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REPORT No. 24/R/59

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The Electrostatic Spark Sensitiveness of Initiators: Part 5: Further Study of Ignition with Metallic and Antistatic Rubber Electrodes

R. M. H. Wyatt

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The Electrostatic Spark Sensitiveness of Initiators: Part 5: Further Study of Ignition with Metallic and Antistatic Rubber Electrodes

by

R.M.H. Wyatt

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CONTENTS

Reference: WAC/91/27

1. SUMMARY

The results quoted in Part 3 of this series, i.e., obtained by the use of antistatic-rubber base electrodes, have been amplified and extended. Oscillographic data are presented which show the similarity between discharges from a metal needle to the rubber base electrode and discharges from a human being. Oscillograms of the phenomenon of spark splitting are also shown. It has been demonstrated that the main function of the rubber, apart from the elimination of short arc discharges, is to act as a resistance. The effect of capacitance on the threshold energy for metal/metal discharges has been investigated over a much wider range than before. An attempt has been made to interpret the type of curve relating threshold ignition energy and capacitance using rubber base electrodes.

2. INTRODUCTION

The object of the report is to amplify and extend some of the results quoted in Part 3 of this series, i.e. results obtained by the use of antistatic rubber base electrodes, and to record various observations with rubber and metal base electrodes which may lead to a better understanding of the ignition of primary explosives by accidental discharges.

3. RESULTS OF FURTHER TESTS USING ANTISTATIC-RUBBER BASE ELECTRODES

Part 3 (1) in this series of reports showed how the electrostatic hazard of initiators could be assessed by determining ignition energies using an antistatic-rubber base electrode instead of a steel one. This provided test conditions much more closely related to the conditions under which discharges take place accidentally.

That report (i.e., Part 3) revealed the existence of a minimum capacitance for ignition and an optimum one at which the threshold energy was a minimum. The data given have been extended wherever necessary to cover a wider range of capacitances and to include other initiatory explosives. The values of threshold energies at various capacitances have been plotted on a logarithmic scale and the graph (Fig. 1) shows up the minimum energies and minimum capacitances for ignition, as already described. Table 1 gives the numerical values of these. This table should be compared with Table 2 of Part 3 (1), Table 8 of Wyatt et al. (2) and Table 1 of Scaife and Sumner (3). In the latter two papers, the threshold energy was taken as the lowest energy at which one ignition in 50 trials was observed. Since a non-normal distribution of ignitions with energy is obtained, especially with small capacitances, it is essential that the lowest energy for one ignition in 50 trials is confirmed by carrying out 50 trials at an energy level even lower, to give no ignitions. In this report the threshold energy is the energy for this "0 per cent" ignitions (i.e. no ignitions in 50 trials) determined in this way. The numerical difference between the two energies is usually quote small, and is barely noticeable on a logarithmic graph.

/TABLE 1 .....

TABLE 1

Values of Minimum Capacitance and Minimum Threshold Ignition Energy, Rubber Base Electrodes

Explosive	Type of Electrode	Minimum Capacitance $\mu\mu F$	Minimum Threshold Ignition Energy
Lead styphnate R.D.1303 (0)	N	20	75 ergs at 30 $\mu\mu F$
Tetrazene, Lot 19	N	35	950 " at 120 "
L.D.N.R. R.D.1337 XMG.21	PB	40	1600 " at 100 "
Service lead azide CY.3628	N	400	2250 " at 1500 "
Mercury fulminate	PB	450	3100 " at 1000 "
Silver azide R.D.1336, XTA.52	N	500	4000 " at 1000 "
Dextrinated lead azide, D.115	PB	2000	20,000 " at 6000 "

In some cases, the old values are superseded by more precise figures, or in others they are revised due to a correction for the capacitance of leads to, and including, the switch used to connect the Lindeman electrometer for checking residual voltage. A value of 25 $\mu\mu F$ has been determined for this, and since this capacitance is in parallel it has to be added to the capacitance selected for the test. The usual practice since these initial experiments has been to use a Cambridge electrostatic voltmeter permanently in circuit. Values of 20 $\mu\mu F$ have been determined for the capacity of three instruments, with the following ranges 0 - 1.5 kV, 0 - 5kV and 0 - 10 kV. This limits the low range of capacitance to 20 $\mu\mu F$. If smaller capacitances are needed, then the voltmeter is placed in the charging circuit, so that it is not connected when the upper electrode is brought down to the explosive. Under these conditions no check can be made to see whether the condenser is discharged completely. The figures previously quoted (1, 2, 3) for lead styphnate R.D.1303(0), are too low, since they were not corrected for circuit capacitance. However milled U.S. normal lead styphnate can be ignited with a capacitance as low as 5 $\mu\mu F$, the minimum energy being less than 10 ergs (5). Diazo dinitrophenol has also been studied (5), the minimum capacitance being 150 $\mu\mu F$.

Figure 2 shows the results for normal lead styphnates R.D.1302 and R.D.1303(M), and two monobasic lead styphnates R.D.1346 and R.D.1349, together with that for R.D.1303(0) as a reference (the scale of Fig. 2 is much larger than that of Fig. 1). It can be seen that there is very little difference in the sensitiveness of these normal and monobasic lead

/styphnates .....

styphnates though preliminary estimates suggested that the latter were less sensitive than the former, (see also Wyatt (5) for information on U.S. monobasic lead styphnate). The common yellow monobasic lead styphnate is more sensitive, the values of the threshold energy being 31 ergs at 125 μμF and 18 ergs at 30 μμF (see Fig. 11). The curve for R.D.1303(M) falls within the same area as the other lead styphnates. However, as previously noted (6), ignitions with this material are mainly partial ones. This is in contrast to R.D.1349. Though R.D.1349 gave mainly partial ignitions using two metal electrodes, the majority of ignitions were complete when tests were carried out with rubber base electrodes. The relative incidence of partial and complete ignitions plus the larger energy for two metal electrodes justifies the use of R.D.1303(M) instead of R.D.1303(O).

Figure 3 shows the values determined for several lead 2,4-dinitroresorcinates, the alpha normal salts R.D.1305, 1307 and 1337, the beta normal salt R.D.1344, and the alpha normal salt containing 2.5 per cent gum arabic, R.D.1341(7). It can be seen that R.D.1305, 1337 and 1341 are very similar in sensitiveness, whereas R.D.1307 and R.D.1344 are significantly more sensitive. In fact, in the region of 100 μμF capacitance the two curves touch the curve for normal lead styphnate. Table 2 gives the numerical values for the minimum capacitance and minimum threshold energy, in order of decreasing sensitiveness.

TABLE 2

Sensitiveness of Lead 2,4-D.N.R.s

Explosive	Minimum Capacitance, μμF	Minimum Threshold Ignition Energy
R.D.1344	20	330 ergs at 70 μμF
R.D.1307	25	330 " " 60 "
R.D.1337	40	1600 " " 100 "
R.D.1305	30	2100 " " 350 "
R.D.1341	40	2000 " " 300 "

N.B. R.D.1344 has been placed above R.D.1307 partly on the basis of the M/M results given in Section 6.3

4. COMPARISON OF DISCHARGES FROM A HUMAN BODY WITH THOSE OBTAINED USING RUBBER BASE ELECTRODES. OSCILLOGRAMS OF SPARK SPLITTING

The use of rubber electrodes rests entirely on the supposition that the discharge passing between the steel needle and the rubber base is very similar to that passing between the finger of a charged human being and some metal object. Ignition tests (1) showed that this was likely to be true. However, it was thought desirable to have direct oscillographic evidence (8). Accordingly a series of oscillograms were prepared of

/discharges .....

discharges under the following conditions:

(a) A 500 $\mu\mu F$ silver ceramic capacitor, raised to a potential of 1000 volts was discharged through a carbon resistor using two metal electrodes, - Fig. 4(a).

(b) A 500 $\mu\mu F$ silver ceramic capacitor, raised to a potential of 1000 volts, was discharged via a steel needle to the rubber base electrode, - Fig. 4(b).

(c) A human being, raised to a potential of 1000 volts, was discharged via his finger to a metal base electrode - Fig. 4(c).

Oscillograms similar to Fig. 4(a), i.e. of experimental current decays have been shown in Part 1 (9). In the present connection it is sufficient to note that there is an almost instantaneous breakdown of the spark gap as shown by the very rapid rise in current at the beginning of the trace. This initial current is determined by the potential to which the capacitor was charged and by the value of the carbon resistor. The resistance across the gap is comparatively small. Fig. 4(b) is similar (ignoring the dotted portion, referred to later) except that there is an appreciable period of time required to establish the maximum current and the total duration of the trace is longer. It is believed that the former is due to the fact that antistatic rubber, i.e., rubber made conducting by the incorporation of carbon black, does not obey Ohm's Law even with low current densities (10). Consequently a maximum current caanot be set up instantaneously. Heat is liberated within the rubber, decreasing the resistance and increasing the current. The current decay is not a simple exponential one since the resistance is changing as the current and potential decrease. It is estimated from Fig. 4(b) that the total resistance including the detector resistance of 100,00 ohms, is about 200,000 - 250,000 ohms at the peak, increasing to 300,000 - 350,000 ohms at the end of the solid line. This accounts for the longer duration of the discharge in Fig. 4(b). Many traces have shown a second peak (indicated by the dotted line) and this is believed to be due to a second conduction channel in the rubber.

The shape of Fig. 4(c) is almost the same as 4(b), leaving out the dotted portion. Again a period of time is required for the attainment of maximum current, indicating that the skin does not obey Ohm's Law. However, the discharge time is much less than in 4(b). This is due to the use of a smaller detector resistance (20,000 ohms instead of 100,000 ohms), a smaller value for the resistance of the skin as compared with rubber, and a smaller effective capacitance than 500 $\mu\mu F$. It is hoped to obtain numerical values of these by varying the detector resistance and initial potential.

These oscillograms show that a discharge from the finger of a charged human being is reproduced in a spark gap circuit using a rubber base electrode.

A second characteristic of discharges in circuits containing an appreciable resistance is the occurrence of spark splitting, which depends upon the value of the capacitor, and the potential to which it is raised. Again it was desirable to show that splitting does in fact occur with rubber base electrodes under those conditions in which spark splitting has been invoked to explain the ignition curve, and does occur with discharges from human beings under certain conditions.

/Fig. .....

Fig. 5(a) shows a current oscillogram for a set of three sparks obtained when a 50 μμF capacitor is charged to 4 kV and allowed to discharge from a metal needle to a rubber base electrode. Using a short time scale it can be seen that the individual sparks lasted about 60 microseconds. This is to be expected, taking into account the values of the capacitor and resistance of the rubber. Fig. 5(b) shows a similar discharge of two sparks, on a long time scale. The interval between the two sparks is about 7 milliseconds. These conditions apply to the ignition curve for L.D.N.R. R.D.1337.

Figure 6 shows a corresponding set of oscillograms for a charged human being. In this case the subject, raised to a potential of 1 kV, held a brass rod in his hand, which was connected to the approaching electrode apparatus, i.e., the upper needle electrode. The base electrode was steel. Fig. 6(a) and (b) show the resultant spark splitting. Each trace is a function mainly of the effective capacitance of the leads and the human body, and of the detector resistance used for deriving the current. As before, the interval between the sparks is of the order of milliseconds, whereas the sparks themselves last about 20 microseconds. This spark duration supports the hypothesis that the effective capacitance is small since the resistor used for deriving the current oscillogram was the same as in the previous case involving a rubber base electrode with a 50 μμF capacitor (Fig. 5).

Then observations agree with the supposition that spark splitting is due to the mechanical approach of the electrodes at the rate of a few centimetres per second, providing there is a large enough resistance in the circuit and sufficient initial potential, to give more than one spark.

This oscillographic work is part of a more detailed investigation by Sumner (8) on the electrical characteristics of human beings and of anti-static rubber in circuits capable of giving a discharge sufficiently energetic for ignition.

5. MODE OF ACTION OF THE RUBBER IN THE IGNITION PROCESS

The use of a rubber base electrode has at least two effects. They are:

(a) the elimination of short arc discharges, since the latter cannot be set up unless both electrodes are either metal or carbon, and (b) the introduction of a resistance of the order of 100,000 ohms. Thus, because of (a), comparison of ignition properties can be made only in the gaseous discharge region, where it is likely that the rubber acts purely as a resistance. Tests have been carried out with lead styphnate and lead azide.

5.1 Lead Styphnate

A comparison has been made of the threshold ignition energies for rubber base electrodes, with the energies obtained for two metal electrodes in a circuit containing a carbon resistance of 100,000 ohms. Fig. 7 shows the two curves, and it will be seen that they follow the same trend. Agreement is actually better than the figure indicates. The metal to metal ignition curve should be modified since the threshold energy should be obtained by extrapolating the gaseous discharge portion of the percentage ignition/energy curve (see inset of Fig. 7). It is not possible to carry out this extrapolation with sufficient accuracy, particularly with smaller capacitances, and no attempts have been made to do so. It appears from these tests with lead styphnate that the rubber is acting purely as a resistance.

/5.2 .....

5.2 Lead Azide

As already stated, comparison has to be made with gaseous discharges. However, after a gaseous spark has passed in a circuit containing a resistance of 100,000 ohms there will be sufficient energy left on the capacitor to ignite lead azide on contact when two metal electrodes are used (see Fig. 6 of Moore (1)). Consequently contact discharges have to be eliminated. This was achieved by lowering the platform upon which the roller rests, so that there was a gap of 0.0015 inch between the top of the roller and the tip of the needle at its lowest position. In this way a single or several gaseous discharges can be obtained without the final discharge on closure.

In the case of lead styphnate this precaution was not taken because the contact and gaseous discharge portions of the ignition curve (see inset Fig. 7) are too near together to get a clear cut separation of the two types of discharge. A very small gap would be needed to ensure that a gaseous discharge took place since the level of energy is much lower than for lead azide. Moreover the platform of the apparatus was not made to such precision that the same gap would be obtained on moving the roller so that a fresh portion of the sample could be tested.

Figure 7 compares the results of rubber/metal experiments for Service lead azide (i.e, the same curve as in Fig. 1) with results using gaseous discharges between two metal electrodes in a circuit containing a resistance of 100,000 ohms. As can be seen, almost identical values are obtained, showing that the rubber is acting purely as a resistance.

6. EFFECT OF CAPACITANCE ON THRESHOLD ENERGY USING DISCHARGES BETWEEN TWO METAL ELECTRODES.

Previous experiments had shown that over a certain range of capacitance the threshold energy using two metal electrodes (with no added resistance) was independent of capacitance, e.g., Figs. 3 and 4 of Part 2 (5) with Service lead azide, the energy remained at 20 ergs whilst the capacitance was varied from 200 μμF to 1000 μμF. It was of interest to investigate the relationships between threshold energy and capacitance over a much wider range, particularly in the direction of large capacitances so that the initial potential on the capacitor approaches the value which theoretically is just capable of setting up an arc discharge. For example, Kusliuk (11) has shown that the arc voltage is only a little more than the sum of the ionisation potential and work function of the metal. For iron these two values are 7.8 and 4.7 volts respectively. Consequently the arc voltage would be about 13.

6.1 Service Lead Azide

Fig. 8 shows the results for the threshold ignition energy and potential on the capacitor for Service lead azide over the range of capacitance 30 μμF to 60 μF. Batteries were used for potentials less than 120 volts. The dotted line shows the potential originally required on the capacitor if the threshold energy had remained at 20 ergs throughout. It will be seen that a divergence occurs above 1000 μμF, when potentials appreciably greater than those corresponding to an energy of 20 ergs are required. Above 5000 μμF an abrupt change is found, when much larger potentials are required. Above 10,000 μμF, the potential curve resumes a slope similar to the original one. At 10μF the potential has equalled the theoretical requirement of approximately 13 volts, and at 60 μF the potential on the capacitor

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is less than 9.5 volts, i.e., it appears that potentials less than the arc voltage of 13 volts are capable of igniting the explosive. However another factor affects the setting up of an arc and that is the inductance of the circuit (12, 13). With these large capacitors, the self-inductance is appreciable, and this can provide a higher discharge voltage than the potential to which it was charged. It is well known that an arc can be obtained from a 6-volt car battery. This is due to the self-inductance in the circuit acting in conjunction with the contact capacitance.

The interesting points are the departure from the 20 erg curve above 1000 $\mu\mu$F and in particular the discontinuity in the region of 5000 - 10,000 $\mu\mu$F. No explanation can be put forward at this time, as it is not known whether it can be related to changes in discharge characteristics in this region. This is not improbable and it is hoped to resolve this phenomenon during a study of short arc discharges (see Section 8).

At the low capacitance end of the curve, i.e. below 200 $\mu\mu$F, the threshold energy increases to 25 ergs at 125 $\mu\mu$F and then falls to approximately 10 ergs as the capacitance is reduced to 80 $\mu\mu$F. Below 70 $\mu\mu$F the energy rises again, and this is due to the onset of gaseous discharges. Potentials in excess of 250 volts are required for capacitances less than 55 $\mu\mu$F. Lead azide is known to be much less sensitive to gaseous discharges (4), consequently the threshold energy increases. Moreover the spark channel becomes increasingly narrower as the capacitance is reduced.

When the capacitance is greater than 55 - 60 $\mu\mu$F, contact discharges are responsible for ignitions at the threshold since the potential on the capacitor is always less than 200 - 250 volts.

6.2 Lead Styphnate

Fig. 9 shows the results for lead styphnate R.D.1303(0), Lot Sy 4/49. The dotted line shows the potential required on the condenser if the threshold energy had remained at 110 ergs. It can be seen that at the large capacitance end, departure from the 110 erg line occurs above 20,000 $\mu\mu$F (the potential at that capacitor value being approximately 30 volts) with the threshold energy rising to 600 ergs at 2 μF. A value given by Bean (14) for I.C.I. lead styphnate of 1550 ergs at 14 μF (4.7 volts) fits in quite well. A fairly rapid rise in energy for lead styphnate has been found by Taylor and Hall, quoted by Morris (15). As with lead azide, capacitor potentials less than the arc voltage are sufficient to cause ignition.

At the small capacitance end the threshold energy rises slightly at 125 $\mu\mu$F. The potential on the capacitor for value below 200 $\mu\mu$F exceeds 300 volts. Again there seems to be no explanation for the drop in energy or the slight rise at 125 $\mu\mu$F. The rise below 60 $\mu\mu$F is due to the onset of gaseous discharges whose spark channels become narrower as the capacity is decreased.

6.3 L.D.N.R.

It was realised that the threshold ignition energy of L.D.N.R. varied much more with capacitance than did that of lead styphnate. Consequently several forms of L.D.N.R. have been studied though not over a very wide range of capacitance. Fig. 10 shows the results for alpha lead 2,4-dinitroresorcinates R.D.1305, 1307 and 1337, and beta lead 2,4-dinitroresorcinate R.D.1344. The values given in Fig. 10 of Part 2 (4) have been

/revised .....

revised in the case of R.D.1305 and 1337 to take into account the extra capacitance of the switch and leads (as mentioned in Section 3), and fit in well with the new determinations as shown in Fig. 10. The previous results for R.D.1307 did not fit in so well, and this substance has been completely re-investigated. Fig. 10 shows that above 500 μμF there is some separation, sensitiveness decreasing in the order R.D.1307, 1337 and 1305. The beta salt is somewhat more sensitive.

The values quoted in Table 8, (2) are for a different sample of L.D.N.R. with somewhat different properties. The R.D.1337 figures quoted have shown that at a capacitance of 5000 μμF the potential for the threshold energy is 300 volts. At 500 μμF the corresponding figures are 500 ergs and 425 volts and at 75 μμF they are 200 ergs and 750 volts. From this series of figures it is not possible to decide unequivocally whether contact discharges are capable of igniting L.D.N.R. This point will be discussed again in Section 8.

7. INTERPRETATION OF THE FORM OF THE ENERGY/CAPACITANCE CURVES OBTAINED WITH RUBBER BASE ELECTRODES

It will be noticed that the series of curves in Fig. 1 as obtained with rubber base electrodes (or with two metal electrodes in a circuit containing 100,000 ohms resistance as in Fig. 7) show a definite pattern in their shape and in their relation to one another. As mentioned previously, the left hand portion of each curve is in a capacitance region for the particular compound, such that the energy in any one of the series of discharges as a result of spark splitting is just sufficient to cause ignition. Consequently to maintain the energy of any of the separate discharges as the capacitance is decreased, the total energy must be increased and so the curve bends upwards.

For the rest of the curve only one discharge occurs. This is more nearly true the larger the capacitance. Thus the capacitor needs to be charged up to a potential such that a gaseous discharge is obtained. The actual potential will vary from explosive to explosive, since some will need a larger energy than others, but the lowest potential will be 200 - 250 volts, this being the figure obtained in the early experiments using two metal electrodes (point to plane discharge) described in Part 2 (4). Figure 11 shows the ignition curves of Fig. 1, plus curves for basic lead styphnate (common yellow form) and U.S. milled normal lead styphnate. The three straight lines are lines of constant potential, 200, 300 and 400 volts. As can be seen the lead styphnate R.D.1303 curve approaches the 400 volt line at a capacity between 2000 and 5000 μμF. With more sensitive materials, or ones of smaller particle size, the potential capable of giving rise to ignition will be less. For example, the minimum potential for yellow monobasic lead styphnate is about 225 volts. Milled U.S. lead styphnate quoted in (5) has a minimum potential of about 250 volts.

The diagram inset in Fig. 11 shows the idealised case. The left hand portion AB covers the spark splitting region. At a certain capacitance value the threshold energy E is reached, and the energy remains constant while the capacitance is increased, BC, until the minimum potential line is met at C. From this point upwards in the capacitance scale, the energy must follow the line given by charging the capacitance to the minimum potential capable of giving a gaseous discharge, CD. At very high capacitances there may be some departure from this line in the

/direction .....

direction of larger energies, due to the slower rate of energy release. It can be seen that, on the whole, this form of curve is obtained in practice.

8. DISCUSSION

As a result of several years experience with the rubber base electrode method, coupled with the work now reported, it seems fairly well established that the method provides a good assessment of electrostatic hazard. One of the most encouraging aspects is that for the first time in explosives testing the form of spark discharge used is very similar to the one taking place in practice from the finger of a charged operative, or other non-metallic body having an appreciable resistance. However the occasions when a discharge takes place between two metallic surfaces must not be ignored.

The mechanism of ignition has received a little attention. Gaseous discharges of duration between 150 and 500 microseconds have suggested a thermal mechanism in the case of lead azide (4). The contribution of the light emitted in a spark discharge has been the subject of Part 4 in this series (16). However the mechanism of ignition by contact discharges has not been studied, and it is intended to carry out work in this direction. For example it is very desirable to know whether, on closure of two metallic electrodes such that an arc is not formed, ignition is impossible or extremely unlikely, since the energy is not dissipated at the contact but throughout the resistance of the circuit. Likewise it is desirable to know if the converse is true, i.e., if an arc is formed there is an appreciable probability of ignition, since most of the energy is dissipated in the arc in close proximity to the explosive. The distinction has been assumed up to the present and, to prove it, it is necessary to know whether an arc is formed or not, and this can only be done oscillographically, for which a high speed transient oscilloscope is required. If the arc is responsible for ignition, then means for its suppression under practical conditions will have to be sought.

Some of the doubts about the types of spark responsible for the ignition of L.D.N.R. could be dispelled, since voltage around 300 volts give rise to contact or gaseous discharges depending upon the geometry of the electrode and particle size of the explosive. The former, i.e., the use of a needle or plumb-bob electrode, depends upon the response of the explosive. Needles are always used if possible, and they enable gaseous discharges to be obtained at slightly lower capacitor potentials than with plumb-bob electrodes. Oscillographic work would also check the figure of 200 - 250 volts as the minimum potential for gaseous discharges, cited in the metal to metal, point to plane, case for lead azide, and in the metal to rubber case for lead styphnate.

The abrupt change in energy in the lead azide curve for two metal electrodes at 5000 $\mu\mu F$ capacitance may also be elucidated by oscillographic observation of the arc under those conditions. Information may also be gained about contact capacitance, an aspect which has so far been ignored.

The deposition of graphite and metals on initiator crystals causes large changes in their sensitiveness. With small percentages deposited there is usually an increase in sensitiveness. Contact discharges are again predominantly responsible, and detailed investigation will require oscillographic techniques. It is hoped that such a study will provide

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information on the mechanism of sensitisation and desensitisation by the deposits of conducting materials e.g. whether sensitisation occurs by the conducting material being heated up by a current passing through it, and this heat is transmitted to the explosive in intimate contact, or an arc is set up between adjacent particles of conductor and this causes ignition.

9. BIBLIOGRAPHY

1. P.W.J. Moore, E.R.D.E. Report No. 22/R/56

2. R.M.H. Wyatt, P.W.J. Moore, G.K. Adams and J.F. Sumner, Proc. Roy. Soc., 1958, A.246, 189

3. D.B. Scaife and J.F. Sumner, Eighth Tripartite A.X.P. Research Conference, Vol. 5, Session B.5

4. P.W.J. Moore, J.F. Sumner and R.M.H. Wyatt, E.R.D.E. Report No. 5/R/56

5. R.M.H. Wyatt, NAVord report in preparation

6. G.W.C. Taylor, J.R. White and R.M.H. Wyatt, E.R.D.E. Report No. 17/R/58

7. G.W.C. Taylor and J.R. White, E.R.D.E. Report No. 30/R/59 in preparation

8. J.F. Sumner, E.R.D.E. Report in preparation

9. P.W.J. Moore, J.F. Sumner and R.M.H. Wyatt, E.R.D.E. Report No. 4/R/56

10. R.H. Norman, "Conductive Rubber", p.51 - 54, McLaren, London, 1957

11. P. Kusliuk, J.Appl.Phys., 1954, 25, 897

12. F. Llewellyn Jones, "The Physics of Electrical Contacts", O.U.P., 1957

13. L.H. Germer and F,E, Haworth, J.Appl.Phys., 1949, 20, 1085

14. C.M. Bean, A.C. 2011, (1942)

15. G. Morris, Engineering, 1947, 164, 73.

16. D.B. Scaife, E.R.D.E. Report No. 9/R/59

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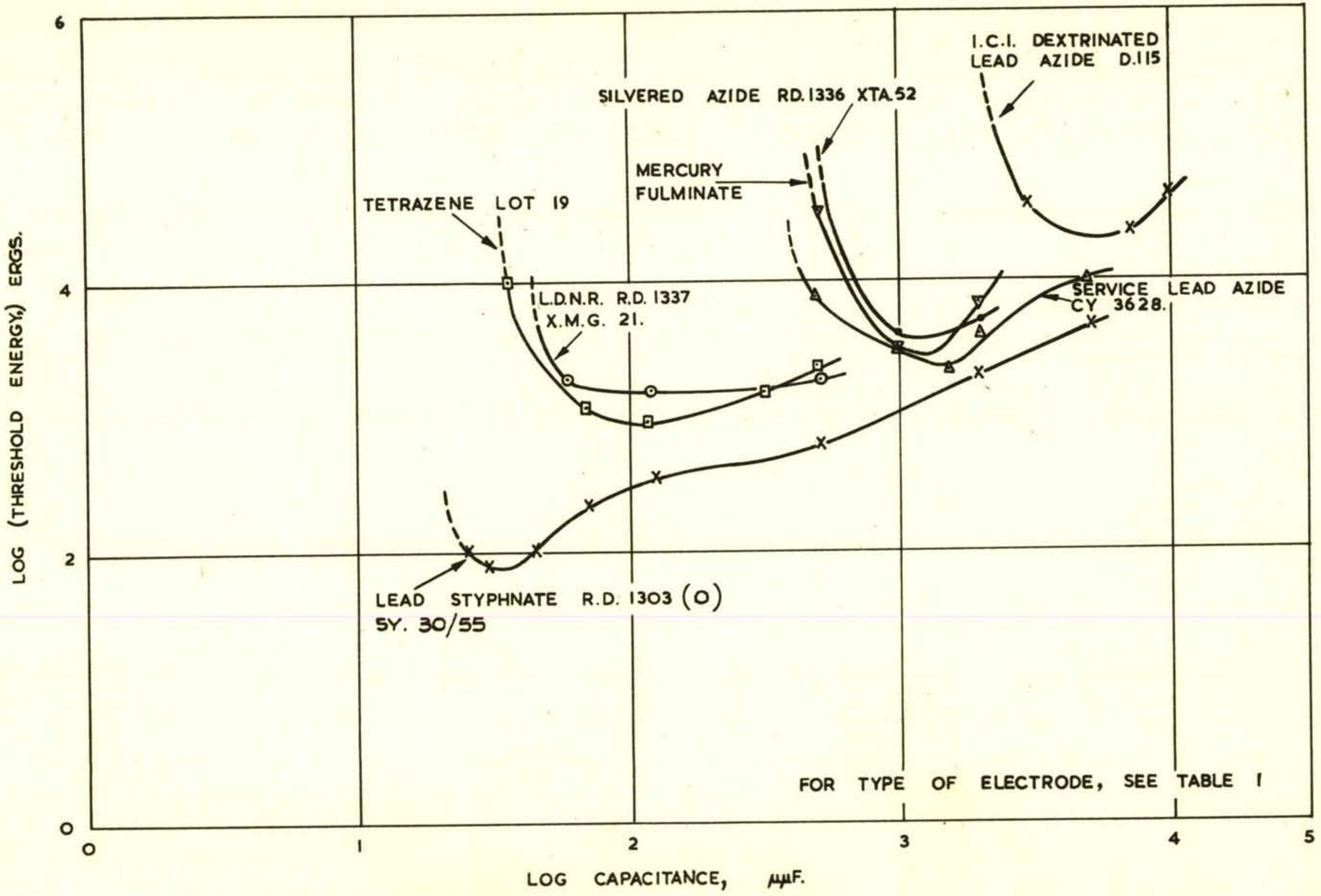
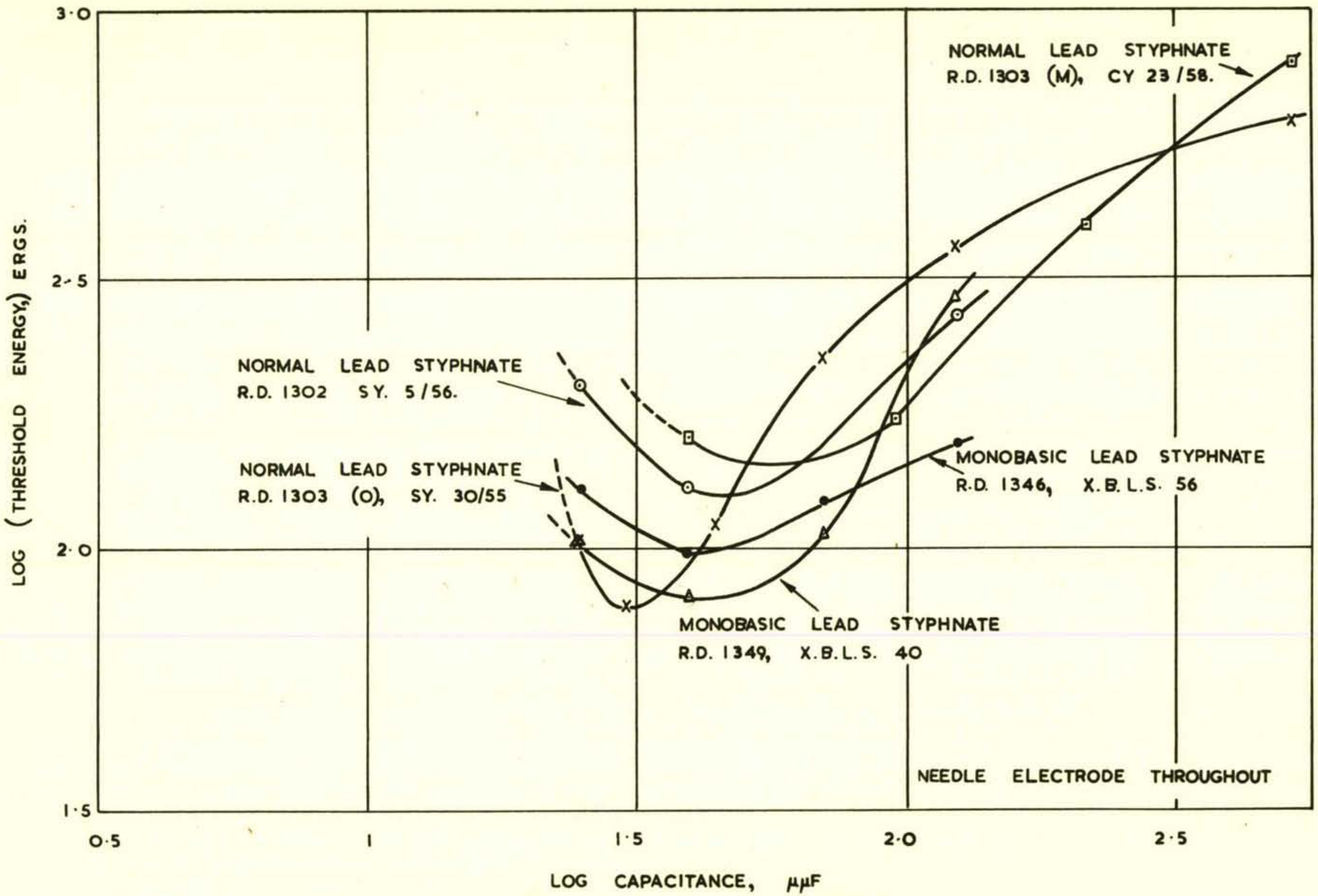
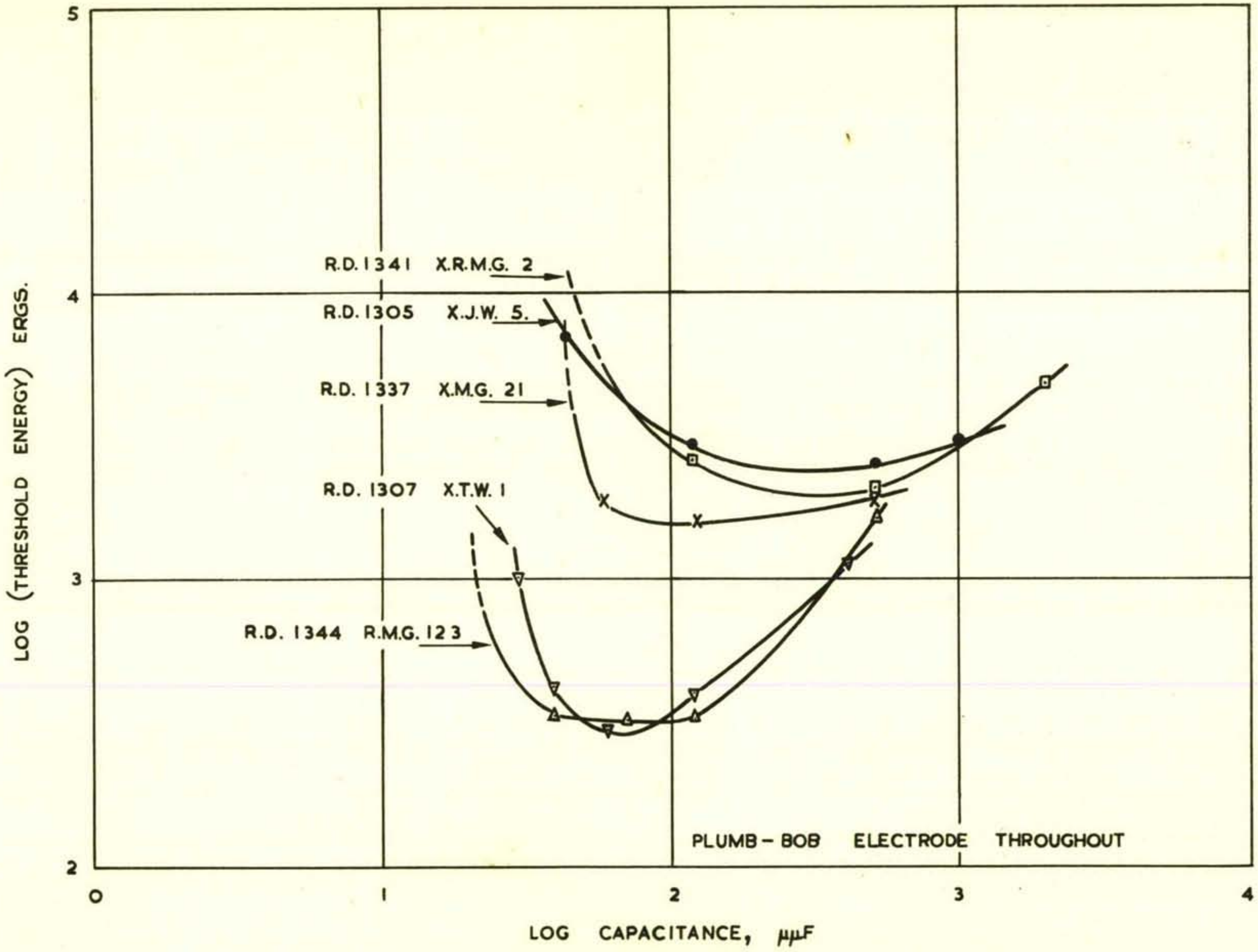
S.645/SS



VARIATION OF LOG (THRESHOLD ENERGY) WITH LOG CAPACITY, RUBBER BASE ELECTRODE. FIG. 1.



SENSITIVENESS OF NORMAL AND MONOBASIC LEAD STYPHNATES; RUBBER BASE ELECTRODE. FIG.2.



SENSITIVENESS OF LEAD 2, 4 - DINITRORESORCINATES; RUBBER BASE ELECTRODE. FIG. 3.

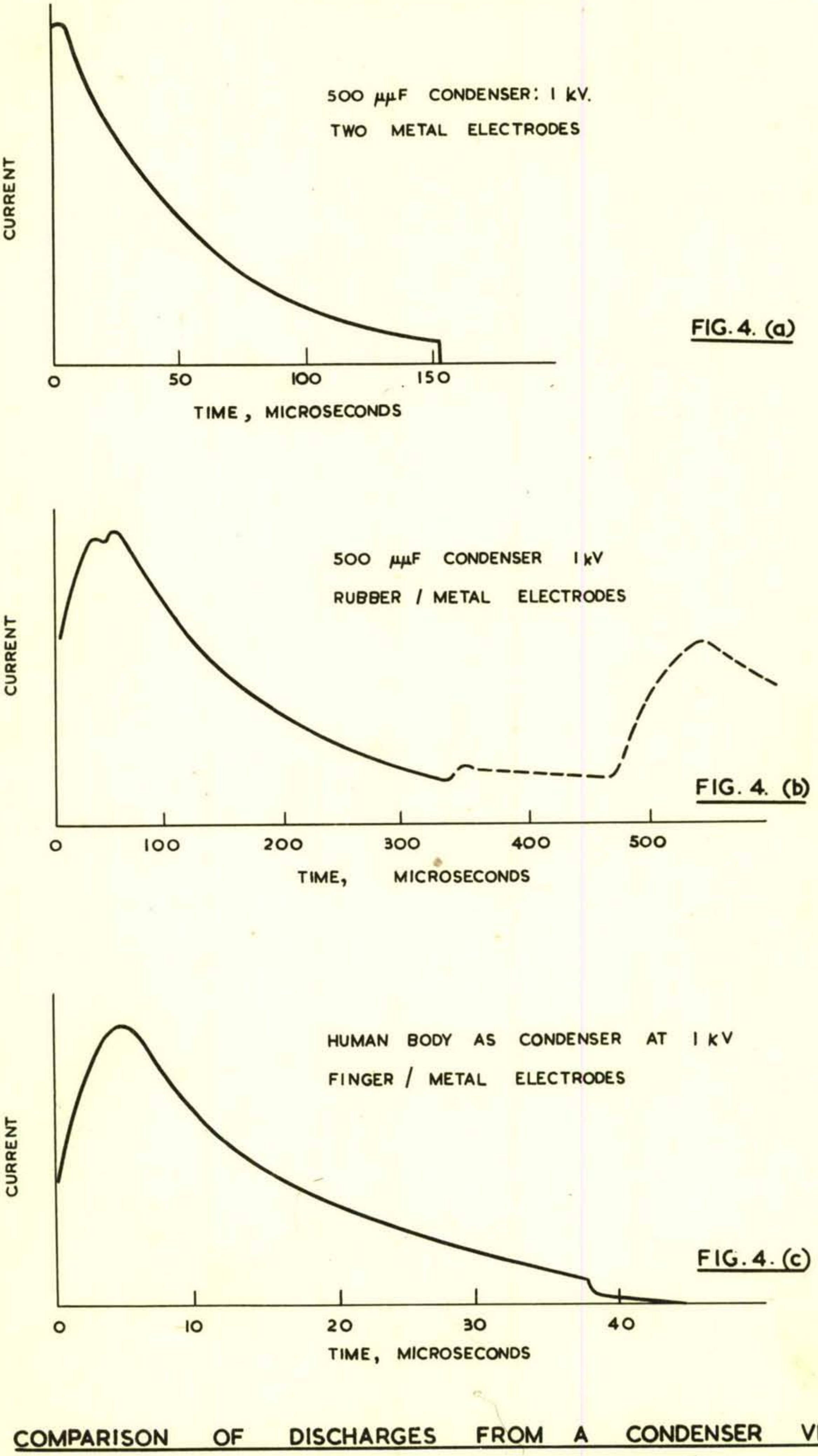


FIG. 4. (a)

FIG. 4. (b)

FIG. 4. (c)

COMPARISON OF DISCHARGES FROM A CONDENSER VIA (a) TWO METAL, (b) RUBBER/METAL ELECTRODES WITH THAT (c) FROM FINGER OF CHARGED HUMAN BEING. FIG. 4.

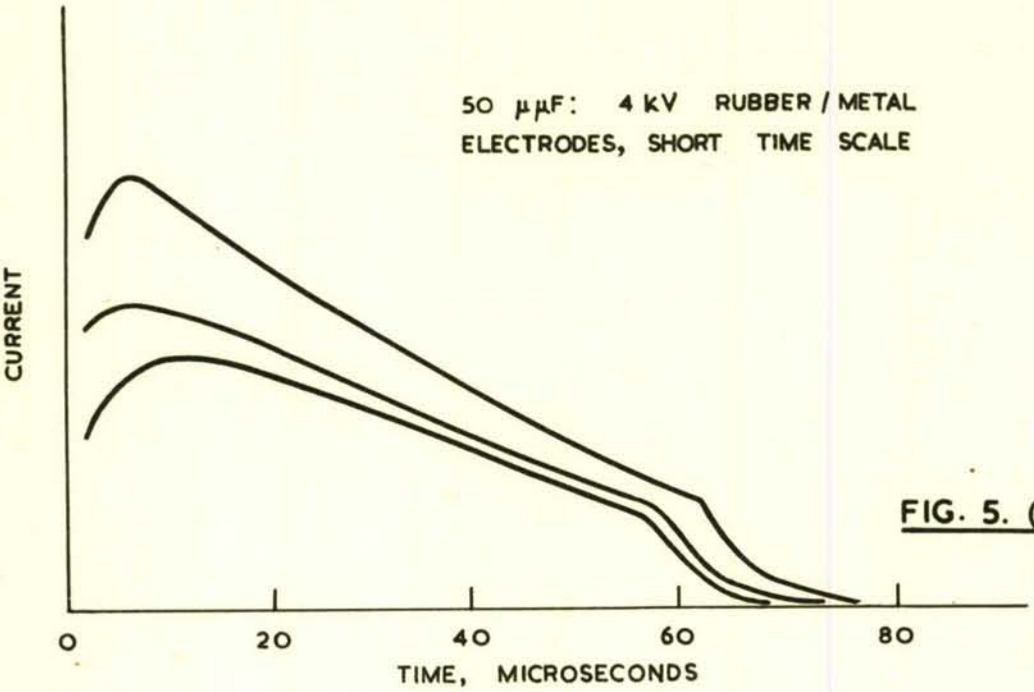


FIG. 5. (a)

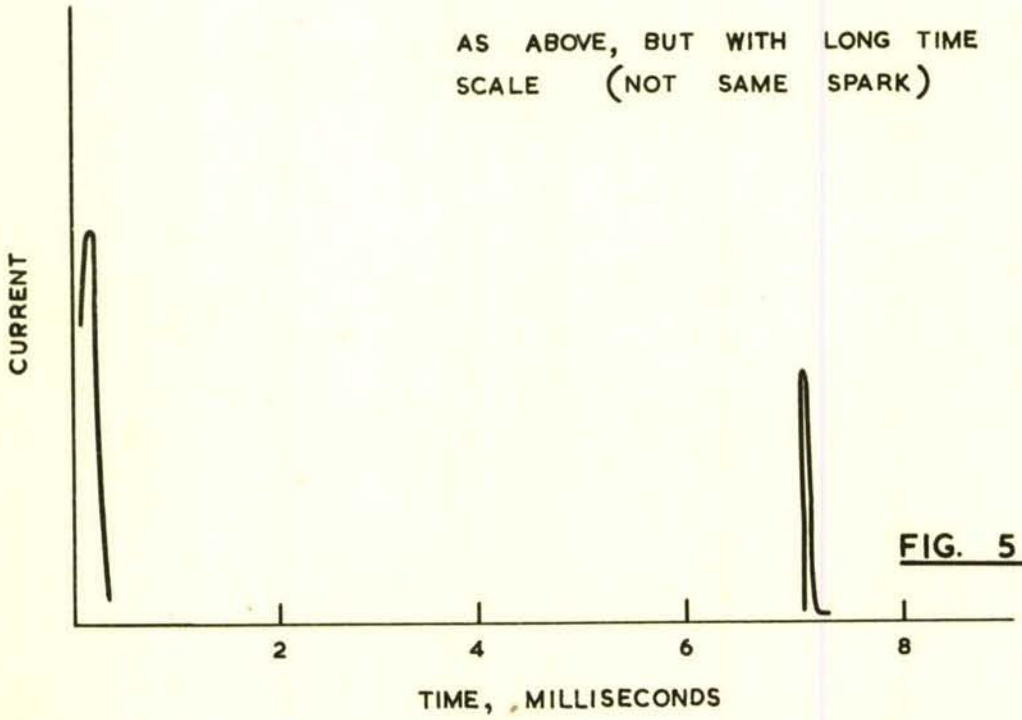


FIG. 5 (b)

OSCILLOGRAMS OF SPARK — SPLITTING OBTAINED FROM A FIXED CAPACITOR. FIG. 5.

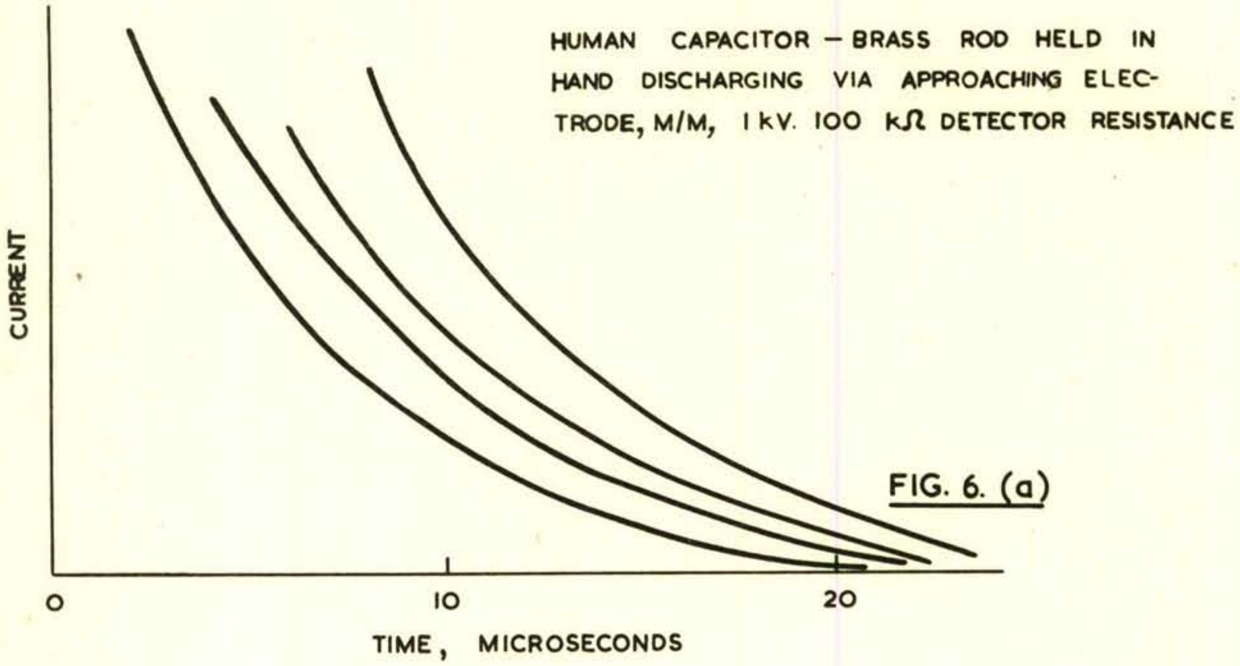


FIG. 6. (a)

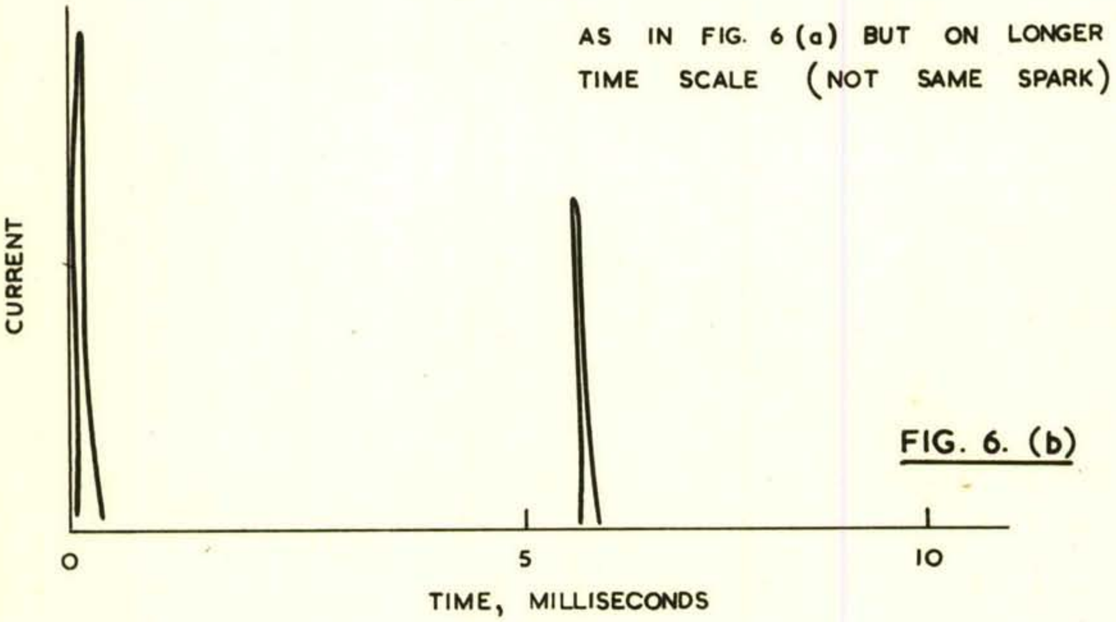
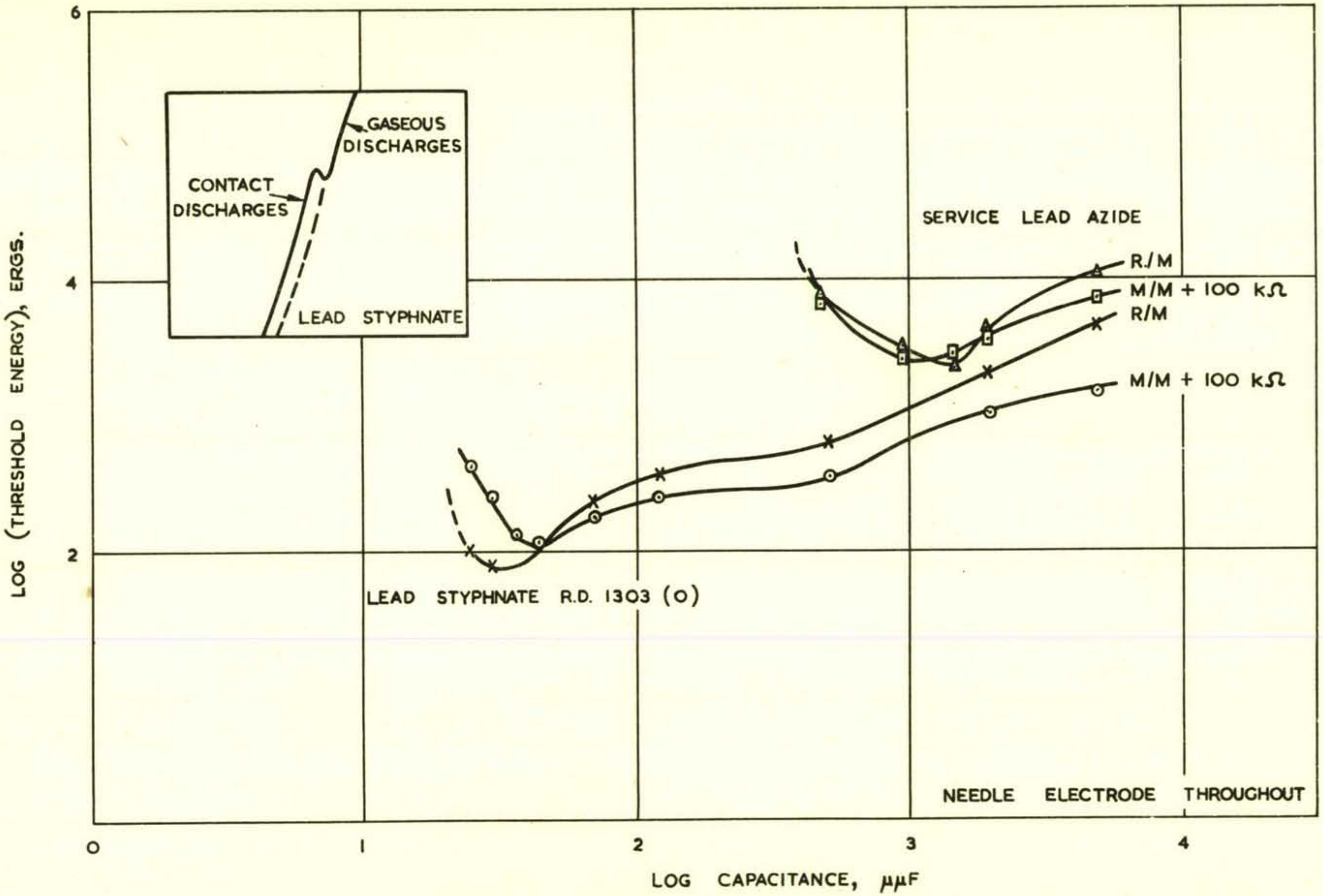
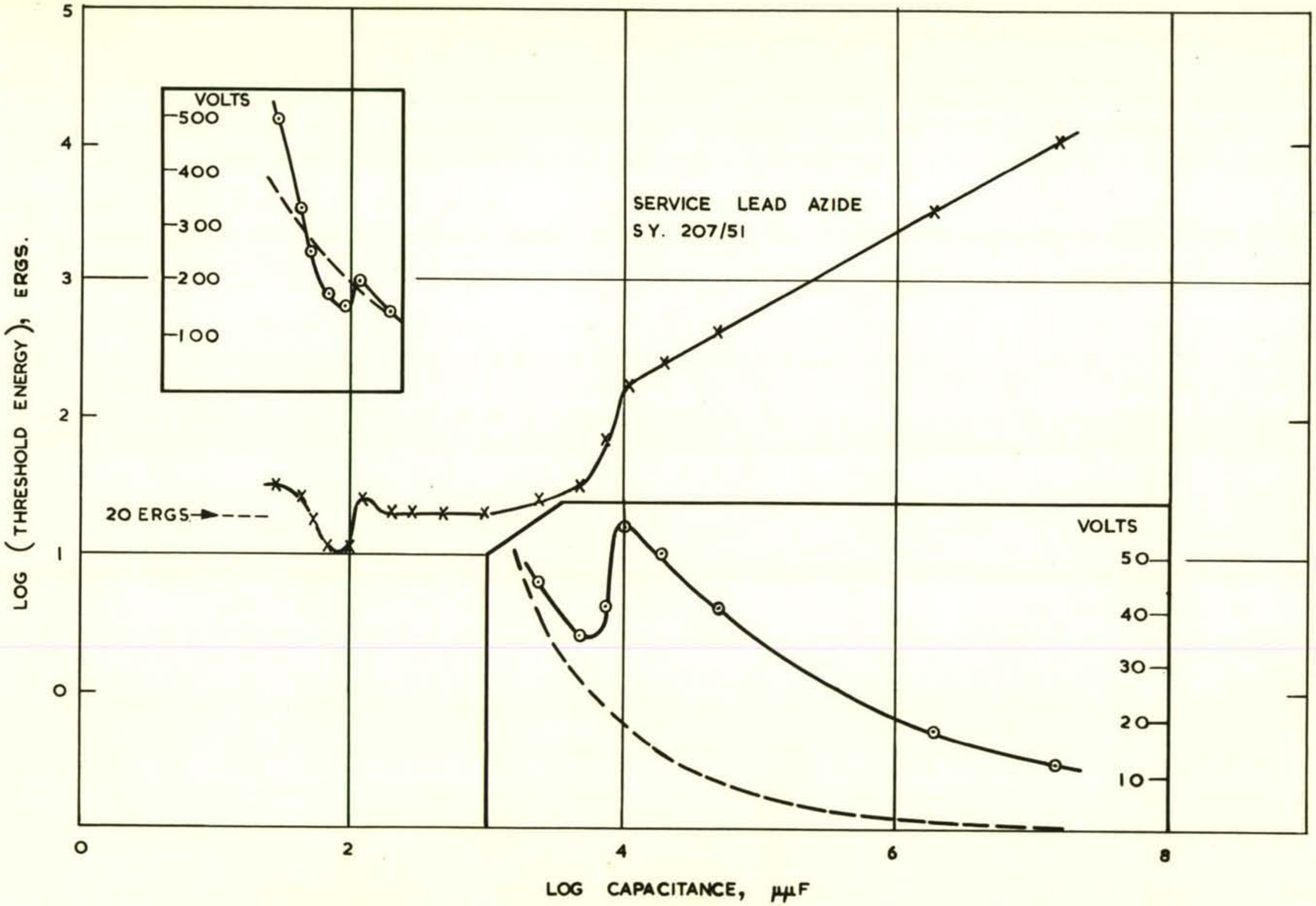


FIG. 6. (b)

OSCILLOGRAMS OF SPARK – SPLITTING OBTAINED FROM A CHARGED HUMAN BODY. FIG. 6.

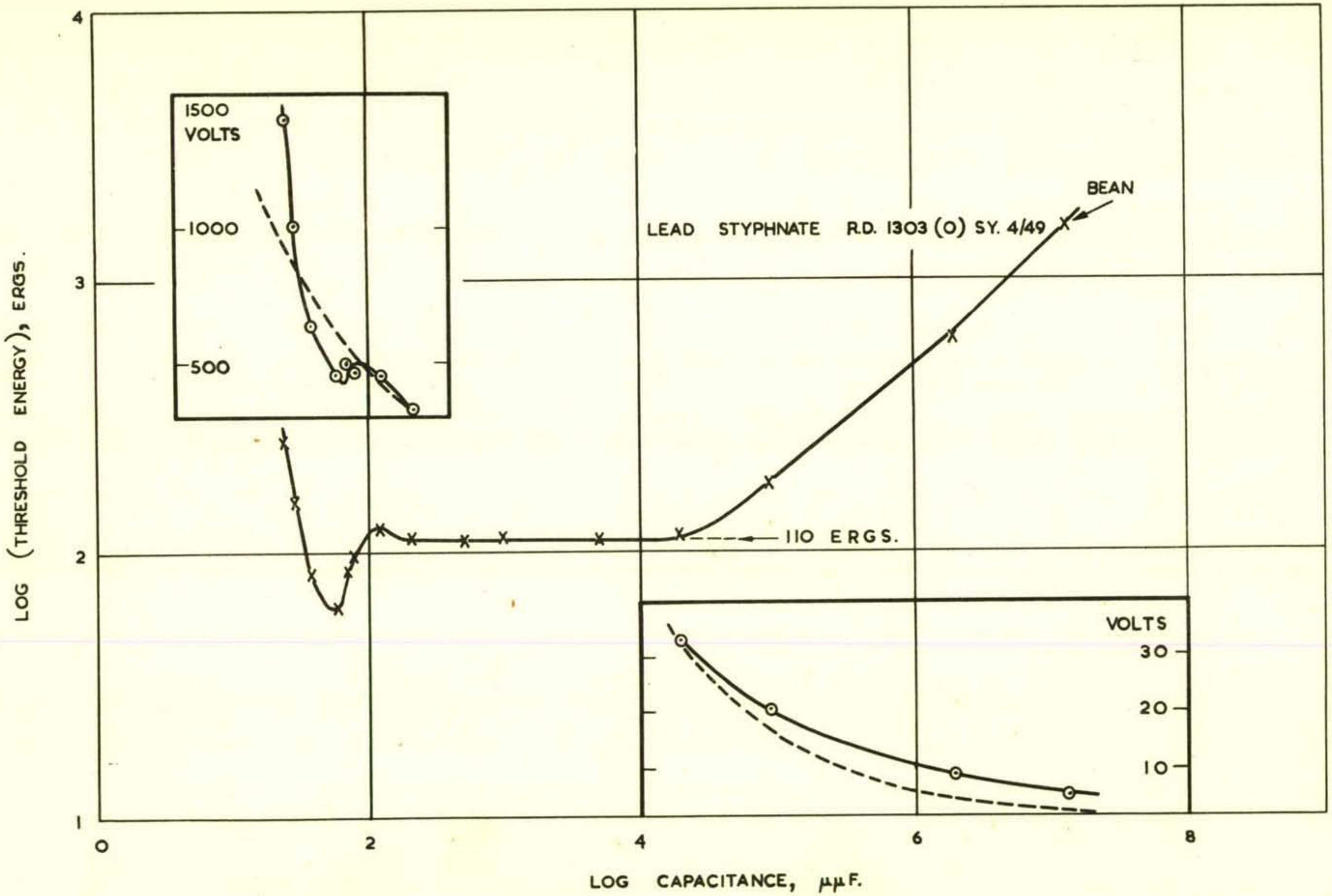


COMPARISON BETWEEN GASEOUS DISCHARGES USING A METAL BASE ELECTRODE (WITH CIRCUIT RESISTANCE OF 100, 000 OHMS), AND RUBBER ELECTRODE. FIG. 7.



VARIATION IN LOG (THRESHOLD ENERGY) WITH CAPACITY, SERVICE LEAD AZIDE, TWO METAL ELECTRODES.

FIG. 8.



VARIATION IN LOG (THRESHOLD ENERGY) WITH CAPACITY NORMAL LEAD STYPHNATE. TWO METAL ELECTRODES. FIG. 9

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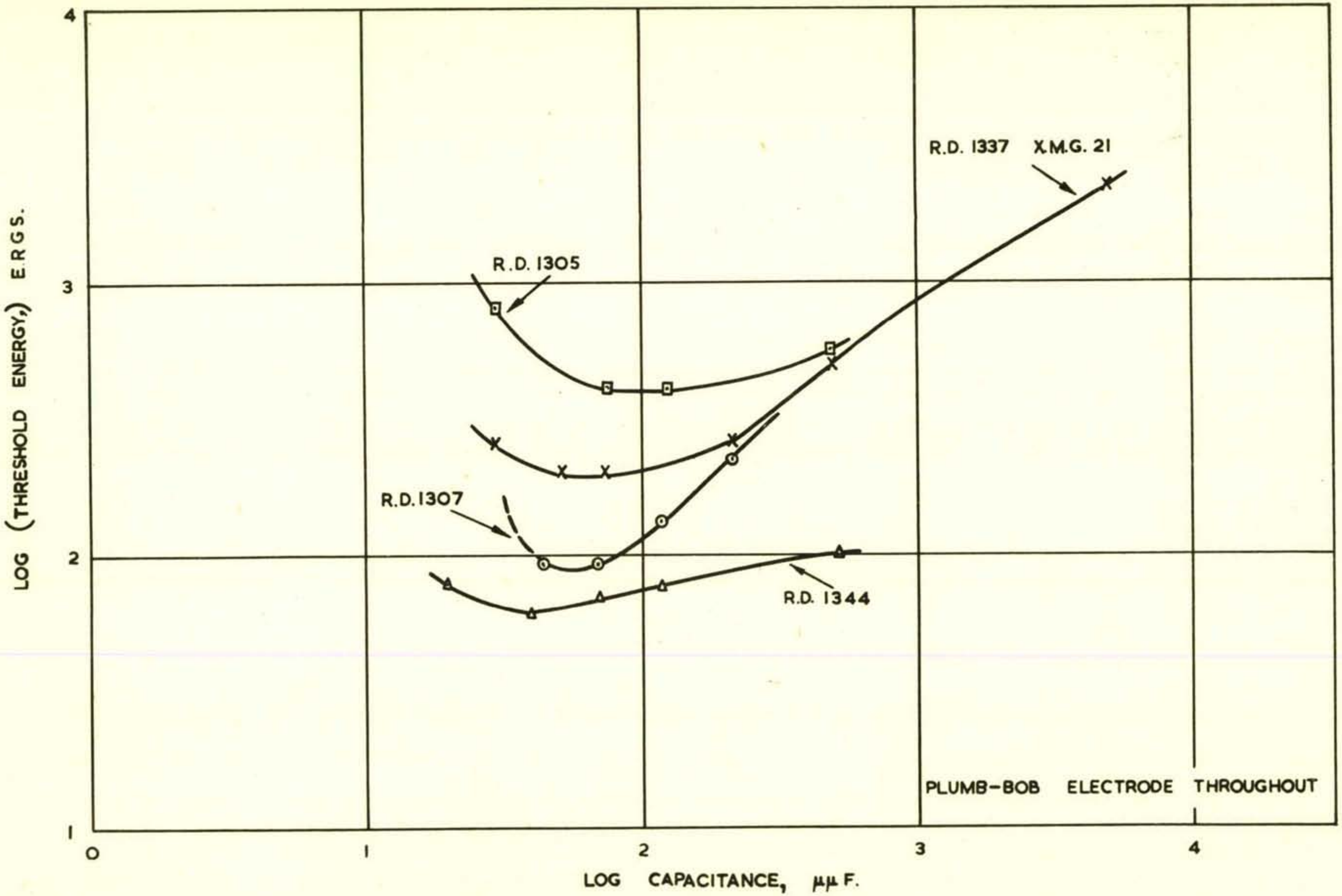

VARIATION IN LOG (THRESHOLD ENERGY) WITH CAPACITY, LEAD 2, 4.- D. N. R.s, TWO METAL ELECTRODES. FIG.10.

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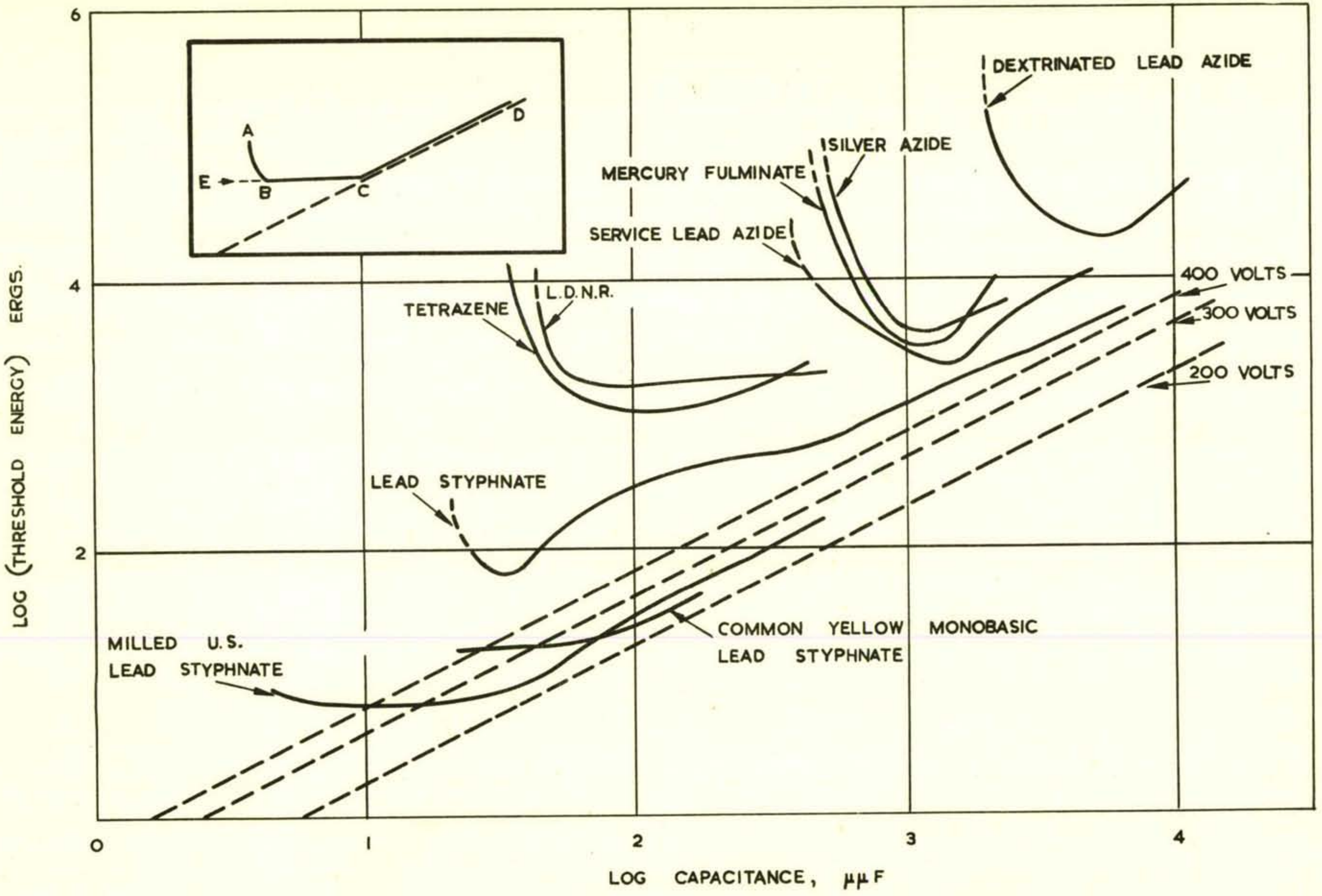

INTERPRETATION OF RESULTS OBTAINED WITH ANTISTATIC RUBBER BASE. ELECTRODES. FIG.11.

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E.R.D.E. Report No. 24/R/59	The Electrostatic Spark Sensitiveness of Initiators: Part 5: Further Study of Ignition with Metallic and Antistatic Rubber Electrodes

R.M.H. Wyatt October, 1959

The results quoted in Part 3 of this series, i.e. obtained by the use of antistatic-rubber electrodes, have been amplified and extended. Oscillograms are given of spark splitting, discharges from a metal needle to a rubber base electrode and discharges from a human being. The main function of the rubber, apart from elimination of short arc discharges, is to act as a resistance. The effect of capacitance on the threshold energy for metal/metal discharges has been investigated over a much wider range than before.

10 pp., 11 fig., 2 tables

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