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EFFECT OF ELECTRODE CONDITIONING ON IGNITION SENSITIVITY VARIABILITY FOR THE STANDARD V.D.E. INTRINSIC SAFETY TEST APPARATUS

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ABSTRACT

The variability and non-repeatability characteristics of the German standard intrinsic safety test apparatus (V.D.E.), have been noted by operators here and abroad. This investigation covers the changes in ignition sensitivity which are directly related to the mechanical variations of the sparking mechanism.

The physical aspects of the sparking mechanism that were investigated include the tip erosion of the wire electrode due to wear and burning, effect of free lengths of the wire electrodes, changes in the distances between the electrode holders, and changes in the cadmium disc electrode due to ordinary wear with and without excess cadmium particles.

The close examinations of the tips of the wire electrodes, before and after testing, showed that part of the ignition variability of the apparatus is due to the gradual and not so gradual erosions of the wire tips after explosions occur. The other factors which enhance these changes are the wire electrode lengths, variation in distances between the electrode holders, and the condition of the surface of the cadmium disc electrode, with and without cadmium dust particles.

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INTRODUCTION

Both here and abroad, the operators of the German standard intrinsic safety test apparatus (V.D.E.) have expressed concern (ref. 1, 2 and 3) on the difficulties they have experienced to attain and hold this apparatus in calibration. And more discouraging yet, one operator (ref. 2) stated that "from the variability of the sensitivity of the apparatus it clearly follows that a piece of electrical equipment may be tested one day and cause no ignitions, but ignitions may result when tested another day".

The ignition variability, as displayed in this apparatus, may be caused indirectly by such external parameters as atmospheric pressure, variation in the explosive gas to air ratios, humidity, temperature, etc. which have been investigated in an earlier report (ref. 4), and directly by the mechanical variations of the sparking mechanism that this apparatus employs. This latter aspect is investigated in this report.

The areas covered here include the physical examinations (via a microscope) of new and used wire electrodes, and various experimental tests that check the ignition sensitivity as the electrodes change with usage.

METHOD

(A) Variation of the Ignition Sensitivity

In order to determine the degree of ignition stability of the German standard intrinsic safety test apparatus (VDE 0170/0171, 1963), a three hour test program was carried out. Each individual test was conducted as required for calibration of the apparatus. That is, the standard series electrical circuit was used which consists of a 95 mH air-core inductor supplied from two 12 volt d.c. batteries through a variable non-inductive resistor for current limitations. For each test, which lasted a maximum of 5 minutes, the explosion chamber was evacuated and allowed to fill up with a 22% hydrogen-air mixture, previously prepared in a "binary mixer" reservoir, a method which has a reported accuracy of 0.01% (C.E.A.L. Report No. 172).

The apparatus was fitted with four new tungsten wire electrodes (prepared by electrical fusion) and a cadmium disc electrode which was in a fairly new condition. The tests were started with a circuit current which is high enough to ignite the gas mixture with a reasonable probability. The current was then reduced progressively in successive tests by 10% until a "miss" was obtained. The previous ignition current was then recorded as the lowest ignition current (l.i.c.) value for that test period. The following test period was started with the previous l.i.c. value, and the tests repeated until a "miss" was obtained instead of a "hit" or vice versa and new l.i.c. values are thus established. The results of the three hour test program are recorded in Table 1, and is graphically represented by the curve shown in figure 1.

(B) Examination of Electrodes

At the completion of the three hour test program, measurements were made of the free lengths of the tungsten wire electrodes, the distance between the electrode holders, microscopic examinations of the tips of the wire electrodes and condition of the surface of the cadmium disc electrode. All of these parameters which are directly concerned with the efficiency of the sparking mechanism, were seen to change considerably from those conditions at the start of the test program. Thus the remainder of this report is a study of the effect of these changes (by each of the above mentioned parameters) on the ignition sensitivity of the apparatus.

1) Wire Electrodes

The free lengths of all four tungston wire electrodes were measured after the three hour test program and were found to be shorter by 1 to $1\frac{1}{2}$ mm from the original length. The wire tips were examined under a microscope. Four typical tips that had undergone more than 10 explosions were microphotographed (X64), see Figure 4.

New wire electrodes were then prepared, using the technique described in I.E.C. specifications. This fusion process resulted in the formation of balls (of various sizes) on the ends of the wire, see Figure 2. After the de-balling process, where these balls are pulled off with pliers, the wire ends appear as shown in Figure 3.

It was nearly impossible to check on the general erosion of wire tips when, at the start, the tips were of various shapes (flat, chisel pointed, or splintered). Consequently, these wire ends were electrically fused a second time under an oil bath to produce tips such as shown in Figure 5.

Then, with one wire electrode in the holder at a time, the wire tips were examined after the following conditions prevailed:

a) thirty minutes run (no explosions) Figure 6a;
b) one explosion, Figure 6b;
c) three explosions, photo 6c;
d) four explosions, photo 6d;
e) five explosions, photo 6e.

2) Cadmium Disc Electrodes (Old versus New)

An "old" cadmium disc electrode (one with deep grooves) and four new tungsten wire electrodes were carefully clamped into their proper positions on the apparatus. Under these conditions two l.i.c. values were determined as described in the earlier sections of this report. Then the test was repeated with a new cadmium disc replacing the old one. The whole procedure was repeated a second time starting again with the old cadmium disc in position. The results were tabulated in Table 2 and are graphically represented in Figure 7.

3) Cadmium Disc Electrodes (With and Without Cadmium Dust Present)

A fairly well-used cadmium disc electrode (at least 2 hours or more of wear) and four new tungsten wire electrodes were fitted to the apparatus for those tests which required the presence of cadmium dust. For the tests which required the presence of only minimum amounts of cadmium dust, the surface of the cadmium disc electrode was filed down and thoroughly cleaned before each test was conducted. A total of 24 l.i.c. values were determined and were recorded in Table 3 and represented graphically in Figure 8.

(C) Adjustment Distances Between Electrode Holders

Employing only one tungsten wire electrode (tip fused closed) in the wire holder of the apparatus and the cadmium disc surface was made fairly smooth to reduce the production of cadmium dust, several l.i.c. values were determined as the distance between the electrode holders were varied from its normal specified position. The results are recorded in Table 4 for each incremental distance change and a curve drawn of the l.i.c. values vs distances, see Figure 9.

(D) Adjustments to the Lengths of the Wire Electrodes

A similar series of tests as above were conducted to determine the l.i.c. values as the free length of the tungsten wire electrode (tip fused closed again) was varied while all other factors were held as constant as possible. The results are recorded in Table 5 and represented graphically in Figure 10.

RESULTS

TABLE 1

Stability of Ignition Sensitivity

Elapsed Time Min.	l.i.c. mA
15.0	60
23.5	45
32.5	45
38.5	45
44.5	40
46	30
56.5	35
64	30
74	50
85.5	35
116.5	45
125.5	40
133	40
140	37.5
147.5	30
152.5	35
167	30
185	50

TABLE 2

Effect of Changes to the Cadmium Disc Surface

Elapsed Time	l.i.c. (mA)	
mA	Old Disc	New Disc
2	32	-
5	32	-
15	-	60
20	-	60
30	32	-
35	-	60
40	-	60

TABLE 3

Effect of Cadmium Particles

(a) Particles Present		(b) No Particles Present	
Elapsed Time Min.	l.i.c. mA	Elapsed Time Min.	l.i.c. mA
1	34	5	50
4	34	6	50
7	34	12	50
12.5	36	15	50
16.5	36	19.5	52
17	34	23.5	52
21	36		
22	34		
25	34		
28.5	34		
30.5	32		
37	32		
39	32		
44.5	34		
47.5	34		
47.5	32		
50.5	32		
53	32		

TABLE 4

Effect of Variations of the Distances Between Electrode Holders

Distance mm.	l.i.c. mA
8.5	30
9.0	40
9.5	35
10.0	42
11.0	45

TABLE 5

Effect of Variations to the Free Wire Electrode Lengths

Electrode Lengths mm.	l.i.c. mA
10.0	45
10.5	42
11.0	40
11.5	35
12.5	32.5

OBSERVATIONS

(A) Ignition Stability

The l.i.c. values obtained for the standard V.D.E. Intrinsic Safety Test Apparatus (see Figure 1) over a three hour test period demonstrated the ignition variability. The apparatus was found to be in a "calibrated" condition (as defined by I.E.C. specifications) at elapsed times of 45, 63, 145 and 167 minutes. At the 14 other test points, spanning the above four periods the apparatus was found to be out of calibration by 20 to 100%.

(B) Examinations and Tests on the Electrodes

1) Wire Electrodes

The microscopic examinations of each of the four wire electrodes at the end of the three hour test program, see Figure 4, showed ends that were splintered, shattered, and chisel pointed. This may be the cause for differences noted in the overall free lengths of the wires.

The photomicrographs, Figures 2 and 3 show various sizes of balls formed at the wire ends due to electrical fusion, and the final results after de-balling. In their final form, the wire ends are not too uniform.

Special wire ends that appear to be less likely to splinter have been manufactured by a second electrical fusing process conducted under an oil bath, see Figure 5. These ends have no sharp edges but are still not too uniform in appearance.

These special wire electrodes were tested singly in the apparatus. A thirty minute run with continuous sparking at the electrodes, and not surrounded by any explosive atmospheres, produced very little wear at the wire end, see Figure 6a.

The progress of tip erosion by one, three and four explosions are depicted by Figures 6b, 6c and 6d. After five explosions, Figure 6e shows the wire end to have splintered. With other factors being equal, a snub-nosed wire electrode caused ignitions at 36 mA, chisel pointed ones, about 32 mA, and those with ends that splintered, 30 mA and lower (down to 26 mA in one case).

2) Cadmium Disc (Old Versus New)

By interchanging the old and the new cadmium discs several times during the 40 minute test run, the other parameters appear to be cancelled out. With the old cadmium disc in position, the apparatus displayed about twice the ignition sensitivity compared to that of new cadmium disc (32 to 60 mA), see Figure 7.

3) Cadmium Disc - Dust Particles of Cadmium

The excursions of the l.i.c. values were found to be 36 to 32 mA, (see Figure 8) when the tests were conducted under strictly controlled conditions except for the cadmium dust. After the dust factor was reduced to a large extent by brushing both electrodes clean between test periods the l.i.c. excursions were still further reduced to only a few milliamperes 50 to 52 mA, but the median value is almost twice that obtained with the cadmium dust present.

(C) Variation of the Distances Between Electrode Holders

Under standard test conditions for this apparatus - but with only one wire electrode (end closed by fusion) in position - the l.i.c. value was found to be 40 mA. The l.i.c. value increased to 45 mA when the distance between the wire electrode holder and the cadmium disc was increased by 1 mm, and decreased to 30 mA for a 1½ mm decrease, see Figure 9.

(D) Variation of the Lengths of the Tungsten Wire Electrode

This test program was started under standard test conditions (same as outlined in C), and the l.i.c. value was again found to be 40 mA. The l.i.c. value increased to 45 mA when the free length of the wire electrode was decreased by 1 mm and decreased to 32 mA for a 1½ mm increase, see Figure 10.

CONCLUSION

The ignition stability performance of this V.D.E. Test Apparatus is depicted by the up and down excursions of the l.i.c. (lowest ignition current) values shown in Figure 1. This investigation on the two components of the sparking mechanism has pin-pointed various features each of which could be a contributor to this phenomenon. A brief recapitulation of the results is in order:

(a) Tungsten wire electrodes -

1. when formed by the electrical fusion method, the ends are non-uniform and tend to splinter and erode in several different ways.
2. the ones with snub-nosed ends are not as sensitive as those with sharp chisel-like edges to cause ignitions (about 15% difference), and those with splintered sections are even more sensitive (by another 15% difference).
3. when in position on the holder, changes in the free length of $\frac{1}{2}$ to $1\frac{1}{2}$ mm have caused ignition sensitivity variations of 10 to 20%. Similar variations were obtained when the distances between the holders were changed by the same amounts.

(b) Cadmium disc electrode -

1. a change in the condition of the surface (old to new), can change the ignition sensitivity by 50%.
2. a change in the amount of cadmium dust near the sparking areas, can change the ignition sensitivity by 40%.

Thus, the ignition stability may be improved (see Figure 8) if the above variables can be sufficiently reduced (probably with some difficulty) to the limit suggested below:

1. the measurement tolerances for the electrodes should be specified - perhaps $\pm \frac{1}{2}$ mm would be suitable.
2. the sparking tips of the tungsten wire electrodes should be fused closed by the second electrical fusion method. The fused material should be at least $\frac{1}{2}$ mm thick.

3. the wire electrodes should be replaced before $\frac{1}{2}$ mm of the ends are eroded away.

4. the surface of the cadmium disc electrode should be renewed after every test, and any loose cadmium dust brushed off.

REFERENCES

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2. Cooper, "Experience with the Cadmium Breakflash Testing Equipment."
3. Morgan, "Electrodes, Wiring and Barriers."
4. Silver, "Variations of Ignition Sensitivity for V.D.E. Standard Intrinsic Safety Apparatus and Other Factors Affecting its Calibration," Report ERP/ERL 75/64.

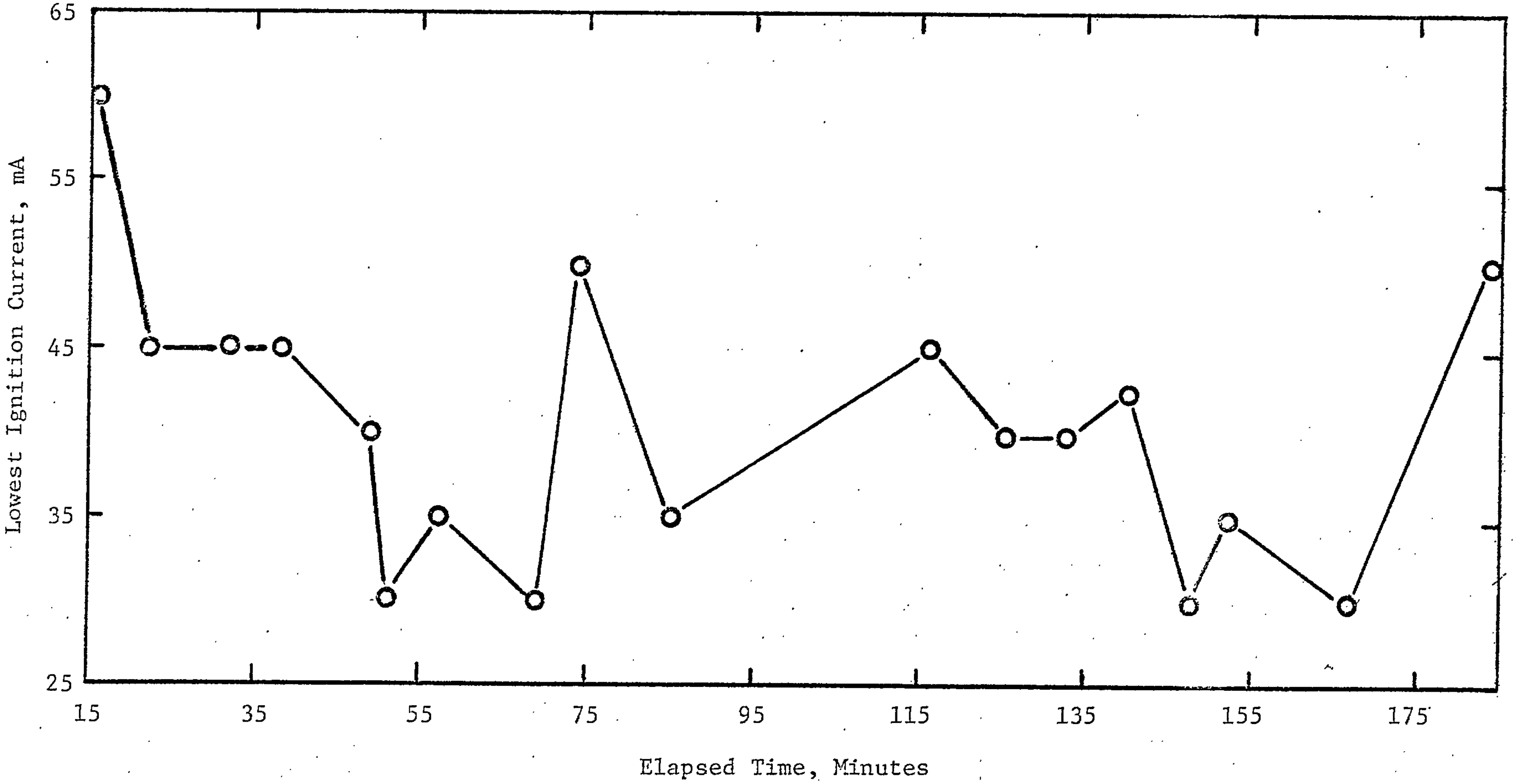

FIGURE 1: Ignition Sensitivity Stability of a V.D.E. Test Apparatus

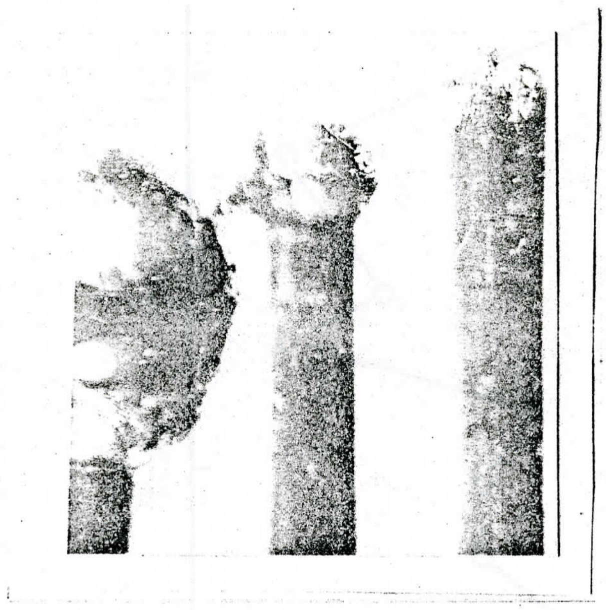

FIGURE 2: Formation of Balls on Ends of Wires by Electrical Fusion Process

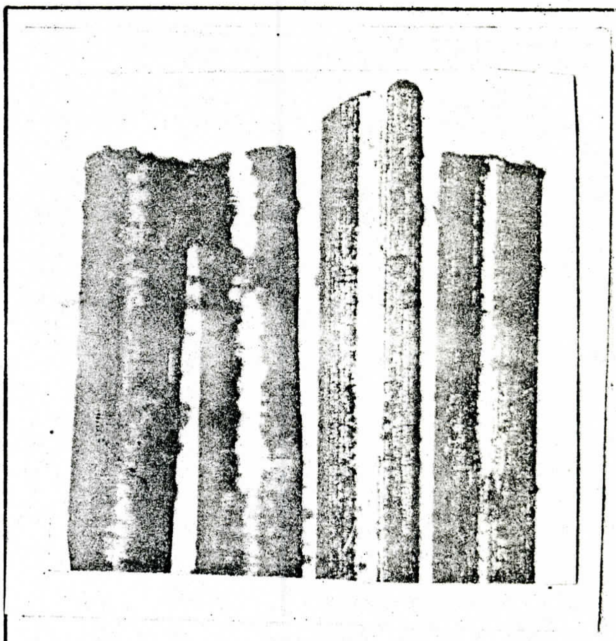

FIGURE 3: Final Appearances of Wire Ends After "De-balling"

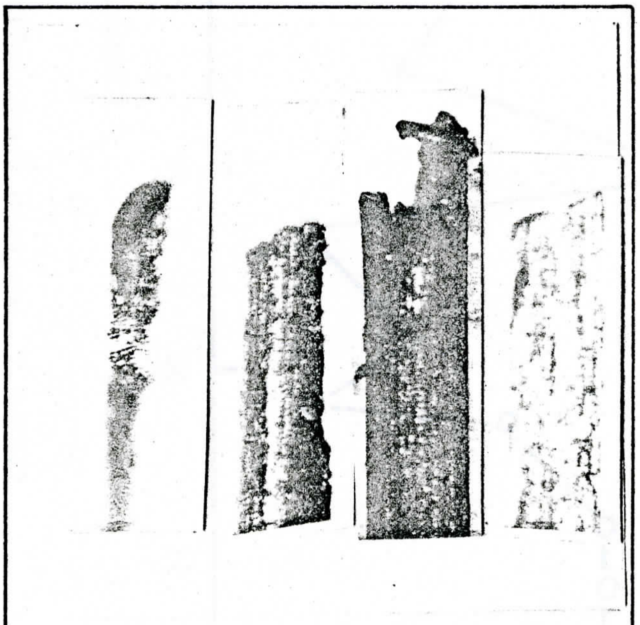

FIGURE 4: Results to "De-balled" Ends (Figure 3) After 10 or More Explosions

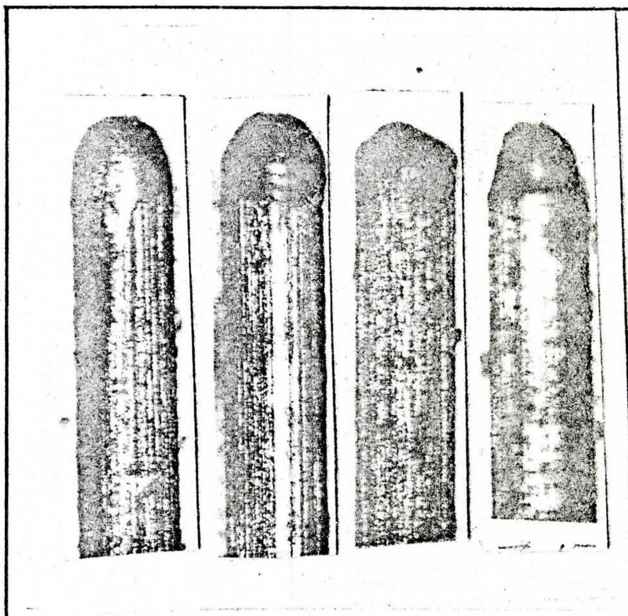

FIGURE 5: "De-balled" Ends (Figure 3) After Second Electrical Fusion Process

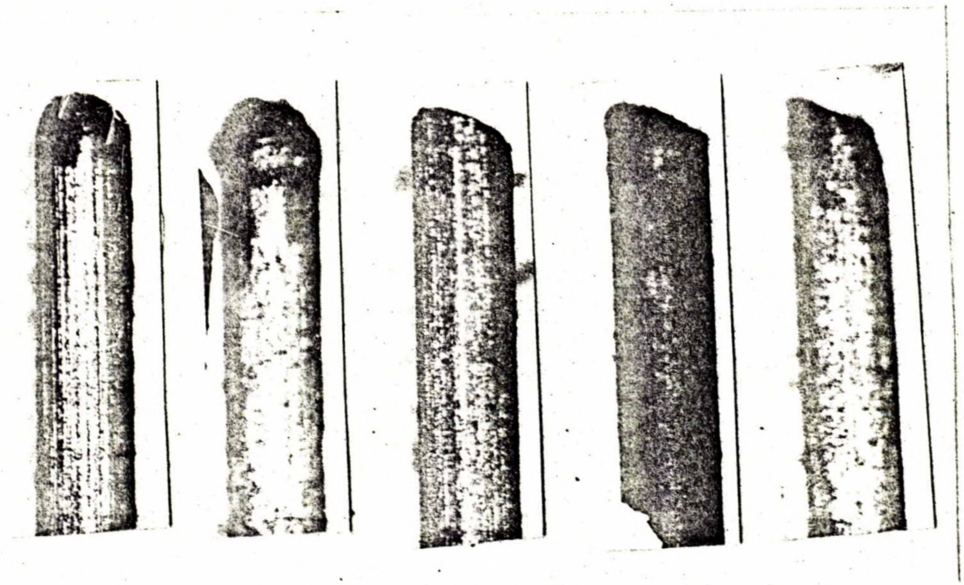

FIGURE 6: Final Appearances of Doubly Fused Wire Ends (Figure 5) After Wear and Erosion Processes

a) Thirty minutes of wear (sparking but no explosions)

b) After one explosion

c) After three explosions

d) After four explosions

e) After five explosions

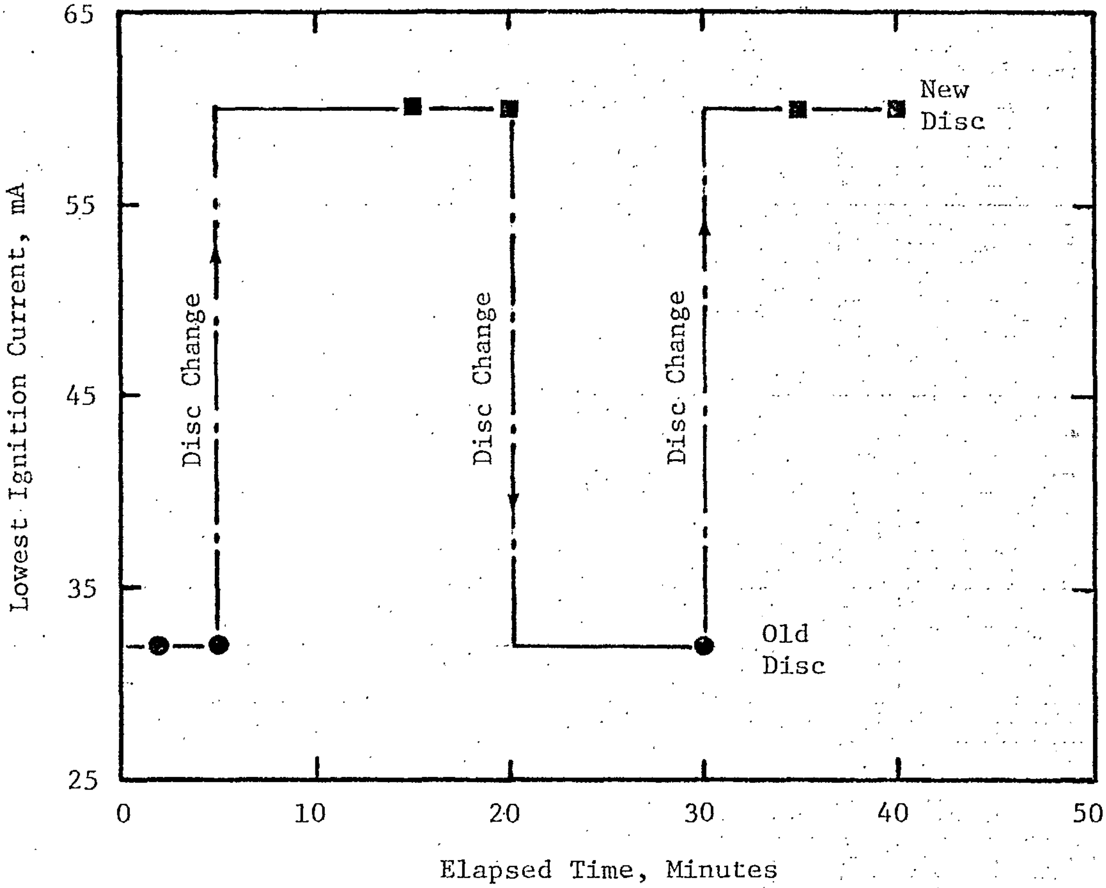

FIGURE 7: Change of Ignition Sensitivity with Condition of Disc Electrode

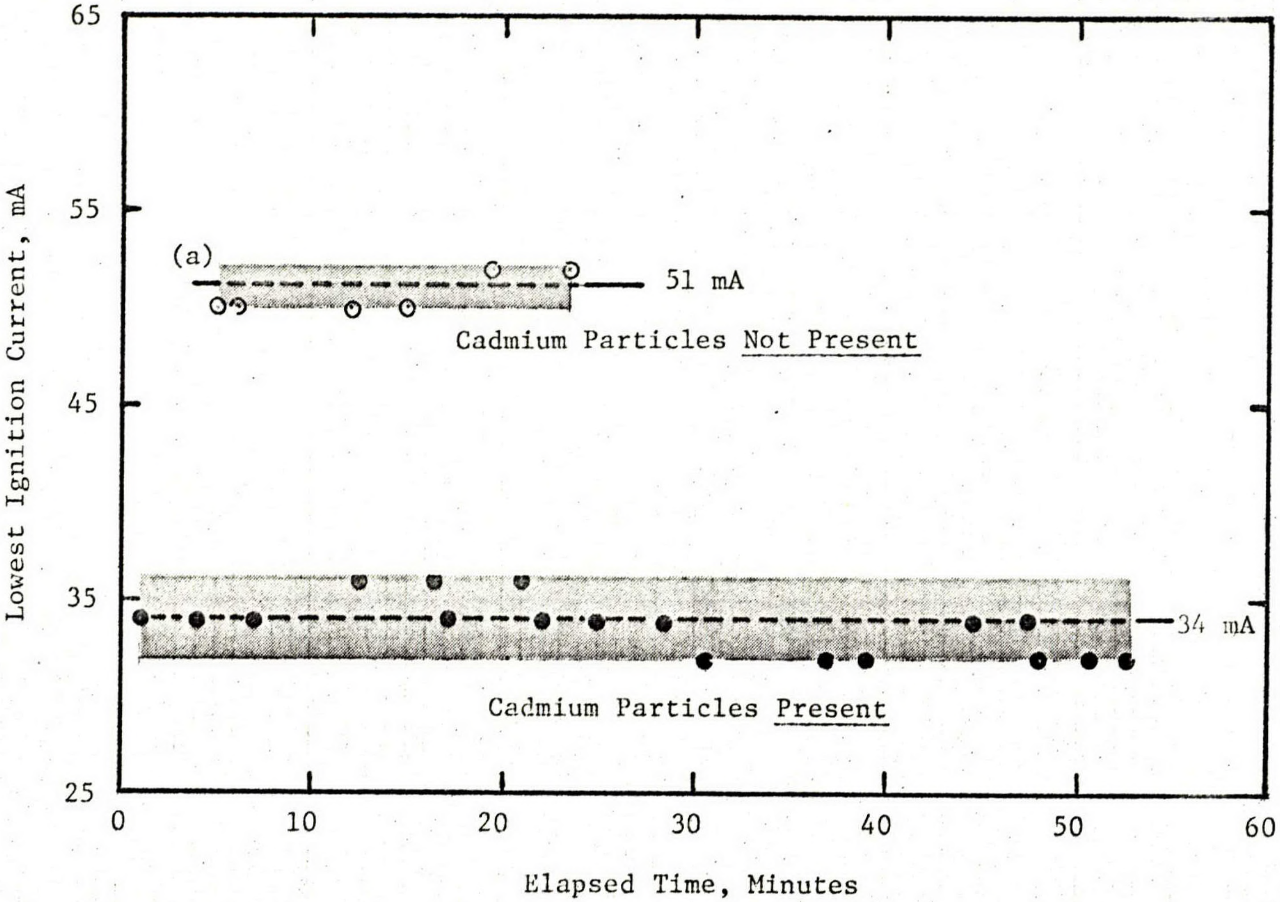

FIGURE 8: Effect of the Presence and Absence of Cadmium Particles

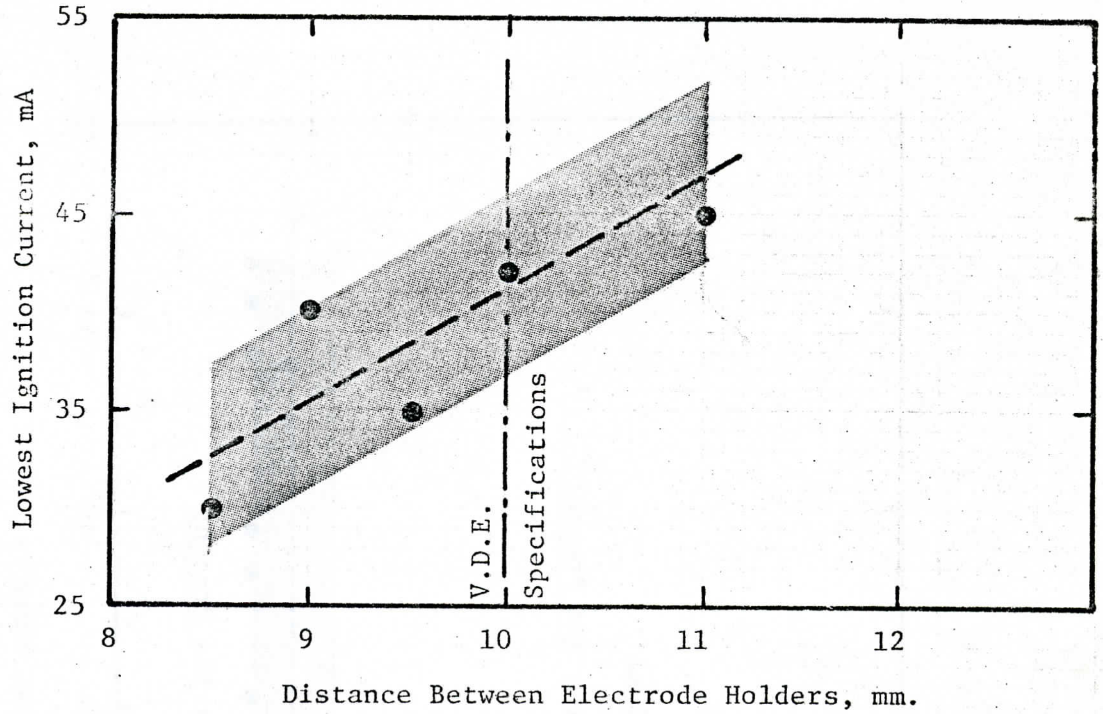

FIGURE 9: Effect of Distances Between Electrode Holders

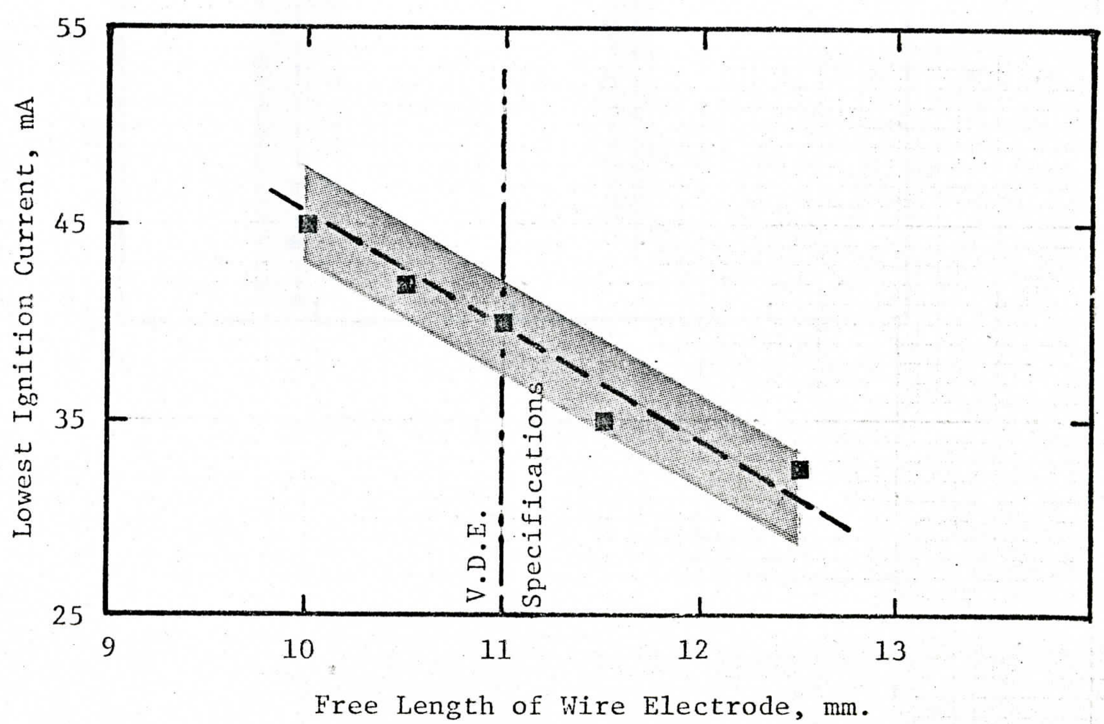

FIGURE 10: Effect of Different Lengths of Wire Electrode