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THE INITIATION OF ELECTRIC FUZE PRIMERS BY ELECTROSTATIC DISCHARGE

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THE INITIATION OF ELECTRIC FUZE PRIMERS BY ELECTROSTATIC DISCHARGE

Introduction

1. During the past two years three accidents involving the use of Mk 112, Mk 113 or Mk 114 electric fuze primers have been brought to the attention of the authors. In two of these instances, the accidental firing could possibly be explained by mechanisms other than electrostatic discharge but the third seemed to indicate that discharge of body static was the most probable cause.

2. Since these primers are used in a relatively large number of naval ordnance devices, it was deemed essential to (a) prove whether or not they could be initiated by a static discharge such as that which can be built up on a human body, (b) show what conditions must prevail to do this if proved possible and (c) recommend the measures to be taken to make handling operations safe.

3. According to the U. S. Bureau of Mines[1], the human body is capable of discharging approximately 150,000 ergs at 10,000 volts. This corresponds to a body capacitance of roughly 300 micro microfarads. In a few cursory tests it was found here at the Naval Ordnance Laboratory that an insulated man getting off of a grounded chair generated potentials in excess of 7000 volts. If a potential of 8000 volts is used in conjunction with the calculated body capacitance it will be found that for the tests to be discussed it can be assumed that the charged man was capable of discharging at least 96,000 ergs.

Susceptibility of Mk 112, 113, and 114 electric primers to firing by electrostatic charges

4. A number of people have felt that it is impossible to initiate the Mk 112, 113 or 114 primer by discharging the body directly through the bridgewire. This is so because the body resistance is high enough to (a) limit the peak current to a safe value and (b) dissipate the major portion of the energy which is divided during discharge between the body and the bridge according to the ratio of their resistances. For a standard primer the bridge resistance is never more than 7 ohms. For the human body the lowest measurement made in our test on a number of individuals was 500 ohms. This then indicates that under excellent conditions

1. U.S. Bu. of Mines Report of Investigations 3852.

ABSTRACT: (continued)

It is recommended that (a) proper grounding be used whenever electric fuze primers are handled, (b) the primer leads be shorted to the primer case until the primer is connected into the circuit in which it is to be used, and (c) all firing lines be shorted and grounded until after the primer is connected into the circuit.

NAVORD Report 1762 18 January 1951

This report describes the experimental work performed and results obtained by the Chemistry Division of the Engineering Department of the Naval Ordnance Laboratory in connection with the investigation of accidental firing of a Mk 112 type electric primer. The results indicated that some electric fuze type primers are extremely susceptible to initiation by static electric discharges accumulatable in handling procedures. For this reason, this report is intended to point out some of the more insidious dangers and recommend procedures to make handling procedures less dangerous. Acknowledgements to B. E. White and E. D. Metz for assistance in accumulating data.

W. G. SCHINDLER
Rear Admiral, USN
Commander

S. W. BOOTH
By direction

CONTENTS

ILLUSTRATIONS

THE INITIATION OF ELECTRIC FUZE PRIMERS BY ELECTROSTATIC DISCHARGE

Prepared by:

I. Kabik and J. N. Ayres

ABSTRACT: During the past two years there have been at least three accidents at the Naval Ordnance Laboratory attending the use of the Mk 112, Mk 113 and Mk 114 electric fuze primers (formerly called ND-24). Two of these accidents have occurred during the past two months. The circumstances under which these accidents occurred cast doubt upon the safety of these primers, particularly when handled under conditions where electrostatic charges may accumulate. In the past it has been believed by some that the discharge of body static through the primer bridge wire would not initiate Mk 112 type primers because the body resistance is so large compared to the bridge resistance that practically all the stored energy will be dissipated in the body resistance when electrostatic discharge occurs. This feeling has been largely substantiated by a few cursory tests. The authors have been led to suspect the existence of mechanisms whereby the body charge may be transferred to an inanimate object of sufficiently low impedance to fire the primer when the charge is discharged through the primer bridge. The workability of this mechanism has been demonstrated, the inanimate object being a 3.5 ft. piece of coaxial cable such as might be used in a firing line. It was also proved that breakdown between the primer case and leads can occur at potentials below those capable of being built up on the human body.

These results led to the testing of other fuze primers which are now contemplated for use in naval ordnance fuzes. The Mk 121 and Mk 122 electric fuze primers were shown to be exceedingly dangerous in that they can be set off directly from body static without the necessity of first transferring the charge to some object of low impedance. Not only may direct firing occur when the body is discharged through the bridge but also by breakdown of insulation between the primer case and the primer leads (even when the leads are shorted together).

Primer initiators of the Ex-7, Ex-8 and Ex-9 types which are under development at NOL could not be fired directly from the body, but could be fired by the same mechanism given above for the Mk 112 type primers.

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White Oak, Maryland

the bridgewire would not receive more than $150{,}000 \times \frac{7}{5000}$ or 210 ergs. Since this is lower than the smallest energy necessary to set off these primers by a factor of 10 it appears that the feeling referred to above is well founded. A number of tests were made to lend further proof to this belief. A suitable charge was developed by having a seated man slide around on a grounded chair and then stand up with his feet resting on an insulating sheet of plexiglass. This charge was then discharged through the primer bridge by having the man touch the point indicated in Figure 1, page 3. The primers could not be initiated in this fashion. To prove that current was passing through the bridgewire, several tests were made with the ground return lead shown in Figure 1 actually separated from the ground by a small air gap. On discharge a visible spark appeared in the air gap showing that current had passed through the bridgewire.

5. It is possible to fire a primer without passing current through the bridgewire by having a spark jump between the primer case and the primer leads through the explosive charge as shown in Figure 2, page 4. All Mk 112, 113 and 114 primers are tested for breakdown between leads and case at 1000 v. before acceptance. However, a series of tests were made using the static sensitivity tester described in NOLM 9959. At 5000 v. it was found possible to breakdown the insulation and to initiate the primer. In order to do this a condenser of 750 micro microfarads had to be used. This corresponds to an energy of 94,000 ergs. Whether or not the firing source has to be of low resistance in order to obtain initiation of this sort is open to question. Obviously the resistance between leads and case in a good primer is quite high (50 megohms or higher at 1000 v.), however the impedance value obtained when breakdown occurs is unknown and the impedance match between body and primer when sparking from leads to case has not been determined. Suffice it to say however, that although a number of tests were made by the authors, it was not found possible to fire these primers by a direct electrostatic discharge from the body when sparking from case to leads. Since the energy stored on the body can be higher than that required by the electrostatic sensitivity tester to initiate the primers in this fashion, it appears reasonable to assume that the impedance match for initiating is more favorable when the energy source is of low impedance.

6. In summarizing the foregoing, it appears highly improbable that a Mk 112, 113 and 114 electric primer can be fired by the discharge of an electrostatic charge directly from the human body through the primer bridgewire, and relatively improbable that

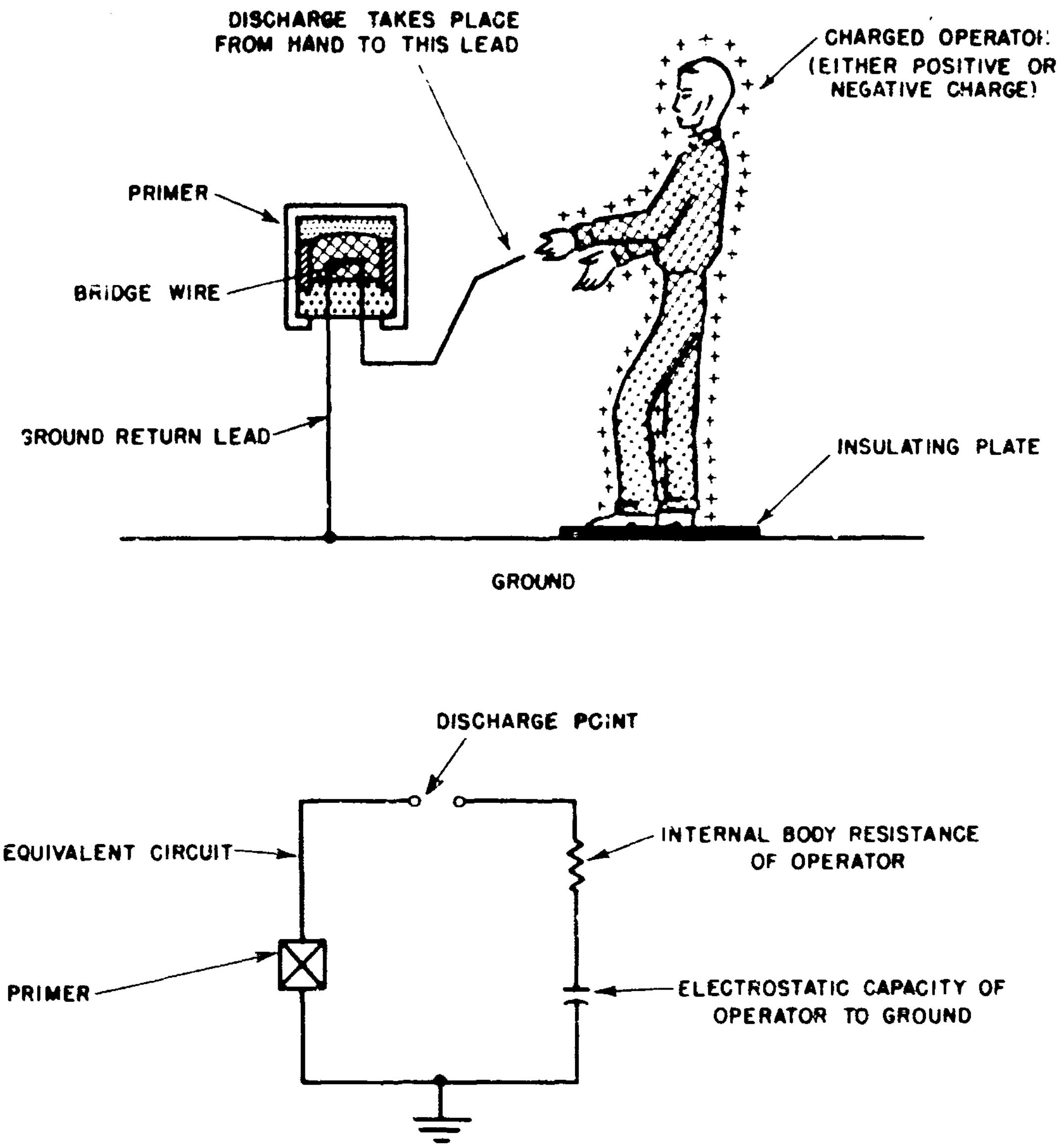
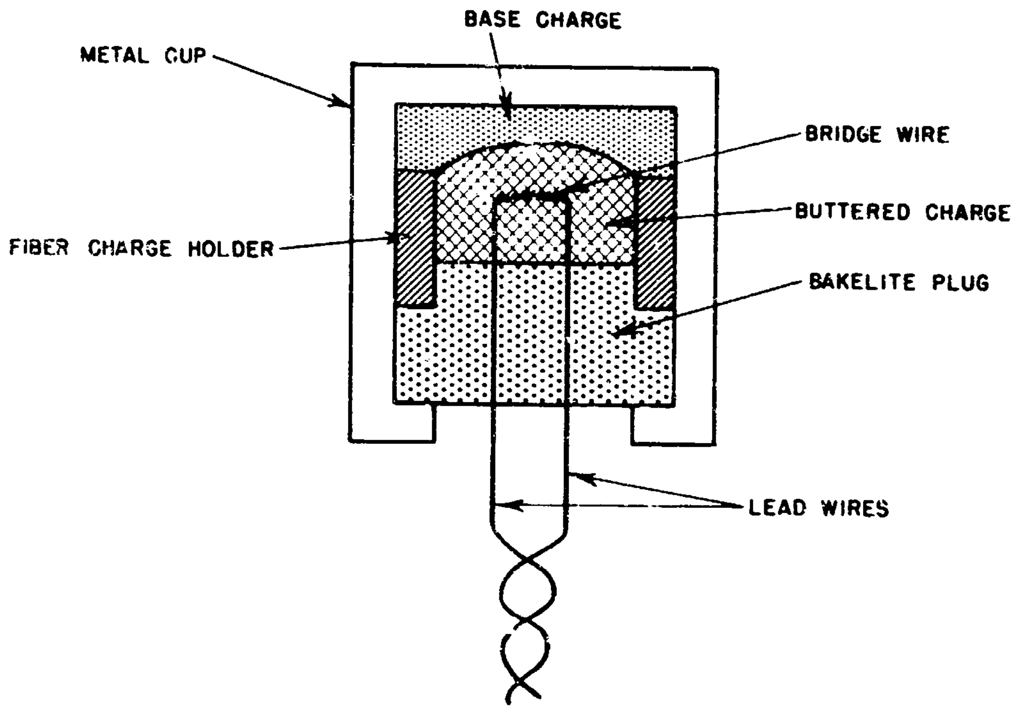
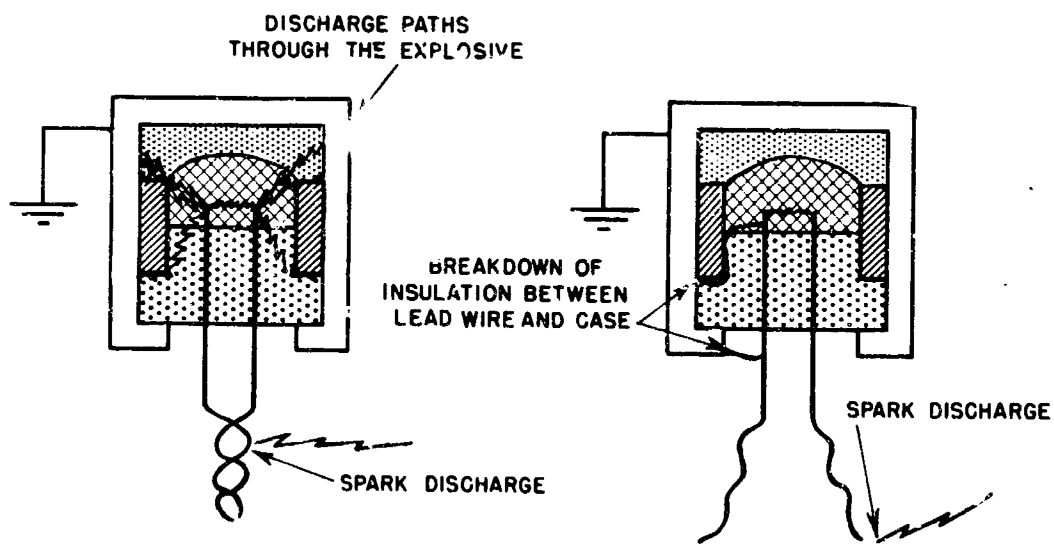


FIG. I SETUP FOR TESTING SENSITIVITY OF ELECTRIC PRIMERS TO STATIC DISCHARGE FROM OPERATOR THROUGH THE BRIDGE



MK 112 TYPE PRIMER



a. DIELECTRIC BREAKDOWN OF EXPLOSIVE

b. INSULATOR BREAKDOWN LEADING TO HEATING OF BRIDGE OR EXPLOSIVE

FIG. 2 SOME OF THE POSSIBLE MECHANISMS INVOLVING FIRING BY DISCHARGE THROUGH LEADS TO CASE firing will occur by such a discharge from the primer case to either lead or to both leads which have been shorted together. This conclusion is justified, even though more than enough energy is stored on the body, because it appears that the impedance match between the primer and the charged body is sufficiently poor to prevent the primer from obtaining the required energy.

7. The above results do not substantiate the circumstantial evidence indicating that at least one of the accidents experienced with Mk 113 type primers was caused by an electrostatic discharge. After further consideration it became obvious that a low impedance device could receive and store a charge from the body and this low resistance device could then be discharged through the primer (either through the bridge or from the case to the leads).

8. A series of experiments were then set up to test this principle. One lead of the primer was grounded (actually it is immaterial whether it is grounded or left floating), the other lead was connected to one end of a condenser. A man generated a static charge as before and then touched the free terminal of the condenser, thus charging it. The free condenser therminal was then touched to the opposite primer lead. The results obtained by this procedure are shown in Table I, page 6. During the course of testing to obtain the data shown in Table I, it was suspected that the 164 micro microfarad condenser which was rated at only 1000 volts broke down and that less than 360 micro microfarads were actually needed. Therefore several trials were made using a 180 micro microfarad condenser. With this condenser two out of two primers fired. When this condenser broke down after the second test, these tests were discontinued since it was felt that the suggested principle was sufficiently substantiated.

9. This series of experiments was repeated with the connections made to the primer case and the shorted primer leads, but no firings were obtained in five trials using a 560 micro microfarad condenser.

10. The above work indicated that a static charge could easily cause the accidental firing of a primer Mk 113, provided a suitable capacitance was available. In considering the accidental firing which prompted this work, one glaring possibility was the capacitance of the firing line which was being used. The capacitance of this line was measured and was found to be 1000 micro microfarads. However, it was not possible to set off any primers with this particular line acting as a condenser because its leakage resistance was low enough to prevent build up of a sufficient charge. However, it is not known whether or not this line had low leakage resistance prior to the accident, it being conceivable that breakdown may have occurred at that time.

11. In order to show however that firing lines can constitute a hazard, a piece of coaxial cable having high leakage resistance was used as a condenser. It was now found that four of seven primers fired when a piece of coaxial cable only 3.5 feet long was used. This cable had a capacitance of approximately 50 micro microfarads.

TABLE I

Primer No.	Capacitance in micro microfarads					
	33	82	*164	180	360	560
1	failed	-	-	fired	-	-
2	-	failed	-	failed	failed	fired
3	-	failed	failed	-	failed	fired
4	-	failed	failed	-	fired	
5	-	failed	failed	-	fired	
6	-	failed	failed	-	fired	
7	-	failed	failed	-	fired	
8	-	failed	failed	-	fired	
9	-	failed	failed	-	fired	
10	-	failed	failed	-	fired	

* It was suspected that this condenser had broken down. Two tests were made with a new 180 micro microfarad condenser. Initiation occurred in both tests.

12. This then constitutes a real hazard for all that is necessary to set off the primer is to have one end of an open cable connected to one end of the primer and then to have a sufficiently well charged person connect the other end of the cable to the other primer terminal. It should be made clear that no other circuitry is necessary; the other ends of the firing cable need not be attached to anything. They can be open. This condition is one that can occur most readily in ordinary experimental work and must be guarded against at all times. The methods whereby a primer can be fired by this mechanism are shown in Figure 3, page 8, and Figure 4, page 9.

13. It should be obvious that devices other than a cable can act as the condenser. The cable is pointed out here because it is part of test systems ordinarily used in experimental work with electric primers.

Susceptibility of other electric fuze primers to firing by electro static charges

14. Electrically fuzed naval ordnance devices employing electric primers are becoming more and more numerous. To meet the demands of these fuzes, electric primers of special characteristics have been designed and are now contemplated for use. These primers require very small energies to fire (approx. 100 ergs) and may for our purposes be divided into two groups: (a) those of high resistance and (b) those of low resistance. Typical of the low resistance group are the NOL experimental primers of the Ex-7, Ex-8, and Ex-9 type. Resistances of these primers fall within 2-7.5 ohms. The high resistance group primers are typified by the Mk 121 and Mk 122 electric fuze primers. These have resistances of 1000-10,000 ohms. It is desired to consider here the possible hazard from static charges to handlers of these primers.

15. The NOL primer contains a fine bridge wire and has a maximum resistance of 7.5 ohms. Based on the assumptions previously given, a charged individual of 5000 ohms resistance should be able to transfer 150,000 x 7.5/5000 = 225 ergs. This should be sufficient to initiate one of these primers directly from body discharge without the aid of any external condenser. A number of attempts were made to do this but they were without success. This was probably due to the inability to obtain the ideally low body resistance of 5000 ohms on discharge. However, the calculations above show that the energy under good conditions may fire this primer when discharged through the bridge and all precaution should be taken to guard against this possibility. When a 10 micro microfarad condenser was placed in the line as previously described these primers could be made to fire. Five tests were made using a 560 micro microfarad condenser charged from static

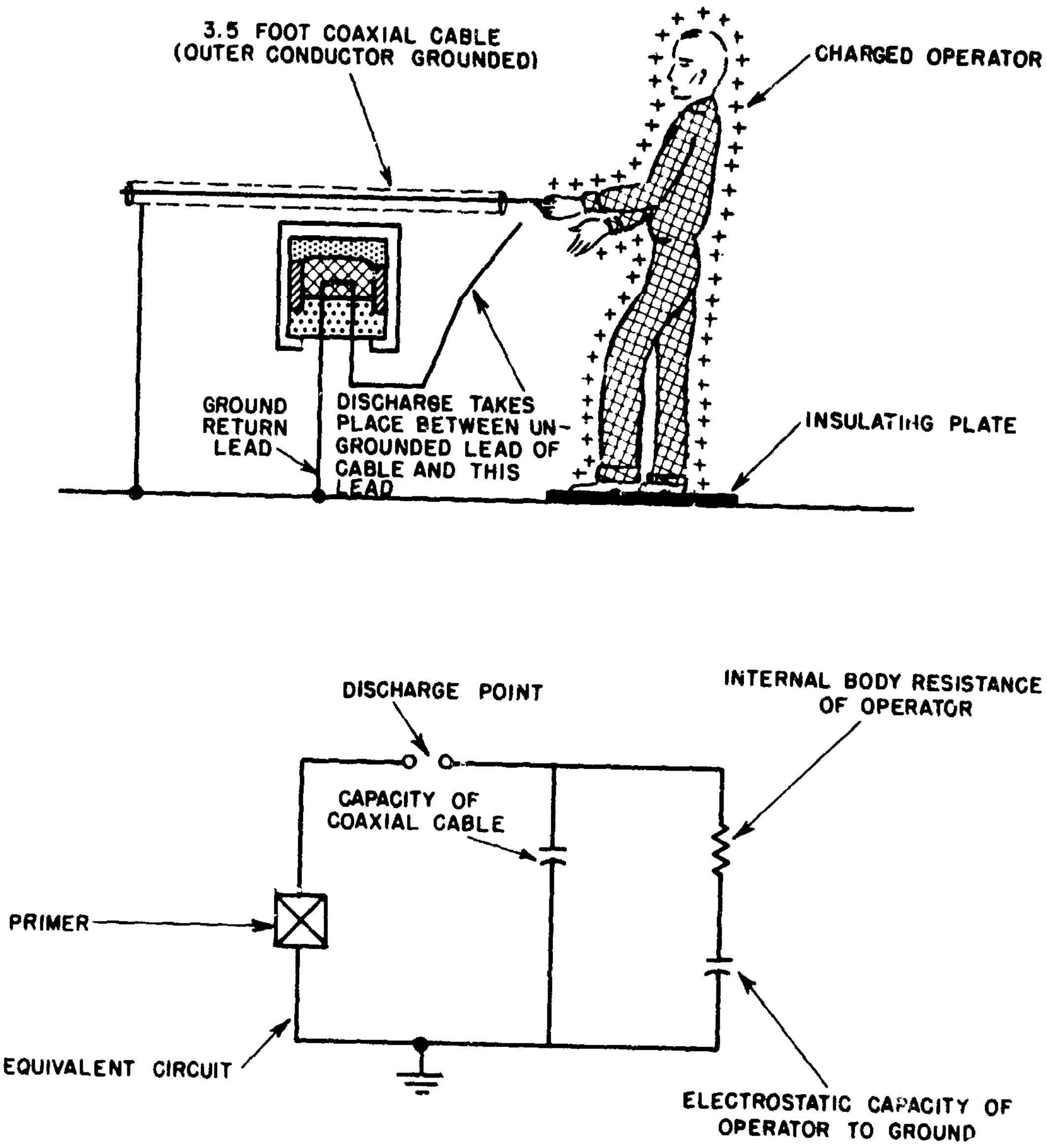


FIG. 3 SETUP FOR TESTING EFFECT OF AUXILIARY CAPACITY ON THE SENSITIVITY OF ELECTRIC PRIMERS TO STATIC DISCHARGE DIRECTLY THROUGH THE BRIDGE

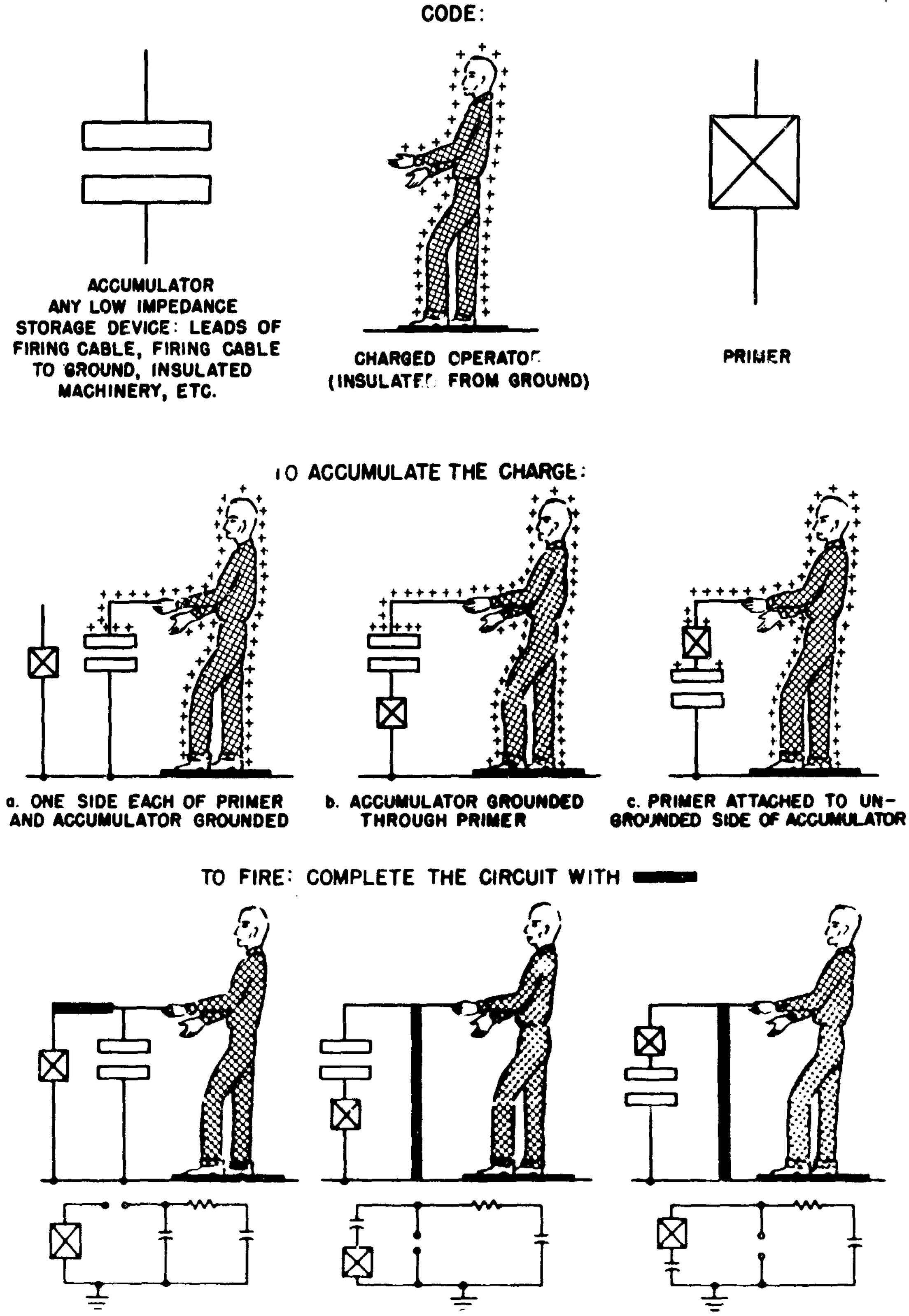


FIG. 4 SOME OF THE WAYS A MK 112 TYPE PRIMER CAN BE FIRED BY OPERATOR-ACCUMULATED ELECTROSTATIC ENERGIES

on the human body and discharged from the primer charge holder to the contact prongs but none could be made to fire. However, from numerous laboratory tests made on this primer during its development, it is known that sometimes the insulation can be broken down by potentials less than 1000 volts and thus this primer could constitute a hazard from high potentials between primer case and contact prongs.

16. The Mk 121 and Mk 122 electric fuze primers require only 100 ergs for firing and have graphite bridges with resistances of from 1000 to 10,000 ohms. Making our calculation on these primers, at the low resistance range 150,000 x 1000/6000 = 25,000 ergs can be transferred to the bridge and at the upper resistance level 150,000 x 10,000/15,000 = 100,000 ergs can be transferred to the bridge. Thus the probability of setting these primers off by electrostatic discharge from the human body is extremely great. Indeed in our tests it was found possible to fire both Mk 121 and Mk 122 primers by discharge directly from the body through the bridge in every trial. (Five of each were tried). In additional tests run on the Mk 122 primer, it was found possible to fire them by direct body discharge from case to shorted leads. It is probably possible to do this with Mk 121 primers also, although none were available for this test.

17. These graphite bridge primers constitute a great hazard and every possible precaution should be taken to guard against the build-up of static when they are handled.

Conclusions

18. Mk 112, 113 and 114 electric fuze primers cannot be fired by electrostatic discharges directly from the body, but do constitute a hazard when the body charge can be transferred to a low impedance storage device which may be subsequently discharged either through the primer bridge or from the primer case to the primer leads.

19. NOL primers of the Ex-7, Ex-8 and Ex-9 type although not initiated by electrostatic discharge directly from the body are believed to be marginal in this respect and should be treated as if they would function. This applies both to discharge taking place either through the bridge or from charge holder to contact prongs.

20. Mk 121 and Mk 122 type primers are exceedintly dangerous to handle. They can be readily fired by electrostatic discharge from the body directly through the bridge or between the leads and the case.

Recommendations

It is recommended:

a. That in handling electric fuze primers, proper grounding procedures for both personnel and equipment be followed.

b. That primer leads be shorted together and that they then be shorted to the case.

c. That firing circuit leads be shorted together and grounded until after the insertion of the primer into the electric circuit.

d. That any equipment or instruments that may act as condensers (charge accumulators) be shorted and grounded until after the primer is connected into the circuit and personnel cleared from the danger zone.