8.6	4.1	7.3	7.8
1 month	8.8	3.5	9.0	2.9	7.8	6.0
3 months	9.0	3.0	9.0	2.9	7.8	6.0
6 "	8.6	3.1	8.5	3.7	7.7	2.8
12 "	8.6	3.9	8.8	4.0	7.9	5.2
15 "	8.1	6.0	8.1	6.2	7.2	5.9
18 "	8.7	6.3	8.7	3.7	7.9	5.6
21 "	8.7	4.4	8.7	5.8	8.2	5.4
24 "	8.8	4.2	8.8	4.0	7.9	9.3
24 normal storage	8.9	6.6	9.0	4.7	7.7	8.9

CLIMATIC TRIALS: PRESSURE BAR RESULTS BY D.I. ARM.

ISAT(B) CONDITIONS

TABLE XXIX

2.4 gr. LZ 0.4" Bar Pressures in tons/sq.in.

	Service azide		RD.1343		RD.1352	
	Mean	C.V.%	Mean	C.V.%	Mean	C.V.%
Controls(1)	12.3	3.8	11.8	2.8	10.6	4.3
" (2)	12.3	4.9	11.8	4.7	10.5	5.3
1 month	11.6	10.6	11.5	3.7	9.9	8.7
3 months	12.0	4.5	11.6	3.7	10.6	4.1
6 "	12.6	3.4	12.1	4.3	11.3	4.8
12 "	12.0	4.2	11.6	4.4	10.7	5.1
15 "	11.9	5.6	11.8	6.9	10.6	5.5
18 "	12.4	3.5	12.0	5.5	10.9	4.5
21 "	12.3	3.6	12.2	3.8	10.9	4.6
24 "	12.4	3.9	12.0	3.5	11.0	4.4
24 normal storage	12.2	4.7	12.1	3.4	10.8	3.8

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