GE-MTSD-R-052

PYROTECHNIC HAZARDS CLASSIFICATION AND EVALUATION PROGRAM

ELECTROSTATIC VULNERABILITY OF THE E8 AND XM15/XM165 CLUSTERS

PHASE I FINAL REPORT

DECEMBER 31, 1970

PREPARED FOR
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MISSISSIPPI TEST FACILITY

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GENERAL ELECTRIC
Management and Technical Services Department

GE-MTSD-R-052

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This report has been reviewed and approved by:

CHARLES E. McGEE, PROJECT ENGINEER
E8 AND XM15/XM165 ELECTROSTATICS
VULNERABILITY PROJECT
MATERIEL TESTING AND RESEARCH
MTSD-GENERAL ELECTRIC COMPANY

PAUL V. KING, MANAGER
MATERIEL TESTING AND RESEARCH
TECHNICAL PROJECTS OPERATION
MTSD-GENERAL ELECTRIC COMPANY

Prepared by

GENERAL ELECTRIC

SPACE DIVISION
MANAGEMENT AND TECHNICAL SERVICES DEPARTMENT
BAY SAINT LOUIS, MISSISSIPPI 39520

FOREWORD

The studies described in this report comprise Phase I of Edgewood Arsenal's two-phase study of the electrostatic vulnerability of the E8 and XM15/XM165 clusters. The report was prepared by the General Electric Company, Management and Technical Services Department (GE-MTSD), Bay St. Louis, Mississippi, under National Aeronautics and Space Administration (NASA) Contract NAS8-23524 for the Smoke and Riot Control Branch, Production and Maintenance Engineering Laboratory (administered through the Engineering Test and Evaluation Section, Process Technology Branch, Chemical Process Laboratory), Weapons Development and Engineering Laboratory, Edgewood Arsenal, Edgewood, Maryland.

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- W. P. Junkin, Chief, Chemical Process Laboratory
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- P. V. King, Manager, Materiel Testing and Research
- Dr. T. M. Small, Acting Manager, Project Engineering
- E. H. Huck, Systems Design (Chemical) Engineer,

- J. C. Boatner, Electrical Engineer
- J. E. Templet, Supervisor, Electronic Calibration and Repair
- R. I. Cedar-Brown, Consulting Engineer, Systems Design
- C. E. McGee, Project Engineer, E8 and XM15/XM165 Project
- D. M. Koger, Manager, Pyrotechnic Hazards Classification and Evaluation (KEMOPS) Program

EXECUTIVE SUMMARY

Recent incidents with XM15/XM165 CS clusters indicate that electrostatic effects may have been responsible for premature functioning of the units. Additionally, an E8 manufacturing facility was destroyed by a fire which could have resulted from electrostatic buildup during one of the manufacturing processes. Both of these units disperse CS gas. As the results of the incidents and Edgewood Arsenal's Modernization Program, a systems approach was selected by Edgewood to determine the electrostatic vulnerability of the XM15/XM165 cluster and E8 launcher. Initially two phases of study were identified. The first two phases would be a study of the fuse train and their component parts. From the results of the first and second phases (identification and subsystem testing, respectively) a third phase, System Study and Test, will be planned to evaluate the complete systems.

This report covers the results of the first phase and includes:

- Describing electrostatic theory as it applies to system vulnerability.
- Evaluating XM15/XM165 and E8 material characteristics.
- Determining conditions which affect electrostatic initiation sensitivity.
- Constructing equivalent electrical circuits to facilitate analysis and interpretation of data.
- Developing Phase II test plan.

The second phase will consist of:

- Conducting electrostatic spark ignition and triboelectrification tests on subsystems and components of the E8 and XM15/XM165 clusters.
- Evaluating prior incidents of the E8 and XM15/XM165 clusters from an electrostatic viewpoint.
- Refining the equivalent electrical circuits generated in Phase I.
- Plotting equipotential curves of simulated E8 and XM15/XM165 configuration to provide a visual display of the electric field.
- Performing a systems test program to verify proper functioning of modified components.
- Recommending measures to eliminate or neutralize potential accidents.
- Proposing a future system test program.

The intent of this approach is to provide a logical, economical, sequential test methology; whereby, not only can the electrostatic vulnerability be determined, but a baseline of information is established for future reference and utilization.

Initial Phase II spark ignition tests have been conducted on components and subsystem configurations of the XM15 fuse train to provide Edgewood the benefit of test data prior to the start of production of the XM15 cluster. As the results of these tests and Edgewood's ignition tests, the following changes were incorporated early in the production cycle:

- Aluminum junction blocks were used in lieu of lexan (plastic) junction blocks as originally proposed by Edgewood Arsenal.
- Conductive cements are used to electrically bond the delay fuses to the junction blocks.

While the changes appear simple in nature, they constitute major improvements to reduce the electrostatic vulnerability of the XM15/XM165 cluster.

ABSTRACT

This report describes the results of investigations conducted by the Materiel Testing and Research Subsection (MT&R), Management and Technical Services Department, Space Division, of the General Electric Company in conjunction with the Smoke and Riot Control Branch, Production and Maintenance Engineering Laboratory, and Engineering Test and Evaluation Section, Process Technology Branch, Chemical Process Laboratory, Weapons Development and Engineering Laboratory, Edgewood Arsenal, Edgewood, Maryland. This two-phase investigation is concerned mainly with electrostatics. Phase I consists of electrostatic vulnerability identification and the survey of manufacturers' facilities; and Phase II will consist of implementing the test plan as described in Section 7 of this report.

Two inadvertent ignitions of the XM15/XM165 cluster and one ignition of the E8 launcher occurred without the cause being understood at the time.

During the course of the investigations, the XM15/XM165 and the E8 launcher were shown to be susceptible to electrostatic ignition. The pyrotechnic hazard of prime concern associated with electrostatics is that of the spark which can be generated. The heat, shock, and ionization produced by the spark can cause ignition of pyrotechnics. However, as a result of the initial ignition tests (XM15 fuse train), changes have been incorporated to make the fusing system relatively safe from premature electrostatic activation.

Included in this report is a summary of a visit to the E8 launcher manufacturing facility. An XM15/XM165 manufacturing facility was also visited, and the results of this investigation have been submitted under separate cover as Report No. GE-MTSD-R-047, "Inadvertent Functioning of an XM15 Cluster During Manufacturing," dated October 29, 1970.

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SECTION 1
INTRODUCTION

1.1 GENERAL

This report contains the results of Phase I of a two-phase investigation of the electrostatic vulnerability of the E8 and XM15/XM165 clusters being conducted by the General Electric Company, Management and Technical Services Department (GE-MTSD) for the Smoke and Riot Control Branch, Production and Engineering Laboratory (administered through the Engineering Test and Evaluation Section, Process Technology Branch, Chemical Process Laboratory), Weapons Development and Engineering Laboratory, Edgewood Arsenal, Edgewood, Maryland. The contracting agency is the National Aeronautics and Space Administration (NASA), George C. Marshall Space Flight Center, Huntsville, Alabama. This program is being conducted at the NASA Mississippi Test Facility, Bay St. Louis, Mississippi, under contract NAS8-23524.

Phase I consisted of identification of the characteristic of the E8 and XM15/XM165 system which affect its electrostatic vulnerability and a survey of the manufacturers' facilities. Phase II will be the implementation of the test plan detailed in Section 7 of this report.

The objectives of Phase I were to:

- Identify areas of potential electrostatic hazards
- Collect all available literature and information related to this study.
- Construct equivalent electrical circuits to facilitate analysis and interpretation of data.
- Construct equivalent electrical circuits
- Define the Phase II test plan

To accomplish these objectives, Phase I was divided into the following five tasks:

- Task I - Identification of the locations and operations where electrostatic potentials may be generated.
- Task II - Determination of engineering characteristics and evaluation of properties of materials and discrete components used in the assemblies to disclose the individual electrostatic sensitivity values.
- Task III - Evaluation of the process equipment and procedures for determination of hazards.
- Task IV - Generation of equivalent electrical circuits.
- Task V - Development of the Phase II test plan.

Each task was implemented as shown in the Phase I logic diagrams, Figures 1-1 through 1-6. The results of these tasks are presented in this report as follows:

- Section 2 - Summary Discussion
- Section 3 - Electrostatics
- Section 4 - Material Characteristics
- Section 5 - Potential Electrostatic Hazards
- Section 6 - Equivalent Electrical Circuits
- Section 7 - Phase II Test Plan
- Section 8 - References

The following paragraphs present those aspects of the physical design and functioning of the XM15/XM165 cluster and E8 launcher necessary to the understanding of the technical task results included in the remainder of this report.

1.2 XM15/XM165 CLUSTERS

1.2.1 DESIGN

The XM165 chemical agent canister cluster assembly (Figure 1-7) is designed to disperse tactical CS from an aircraft or helicopter. The XM165 cluster consists of an XM43 adapter ("2" in Figure 1-7), two XM15 clusters ("15" in Figure 1-7), and an XM1 explosive bolt ("12" in Figure 1-7).

The XM15 cluster (Figures 1-8 and 1-9) consists of eight modules that are heat-sealed together, an XM721 time fuze and an ignition system sealed in a rubber compound. Each module contains 33 XM16 canisters, yielding 264 canisters in each XM15 cluster (see Figures 1-9 and 1-10).

1.2.2 FUNCTIONING

The XM165 cluster is designed to be initiated either electrically or mechanically.

1.2.2.1 Electrical Initiation

The XM165 cluster explosive bolt is activated in flight when the pilot pushes a firing switch on the control stick grip. This fires the constraining explosive bolt. As the bolt shears, the end clamps of the adapter move outward, allowing the hinged clamps to pivot upward. The two XM15 clusters are forced downward by four leaf springs located under the adapter. When the XM15 clusters drop, the arming wire, the safety cover, and the safety wire attached to the tie rod are pulled from the XM721 fuze. This starts the time initiator and releases the interrupter from its position blocking the slide.

The parts of the XM15 cluster fusing system are labeled in Figure 1-11. As depicted, completion of the timing cycle releases the detonator slide. The M55 detonator impacts a firing pin and

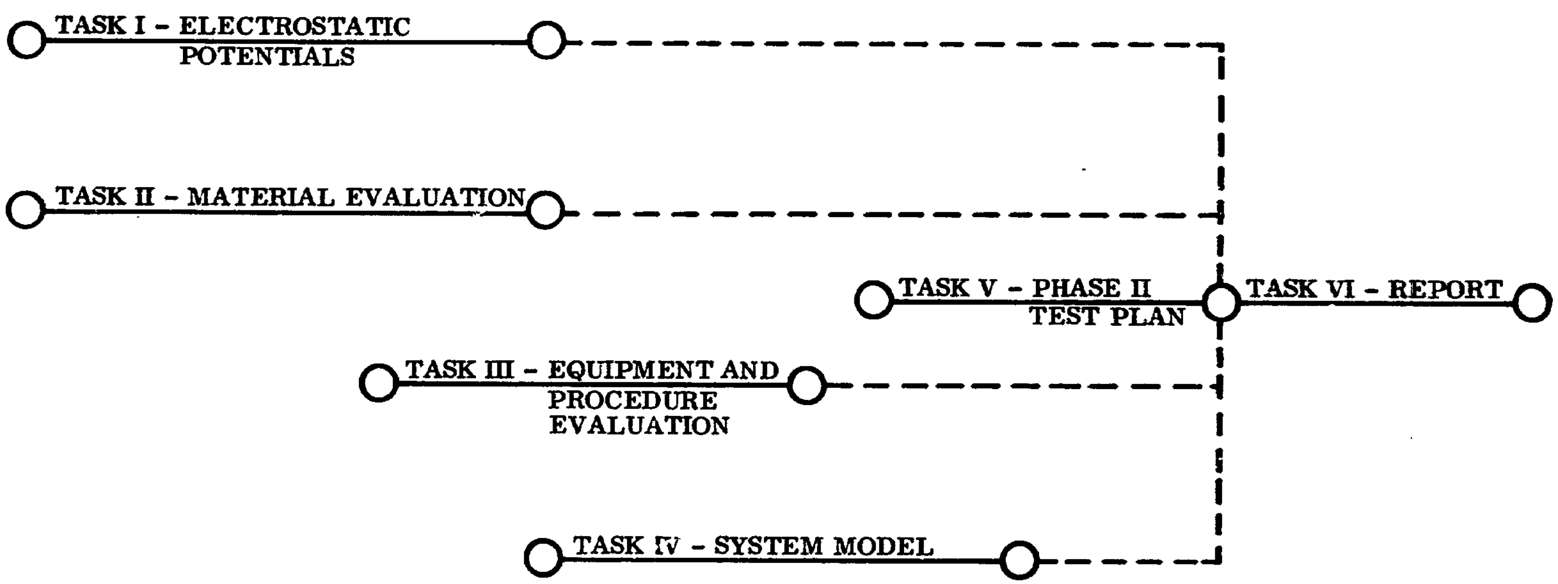


Figure 1-1. Phase I Logic Diagram

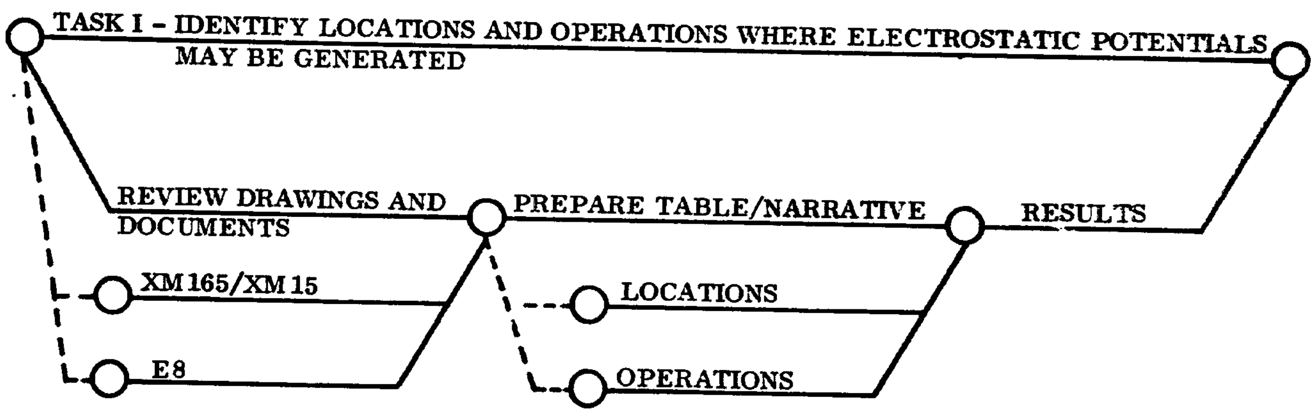


Figure 1-2. Phase I, Task I Logic Diagram

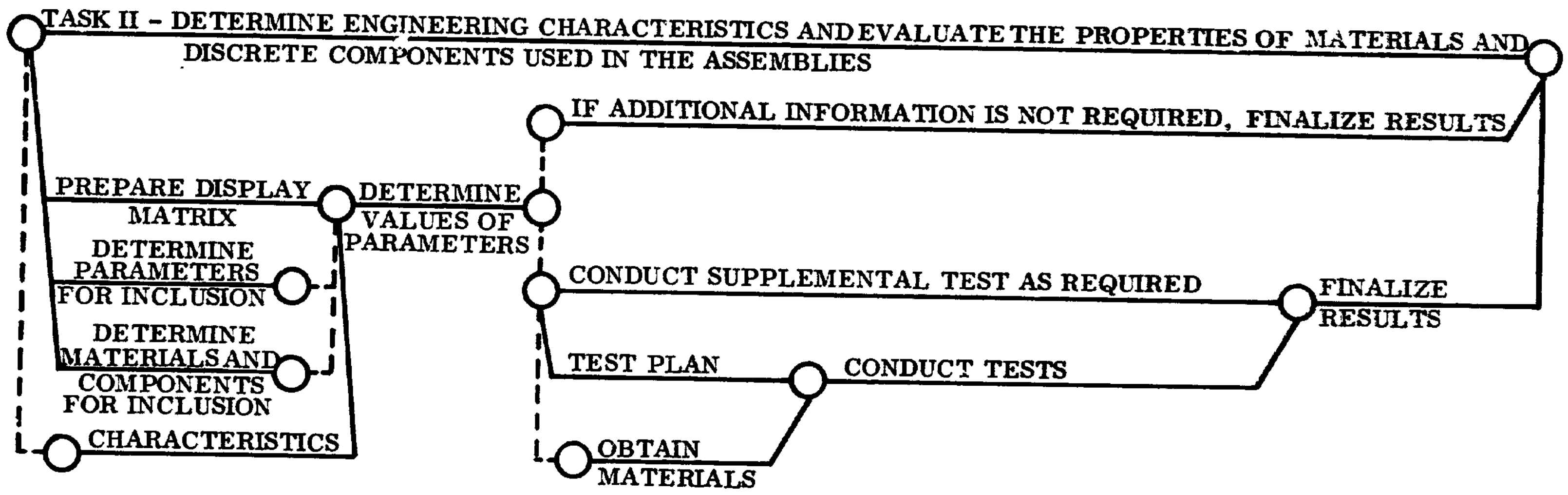


Figure 1-3. Phase I, Task II Logic Diagram

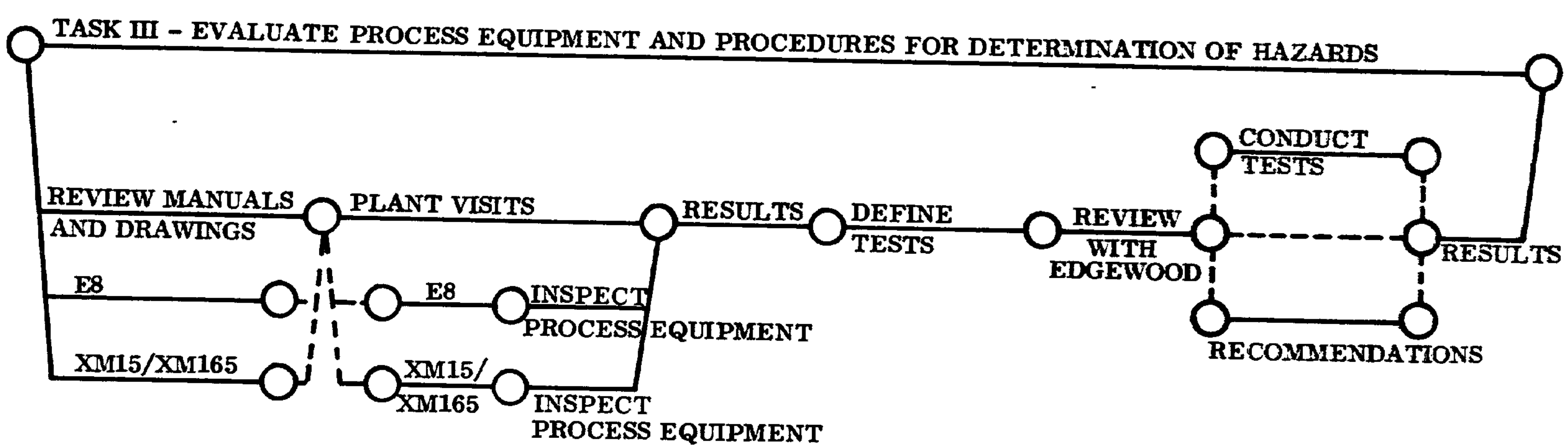


Figure 1-4. Phase I, Task III Logic Diagram

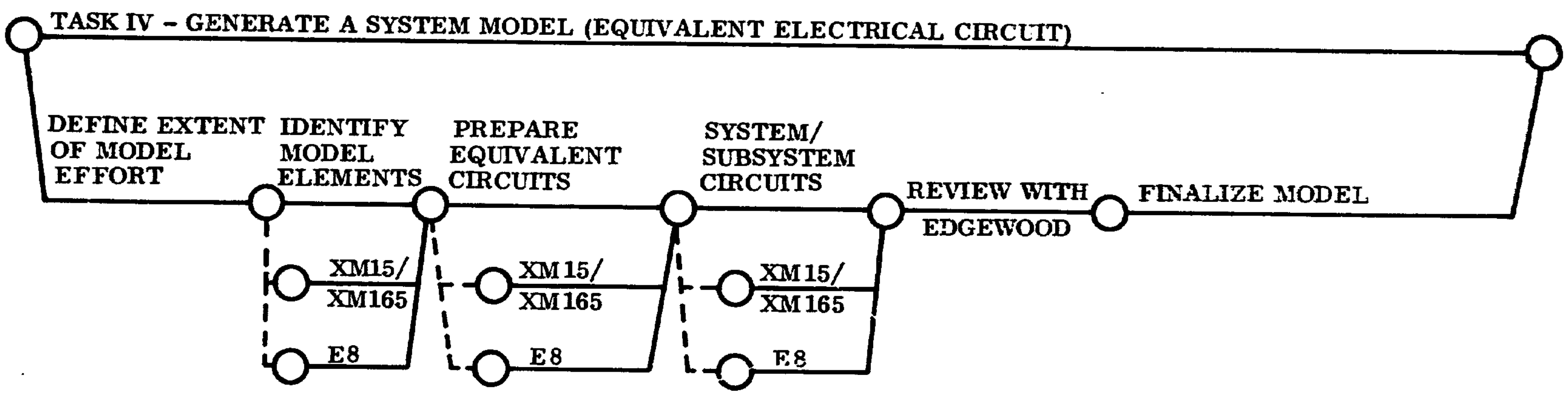


Figure 1-5. Phase I, Task IV Logic Diagram

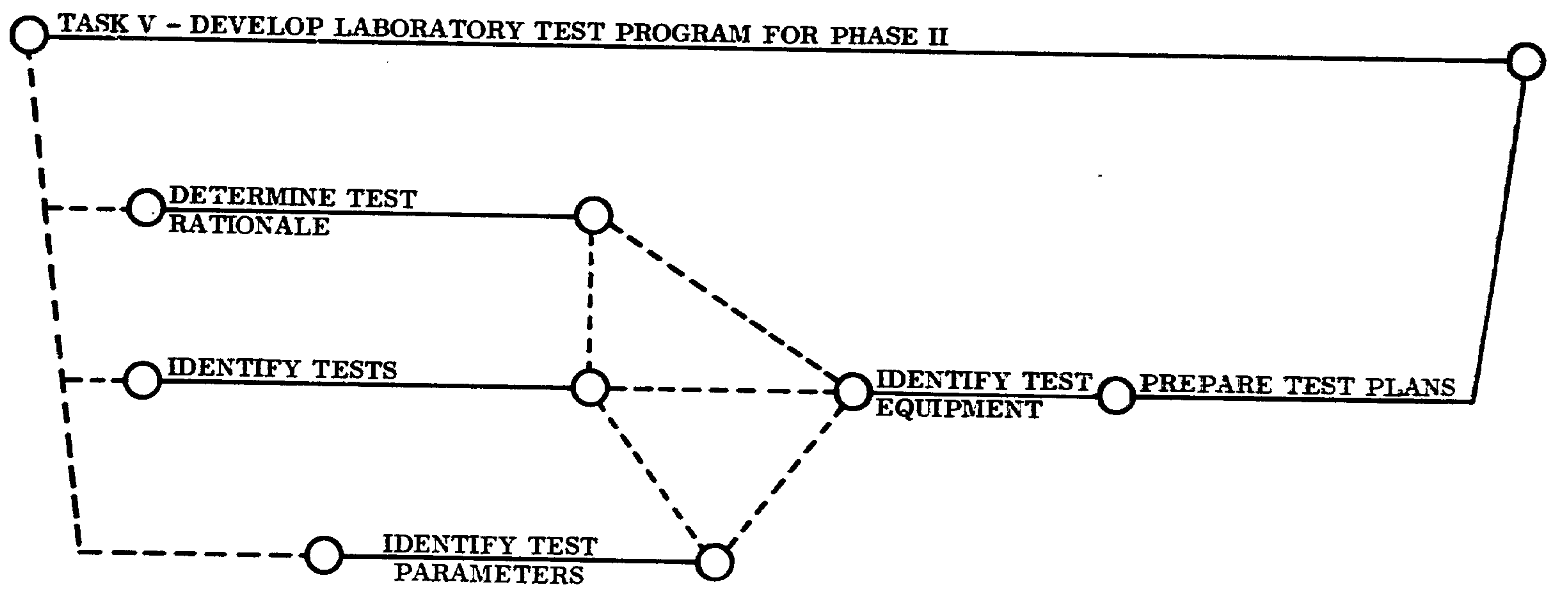
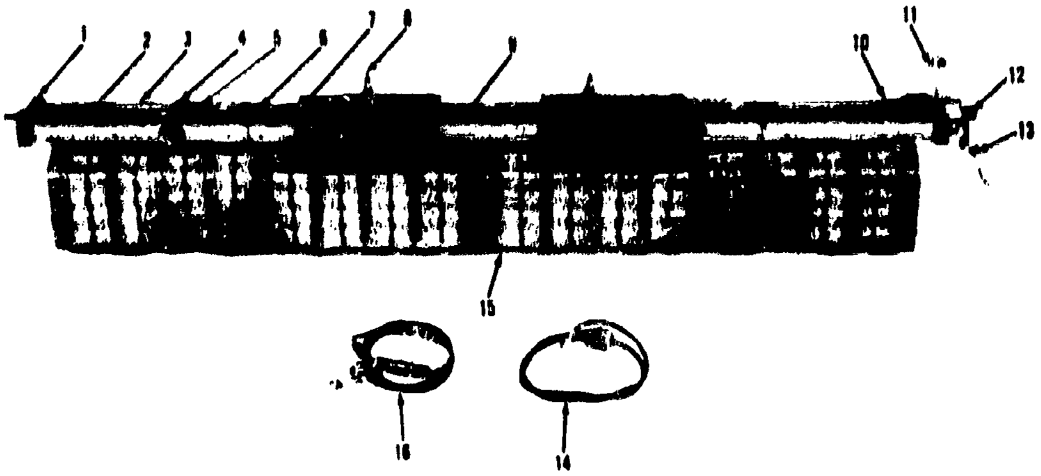


Figure 1-6. Phase I, Task V Logic Diagram



1	End clamps	9	Tie rod
2	XM43 adapter	10	Arming wire tube
3	Hinged clamp	11	Detonator boot
4	Safety clamp	12	XM1 explosive bolt
5	Cover tiedown screw	13	Clip
6	Tie rod yoke	14	Wiring harness
7	XM166 arming wire	15	XM15 cluster
8	Suspension lugs	16	Wiring harness

Figure 1-7. XM165 Cluster

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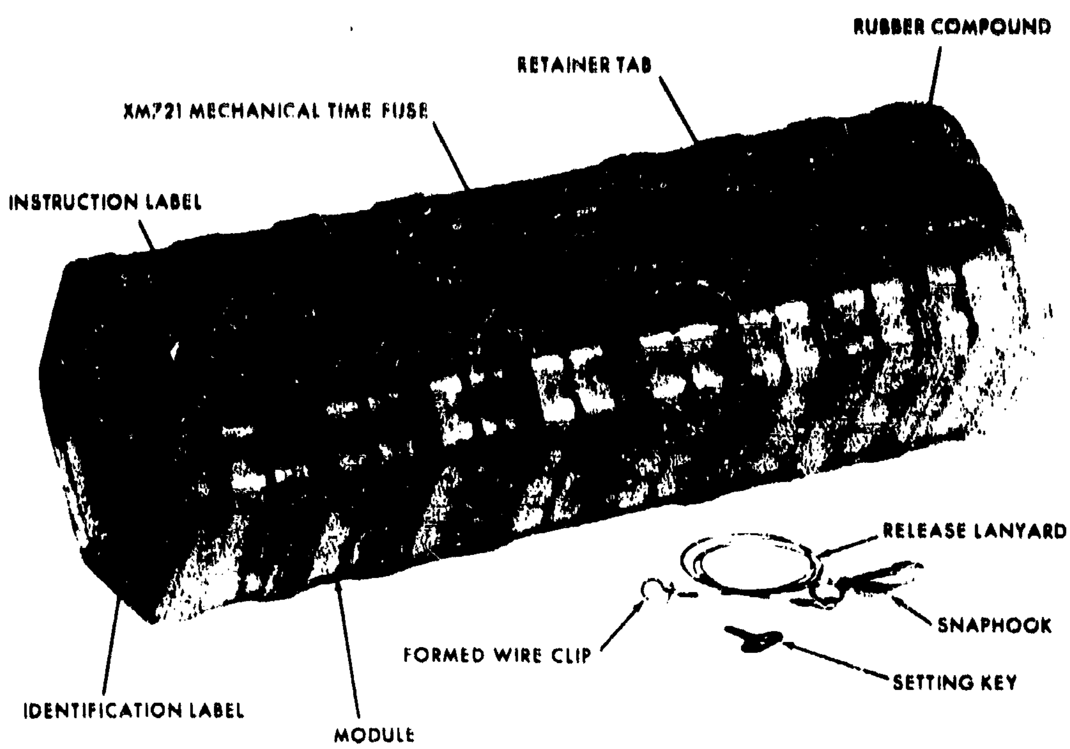


Figure 1-8. XM15 Cluster

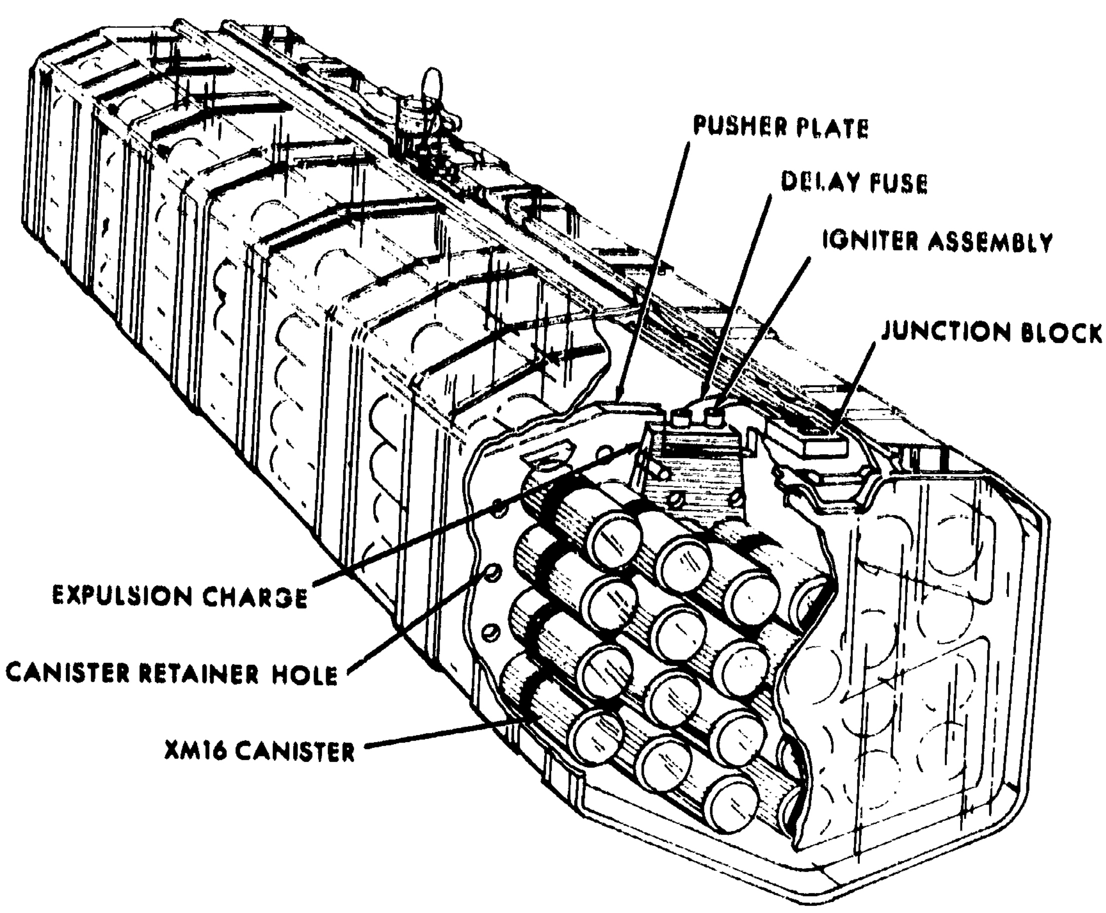


Figure 1-9. XM15 Canister Module, Cross-Section View

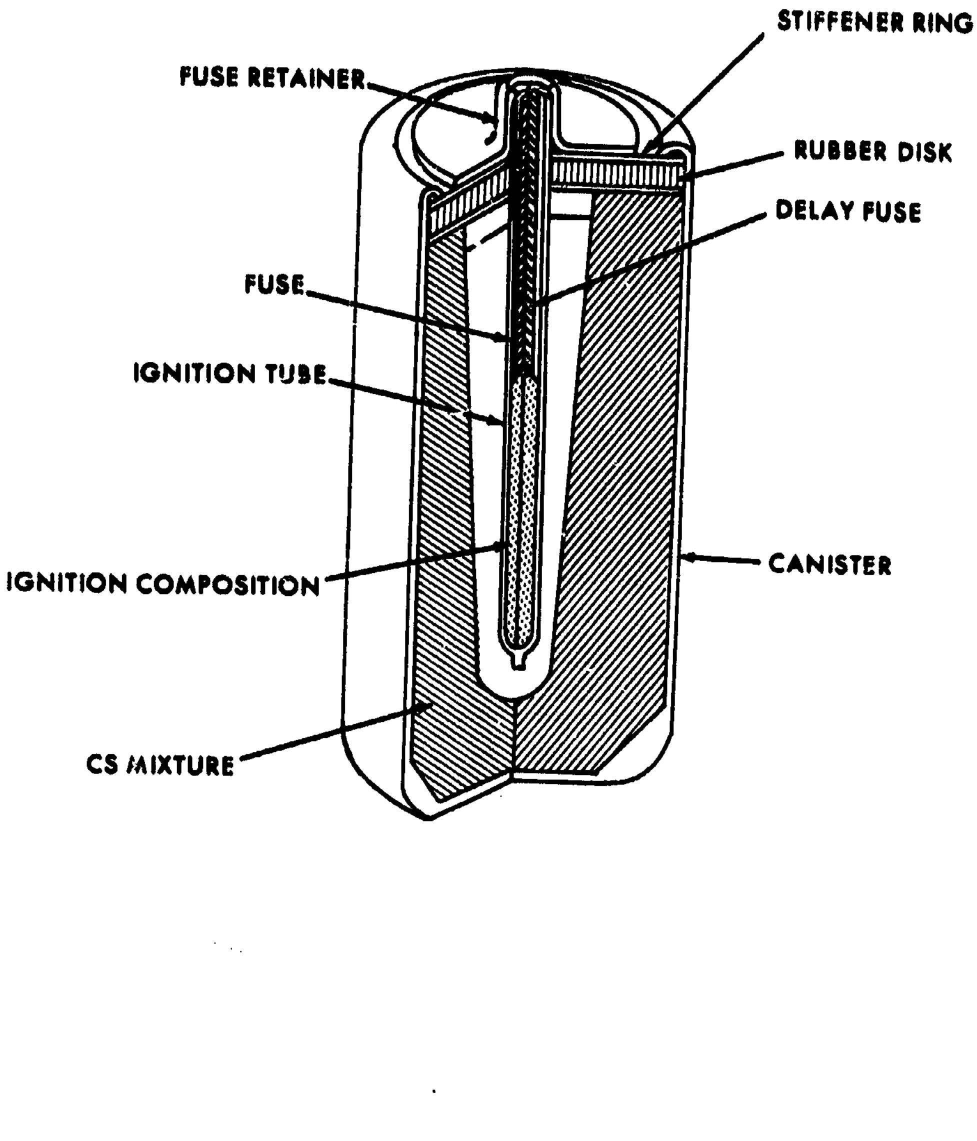


Figure 1-10. Cross Section of XM16 Canister

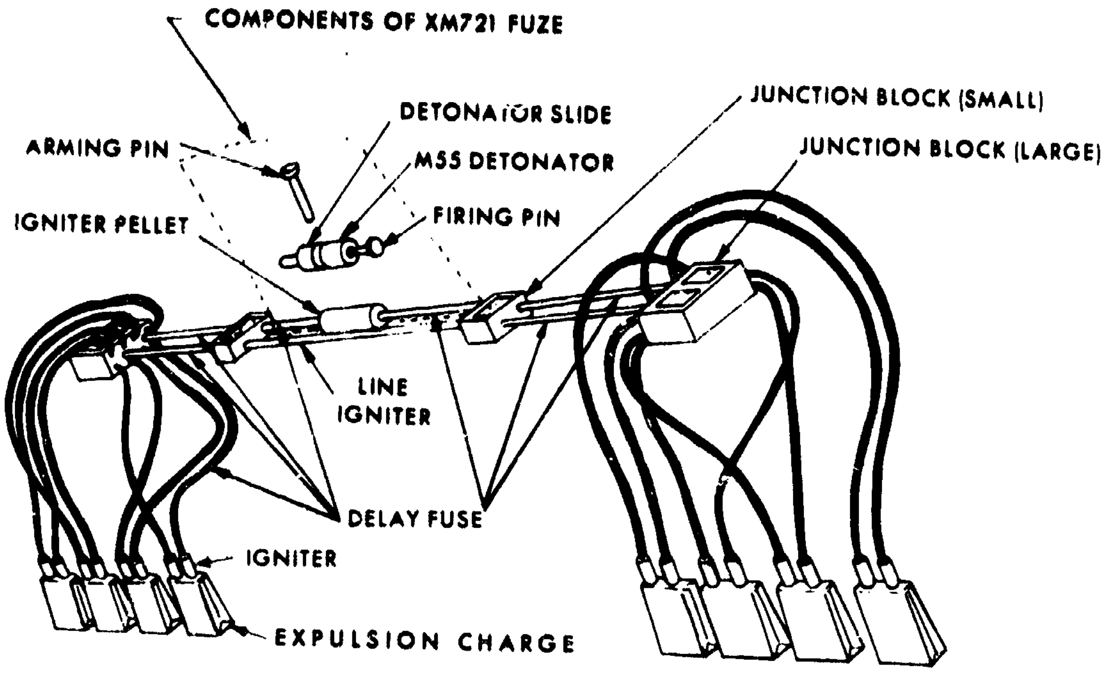


Figure 1-11. XM15 Cluster Fusing System

detonates, activating an igniter pellet located below the slide. Through a delay fuse, the firing train is continued to two small junction blocks located on each side of the XM721 fuze. The small junction blocks are also connected by a line igniter that bypasses the XM721 fuze, ensuring ignition of both junction blocks in the event of a failure at either end of the delay fuse connected to the igniter pellet. Each small junction block contains an ignition mixture and is connected to a large junction block by two delay fuses. Each of the two large junction blocks contain ignition mixture and eight delay fuses which lead to igniters. Sixteen igniters, two for each module, ignite 25-gram black powder bags to expel the XM16 canisters from the modules.

The two delay fuses and two igniters connecting the large junction block and each module, and the two delay fuses connecting each small junction block and each large junction block, provide two independent ignition systems. Function of either ignition system is sufficient to ignite the black powder expelling charge in a module. The canisters of the end modules are expelled 2.4 seconds after the igniter pellet is activated. The canisters in the remaining modules are expelled at 0.5-second intervals. The initiation of the black powder bags in the module also ignites the fuse in each XM16 canister (Figure 1-10).

At the end of the fuse delay period, the ignition mixture is ignited. The burning of the ignition mixture is so rapid that the burned fuse is blown out of the rubber disk assembly and the canister is propelled. This initial displacement aids in dispersing the canisters for better area coverage. The CS mixture is also ignited. As the CS mixture begins burning, pressure builds up and the XM16 canister continues to be propelled along the ground in an erratic path with some canisters becoming airborne. The CS is disseminated during the burning period.

1.2.2.2 Mechanical Initiation

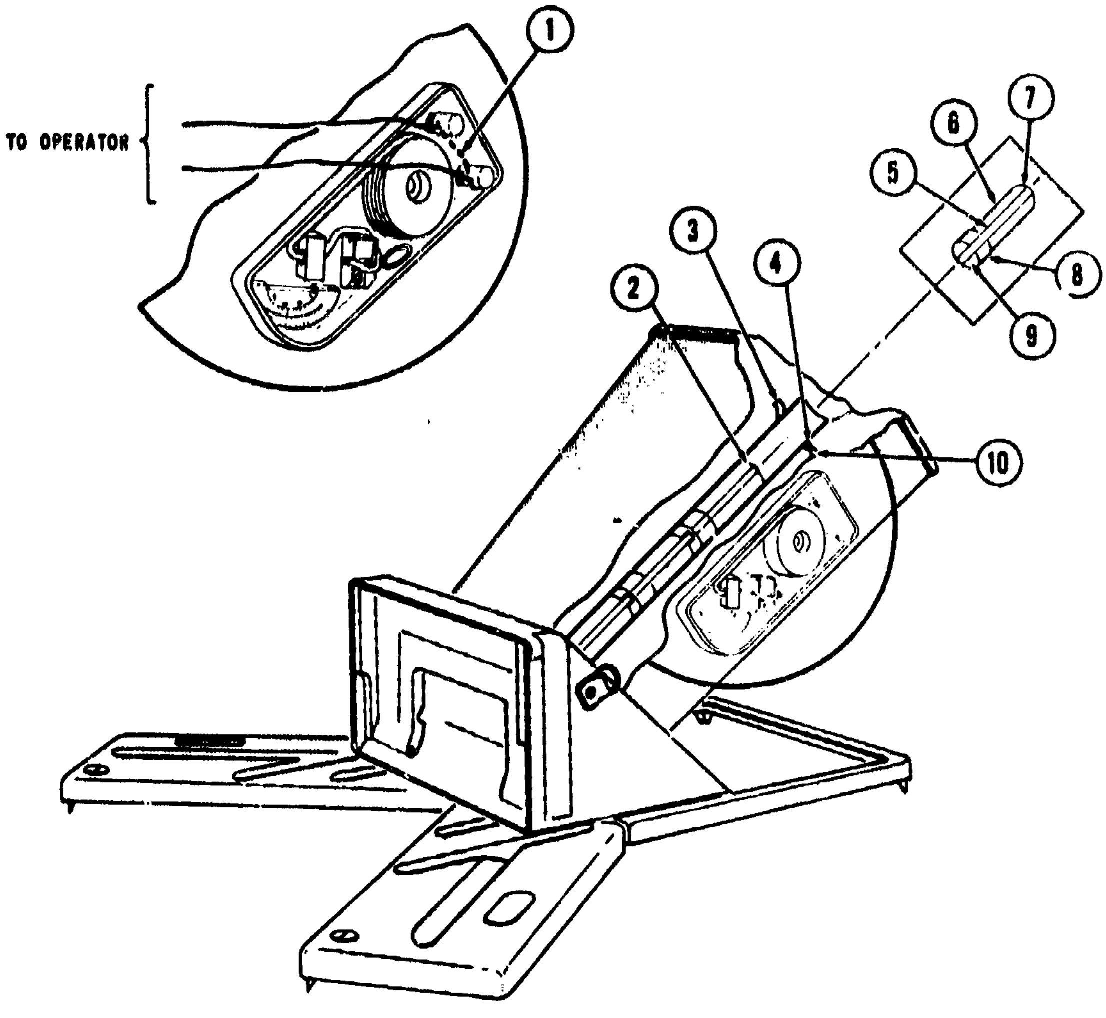
When the XM165 cluster is released mechanically, the adapter is dropped with both XM15 clusters attached. The XM166 arming wire is attached to the bomb rack of the aircraft and extends through the arming wire tube of the adapter to the explosive bolt. When the XM165 cluster is dropped, the arming wire frees the firing pin in the explosive bolt which impacts the M55 detonator. The M55 detonator then initiates an explosive train which shears the explosive bolt. The sequence, thereafter, is as described in paragraph 1.2.2.1.

The XM15 cluster may also be considered as an individual system and dropped independently. In this mode the XM43 adapter is not used.

1.3 E8 LAUNCHER

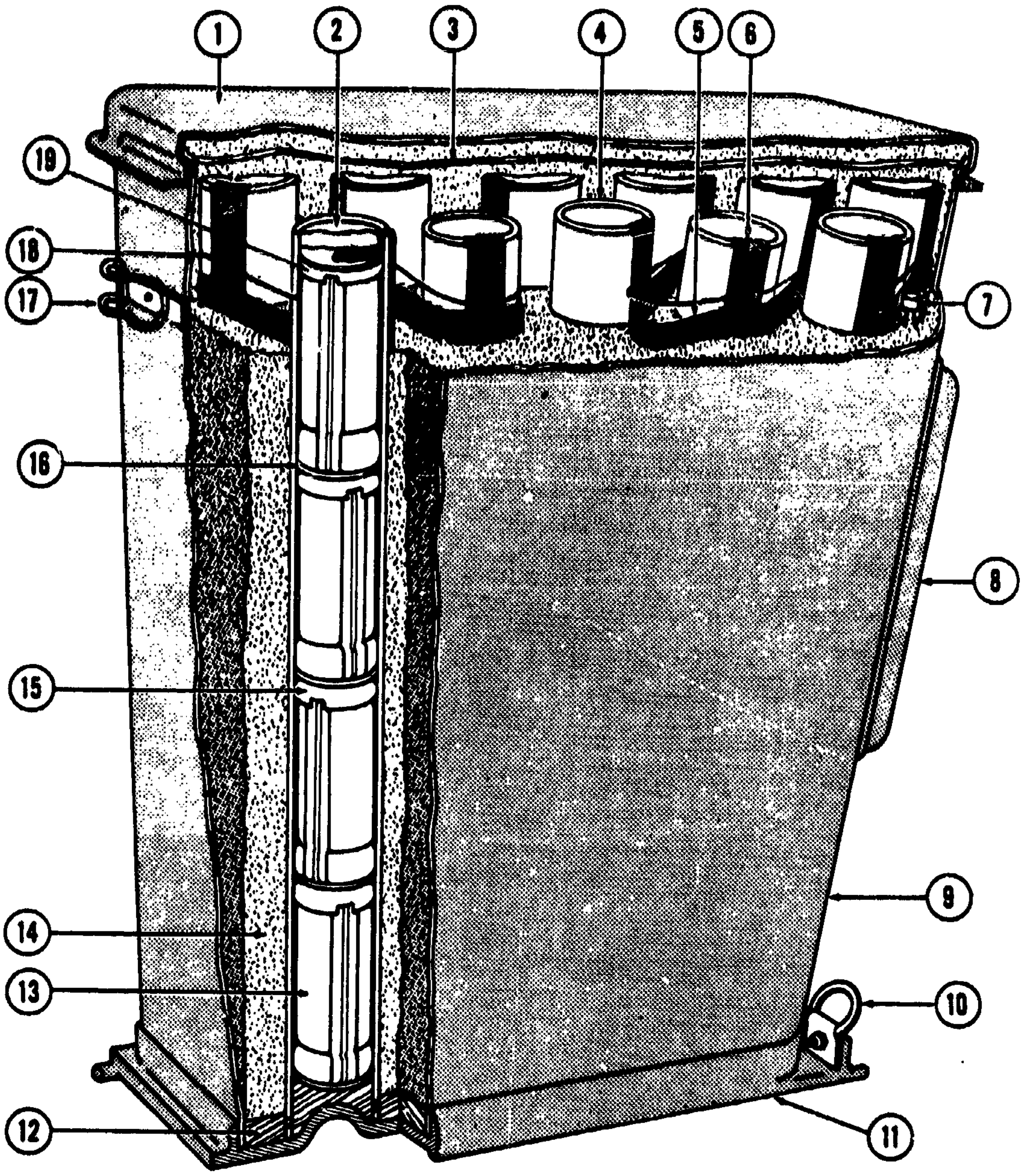
1.3.1 DESIGN

The E8 launcher (Figure 1-12) is designed to disperse tactical CS canisters through built-in launch tubes. The E8 consists of a launcher module (Figure 1-13) and a firing platform (Figure 1-14). The launcher weighs approximately 34 pounds and may be transported,



1	Shorting bar	6	E23 cartridge
2	Pyrotechnic disc	7	Pyrotechnic disc
3	Branch fuse strip	8	Propellant cup
4	Electric squib	9	Lacquered diaphragm
5	Cartridge fuse strip	10	Main fuse train

Figure 1-12. E8 Launcher - Electrical Functioning



1	Top cover	11	Baseplate
2	Foam cap	12	Epoxy resin
3	Foil vapor barrier	13	E23 cartridge
4	Paper tube	14	Polyurethane foam
5	Main fuse train	15	Plastic separator cap
6	Fuse strip	16	Cardboard separator disc
7	Electrical squib	17	Trail release catch
8	Firing well cover	18	Auxiliary fuse train
9	Plastic case	19	Plastic separator cap, flanged
10	Carrying harness attachment ring		

Figure 1-13. Launcher Module - Cutaway View

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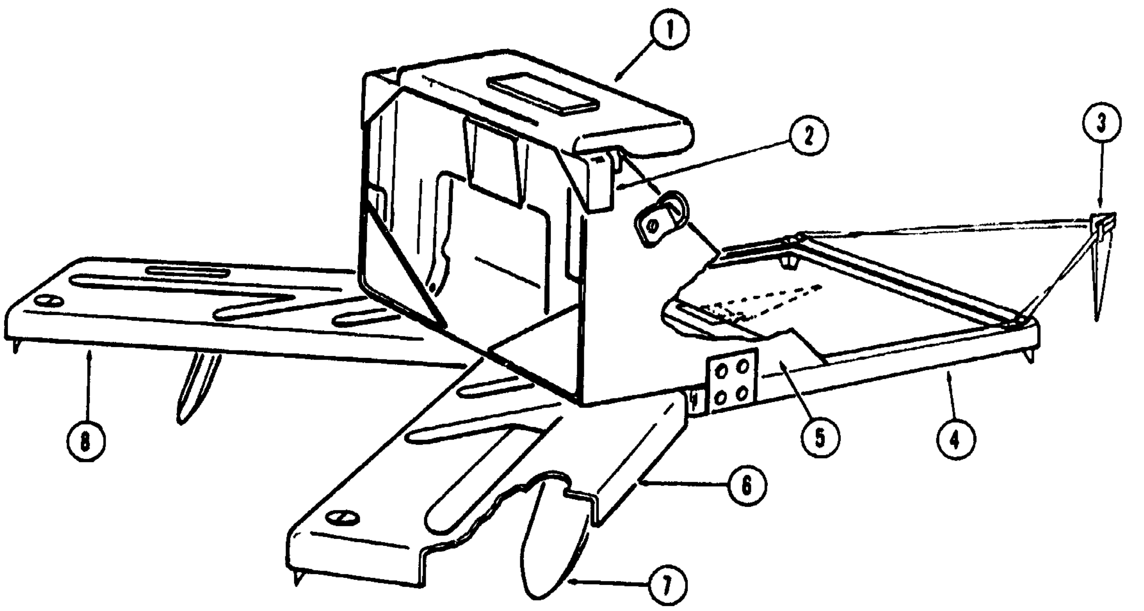


1	Back pad	5	Base
2	Position panel	6	Trail (right hand)
3	Tether spike	7	Spike
4	Stability platform	8	Trail (left hand)

Figure 1-14. Firing Pla‧ ‧rm (Components)

emplaced, sighted and fired by one man. A total of 64 E23 cartridges (Figure 1-15) are fired from 16 tubes arranged in a rectangular pattern.

1.3.2 FUNCTIONING

The E8 launcher can be fired either electrically or manually.

1.3.2.1 Electrical

The E8 launcher functions electrically as follows (reference the parts identified in Figure 1-12):

- With the shorting bar (1) removed, the M2 electric squibs (4) are fired by an electric signal generated by the operator.
- When the squib ignites, the flame starts the main fuse train (10) burning.
- The main fuse train connects to 16 branch fuse strips (3), each connected to an individual tube.
- As the branch fuse strip burns to completion, the pyrotechnic disc (7) of the first E23 cartridge (6) of each tube is ignited. The remaining tubes are fired in predetermined sequence.
- The pyrotechnic disc transfers the flame to the cartridge fuse strip (5).
- The fuse strip burns down both sides of the cartridge, burns through a lacquered diaphragm (9), and ignites the black powder inside the propellant cup (8).
- Burning of the black powder will eject the cartridge from the launcher and ignite the pyrotechnic disc (2) on the second cartridge.

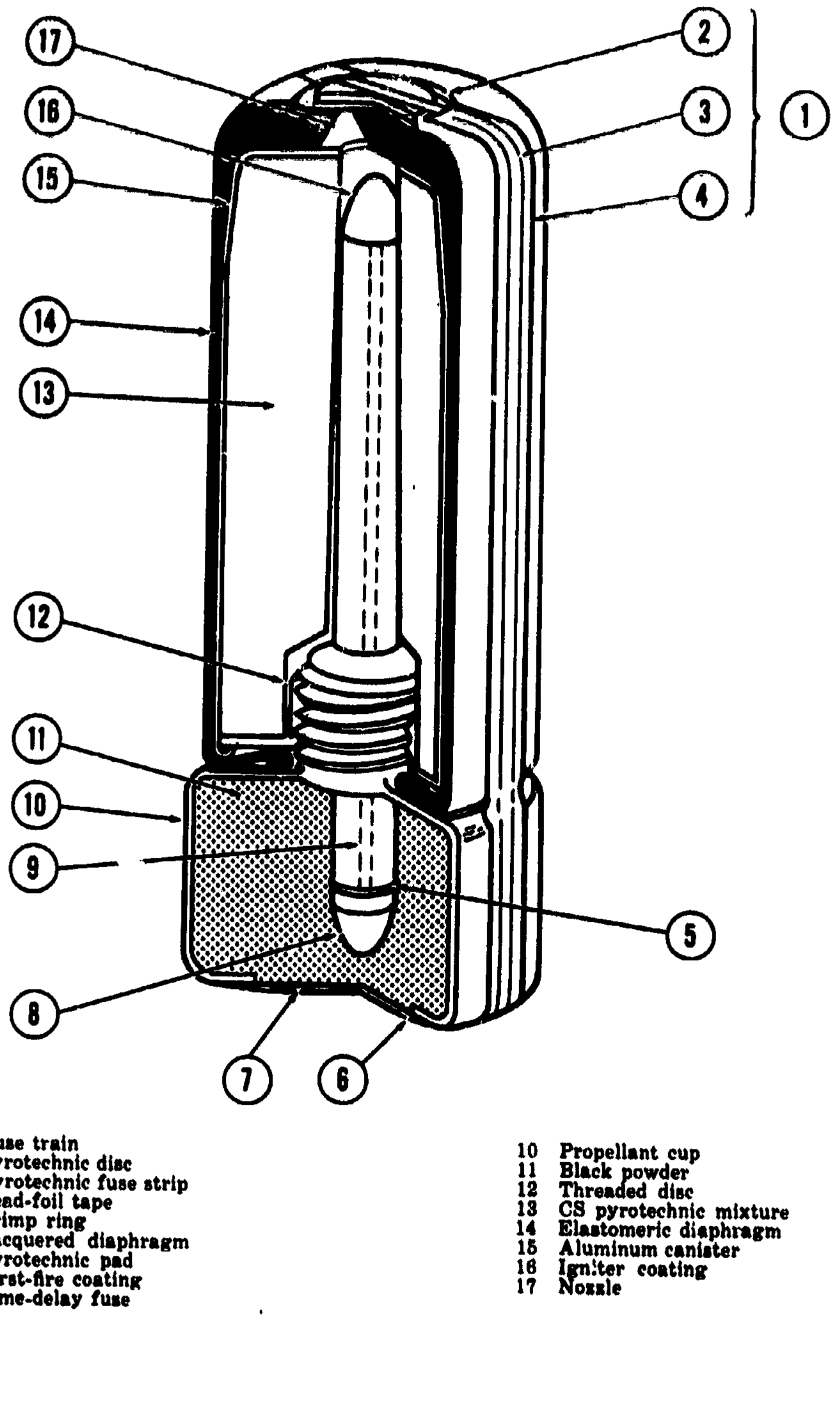
This sequence is repeated until all the cartridges are fired from each tube.

1.3.2.2 Manual

The E8 launcher can be fired manually as follows (reference the parts identified in Figure 1-16):

- The launcher can be fired by removing the lanyard reel (1) and safety pin (4) and pulling on the lanyard (7).
- As the lanyard is pulled, the firing release pin (6) slides out of the spring-loaded mousetrap-type manual actuator (3) and releases the striker arm (2).
- The spring-powered striker arm swings over and strikes the M42 percussion primer (5). After a delay ot 5 seconds, heat from the burning primer ignites the primer fuse train. The primer fuse train ignites the main fuse train.

The remainder of the firing cycle is identical to that described in paragraph 1.3.2.1 after squib ignition.



1 Fuse train
2 Pyrotechnic disc
3 Pyrotechnic fuse strip
4 Lead-foil tape
5 Crimp ring
6 Lacquered diaphragm
7 Pyrotechnic pad
8 First-fire coating
9 Time-delay fuse
10 Propellant cup
11 Black powder
12 Threaded disc
13 CS pyrotechnic mixture
14 Elastomeric diaphragm
15 Aluminum canister
16 Igniter coating
17 Nozzle

Figure 1-15. E23 Cartridge - Cutaway View

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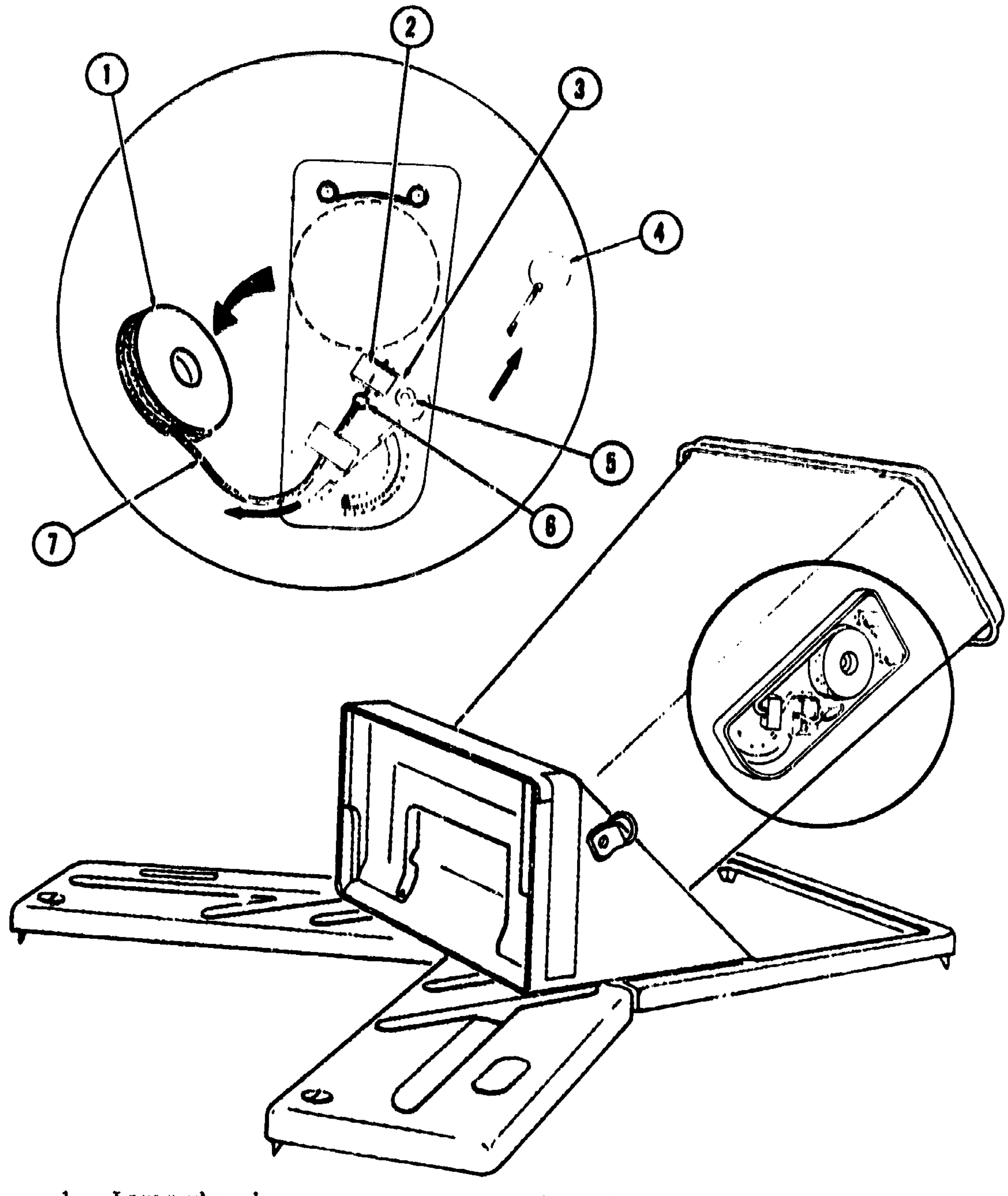


1	Lanyard reel	5	Primer
2	Striker arm	6	Firing release pin
3	Manual activator	7	Lanyard
4	Safety pin		

Figure 1-16. E8 Launcher - Manual Functio·ing

Referencing the parts identified in Figure 1-15, the E23 cartridge functions as follows:

- The functioning cycle begins when the heat from the pyrotechnic pad (7) burns through the lacquered diaphragm (6) and ignites the black powder (11) as described in paragraph 1.3.2.1. When the black powder ignites, the gas produced expels the cartridge from the launcher.
- At the same time the black powder ignites and the first-fire coating (8) is ignited and in turn ignites the 5- to 6-second time-delay fuse (9) inside the cartridge.
- At the end of the delay time, the delay fuse ignites the igniter coating (16) which in turn ignites the CS pyrotechnic mixture (13).
- The pressure builds up within the canister opening the nozzle (17).

The mixture burns for 10 to 15 seconds. Thrust exerted by the burning mixture propels the cartridge along the ground in a zigzag path while the agent is being released.

SECTION 2
SUMMARY DISCUSSION

2.1 INTRODUCTION

This discussion relates the results obtained in the first phase of a two-phase investigation of the electrostatic vulnerability of the E8 and XM15/XM165 clusters.

Phase I consists of electrostatic identification of materials' properties and characteristics, a survey of the manufacturer's facilities, identification of areas of potential electrostatic hazards, construction of equivalent electrical circuits, and definitization of the Phase II test plan.

Phase II of this investigation will be the implementation of the test plan, as detailed in Section 7 of this report. The objectives of Phase II are to:

- Conduct electrostatic spark ignition and triboelectrification tests on subsystems and components of the E8 and XM15/XM165 clusters.
- Evaluate prior incidents of the E8 and XM15/XM165 clusters from an electrostatic viewpoint.
- Refine the equivalent electrical circuits generated in Phase I.
- Recommend measures to eliminate or neutralize hazards areas.
- Propose a future system test program.

2.2 XM15/XM165 CLUSTER

The XM15/XM165 tactical CS canister cluster appears to be vulnerable to premature activation by electrostatic charge. This assumption is based on the general design features of the unit (i.e., use of nonconductive plastics and other nonconductive materials) and on two premature activations of the XM165 during unloading operations. However, because of the results of Edgewood ignition tests and the initial Phase II XM15 fuse train tests, changes have been incorporated to make the fusing system relatively safe from premature activation by electrostatic charge.

The modifications designed to decrease electrostatic ignition sensitivity, requires validation to verity that they are functioning as intended. The new ignition sensitivity level must be established, and the possibility that a new potentially hazardous situation will be introduced must be investigated.

The pyrotechnic hazard of prime concern that is associated with electrostatics is that of the spark which can be generated during the charging/discharging phenomena. If a gap exists and if the applied voltage potential is sufficient, the gap will break down and a spark will occur. The heat, shock, and ionization produced by the spark can induce ignition of pyrotechnics.

Gaps can occur at several locations within the XM15/XM165 cluster. Those in the vicinity of the pyrotechnics are:

Location	Gaps	Dielectric	Approximate Breakdown Voltage
Between the fuse and the pellets in the block	31 Mils	Air	3900 V
Between the fuse and block	5 to 10 Mils	Air or RTV	1000 to 6000 V

Since the XM43 adaptor is in electrical contact with these gaps, any voltage that is induced to the adaptor will be present at the gap. For example, if a man has a charge of 3000 volts and comes in contact with the adaptor, most of this potential (3000 volts) will appear across the gap. It is not uncommon for a man to develop a potential of 3000 to 10,000 volts in normal work activities. Assuming that a man is charged to 10,000 volts and has a capacitance of 200 picofarads (reference 37, Section 8), then he has the capability of delivering .01 joules of energy to the gap ($E = 1/2\ CV^2$).

Initial Phase II testing of the XM15 fuse train (reference 9, Section 8) revealed that the unit can be ignited with .006 joules; therefore, it is very feasible for the system to ignite prematurely if a charged man comes in contact with the XM43 adaptor. However, with the changes that have been recently incorporated (aluminum junction blocks and conductive cement to bond the delay fuses to the junction blocks), one of the potential gaps has been eliminated and the other gap should not present a problem since a good conductive path is provided to conduct any potential around the gap. (Phase II testing will reveal whether or not this is the case.) Factory assembled fuse trains, changes incorporated, will be tested for electrostatic spark ignition sensitivities.

From the evaluation of potential electrostatic hazards it appears that hazardous manufacturing conditions have been negated by implementation of techniques of electrostatic suppression and personnel safety. Other areas of potential electrostatic hazards are identified in Section 5 and can be eliminated by using either conductive materials or antistatic aerosols.

The main factors in generating electrostatic potential are the properties of the materials involved. Section 4 contains the properties and characteristics of the materials used in the XM15/XM165 cluster and provides a ready reference of pertinent information that is required for an electrostatic evaluation. This information can also be used for other studies or further designs/modifications relating to the XM15/XM165 type systems. For example, the expulsion charge assembly (black powder bag) is placed between two expulsion pads. From Table 4-1 (line numbers 16 and 19-1) it can be seen that these two items are separated by 10 units on the triboelectric series which indicates that a charge can easily be generated between the two units. Therefore, extra caution should be exercised during this part of the assembly operation.

The equivalent electrical circuit for the XM165 is presented in Section 6. From a generalized equivalent circuit many types of investigations can be made depending on the assumed conditions.

To investigate what happens when a man carrying an electrostatic charge touches the XM43 adapter, the circuit shown in Figure 2-1 can be used to represent the man and the XM165. (The derivation for this circuit and the components are explained in Section 6.) The charged man can be represented by a capacitor C_0 in series with a resistance R_0. C_0 is the ratio of the charge on the man to the voltage between his body and the ground. (These quantities may all vary as the man moves about; for example purposes use the values existing at the instant the man touches the equipment.) R_0 represents the resistance to the flow of current between the man and the equipment.

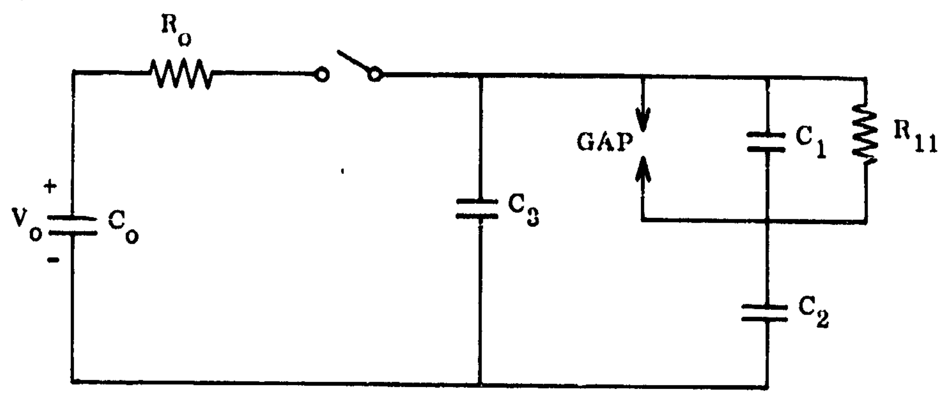


Figure 2-1. Circuit for Analysis of Redistribution of Charge

Determination of the circuit component values are not part of this phase. However, an attempt will be made to determine these values during Phase II (reference paragraph 7.4.2).

2.3 E8 LAUNCHER

The E8 tactical CS backpack appears to be vulnerable to premature activation by electrostatic charge. This assumption is based on the general design features of the unit (i.e., use of non-conductive plastics and other nonconductive materials) and a premature activation and ensuing fire at a production facility.

From the electrical conception standpoint the E8 launcher is constructed differently than the XM165. The E8 launcher is completely encased in insulating material. The housing itself represents a multiple layer dielectric insulator surrounding all critical parts of the system. The existence of such an insulator around the critical "circuits" would appear to be a good safety measure; however, there are conditions that can occur whereby this insulator may contribute to the electrostatic ignition sensitivity of the system. This condition is described in paragraph 6.3 of this report.

Normal use of the E8 launcher is expected to include considerable amounts of movement and rubbing of the Royalite case against other material. A larger percentage of this action might occur against material worn by a man and some would occur against his skin as he prepares the launcher for use. It would also be expected that the same man could be involved in preparing the launcher for firing, which includes removing the firing well cover and touching parts of the manual activator assembly or squib input leads.

The functional contact between the man and the E8 launcher can induce electrostatic charge separation by triboelectric effects. The potential that would result between the man and launcher would be expected to be caused by a negative charge or electron excess on the Royalite and a depletion of electrons or a positive charge on the man. The extent of charge separation depends upon the material on the man (and also the Royalite), the extent of agitation, the length of time after the agitation that the charge is "utilized," and the existing humidity. When the man removes the firing well cover and touches any part of the manual activator assembly, he will transfer his charge depletion to the igniter cord and fuse strip critical area as shown in Figure 2-2, simplified equivalent circuit of manual activator-primer fuse assembly.

The components C_o and R_o represent the internal impedance and energy storage capability of the energy source. In this case, consider a man who may generate or transfer an energy charge from a source. R_o and C_o may be replaced by other types of sources as would appear when considering the electromagnetic case. The components R_A and C_A represent the equivalent circuit values of the "metal to metal" contact resistances and the corresponding capacitance. The simplified distributed circuit "transmission line" is represented by R_B, R_C, R_D, C_B, and C_C. The components C_D, C_E, and C_F are simplified circuit capacitances of the aluminum frame, fuse strip, and igniter cord to the case.

If no breakdown occurs, the charge originally generated between the man and the case will be distributed to C_D, C_E, and C_F.

The length of time the charge remains across the capacitors is a function of the conductivity of the imperfect dielectric. It may be possible to accumulate the charge or under certain circumstances have it oppositely charged from that described. When two charge accumulations occur which are of opposite polarity the transient breakdown conditions can increase considerably.

From the manufacturing standpoint, the prime area of concern is the foaming operation. One of the final process steps is that of filling the voids of the E8 with polyurethane foam. This operation appears to be conducive to production of high electrostatic potentials. An E8 foaming operation test will be conducted during Phase II as defined in Section 7 of this report. The objective of this test is to measure the electrostatic potentials induced during each phase of the foaming operation, to determine from these data the feasibility of electrostatic discharge, and to establish the likelihood of ignition of the system by this means.

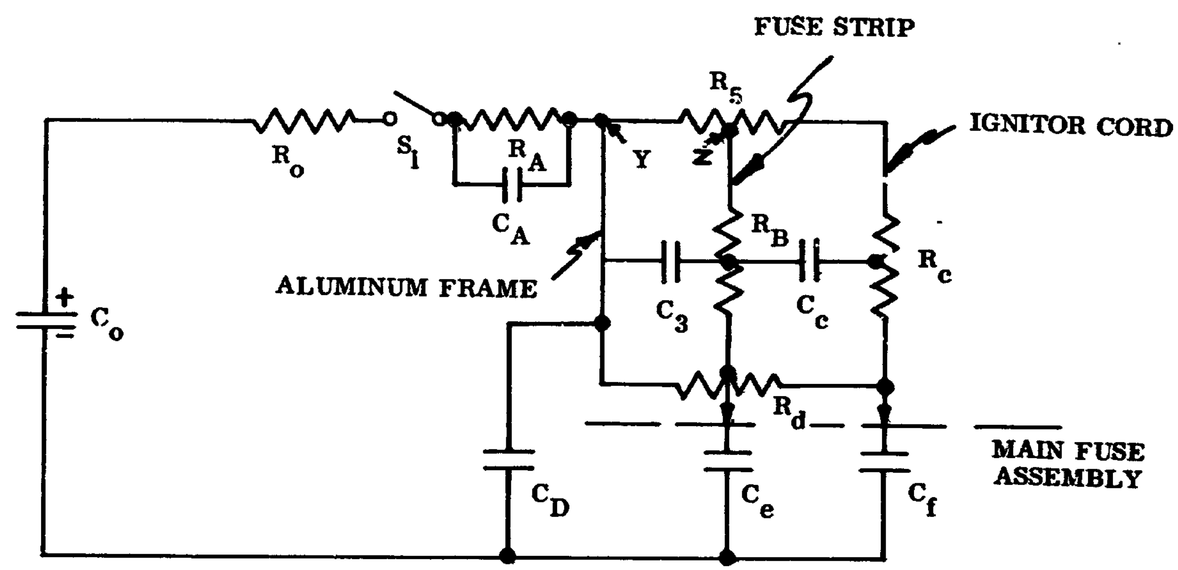


Figure 2-2. Simplified Equivalent Circuit of Manual Activator-Primer Fuse Assembly

SECTION 3
ELECTROSTATICS

3.1 GENERAL

Electrostatics is the physics that deals with phenomena due to attractions or repulsions of electric charges but not dependent upon their motion (reference 15, Section 8). The mechanisms involved in the process of developing the electric charges are still subject to further research even though multi-volume books have been written on the mathematics of electrostatics; this branch of electrical studies, which is the oldest, is still in its infancy.

Electrostatics has to be considered as a hazard to pyrotechnics since the forces involved can cause ignition. Elimination of the forces that can cause ignition is the problem to be solved when pyrotechnics are exposed to electrostatic charges. Because of the many variables and factors involved in electrostatics, each case where electrostatics may be a hazard to pyrotechnics is almost unique.

The prime point to consider is that of a spark occurring when an electrostatic charge is being created or neutralized. A spark produces heat, light, a small shock wave, and an electromagnetic field. It is the heat of the spark that is the most probable cause of ignition of pyrotechnics although the other forces can also cause ignition.

3.2 ELECTROSTATIC CHARGE

Table 3-1 shows three theories of the ways in which a material may become charged. Of the three, the electron theory is considered the classical.

Table 3-1. Theories of the Ways in which a Material May Become Charged*

Charge carrier	Why does the carrier move?	Why does the movement terminate?
electrons	going to lower energy levels <u>or</u> thermal e.m.f.	Energy levels at same height, hot spot cooled off, <u>or</u> capacitance fully charged
ions	going to lower energy levels <u>or</u> diffusion down concentration gradient <u>or</u> electrolytic e.m.f.	levelling complete <u>or</u> shortage of ions back e.m.f. capacitance fully charged
bulk	adhesion of parts of opposing surfaces <u>or</u> particulate contamination transferred mechanically	surfaces separated surfaces separated

*Reference 13, Section 8

Whenever two surfaces, whether liquid or solid, come into contact (no matter how gently), their surfaces are crushed on the atomic level and electrons pass back and forth between the objects. On separation, one surface always comes away with more electrons (negatively charged) than the other surface (positively charged). Therefore, a charge (or more appropriately, a static charge or electric charge) may be defined as an accumulation of an excess or deficit of electrons on an insulating (or insulated) object. Friction or rubbing is not necessary for this charging to take place; mere contact and separation are enough. Rubbing merely increases the number and frequency of contact-separation incidents, each of which causes local electrification.

The degree and polarity of the imparted charges depend to some degree on the relative position of the materials in the triboelectric series (reference paragraph 3.3). Static charges, because they are all of the same polarity on an object, repel one another and therefore accumulate on the outermost surfaces of the charged object. If a conductive coating, no matter how miniscule, is present on the surface of an item, the charge will spread over the entire surface, so that a grounding touch at any point can bleed off the whole charge. The conductivity of this surface layer may be very small, provided it is continuous, because, while high voltages are common in static phenomena, amperages are almost immeasurably low (reference 16, Section 8).

Insulators exhibit the charging phenomena more pronouncedly. As shown in Table 3-2 (reference 1, Section 8), insulators can be classified as materials that exhibit a resistivity of 10^8 ohm-cm or higher.

Table 3-2. Classification of Materials Based on Resistivity*

RESISTIVITY, OHM-CM**	CLASS
$0-10^3$	Conductor
10^3-10^8	Partial Conductor
10^8-10^{18} (or higher)	Insulator

*Reference 1, Section 8
**Unit resistance between two opposite faces of a 1-cm cube.

Conductors and partial conductors, when electrically isolated from earth, can also become charged.

3.3 TRIBOELECTRIC SERIES

The term triboelectric stems from triboelectricity which is a charge of electricity generated by friction (tribo meaning friction) (reference 15, Section 8).

When two materials (insulated from ground) are rubbed together they will assume opposite charges. If a third material is introduced, then a series can be formed if material A becomes

Table 3-3. Triboelectric Series

POSITIVE END

	SERIES I (Reference 1, Section 8)	SERIES II (Reference 22, Section 8)	SERIES III (Reference 22, Section 8)
1	Polyester Resin (CR-39, Pittsburg Plateglass)	Asbestos	Asbestos
2	Poly (Methyl Methacrylate)	Glass	Glass
3	Pyrex Glass	Mica	Mica
4	Muscovite Mica	Wool	Wool
5	Melamine Resin - Glass Laminate	Nylon	Cat Fur
6	Molded Wood Flour-Filled Phenolic Resin	Viscose	Lead
7	Cassiterite (a tin ore)	Rayon	Silk
8	Steel, Copper, Aluminum, Silver	Lead	Aluminum
9	Barium Titanate	Silk	Paper
10	Hard Fiber	Fiberglass	Cotton
11	Polyester Resin (Paraplex P13, Rohm and Haas)	Aluminum	Wood, Iron
12	Nylon	Cotton	Sealing Wax
13	Cellulose Acetate	Chrome	Ebonite
14	Butyl Rubber	Acetate	Nickel, Copper, Silver, Brass
15	Epoxy Resin (Epon 828, Shell)	Acrylic	Sulfur
16	Glass - Bonded Mica	PVA	Platinum, Mercury
17	Phenolic Resin - Glass Laminate	Polyester	India Rubber
18	Steatite	Vinyl (PVC)	
19	Silicone Rubber	Polyethylene	
20	Polystyrene	Teflon	
21	Polyethylene	Nickel, Copper, Silver	
22	Polytetrafluoroethylene (Teflon, DuPont)	Brass, Stainless Steel	
23	Poly (Ethylene Terephthalate) (Mylar, DuPont)	Sulfur	
24	Teflon - Glass Laminate	Platinum, Mercury	
25	Polychlorotrifluorethylene		
26	Unplasticized Poly (Vinyl Chloride)		

NEGATIVE END

positive with respect to B and C and if B becomes negative with respect to C. Table 3-3 shows three series of this nature. The material uppermost in the series becomes positively charged when rubbed by a material lower in the series; the lower material becomes negatively charged. This type of series is called the "triboelectric series."

Imperfections in materials and surfaces, variations in rubbing techniques, surface contamination, and the breakdown of the surrounding gaseous medium make it impossible to develop a quantitative triboelectric series based on charge difference. As can be seen in Tables 3-3 and 3-4, the series can be altered as these conditions vary. Therefore, because the triboelectric series is inconclusive in describing the behavior of electrostatic charges, it can only be used as a tool in the evaluation and analysis of electrostatics.

No correlation of triboelectrification with other properties such as surface or volume resistivity or dielectric constant has been found.

Table 3-4. Triboelectric Series (Reference 26, Section 8)

(Reference 27, Section 8)	(Reference 28, Section 8)	(Reference 29 Section 8)	Gruner's Contact Potential Series (Reference 30, Section 8)	
Positive	Positive	Positive	Material	Potential
Asbestos	Wool	Wool		
Glass	Nylon	Nylon		
Mica	Silk	Viscose	Wool	+42
Wool	Viscose	Cotton	Perlon II	+20
Cat's fur	Cordura	Silk	Dacron*	+14
Lead	Human skin	Acetate	Paper	+12
Silk	Fiberglass	Lucite	Glass, steel	+10
Aluminum	Cotton	Polyvinyl alcohol	Nylon	+7
Paper	Glass	Dacron*	Cotton	+5
Cotton	Acele	Orlon**	Brass	0
Sealing wax	Dacron*	Dynel	Orlon**	-4
	Chromium			
Ebonite	Orlon**	Velon		
Brass	Polyethylene	Polyethylene	Hard rubber	-14
Sulfur		Teflon	Rubber	-20
Platinum				
India Rubber				
Negative	Negative	Negative		

*DuPont polyester fiber
**DuPont acrylic fibers

3.4 ANTISTATICS

To remove or neutralize electrostatic charges it is necessary to provide a conductive path to a medium that can consume the charge. Earth ground and the surrounding atmosphere are the two available media. Connecting the insulators directly to the ground will only remove those charges in the immediate area of the connecting point since the insulator is nonconductive and the charges are localized. Therefore, the insulator's surface must be made conductive or the ground point wiped over the surface area if the charge is to be removed. If a grounded surface is used, a charge will be developed when the surfaces are separated. If the surrounding air is conductive (high moisture content or ionized) the charges will bleed off. Some of the ways to ionize air are:

- Open flame
- Infrared heaters
- X-Rays
- Certain wavelengths of ultraviolet light
- Radioactive sources such as Polonium 210
- Sharp point, charged or uncharged, connected to ground and placed near the object to be destationized

The most important factor in removing electrostatic charge is to prevent electrostatic discharge. The spark produces intense light and heat, shock waves, and electromagnetic fields, any of which can detonate explosives and ignite flammable mixtures.

There are several methods which can be used to make the surface of insulators conductive (assuming that consideration of the surface is sufficient since electrostatic charge is primarily located on surfaces). These methods can be broadly classified as inducing conductive materials and applying a conductive spray or coating.

3.5 THE STREAMER THEORY OF THE SPARK (Reference 38, Section 8)

Consider the application of a voltage gradient of E volts per cm across a gap of length d cm between parallel plane electrodes in a gas at a pressure of p mm Hg. If the ratio $\frac{E}{P}$ is sufficiently high, an electron leaving the cathode will ionize the gas molecules, and the additional electrons so formed will be accelerated in the applied field and cause further ionization. The process is rapidly cumulative and is appropriately termed an electron avalanche. In a field of the magnitude required to cause breakdown, the electrons travel at a speed of the order of 2×10^7 cm/sec, while the positive ions from which the electrons have been detached have a speed of about 2×10^5 cm/sec. The positive ions may therefore be considered stationary in comparison with the more rapidly moving electrons, and the avalanche develops across the gap as a cloud of electrons behind which is left a positive ion space charge, in the manner indicated in (a) on Figure 3-1.

The space charge produced by the electron avalanche produces a distortion of the field in the gap, as shown in (a) on Figure 3-1. The distortion is greatest in the region of the head of the avalanche where the ion density reaches its highest value. The space-charge field E_r augments the externally applied field E and also creates a field in the direction radial to the axis.

When the avalanche has crossed the gap, the electrons are swept into the anode and the positive ions remain in a cone-shaped volume extending across the gap, as shown in (b) on Figure 3-1. The ion density is relatively low except in the region near the anode, and therefore the presence of the positive ions does not in itself constitute breakdown of the gap. However, in the gas surrounding the avalanche photo-electrons are produced by photons emitted from the densely ionized gas constituting the avalanche stem. These electrons initiate auxiliary avalanches which, if the space-charge field developed by the main avalanche is of the order of the external field, will be directed toward the stem of the main avalanche. The greatest multiplication in these auxiliary avalanches will occur along the axis of the main avalanche where the space-charge field supplements the external field. Positive ions left behind by these avalanches effectively lengthen and intensify the space charge of the main avalanche in the direction of the cathode, and the process develops as a self-propagating streamer, shown in (c) on Figure 3-1. The streamer proceeds across the gap to form a conducting filament of highly ionized gas between the electrodes. This filament constitutes the initial stage of the spark channel through which the external circuit discharges.

When a voltage gradient is applied to the gap in excess of the minimum breakdown value, the space-charge field developed by the avalanche attains a value of the order of the external field before the avalanche reaches the anode. In this case mid-gap streamers may be expected, and are, in fact, observed.

The transition from an electron avalanche into a streamer is considered to occur when the radial field E_r produced by the positive ions at the head of the avalanche is of the order of the externally applied field E. Unless this is so, there will be no appreciable enhancement of ionization in the region of the avalanche or diversion of subsidiary electron avalanches to the main avalanche.

3.6 BREAKDOWN VOLTAGE CHARACTERISTICS (Reference 38, Section 8)

This paragraph is designed to provide theoretical and experimental values of the voltage breakdown of air. It can be shown that this voltage is a function of the gap distance, or:

$$V = Cd + B\sqrt{d}$$

where
V = breakdown voltage
C and B = constants
d = gap distance

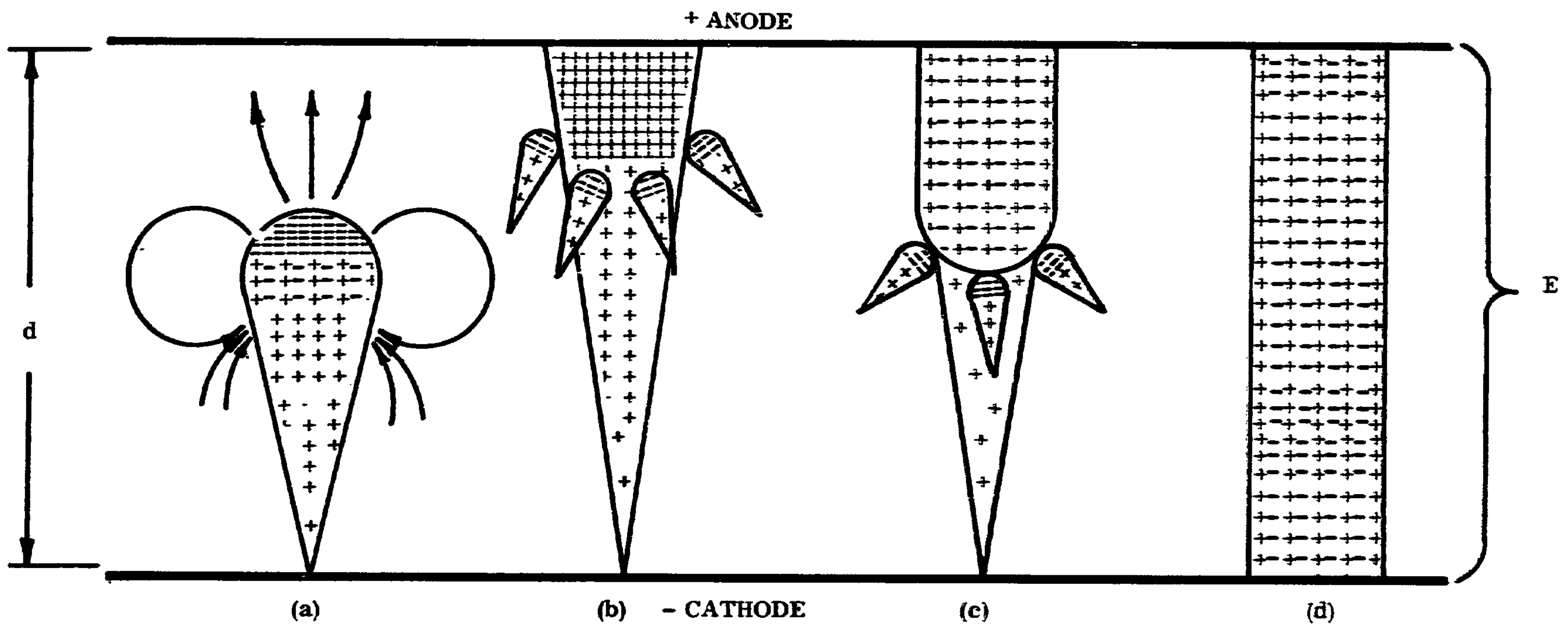


Figure 3-1. Transition from an Electron Avalanche to a Streamer and the Subsequent Growth of a Streamer across the Gap (Reference 38, Section 8)

There have been several expressions derived for the breakdown voltage of air. The following expression is given by Ritz for the variation of breakdown voltage with humidity, gas density, and gap length (reference 38, Section 8).

$$V = 6.66 \sqrt{d\rho} + \left[24.55 + 0.41\left(\frac{e}{10} - 1\right)\right] d\rho$$

where
- V = breakdown voltage
- d = gap length in cm
- ρ = gas density
- e = absolute humidity in mm Hg

Breakdown voltages measured and calculated by Ritz for gaps up to 1 cm are listed in Table 3-5. The breakdown voltage for gaps above 1 cm are given in Table 3-6, where they are compared with the values given by several investigators.

The breakdown voltages given in Tables 3-5 and 3-6 were measured with ac voltages, but the values may be considered to apply equally well to dc voltage breakdown. The results of several investigators (references 44, 45, and 46, Section 8) for dc breakdown agree with or show no noticeable deviation from the values plotted which were obtained with ac voltages. It may therefore be assumed that within the margins of experimental error no difference has yet been detected between the dc and ac breakdown voltages (reference 38, Section 8).

Reference 38, Section 8 provides the results of numerous investigations of breakdown voltages for parallel plates, gaps, sphere gaps, sphere-plane gaps, coaxial cylinders, point-plane gaps, point-point gaps and rod gaps.

The sphere gap is used internationally as an instrument for the measurement of the peak value of ac, dc, and impulse voltages, and calibration tables have been issued giving the breakdown voltages corresponding to different gap lengths between various sizes of spheres (references 43 and 47, Section 8). These tables include figures for spheres up to 200 cm in diameter and voltages up to 2.5 million volts. The breakdown characteristics have therefore been widely studied by numerous investigators (references 44, 45, 48, 49, 50, and 51, Section 8) with the result that many more data have been obtained concerning this type of gap than for the uniform - field gap between parallel plates. For small gaps between large spheres the breakdown characteristics are closely the same as for the uniform field, but with increasing spacing between the spheres the field loses its uniformity and the breakdown voltage falls below that for the uniform field. The greater the diameter of the spheres the greater is the gap length to which the spheres can be separated before the breakdown voltage falls below that for the uniform field.

Values for the ac breakdown voltages of a number of gaps in air at 760 mm Hg and 20°C for several sizes of spheres are given in Table 3-7.

Table 3-5. AC Breakdown Voltages in Uniform Fields in Air at 20°C and 760 mm Hg (Absolute Humidity of 10 mm Hg) (Reference 38, Section 8)

Gap in cm	Breakdown voltages in kV		Measured breakdown gradient in kV/cm
	Measured	Calculated	
0.06	3.13	3.10	52.16
0.07	3.49	3.48	49.86
0.08	3.84	3.85	48.06
0.09	4.18	4.21	46.44
0.10	4.54	4.56	45.40
0.12	5.23	5.26	43.58
0.15	6.25	6.26	41.67
0.2	7.90	7.89	39.50
0.3	11.02	11.01	36.73
0.4	14.01	14.03	35.03
0.5	17.0	16.98	34.0
0.8	25.7	25.60	32.13
1.0	31.35	31.21	31.35

Table 3-6. AC Breakdown Voltages in Uniform Fields in Air at 20°C and 760 mm Hg (Reference 38, Section 8)

Gap in cm	Breakdown voltage in kV				
	Schumann[1]	Ritz[2]	Holzer[3]	Bruce[1]	Sphere gap[5]
1	31.7	31.35	31.66	30.30	31.0
2	59.6	58.7	61.2	57.04	58
3	87.0	85.8	86.94	83.19	86
4	114.0	112.0	113.04	109.0	112
5	140.0	138.5	137.8	134.7	137
6	166.2	163.8	163.44	160.2	164
7	191.8	189.9	187.74	185.6	190
8	216.8	215.0	212.88	211.0	215
9	241.2	240.0	237.78	236.3	240
10	266.0	265.0	263.0	261.4	265
11	290.4	290.0	288.2	286.6	288
12	..	315.5	313.2	311.6	312
13	..	..	338.1	..	336
14	..	..	363.2	..	362
15	..	..	387.7	..	388
16	..	..	412.6	..	412

[1] Reference 40, Section 8
[2] Reference 39, Section 8
[3] Reference 41, Section 8
[4] Reference 42, Section 8
[5] Reference 43, Section 8

Table 3-7. AC Breakdown Voltages (in kv) of Gaps in Air at 20° and 760 mm Hg between Spheres of Different Diameters (References 43 and 38, Section 8)

Gap in cm.	Sphere diameter in cm					
	6.25	12.5	25	50	100	200
1	31.9	31.5	31	..	..	..
1.5	45.9	45.6	45	..	..	..
2	58.2	59.2	59	58	..	..
2.5	69.6	72.0	72	72	71	..
3	79.1	85.2	86	85	84	..
4	94.8	109	112	112	112	..
5	..	129	137	137	137	137
6	..	146	161	164	163	163
8	..	174	205	214	215	215
10	..	..	243	243	266	265
15	..	..	314	372	387	389
20	..	..	..	461	503	510
25	..	..	..	532	611	630
30	..	..	..	591	709	745
35	..	..	..	640	797	858
40	..	..	..	..	876	365
45	..	..	..	..	949	1,070
50	..	..	..	..	1,010	1,180
75	..	..	..	..	1,240	1,600
100	..	..	..	..	..	1,930
150	..	..	..	..	..	2,350

3.7 DEFINITIONS

The properties and characteristics of insulators are expressed in terms such as electric breakdown, dielectric constant, resistivity, etc. Some of these characteristics are summarized in the following paragraphs to provide a quick reference.

3.7.1 ELECTRIC BREAKDOWN

Electric breakdown occurs when the applied voltages can no longer be maintained across the material in a stable fashion without excessive flow of current or the physical disruption of the material (reference 1, Section 8). The factors involved are:

- Thickness
- Spacing
- Area
- Homogeneity
- Shape
- Conducting attachments
- Time
- Temperature
- Thermal aging
- Frequency of applied voltage
- Moisture
- Contamination

These factors must be considered together since each has an effect on the other. There are several types of electric breakdowns, and often two or more will occur at the same time. The types of breakdowns are:

- Intrinsic
- Thermal
- Physical-Defect
- Discharge

The applied voltage stress is called voltage breakdown and the gradient is referred to as the dielectric strength, breakdown stress, breakdown strength, or electric strength.

3.7.2 DIELECTRIC STRENGTH

Dielectric strength is the ratio of the dielectric breakdown voltage to the thickness of an insulating material. The dielectric breakdown voltage is the voltage at which electrical breakdown of a specimen of electrical insulating material between two electrodes occurs under prescribed conditions of test (type of voltage applied, method of application, electrode configuration, thickness of sample, temperature, etc.) (reference 18, Section 8).

Dielectric strength is expressed in voltage per unit thickness; i.e., volts/mil.

There are three different methods for applying the test voltage:

- Short-time test
- Step-by-step
- Slow-rate-of-rise time

Because each method will yield different results, it is necessary to know what method is used. Also, where specimens have a high breakdown voltage, oil is used as the surrounding medium and the value may not be comparable with values obtained in air.

3.7.3 DIELECTRIC CONSTANT

Dielectric constant (permittivity, ϵ' K' K) is defined as the ratio of the paralleled capacitance (C_x) of a given configuration of electrodes with an insulating material as the dielectric to the capacitance (C_v) of the same electrode configuration with a vacuum as the dielectric (reference 19, Section 8):

$$\epsilon' = \frac{C_x}{C_v}$$

In most materials the dielectric constant, a dimensionless number, will vary with frequency.

3.7.4 RESISTANCE

3.7.4.1 Insulation Resistance (R_i)

The insulation resistance between two electrodes that are in contact with, or embedded in, a specimen is the ratio of the direct voltage applied to the electrodes to the total current between them. It is dependent upon both the volume and surface resistances of the specimen (reference 17, Section 8).

3.7.4.2 Volume Resistance (R_v)

The volume resistance between two electrodes that are in contact with, or embedded in, a specimen is the ratio of the direct voltage applied to the electrodes to that portion of the current between them that is distributed through the volume of the specimen (reference 17, Section 8).

3.7.4.3 Surface Resistance (R_s)

The surface resistance between two electrodes that are on the surface of a specimen is the ratio of the direct voltage applied to the electrodes to that portion of the current between them which is primarily in a thin layer of moisture or other semiconducting material that may be deposited on the surface (reference 17, Section 8).

3.7.5 RESISTIVITY

3.7.5.1 Volume Resistivity

Volume resistivity (ρ_V) of a material is the ratio of the potential gradient parallel to the current in the material to the current density. The volume resistivity is numerically equal to the volume resistance in ohms between opposite faces of a 1 cm cube of the material (reference 17, Section 8);

$$\rho_V = \frac{R_V A}{x}$$

where R_V = volume resistance of material
A = cross-sectional area of material
x = length of material

Volume resistance may be expressed in any convenient terms of ohms and physical cube; i.e., ohm-cm, ohm-inches, megohm-inches, etc.

3.7.5.2 Surface Resistivity

Surface resistivity (ρ_s) of a material is the ratio of the potential gradient parallel to the current along its surface to the current per unit width of the surface. The surface resistivity is numerically equal to the surface resistance between two electrodes forming opposite sides of a square (reference 17, Section 8):

$$\rho_s = \frac{R_s x}{y}$$

where R_s = surface resistance
x = distance between electrodes
y = width of material between electrodes

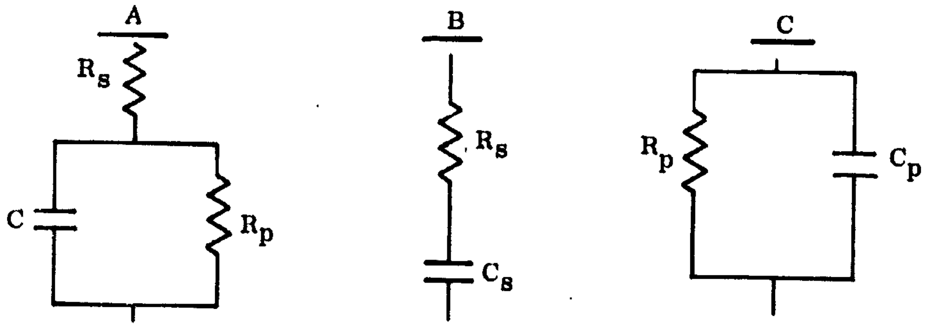
Surface resistivity is expressed in ohms (reference 52, Section 8).

3.7.6 ARC RESISTANCE

Arc resistance is the time required for an arc to track or to establish a conductive path (another term sometimes used to describe electrical breakdown characteristics of insulators when an electric discharge or arc is formed)(reference 1, Section 8). Arc resistance is expressed in seconds.

3.7.7 SCHEMATIC REPRESENTATION (Reference 1, Section 8)

An insulating material (dielectric) can be represented by a combination of lumped resistance and capacitance in several ways, such as the following:



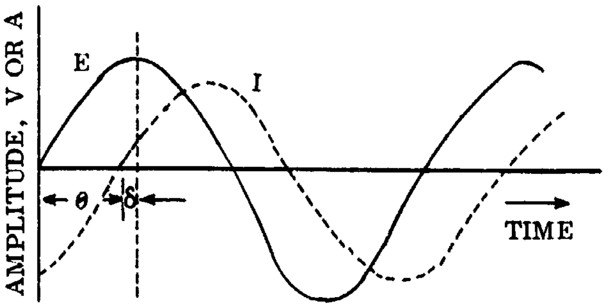
A = schematic representation of an insulating material (dielectric)
B = equivalent series circuit
C = equivalent parallel circuit

C = capacitance, R = resistance, and the subscripts P and S refer to parallel and series, respectively. The more complex (and realistic) relationship (A) can be simplified to the equivalent circuits shown in B and C. If voltage is suddenly applied to the series circuit, a current will flow (limit by the resistance) to charge the capacitance; as voltage (charge) builds up across the capacitance, the current will decrease. The "BETTER" the dielectric the lower the series resistance. In the parallel representation, in contrast, the higher the parallel resistance the loss current is bypassed or "leaked."

Some circuits used to determine the electrical characteristics of insulating materials actually measure the series case. However, the parallel representation is most commonly used, perhaps because in this case a "good" dielectric is represented by a high parallel resistance.

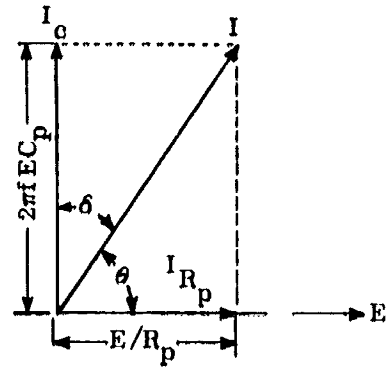
3.7.8 ALTERNATING VOLTAGE FACTORS (Reference 1, Section 8)

When an alternating voltage is applied to a "perfect" dielectric, a current will flow. The current will be displaced in time so that it is 90° out of phase with the voltage. Since no insulating material is perfect, the current actually leads the voltage by something less than 90°, as shown in Figure 3-2. The smaller the angle δ, the better the dielectric. Figure 3-3 shows the vector diagram of the current in a parallel representation of a dielectric.



E = voltage in volts
I = current in amperes
θ = phase angle
δ = loss angle

Figure 3-2. Temporal Relationship to Current to Voltage in an Imperfect Dielectric (Reference 1, Section 8)



E = voltage in volts

I = total current in amperes

I_c = capacitive component of current

I_{Rp} = resistive (loss) component of current

θ = phase angle (power factor angle)

δ = loss angle (phase defect angle)

f = frequency of applied voltage

C_p = parallel capacitance in farads

R_p = parallel resistance in ohms

Figure 3-3. Vector Diagram of the Current in a Parallel Representation of a Dielectric (Reference 1, Section 8)

The "quality" of the dielectric can be expressed by the ratio of the resistive to the capacitive component of the current as shown in Equation 3-1, where $\tan\delta = \cot\theta \approx \cos\theta$

$$\tan\delta = I_{Rp}/I_c = \text{dissipation factor}$$

(Equation 3-1)

for small values. Cos θ is the power factor, which is often referred to instead of the more appropriate dissipation factor.

The power loss in the dielectric can be expressed as shown in Equation 3-2.

$$\text{watts loss} = 2\pi f\, C_p\, \tan\delta\, E^2$$

(Equation 3-2)

Different materials with the same dimensions may exhibit different values of capacitance. The relative dielectric constant (permittivity) is defined by Equation 3-3:

$$\epsilon' = C_p/C_v$$

(Equation 3-3)

where C_p = parallel capacitance of the material and C_v = capacitance of a dimensionally equivalent vacuum. Using these factors it is possible to write the following dimensionless expression which is proportional to the total watts loss of Equation 3-2:

$$\text{watts loss} \approx \epsilon' \tan \delta = \epsilon'' = \text{relative loss index}$$

(ϵ'' is also known as the "loss factor"). The watts loss can also be shown to be proportional to the reciprocal of the parallel resistance (the ac conductance) which is, however, dependent upon the dimensions of the material.

In a more sophisticated approach it is usual to use complex quantities in handling periodic phenomena such as alternating voltage. In this case the factor $j = \sqrt{-1}$ represents an imaginary component oriented in the "+ j" axis (the vertical axis of the vector diagram shown in Figure 3-3). It is then possible to combine dielectric constant and loss index to give a complex dielectric constant, $\epsilon = \epsilon' - j\ \epsilon''$, of which the dielectric constant, ϵ', is the real part and the loss index, ϵ'', is the imaginary part.

In considering the influence of alternating voltage on insulating materials such as plastics, it is important to recognize that all of the conductance observed need not come from the migration of charge carriers in the material. An insulating material may contain bound charges or, under the influence of electrical stress, develop additional bound charges of various types which will be displaced to a limited extent by the action of the electric field. Such displacement constitutes an energy-consuming process which is dependent upon factors such as temperature and the frequency of the applied voltage. These polarization losses are measured as conductance.

3.7.9 ELECTRIC CHARGE

The electric charge q may be defined as an accumulation of an excess or deficit of electrons on an insulating (or insulated) body. The unit of the carge is normally referred to as coulomb.

3.7.10 FORCE BETWEEN CHARGES

Coulomb found that the force between two charges is inversely proportional to the square of the distance between them. This can be expressed in the mks (meter, kilogram, second) system as:

$$F = \frac{qq' \ \bar{r}}{4 \pi \epsilon_o \ r^2}$$

where: q and q' = point charges

r = the distance between q and q'

$\frac{1}{4\pi\epsilon_0}$ = an arbitrary constant determined by the choice of unit system

ϵ_0 = is called the permittivity of free space and is equal to 8.85×10^{-12} farad/m in the mks System.

$\bar{r}$ = a unit vector along r

F = the force on the charge of q' coulombs due to the charge q

The unit of charge in the mks system is called one coulomb.

3.7.11 ELECTROSTATIC UNITS (ESU) SYSTEM

In this system Coulomb's Law takes the form:

$$F = \frac{qq'}{r^2}$$

This unit of charge is called one statcoulomb and it is that charge which repels an equal charge of the same sign with a force of one dyne when the charges are separated by one centimeter:

$$1 \text{ coulomb} = 3 \times 10^9 \text{ statcoulombs}$$

3.7.12 ELECTRIC FIELD

An electric field E is defined as any region in which there would be a force upon a charge brought into the region and is expressed as:

$$E = \frac{F}{q}$$

where E and F are vectors the electric field vector at a point is referred to as the electric intensity (electric field strength, electric field intensity, field intensity) at that point.

3.7.13 CAPACITANCE

The capacitance C of a capacitor is defined as the ratio of the charge q on either plate to the potential difference V between the plates:

$$C = \frac{q}{V}$$

3.7.14 ELECTROSTATIC ENERGY

The energy stored in a capacitor can be expressed as:

$$W = 1/2\ CV^2$$

where: W = the energy in joules

C = the capacitance

V = the voltage

SECTION 4
MATERIAL CHARACTERISTICS

4.1 GENERAL

The theoretical properties and characteristics of the materials affecting electrostatics were discussed in Section 3 of this report. This section presents the electrical, chemical, mechanical, and physical properties and characteristics pertinent to the components of the XM15/XM165 and E8 clusters.

4.2 XM15/XM165 AND E8 COMPONENTS

Tables 4-1 through 4-13 contain material characteristic information for the following components of the XM15/XM165 and E8 clusters:

- XM15/XM165 Cluster
  - Table 4-1. DL14-23-1905, Canister Cluster, Chemical Agent XM15
  - Table 4-2. DL14-23-1887, Adapter, Canister Cluster Assembly XM43
  - Table 4-3. DL14-23-1926, Fuze, Mechanical Time, XM721
  - Table 4-4. DL14-23-1869, Canister Assembly, Erratic Dispersion, XM16
  - Table 4-5. DL14-23-1963, Packing Instruction for XM165 Canister Cluster Assembly
  - Table 4-6. DL14-23-1886, Canister Cluster Assembly, Chemical Agent XM165
  - Table 4-7. DL14-23-1945, Bolt, Explosive, XM1
- E8 Cluster
  - Table 4-8. E146-1-149, Launcher and Cartridge Chemical Agent, TAC CS, Portable, E8 Assembly
  - Table 4-9. E146-1-154, Launcher Tube, Fuze and Case Assembly
  - Table 4-10. DL146-1-49, Cartridge 35mm Riot Control, CS E23 "A" (also serves as DL146-1-50, 51 and 52)
  - Table 4-11. DL146-1-97, Manual Activator Assembly
  - Table 4-12. DL146-1-117, Launching Platform Assembly
  - Table 4-13. DL146-1-25, Harness Assembly

These tables are intended to serve as a centralized source of easily-extractable information for electrostatic evaluation and analysis. For the convenience of the user, the tables, which contain the items listed on the Subject Master Document List (DL), were arranged to be entirely compatible with the drawing system. Detailed information is presented in the tables as follows:

- Line Number - This heading refers to the individual line item number which corresponds to and is listed on the master material list; for example, Line No. 1 on Table 4-1 refers to Item No. 1 of LM14-23-1905. The dash numbers, such as 2-1 on Table 4-2, refer to the item numbers on the next lower drawing; for example, item 2 refers to C14-23-1904 and -1 is the first item on C14-23-1904.

- Description - This column/heading is utilized to describe the item number as it appears on the drawings.

- Specification - This column is used as reference to either a pertinent specification or the specific drawing number of the item as indicated in the material listing referred to in the two preceding columns.

- Material - This column describes the material as to either type, size, particle size, grade, density or whatever is deemed the most appropriate.

- Surface Resistivity - The surface resistivity of a material is the ratio of the potential gradient parallel to the current along its surface to the current per unit width of the surface, expressed in ohms on these tables. (Reference Section 3 for additional information.)

- Volume Resistivity - The volume resistivity of a material is the ratio of the potential gradient parallel to the current in the material to the current density, expressed in ohm - cm on these tables. (Reference Section 3 for additional information.)

- Dielectric Constant - The (relative) dielectric constant of a material is defined as the ratio of the capacitance of a given configuration of electrodes with the dielectric material filling the void between the electrodes to the capacitance of the same electrode configuration with the void left enpty. Some of the reference materials did not identify the test method employed, and in some cases the value was given only at one or two frequencies. Dielectric constants vary with frequency, but it is not feasible to include the total frequency range in this type of table. Therefore, only representative values (mostly at 60 Hz) were selected for the tables. (Reference Section 3 for additional information.)

- Dielectric Strength - The dielectric strength is the ratio of the dielectric breakdown voltage to the thickness of an insulating material, expressed in volts/mil on the tables. (Reference Section 3 for additional information.)

- Water Absorption - Water absorption is the ratio of the weight of water absorbed by a material to the weight of the dry material (reference 20, Section 8). The water absorption is expressed in percentage. Because of the nonporosity/nonabsorbic characteristics of ferrous materials the water absorption is basically non-existent and can be identified only as surface reaction.
- Temperature Coefficient of Resistance - The temperature coefficient of resistance is the resistance change per degree centigrade change.
- Triboelectric Series Number - The triboelectric series term stems from tribo-electricity which is a charge of electricity generated by friction (tribo meaning friction); columns I, II and III under this head refer to series I, series II, and series III in Table 3-3 of this report. The numbers in the column refer to the same number in Table 3-3. (Reference Section 3 for additional information.)
- Electrical Energy for Ignition - Electrical energy for ignition is the energy, measured in joules, that is required to ignite a pyrotechnic mixture.
- Arc Resistance - The arc resistance is the time required for an arc to track or to establish a conductive path. Arc resistance is expressed in seconds. (Reference Section 3 for additional information.)
- Reference - The numbers in this column refer to the references from which the information was obtained. The complete reference list is contained in Section 8.

4.3 INSULATING MATERIALS/PLASTICS

Plastics, the synthetic materials that are processed by molding or forming them to final shape, are the insulating materials most commonly utilized in the fabrication of the XM15/XM165 and E8 clusters. Chemically, plastics are composed of chainlike molecules of high molecular weight, called polymers.

There are about 40 basic families of plastics which are divided into two classes, thermoplastics and thermosets.

Thermoplastics are materials having a linear macromolecular structure that will repeatedly soften when heated and harden when cooled. Typical of the thermoplastics family are the styrene polymers and copolymers, acrylics, cellulosics, polyethylenes, vinyls, nylons, and various fluorocarbon materials.

Thermosets are materials that will undergo or have undergone a chemical reaction by the action of heat, catalysts, ultra-violet light, etc., leading to a relatively infusible and cross-linked state. Typical of the plastics in the thermosetting family are the epoxies, glyptals, melamines, ureaformaldehyde resins, and phenolics.

The resistivity of plastics as compared to rubber, mica, glass and porcelain is shown in Figure 4-1; Figure 4-2 compares the resistivities of several plastics. The dielectric strength of plastics as compared to rubber, mica, glass and porcelain is shown in Figure 4-3; Figure 4-4 compares the dielectric strength of several plastics.

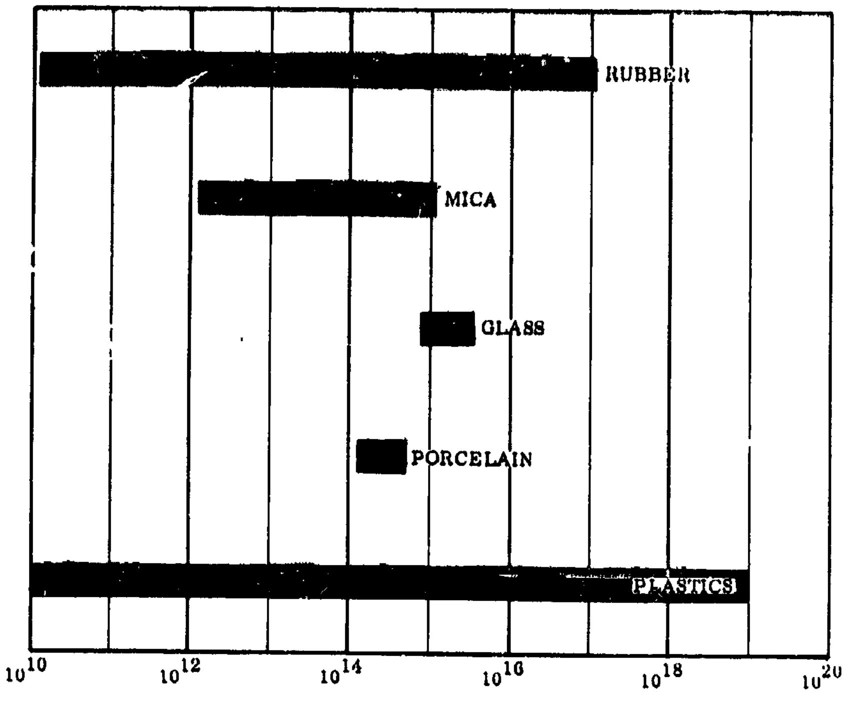


Figure 4-1. Resistivity of Plastics, Porcelain, Glass, Mica, and Rubber

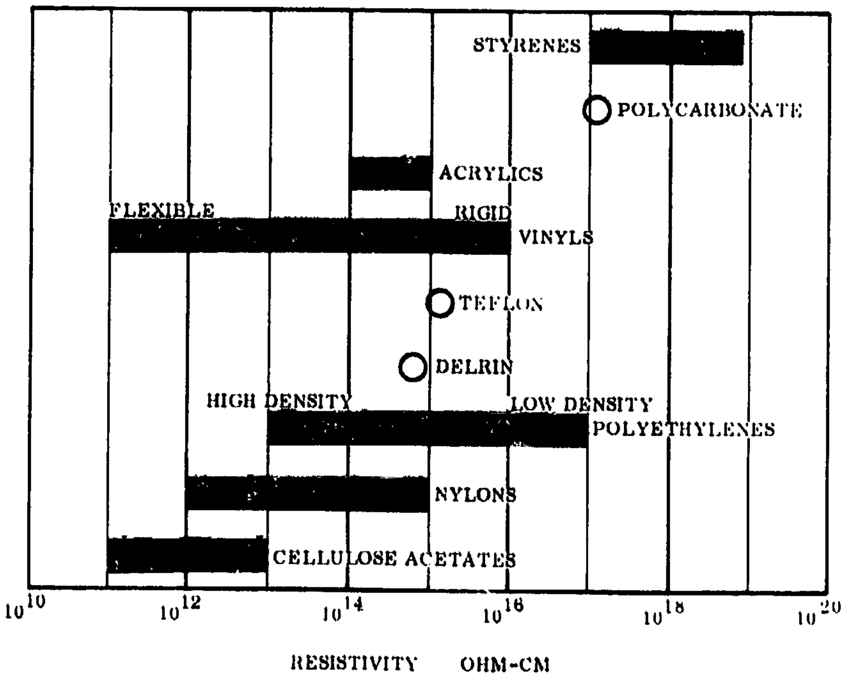


Figure 4-2. Resistivity of Some Plastics

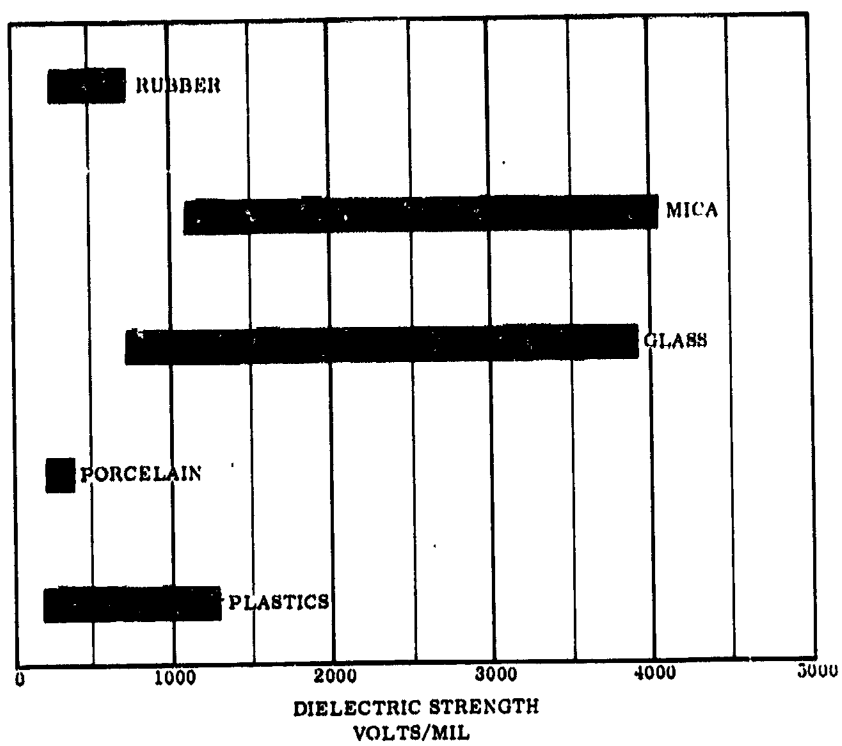


Figure 4-3. Dielectric Strength of Rubber, Mica, Glass, Porcelain, and Plastics

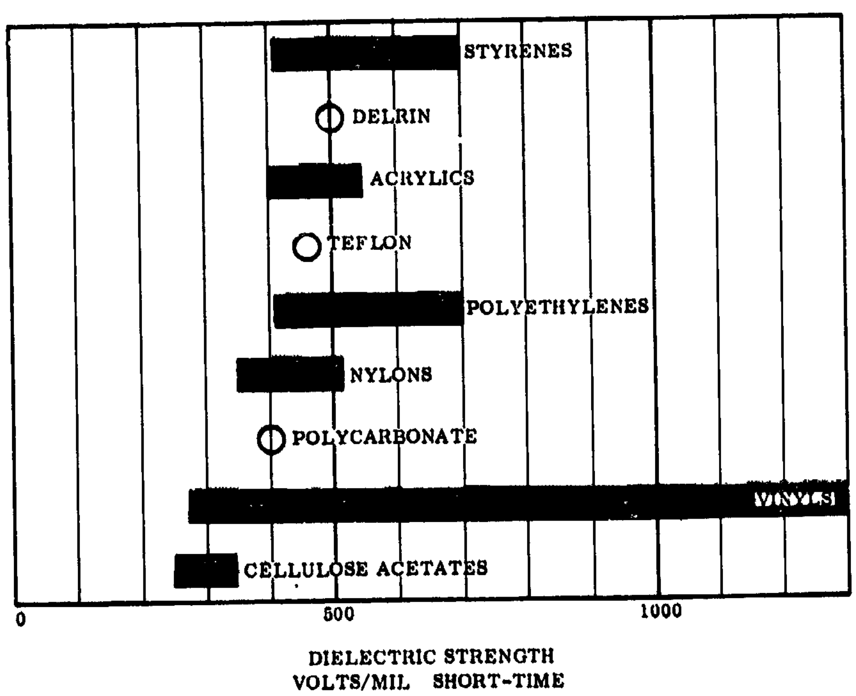


Figure 4-4. Dielectric Strength of Some Plastics

FOLDOUT FRAME I

Table 4-1. DL14-23-1905, Canister Cluster, Chemical Agent

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	[illegible] SERIES I	[illegible] SERIES II
1	Canister, Erractic Dispersion, XM16	See DL-14-23-1869	--	--	--	--	--	--	--	--	--
2	Lanyard, XM15 Cluster	C14-23-1914	--	--	--	--	--	--	--	--	--
2-1	Snap, Spring, Eye	--	Steel	--	$12x10^{-6}$	--	--	0	0.005	8	--
2-2 & 3	Pin and Cable	--	Stainless Steel	--	$12x10^{-6}$	--	--	0	0.005	8	22
2-4 & 5	Sleeve	--	Steel	--	$12x10^{-6}$	--	--	0	0.005	8	--
3 & 4	Shell Assembly,	D14-23-1907	--	--	--	--	--	--	--	--	--
4-1	Shell, Cluster	E14-23-1908	Plastic, Surlyn A1555	DRY 10^{16}	10^{15}	100KC & 1MC 2.4	(In Oil 30 Mil) 1000	1.4	--	--	--
4-2	Wire	QQ-W-00343	#AWG 18 Wire, Type S, uncoated	--	$1.7241x10^{-6}$	--	--	0	0.00393	6	21
5	Plate, Pusher, Cluster	F14-23-1909	Plastic, Surlyn A1555	DRY 10^{16}	10^{15}	100KC & 1MC 2.4	(In Oil 30 Mil) 1000	1.4	--	--	--
6	Cover, Shell	E14-23-1910	Plastic, Surlyn A1555	DRY 10^{16}	10^{15}	100KC & 1MC 2.4	(In Oil 30 Mil) 1000	1.4	--	--	--
7-14	Igniter Assembly	D14-23-1911	--	--	--	--	--	--	--	--	--
14-1	Bushing, Igniter	MIL-R-3065	Class SB608, Rubber	10^{17}	--	$2.3(10^{3}$ Hz)	600	--	--	--	--
14-2	Tube, Igniter	C-14-23-1913	Polystyrene L-P-396, Type I Class I	10^{18-19}	--	2.52 - 2.65 60 Hz	1/8" Thick 500	0.03 - 0.04	--	14 20	--
14-3	Fuse, Delay	C-14-23-1914	--	--	--	--	--	--	--	--	--
--	--	--	Sheath, Lead (Pb)	--	$22x10^{-6}$	--	--	0	0.0039	--	8
--	--		Delay Composition	--	--	--	--	--	--	--	--
--	--	--	Silicon (Si)	--	--	--	--	--	--	--	--
--	--	--	Boron (B)	--	--	--	--	--	--	--	--
--	--	--	Red Lead (Pb_3O_4)	--	--	--	--	--	--	--	--
14-4	Ignition Composition	C143-6-9	--	--	--	--	--	--	--	--	--
--	--	--	Zirconium (Zr) Grade G Avg. Particle Size 2.3 Microns	--	$40x10^{-6}$	12 at 10^{8} Hz	--	--	--	--	--
--	--	--	Molybdenum Trioxide (MoO_3) Powdered, Reagent Grade	--	--	--	--	--	--	--	--
--	--	--	Chromic Oxide, Sesqui (Cr_2O_3) Powdered, Reagent Grade	--	--	--	--	--	--	--	--
--	--	--	Ethyl Alcohol (C_2H_5OH) Denatured, Anhydrous Filmex A-1	--	--	--	--	--	--	--	--
14-5	Resin, Epoxy	--	Epoxy	$5x10^{14}$	$2x10^{14}$	4.0 60 Hz	1/8" Thick 450	0.10 - 0.30	--	15	--
14-6	Hardener, Epoxy	--	--	--	--	--	--	--	--	--	--
15	Fuse, Delay	Same as 14-3									
16) 17) 18)	Pad, Expulsion	D14-23-1915	Polyurethane, Polyester Foam, Nominal 2/lbs/Ft^3 Density	-- -- --	-- -- --	-- -- 1.05 60 Hz	-- --	-- -- 4% by WGT.	-- --	11 --	17 --
19	Charge Assembly, Expulsion	C14-23-1916	--	--	--	--	--	--	--	--	--
19-1	Bag, Plastic	C14-23-1917	Polyethylene 0.001" Thick L-P378, Type B	10^{16}	--	2.3 60 Hz	1/8" Thick 460-470	0.015 Immer.	--	21	19
19-2	Powder, Black	MIL-P-223	Potassium Nitrate - 74% Charcoal - 15-6% Sulfur - 10.4%	--	--	--	--	--	--	--	--

DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER I	II	III	ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	0	0.005	8	--	--	--	--	1,2	--
--	--	0	0.005	6	22	--	--	--	1,2	--
--	--	0	0.005	8	--	--	--	--	1,2	--
--	--	--	--	--	--	--	--	--	--	--
…KC & 1MC 2.4	(In Oil 30 Mil) 1000	1.4	--	--	--	--	--	Less than 90	7	Thermoplastic - Working Range -160°F to 150°F Dissipation Factor (Elec.) 100KC & 1MC = 0.0030
--	--	0	0.00393	8	21	14	--	--	--	Solid Copper Wire, 0.04030" DIAM. Area Cir Mils 1624 Resistance Ohms/1000 ft. = 6.385
…KC & 1MC 2.4	(In Oil 30 Mil) 1000	1.4	--	--	--	--	--	Less than 90	7	Thermoplastic - Working Range -160°F to 150°F Dissipation Factor (Elec.) 100KC & 1MC = 0.0030
…KC & 1MC 2.1	(In Oil 30 Mil) 1000	1.4	--	--	--	--	--	Less than 90	7	Thermoplastic - Working Range -160°F to 150°F Dissipation Factor (Elec.) 100KC & 1MC = 0.0030
--	--	--	--	--	--	--	--	--	--	--
…(10^3 Hz)	600	--	--	14	--	17	--	--	1,2	--
…2 - 2.65 60 Hz	1/8" Thick 500	0.03 - 0.04	--	20	--	--	--	--	1,5	Dissipation Factor (Electrical) 60 CPS=0.0001 - 0.0005
--	--	--	--	--	--	--	Thru Sheath 10 to 50	--	--	--
--	--	0	0.0039	--	8	6	--	--	1,2	M.P. 327°C
--	--	--	--	--	--	--	.0001 to .0002	--	9	--
--	--	--	--	--	--	--	--	--	--	Fuel (Si) Stabilizer
--	--	--	--	--	--	--	--	--	--	Fuel (B)
--	--	--	--	--	--	--	--	--	--	Oxidant (Pb_3O_4) Decomposes 500-530°C
--	--	--	--	--	--	--	--	--	--	--
…t 10^8 Hz	--	--	--	--	--	--	--	--	--	Fuel (Zr) Explosive Primer
--	--	--	--	--	--	--	--	--	--	Oxidant (MoO_3)
--	--	--	--	--	--	--	--	--	--	Oxide (Cr_2O_3) When heated suddenly decomposes @330°C
--	--	--	--	--	--	--	--	--	--	Solvent (C_2H_5OH)
…4.0	1/8" Thick 450	0.10 - 0.50	--	15	--	--	--	90	1,8	Di-Glycerol Ether, High Viscosity, Hardener and Resin Fast Curing System, No great amount of Filler
--	--	--	--	--	--	--	--	--	--	Di-Ethylene Amine
									--	--
--	--	--	--	11	17	--	--	--	6	Disipation Factor (Elec) 0.3-1.3 x 10^{-3} Temp. range to 250°F
-- .05	--	-- 4% by WGT.	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
…3	1/8" Thick 460-470	0.015 Immer.	--	21	19	--	--	Melts	1,5	--
--	--	--	--	--	--	--	--	--	--	See MIL P223 PC 2 for additional info.

FOLDOUT FRAME I

Table 4-1. DL14-23-1905, Canister Cluster, Chemical A

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOEL SERIES N I	II
20	Shell Ass'y, Center	D14-23-1918	--	--	--	--	--	--	--	--	--
20-1	Shell Ass'y.	Same as 3									
20-2	Plate, Cluster	D14-23-1919	Surlyn A1555	DRY 10^{16}	10^{15}	100KC & 1MC 2.4	(In Oil 30 Mil) 1000	1.4	--	--	--
20-3	Plastic	--	Surlyn A1555	DRY 10^{16}	10^{15}	100KC & 1MC 2.4	(In Oil 30 Mil)1000	1.4	--	--	--
20-4	Wire	OO-W-00343	AWG #18 Wire	--	1.7241×10^{-6}	--	--	0	0.00393	8	21
21	Pad, Spring	QQ-A-250/11	Aluminum, 6061 T_4 or T_6	--	2.828×10^{-6}	--	--	0	0.00496	8	11
22	End, Closure, Ass'y.	D14-23-1922	--	--	--	--	--	--	--	--	-
22-1	Shell, Closure	D14-23-1906	Plastic, Surlyn A1555	DRY 1×10^{16}	10^{15}	100KC & 1MC 2.4	(In Oil 30 Mil) 1000	1.4	--	--	
22-2	Plate, Cluster	Same as 20-2	--	--	--	--	-	--	--	--	--
22-3	--	QQ-W-00343	AWG #18 Wire	--	1.7241×10^{-6}	--	--	0	0.00393	8	21
23	Separator, Upper	QQ-S-698 Fin. #1	Steel Sheet, 1008-1020	--	12×10^{-6}	--	--	0	0.005	8	--
24	Spacer, Canister	D14-23-1924	Polyurethane Polyester Foam, 2lbs/Ft Density	--	--	60 Hz	--	4% by WGT.	--	11	17
25	Separator, Lower	QQ-S-698 Fin. #1	Sheet Steel, 1008-1020	--	12×10^{-6}	--	--	0	0.005	8	--
26	Fuze, Mechanical Time, XM721	See D14-23-1926	--	--	--	--	--	--	--	--	--
27)) 28)	Junction Block, Small	QQ-A-591 or QQ-A-200/8	Aluminum Aly Die Castings, Alloy Nos. 13 or A13 or AL Aly Bar 6061 or 6062	--	2.828×10^{-6}	--	--	0	0.00446	8	11
29	Junction Block, Large	QQ-A-591 or QQ-A-200/8	Aluminum Aly Die Castings, Alloy Nos. 13 or A13 or AL Aly Bar 6061 or 6062	--	2.828×10^{-6}	--	--	0	0.00446	8	11
30	Label, Identification, XM15 Cluster Metal Foil Adhesive Backed	MIL-P-19834	Aluminum Foil Adhesive Backed	--	2.828×10^{-6}	--	--	0	0.00446	8	--
31)) 32)	Pellet, Igniter, Junction Block	C14-23-1959	--	--	--	--	--	--	--	--	--
--	--	--	Ethyl Alcohol, Denatured, Anhydrous, Filmex A-1	--	--	--	--	--	--	--	--
--	--	--	Zirconium, (Gr) Grade G, Av. Particle Size-2.3 microns	--	--	--	--	--	--	--	--
--	--	--	Ferric Oxide(Fe_2O_3) Reagent Gr. Powder	--	--	--	--	--	--	--	--
--	--	--	Super Floss (Sil. Powder) Comm. Gr.	--	--	--	--	--	--	--	--
33	Key, Setting	MIL-A-2550	Corrosion Resistant Steel	--	12×10^{-6}	--	--	0	0.005	8	--
34	Screw, Machine	MS 35206-264	Carbon Steel, Cadmium Plated	--	$12x^{10-6}$	--	--	0	0.005	8	--
35	Streamer Ass'y, Warning	NAS1091-30H	Nylon Cord with Cotton Duck Cloth Streamer	--	--	N=3.5 @ 23°C, 10^6 Hz	--	At 24 Hr H_2O immersion N=1.5-2.0% C=7% @ 70°F & 65% RH	--	--	N=5 C=12
36	RTV-116 Red Self-Leveling Adhesive sealant	--	Specimen 24 Hrs. @ 75°F & 50% RH Silicone Rubber-RTV116 Gen. Elec. Co., Red-Pourable	--	3×10^{15}	2.8 60 Hz	0.058 in. Thickness 550 0.103 in. Thickness = 425	0.1	--	19	--
37	RTV-60 Silicone Rubber	--	Specimen 24 Hrs. @ 75°F & 50% RH (RED) Silicone Rubber-RTV600	--	13×10^{14}	3.7 60 Hz	0.049 in. Thick 600 0.075 in. Thick 500	0.1	--	19	--
38	Blue Silicone Primer	--	G. E. Co. SS4155	--	--	--	--	--	--	--	--

ECTRIC NSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER I	II	III	ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
--	--	--	--	--	--	--	--	--	--	--
										→
KC & 1MC 2.4	(In Oil 30 Mil) 1000	1.4	--	--	--	--	--	--	--	Thermoplastic - Working Range -160°F to 150°F Dissipation Factor 100KC & 1MC - 0.0030
KC & 1MC 2.4	(In Oil 30 Mil)1000	1.4	--	--	--	--	--	--	--	Thermoplastic - Working Range -160°F to 150F Dissipation Factor 100KC & 1MC - 0.0030
--	--	0	0.00393	8	21	14	--	-	1,2	Solid Copper Wire 0.04030" Diam. Area Cir Mils 1624, Resistance Ohms/1,000 ft. - 6.385
--	--	0	0.00496	8	11	8	--	--	1,2	--
--	--	--	--	--	--	--	--	--	--	--
KC & 1MC 2.4	(In Oil 30 Mil) 1000	1.4	--	--	--	-	--	Less than 90	7	Working Range - 160°F to 150°F Thermoplastic, Temperature Sensitive Dissipation Factor (Elec.) 100KC & 1MC 0.0030
--	--	--	--	--	--	--	--	--	--	--
--	--	0	0.00393	8	21	14	--	--	1,2	Solid Copper Wire 0.04030" Diam. - Area Cir Mils 1624 Resistance Ohms/1,000 ft. 6.385
--	--	0	0.005	8	--	11	--	--	1,2	--
Hz	--	4% by WGT.	--	11	17	--	--	--	6	Temp. Range to 250°F Dissipation Factor (Elec.) $0.3\text{-}1.3 \times 10^{-3}$
--	--	0	0.005	8	--	11	--	--	1,2	--
--	--	--	--	--	--	--	--	--	--	--
--	--	0	0.00446	8	11	8	--	10-120	1,2	--
--	--	0	0.00446	8	11	8	--	10-120	1,2	--
--	--	0	0.00446	8	--	--	--	--	1,2	--
--	--	--	--	--	--	--	Range of 0.01	--	9	--
--	--	--	--	--	--	--	--	--	--	Solvent (C_2H_5OH)
--	--	--	--	--	--	--	--	--	--	Oxident (FE_2O_3) Reacts With Aluminum
--	--	--	--	--	--	--	--	--	--	Oxident (FE_2O_3) Reacts with Alumimum
--	--	--	--	--	--	--	--	--	--	Stablizer (S_1) Reacts with Halogens
--	--	0	0.005	8	--	--	--	--	1,2	--
--	--	0	0.005	8	--	--	--	--	1,2	--
5 @ 23°C Hz	--	At 24 Hr H_2O immersion N=0.5-2.0% C=7% @ 70°F & 65% RH	--	--	N=5 C=12	--	--	--	1,2	N is Thermoplastic
z	0.058 in. Thickness 550 0.103 in. Thickness - 425	0.1	--	19	--	--	--	--	4,1	Range up to 500°F Dissipation Factor (Electrical) 60 CPS 0.0026 Self-Leveling Silcone
z	0.040 in. Thick 600 0.075 in. Thick 500	0.1	--	19	--	--	--	--	3,1	Brittle Point - 95°F Range - 75°F to 600°F Dissipation Factor (Electrical) 60 CPS = 0.020
--	--	--	--	--	--	--	--	--	--	Used as Primer for 600 Series RTV, Titanate Curing Mechanism (Also for 60 Series RTV)

FOLDOUT FRAME I

Table 4-1. DL14-23-1905. Canister Cluster, Chemical Agent

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES	
										I	II
39	Vacuum Sealant Tape, Type 579.6	--	Rubber	10^{17}	--	2.3 (10^3Hz)	600	--	--	14	--
40	Dibutyl Tin Dilaurate Curing Agent "Thermolite 12"	--	Chemical Catalyst	--	--	--	--	--	--	--	--
41	Lead Azide "Pyrocore", Type 2012	--	Lead Sheath with Lead Azide Core ($Pb(N_3)_2$) (2 Grains per Foot)	--	For Lead - $22x10^{-6}$	--	--	0	0.0039	--	8
42	Tape, Aluminum, Pressure Sensitive	L-T-80	Aluminum	--	$2.828x10^{-6}$	--	--	0	0.00446	8	11
43	Operator and Organizational Maint. Manual	DTM-3-1325 231-12	--	--	--	--	--	--	--	--	--
44	Tab, Fuse Retainer	MIL-S-794	Steel 1095, 0.020" Thickness	--	$12x10^{-6}$	--	--	0	0.005	8	--

05. Canister Cluster, Chemical Agent XM15 (cont'd)

FOLDOUT FRAME II R-062

...CTRIC ...TANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER			ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFER-ENCE	REMARKS
				I	II	III				
)	600	--	--	14	--	17	--	--	1,2	Range to 350°F Working Temp.
--	--	--	--	--	--	--	--	--	--	Dibutyl Tin Dilaurate $(C_4H_9)_2\ Sn(OOCC_{11}H_{23})2$ Used as a Catalyst For Polyurethane Foams and Resins; Condensation Catalyst; Stabilizer For Polyvinyl Chloride Resins.
-	--	0	0.0039	--	8	8	Only with pin point probe Centered exactly on cross section end - .0011	--	1,2	Ignition - 1/2 amp + squib or center align probe into $PB(N_3)_2$, GND sheath add 2000V.
-	--	0	0.00446	8	11	8	--	--	1,2	Sticky side is not conductive
-	--	--	--	--	--	--	--	--	--	--
-	--	0	0.005	8	--	11	--	--	--	--

FOLDOUT FRAME I

Table 4-2. DL14-23-1887, Adapter, Canister

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	[illegible]
1	Arming Wire Ass'y XM166	QQ-W-423, Cond. A	Stainless Steel, 302	--	$12x10^{-6}$	--	--	0	0.005	
2	Spring, Leaf	MIL-S-7947	Steel, 1095, Strip	--	$12x10^{-6}$	--	--	0	0.005	
3	Tube, Arming Wire	WW-T-700/6	Al, 6061, Drawn, Seamless Tube, T6	--	$2.828x10^{-6}$	--	--	0	0.00446	
4	End Clamp Ass'y Plate, Pin, Clamp	D-14-23-1691 QQ-S-764	Stainless Steel, Cres, 303 or 303SE	--	$12x10^{-6}$	--	--	0	0.005	
5	Clamp, Hinge, Cluster	QQ-A-200/9	Aluminum 6063, T6	--	$2.828x10^{-6}$	--	--	0	0.00446	
6	Pad, Swaybrace	QQ-A-200/8	Aluminum 6061, T6	--	$2.828x10^{-6}$	--	--	0	0.00446	
7	Pad, Swaybrace	QQ-A-200/8	Aluminum 6061, T6	--	$2.828x10^{-6}$	--	--	0	0.00446	
8	Adapter	QQ-A-200/8	Aluminum 6061, T6	--	$2.828x10^{-6}$	--	--	0	0.00446	
9	Tie Rod Ass'y Yoke - Tie Rod Retainer, Safety	E14-23-1901 QQ-S-763 QQ-S-766	Stainless Steel Stainless Steel	-- -- --	$12x10^{-6}$ $12x10^{-6}$	-- -- --	-- -- --	-- 0 0	-- 0.005 0.005	
10	Washer	AN 960P D416L	Aluminum Alloy Untreated Surface	--	$2.828x10^{-6}$	--	--	0	0.00446	
11	Washer	MS15795-807	Stainless Steel	--	$12x10^{-6}$	--	--	0	0.005	
12	Nut, Self Locking Ring Base	MS21042-4	Carbon Steel Cadmium Plated	--	$12x10^{-6}$	--	--	0	0.005	
13	Nut, Self Locking Ring Base	MS21042-08	Carbon Steel Cadmium Plated	--	$12x10^{-6}$	--	--	0	0.005	8
14	Clamp	MS21322-2	Alumium Alloy Alclad 2024 T-3 or T-4	--	$2.828x10^{-6}$	--	--	0	0.00446	8
15	Screw	MS24694-C15	Passivated Corrosion Resistant Steel	--	$12x10^{-6}$	--	--	0	0.005	8
16	Screw	MS24694-C29	Passivated Corrosion Resistant Steel	--	$12x10^{-6}$	--	--	0	0.005	8
17	Screw	MS24694-118	Carbon Steel Cadmium Plated	--	$12x10^{-6}$	--	--	0	0.005	8
18	Screw	MS35206-225	Carbon Steel Cadmium Plated	--	$12x10^{-6}$	--	--	0	0.005	8
19	Screw	MS35206-241	Carbon Steel Cadmium Plated	--	$12x10^{-6}$	--	--	0	0.005	8
20	Spacer	NAS43DD-45	2024 Aluminum, Anodized	--	$2.828x10^{-6}$	--	--	0	0.00446	8
21	Screw, Self Locking	NAS1190-04P4W	Carbon Steel Cadmium Plated	--	$12x10^{-6}$	--	--	0	0.005	8
22	Earless Clip	121002	Beryllium Copper Silver Plated	--	$1.7241x10^{-6}$	--	--	0	0.00393	8
23	Clamp	7502-F	Steel, Nickel Plated	--	$12x10^{-6}$	--	--	0	0.005	8
24	Spring, Compression, Adapter Steel, Music, Wire	QQ-W-470	Steel, Music, Wire	--	$12x10^{-6}$	--	--	0	0.005	8
25	Spring, Compression, Adapter Steel, Music, Wire	QQ-W-470	Steel, Music, Wire	--	$12x10^{-6}$	--	--	0	0.005	8
26	Primer	MIL-S-22473 GR N, Form 2	Surface Primer	--	--	--	--	--	--	--
27	Sealing Compound	MIL-S-22473-Grade CV	Sealing Compound	--	--	--	--	--	--	--
28	End Clamp	D14-23-1691 Same as 4	Stainless Steel 303 or 303SE	--	$12x10^{-6}$	--	--	0	0.005	8
29	Strap, Retaining - Cold Rolled	FF-S-760	Steel, Cold Rolled	--	$12x10^{-6}$	--	--	0	0.005	6
30	Thumb Screws - Style 1	FF-T-305	Carbon Steel Cadmium Plated	--	$12x10^{-6}$	--	--	0	0.005	8

DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER			ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFER-ENCE	REMARKS
				I	II	III				
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.00446	8	11	8	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.00446	8	11	8	--	--	1,2	--
--	--	0	0.00446	8	11	8	--	--	1,2	--
--	--	0	0.00446	8	11	8	--	--	1,2	--
--	--	0	0.00446	8	11	8	--	--	1,2	--
--	--	--	--	--	--	--	--	--	--	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.00446	8	11	8	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.00446	8	11	8	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.00446	8	11	8	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.00393	8	21	14	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	--	--	--	--	--	--	--	--	Primer, Normal (Ready To Use) Color - Green
--	--	--	--	--	--	--	--	--	--	Locking Torque (Inch-Pounds) 40/100 Viscosity (Centipoise) 100-250 Color Code Blue
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--
--	--	0	0.005	8	22	--	--	--	1,2	--

FOLDOUT FRAME I

Table 4-3. DL14-23-1926, Fuze, Mechanical Time, XM

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER		
										I	II	III
1	Fuze Mounting Plate	QQ-A-250/11	Aluminum 6061	--	2.828×10^{-6}	--	--	0	0.00446	8	11	8
2	Delay Fuze	C14-23-1914	See Item 14-3 on DL14-23-1905 Chart	--	--	--		--	--	--	--	--
3	Mounting Plate Clip	QQ-S-698	Steel, 1008-1020	--	--	--	--	--	0.005	8	22	--
4	Fuze, Firing Pin	QQ-S-764	Stainless Steel, 303 or 303I	--	--	--	--	0	0.005	8	22	--
5	Wire, Safety, Interrupter	C14-23-1928	Aircraft Wire, Solder, SN60B8	--	--	--	-	0	--	--	-	--
6	Interrupter Assembly	QQ-A-250/11-225/8	Aluminum 6061, T6	--	2.828×10^{-6}	-	--	0	0.00446	8	11	8
7	Slide Assembly, Detonator	C14-23-1932	--	--		-		-	--		-	
-	Slide Detonator	QQ-A-225/6	Aluminum 6061, T6	-	2.828×10^{-6}		-	0	0.00446	8	11	8
-	M55 Stab Detonator	-798331	--	--	-	-	-			--		
8	Plate, End, Fuze	QQ-A-250/11	Aluminum 6061, T6	--	2.828×10^{-6}	-	--	0	0.00446	8	11	8
9	Gasket Plate, End	MIL-R-3065	Rubber Sheet, Grade RN-115	10^{17}	--	$3\text{-}3(10^{3}Hz)$	*600	-	-	14	-	17
10	Spring, Slide	QQ-W-470	Steel Wire, Bright, Music	--	--	--	--	0	0.005	8	22	--
11	Initiator, Mech, Time, XM207	F823771	--	--	--	--	--	--	--	--	--	--
12	Housing, Fuze	QQ-A-200/8	Aluminum, T6,6061	--	2.828×10^{-6}	--	--	0	0.00446	8	11	8
13	Grommet, Fuze, Delay	ZZ-R-765	Silicone Rubber, CLIA GR70	2×10^{15}	--	$3\text{-}3.6(10^{3}Hz)$	--	--	--	19	--	--
14	Disc, Retainer, Safety Wire	ZZ-R-765	Silicone Rubber, CLIA 50 Shore and 70	2×10^{15}	--	$3\text{-}3.6(10^{3}Hz)$	575-700	--	--	19	--	--
15	Disc, Retainer, Safety Wire	ZZ-R-765	Silicone Rubber, CLIA70, Shore	2×10^{15}	--	$3\text{-}3.6(10^{3}Hz)$	575-700	--	--	19	--	--
16	Pellet, Igniter, Fuze	CA-23-1943	C143-9-10	--	--	--	--	--	--	--	--	--
--	--	MIL-S-230	Silicon,GR. II,Class C	--	-	13 @ 9.37 x 10^{9} Hz	--	--	--	--	--	--
--	--	TT-R-191	Red Lead Type I Grade 95	--	--	--	--	--	--	--	--	--
--	--	MIL-T-13405	Titanium	--	--	--	--	--	--	--	--	--
--	--	MIL-N-244	Nitrocellulose Grade D	--	--	--	--	--	--	--	--	--
--	--	O-A-51	Acetone	--	--	--	--	--	--	--	--	--
--	--	MIL-G-155	Graphite, Gr. I or II	--	800-1300 x 10^{-6}-	--	--	Sol. H_2O	--	--	--	--
--	--	--	Alcohol-Anhydrous, Denatured	--	--	--	--	--	--	--	--	--
17	Screw, Cap	MS 16997-19	Alloy Steel Cadmium Plated	--	--	--	--	0	0.005	8	22	--
18	Spring, Helical, Compression	MS24585-1045	Steel (Spring) Cadmium Plated	--	--	--	--	0	0.005	8	22	--
19	O-Ring	MS29513-13	Preformed Hydrocarbon Fuel Resistant "O" Ring	--	--	--	--	--	--	14	--	17
20	Screw	MS35206-214	Carbon Steel Cadmium Plated	--	--	--	--	0	0.005	8	22	--
21	Screw, Fillister Head	MS35266-16	Carbon Steel Cadmium Plated	--	--	--	--	0	0.005	8	22	--
22	Washer, Lock	MS35338-41	Carbon Steel Cadmium Plated	--	--	--	--	0	0.005	8	22	--
23	O-Ring Rubber, Synthetic	MIL-S-6855	Rubber, Synthetic CL I, GR 60	10^{17}	--	$3.3(10^{3}Hz)$	*600	--	--	14	--	17
24	Resin, Epoxy 2774	Union Carbide ERL2774, ERL 2793	--	Megohm at 50% RH and 73°F 5.5×10^{8}	Megohm CM at 50% RH and 73°F 2.0×10^{8}	at 73°F and 60 Hz 4.38	430 for 1/8" specimens	--	--	--	--	--
25	Hardner, Epoxy 2793 #80524)	(Code Ident.	--	--	--	--	--	--	--	--	--	--
26	Lubricant	MIL-L-4343	Lubricating Grease - Pneumatic System	--	--	--	--	--	--	--	--	--

...IC ...T	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER I	II	III	ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
	--	0	0.00446	8	11	8	--	--	1,2	--
	--	--	--	--	--	--	--	--	--	This item contained in DI. 14-23-1905 "Canister Cluster," Chemical Agent XM15
	--	--	0.005	8	22	-	--	--	1,2	--
	--	0	0.005	8	22	--	--	--	1,2	--
	--	0	--	--	--	--	--	--	--	Sn 60% Pb 40% (Solder)
	--	0	0.00446	8	11	8	--	--	1,2	--
	--	--	--	--	--	--	--	--	--	--
	-	0	0.00146	8	11	8	--	--	1,2	--
	--	--	--	--	--	--	--	--	—	
	--	0	0.00446	8	11	8	--	--	--	--
	*600	--	--	14	--	17	--	--	1,2	--
	--	0	0.005	8	22	--	--	--	1,2	--
	--	--	--	--	--	--	--	--	1,2	--
	--	0	0.00446	8	11	8	--	--	--	Clock-Timer
z)	--	--	--	19	--	--	--	--	1,2	--
2)	575-700	--	--	19	--	--	--	--	1,2	--
)	575-700	--	--	19	--	--	--	--	1,2	--
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	1,2	Non Metallic Element, Si, Fuel, Reacts with the Halogens
	--	--	--	--	--	--	--	--	--	PB_3O_4, Oxidant
	--	--	--	--	--	--	--	--	--	Metallic, Ti, Fuel, Dry Powder ignites in air above 250°C
	--	--	--	--	--	--	--	--	--	Easily accumulates static charges, when dry, extremely sensitive to shock and friction explosive. N 10-14% (10.5 to 12.2%. Prep's-12.5-13.5% used for explosive.)
	--	--	--	--	--	--	0.0006	--	33	CH_3COCH_3, Flash Point, (open cup) 15°F, Solvent.
	--	Sol. H_2O	--	--	--	--	--	--	--	Fuel, difficult to ignite, when ignited burns with intense heat
	--	--	--	--	--	--	--	--	--	Solvent, Thinner, C_2H_5OH, Flash Point 57°F, Filmex A-1 is trade name for 5 denatured alcohol, Flash Point - 64°F, Proof 191.20(60°F).
	--	0	0.005	8	22	--	--	--	1,2	--
	--	0	0.005	8	22	--	--	--	1,2	--
	--	--	--	14	--	17	--	--	1,2	--
	--	0	0.005	8	22	--	--	--	1,2	--
	--	0	0.005	8	22	--	--	--	1,2	--
	--	0	0.005	8	22	--	--	--	1,2	--
	*600	--	--	14	--	17	--	--	1,2	Resistant to fuel and petroleum oil
	430 for 1/8" specimens	--	--	--	--	--	--	90	23	Dissipation Factor At 73° And 60 Cycle = 0.0072
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	Used as a Rubber to Metal Lubricant. Silicone-Di-Ester oil blends are suitable for use as a liquid component of this grease.

FOLDOUT FRAME I

Table 4-4. DL14-23-1869, Canister Assembly, Erratic Dis

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER		
										I	II	III
1	Fuze, Orifice Ass'y	D14-23-1858	--	--	--	--	--	--	--	--	--	
1-1	Fuze, Time, Plastic Coated Type 3 Class 2	MIL-F-18215	--	--	--	--	--	--	--	--	--	
1-2	Rubber Orifice Blank Ass'y	MIL-S-6855	Rubber, Synthetic Class 2, GR, 80	--	--	--	--	0.1	--	14	--	1
			Mylar, Commercial Grade	10^{16}	--	2.3 10^3 HZ	480	0.1	--	23	19	
			Adhesive, No. 80	--	--	--	--	--	--	--	--	
1-4	Ring Stiffener	QQ-A-250/4	Aluminum Alloy 2024 Temper T3	--	2.828×10^{-6}	--	--	0	0.00446	8	11	
1-6	Tube, Igniter Fuze	B14-23-1874	Polypropylene 5560, Extruded Tubing	10^{16}	--	2.54 10^3 HZ	750	0.01	--	--	--	
1-7	Retainer, Fuze	QQ-A-250/1	Aluminum Alloy 1100, Temper 0	--	2.828×10^{-6}	--	--	0	0.00446	8	11	
1-8	Acetone	O-A-51	--	--	--	--	--	--	--	--	--	
1-9	Black Powder, Class 8	MIL-P-223	--	--	--	--	--	--	--	--	--	
1-10	Nitrocellulose GR, A, Type 1	MIL-N-244	--	--	--	--	--	--	--	--	--	
1-13	Ignition Composition	C143-8-9	--	--	--	--	--	--	--	--	--	
--	--	--	rconium, Grade G	40×10^{-6}	--	--	--	--	--	--	--	
--	--	--	Mo..odenum Trioxide, Powdered Reagent Grade (MoO_3)	--	--	--	--	--	--	--	--	
--	--	--	Chronic Oxide Sesqui, Powdered, Reagent Grade (CR_2O_3)	--	--	--	--	--	--	--	--	
--	--	--	Ethyl Alcohol, Denatured Anhydrous	--	--	--	--	--	--	--	--	--
2	Canister Loaded	C14-23-1873	--	--	--	--	--	--	--	--	--	--
2-1	Canister	C14-23-1872	Aluminum 1100F or Aluminum 1100 Temp. 0	--	2.828×10^{-6}	--	--	0	0.00446	8	11	8
2-2	CS-Pyro Mixture	C143-14-10	CS-Pyro Mixture	--	--	--	--	--	--	--	--	--
--	--	MIL-M-11361	Magnesium Carbonate GR. B	--	--	--	--	--	--	--	--	--
--	--	MIL-C-51029	CS, Chemical Agent	--	--	--	--	--	--	--	--	--
--	--	JJJ-S-791	Sugar, Type I	--	--	--	--	--	--	--	--	--
--	--	MIL-P-150	Potassium Chlorate Class 7, Grade B	--	--	--	--	--	--	--	--	--
--	--		Binder Solution	--	--	--	--	--	--	--	--	--
--	--	MIL-N-244	Nitrocellulose Grade D	--	--	--	--	--	--	--	--	--
--	--	O-A-51	Acetone	--	--	--	--	--	--	--	--	--
3	Markem Ink or Ind Marking Ink	7133/M GR1001	--	--	--	--	--	--	--	--	--	--
4	Ink Reducer	GR10531M	--	--	--	--	--	--	--	--	--	--

LECTRIC NSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER			ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
				I	II	III				
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	0.1	--	14	--	17	--	--	1,2	--
10^3 HZ	480	0.1	--	23	19	--	--	--	1,2	--
--	--	--	--	--	--	--	--	--		--
--	--	0	0.00446	8	11	8	--	--	1,2	--
10^3 HZ	750	0.01	--	--	--	--	--	--	--	--
--	--	0	0.00446	8	11	8	--	--	1,2	--
--	--	--	--	--	--	--	--	--	--	Solvent (CH_3COCH_3)
--	--	--	--	--	--	--	--	--	--	Made from potassium or sodium nitrate, charcoal, sulfur.
--	--	--	--	--	--	--	--	--	--	Easily accumulates static charge when dry. Explosive.
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	Fuel (Z) (Explosive Powder/Primer)
--	--	--	--	--	--	--	--	--	--	Oxidant (MoO_3)
--	--	--	--	--	--	--	--	--	--	Oxide (CR_2O_3) When heated suddenly dicomposes at 330°C
--	--	--	--	--	--	--	--	--	--	Solvent (C_2H_5OH)
--	--	--	--	--	--	--	--	--	--	--
--	--	0	0.00446	8	11	8	--	--	1,2	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	Additive ($Mg CO_3$)
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	Reducing Material ($C_{12}H_{22}O_{11}$)
--	--	--	--	--	--	--	--	--	--	Oxidant ($KCLO_3$) Sensitive to shock or heat.
--	--	--	--	--	--	--	--	--	--	N_2 10 to 14% (10.15% to 12.2% Prep's) (12.6% to 13.6%) used for explosives.) Easily accumulates static charges when dry. Extremely sensitive to shock and friction. Explosive.
--	--	--	--	--	--	--	--	--	--	
--	--	--	--	--	--	--	0.0006	--	33	Solvent ($CH_3CO CH_3$), Flash Point (Open Cup) 15°F
--	--	--	--	--	--	--	--	--	--	--
--	--	-	--	--	--	--	--	--	--	--

FOLDOUT FRAME 1

Table 4-5. DL14-23-1963, Packing Instruction for XM165 Canister Cl

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER		
										I	II	III
1	Nail, Cement Coated, Type II, Style 4	FF-N-105	Steel	--	12×10^{-6}	--	--	0	0.005	8	22	--
2-1	Panel Assembly, Side	--	--	--	--	--	--	--	--	--	--	--
2-1-1	Plywood 1/4 thk CS 35, GR A, Type I, GR. 3 or 4, Group B, PS Standard Int. with Ext. Glue	NN-P-530	--	--	--	--	--	--	--	--	--	11
2-1-2	Lumber	MIL STD 731, GR I, II, III	Lumber, Wood	--	--	--	--	--	--	--	--	11
2-1-3	Nail, 4 D, Cement Coated	FF-N-105, Type II, Style 4	Steel	--	12×10^{-6}	--	--	0	0.005	8	22	--
2-1-4	Preservative (Wood)	TT-W-572	Comp. A - Penta Chloro Phenol B - Copper Napthenate C - Copper Napthenate (High Conc.) D - Copper-8-Quinolinolate	--	--	--	--	--	--	--	--	--
2-2	Panel Assembly, Bottom	--	--	--	--	--	--	--	--	--	--	--
2-2-1	Lumber	MIL STD 731 Group I, II, III	Wood	--	--	--	--	--	--	--	--	11
2-2-2	Nail, Cement Coated, 10D	FF-N-105, Type II, Style 4	Steel	--	12×10^{-6}	--	--	0	0.605	8	22	--
2-2-3	Preservative	TT-W-572	Preservative	--	--	--	--	--	--	--	--	--
2-3	Panel Assembly End	--	--	--	--	--	--	--	--	--	--	--
2-3-1	Plywood 1/4 thk, CS 35, Group A, Type I, Grade 3 or 4, Group B, PS-1, Std. Int. with Ext. Glue	NN-P-530	Plywood	--	--	--	--	--	--	--	--	11
2-3-2	Lumber	MIL STD 731 Type I, II, III	Wood	--	--	--	--	--	--	--	--	--
2-3-3	Nail, 4D, Cement Coated, Type II, Style 4	FF-N0:-5	Steel	--	12×10^{-6}	--	--	0	0.005	8	22	--
2-3-4	Preservative	TT-W-572	Preservative	--	--	--	--	--	--	--	--	--
2-4	Panel Assembly, Top	--	--	--	--	--	--	--	--	--	--	--
2-4-1	Plywood 3/8 thk Group A, CS 35, Type I, Grade 3 or 4, Group B, PS I Std. Int. with Ext. Glue	NN-P-530	Plywood	--	--	--	--	--	--	--	--	11
2-4-2	Lumber	MIL STD 731	Wood	--	--	--	--	--	--	--	--	11
2-4-3	Nail, 4D, Cement Coated	FF-N-105 Type II, Style 4	Steel	--	12×10^{-6}	--	--	0	0.005	8	22	--
2-4-4	Preservative	TT-W-572	Preservative	--	--	--	--	--	--	--	--	--
3 thru 6	Pad, Cushioning	MIL-C-7769 Type IV	Cushioning Material, Hair, Fiber or Syn. Fiber and Binder Elastomeric Material. No Protein or Starch	--	--	--	--	--	--	--	--	--
7	Sleeve	PPP-F-320	Fiberboard, Corrugated, Type CF, CL Weather Resistant, Variety SW, Grade V3C	--	--	--	--	--	--	10	--	--
8	Cap Assembly, End	--	--	--	--	--	--	--	--	--	--	--
8-1	Fiberboard	PPP-F-320	Corrugated, Type CF, Class Weather Resistant, Variety SW GR V3C	--	--	--	--	--	--	10	--	--
8-2	Metal Fastener, Commercial Type	--	--	--	--	--	--	--	--	--	--	--

...TRIC ...TANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER			ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
				I	II	III				
	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 147[illegible] °C
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	11	--	--	1,2	Glue H_2O proof, type 1 - exterior H_2O proof (Gr. A)
	--	--	--	--	--	11	--	--	1,2	General classification, range - moisture content 12-19%
	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
	--	--	--	--	--	--	--	--		Comp. A TT-W-570 Comp. B & C & D AWPA Std. P8 Water repellent, wood preservative - pentachlorophenol
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	11	--	--	1,2	General classification, range - moisture content 12-19%
	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
	--	--	--	--	--	--	--	--	--	Comp. A TT-W-570. Comp. B-C-D AWPA Std. P8 Water repellent, wood preservative - pentachlorophenol
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	11	--	--	1,2	Glue H_2O proof, type 1 - exterior H_2O proof (Gr. A)
	--	--	--	--	--	--	--	--	1,2	General classification, range-moisure content 12-19%
	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
	--	--	--	--	--	--	--	--	--	Comp. A TT-W-570. Comp. B-C-D AWPA Std. P8 Water repellent, wood preservative - pentachlorophenol
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	11	--	--	1,2	Glue H_2O proof, type 1 - exterior H_2O proof (Gr. A)
	--	--	--	--	--	11	--	--	1,2	General classification, range-moisture content 12-19%
	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
	--	--	--	--	--	--	--	--	--	Comp. A TT-W-570. Comp. B-C-D AWPA Std. P8 Water repellent, wood preservative
	--	--	--	--	--	--	--	--	--	Hair requires not less than 0.50 nor more than 0.70% DDT. (Dichloro-Diphenyl-Trichloroethane)
	--	--	--	10	--	--	--	--	1,2	Single wall, thickness - corrugating medium 0.010" thickness - outer facing 0.023"
	--	--	--	--	--	--	--	--	--	--
	--	--	--	10	--	--	--	--	1,2	Single wall, thickness - corrugating medium 0.010" thickness - outer facing 0.023"
	--	--	--	--	--	--	--	--	--	--

Table 4-5

FOLDOUT FRAME I

Table 4-5. DL14-23-1963, Packing Instruction for XM165 Canister Clu

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER I	II	III	ELE ENE IGN
9	Bag, Barrier	MIL-B-117	Type I, Class E, Style I, Opaque, Polyethylene	10^{16}	--	2,3 60 Hz	1/8" Thick 460 - 470	0.015 (24 Hr. Immersion)	--	21	19	--	
10	Box Assembly, Interior	PPP-B-636	Style FTC, Type CF, Class Domestic, Variety SW, Grade 275, Fiberboard, Fab.	--	--	--	--	--	--	10	--	--	
11	Support Top	--	--	--	--	--	--	--	--	--	--	--	
11-1, 2,3,4	Plastic Foam	MIL-P-60312 Class I	Foam Density 2 PCF, Polystyrene, Foam	--	10^{16}	2,45 - 2,65 60 Hz	1/8" thick 500 - 700	0.03 - 0.05 (24 Hr. Immersion)	--	21	19	--	
11-5	Adhesive	MMM-A-260	Class 2, Water Resistant	--	--	--	--	--	--	--	--	9	
12 &	Filler	PPP-F-320	Fiberboard, Type CF, Class Domestic, Variety SW, Grade 275 Material	--	--	--	--	--	--	10	--	--	
14	Support, FWD End	--	--	--	--	--	--	--	--	--	--	--	
14-1, 2,3	Plastic Foam	MIL-P-60312 Class I	Foam Density 2 PCF Polystyrene	--	10^{16}	2,4 - 2.65 60 Hz	1/8" thick 500 - 700	0.03-0.05 (24 Hr. Immersion)	--	21	19	--	
14-4	Ink, Stencil	TT-I-559	Color Black	--	--	--	--	--	--	--	--	--	
14-5	Adhesvie	MMM-2-260 Class 2	--	--	--	--	--	--	--	--	--	9	
15	Support, FWD Side	--	--	--	--	--	--	--	--	--	--	--	
15-1, 2	Plastic Foam	MIL-P-60312 Class I	Foam Density 2 PCF, Polystyrene	--	10^{16}	2.45 - 2.65 60Hz	1/8" thick 500 - 700	0.03-0.05 (24 Hr. Immersion)	--	21	19	--	
15-3	Adhesive	MMM-A-260 Class 2	--	--	--	--	--	--	--	--	--	9	
16	Support, Aft Side	--	--	--	--	--	--	--	--	--	--	--	
16-1, 2	Plastic Foam	MIL-P-60312 Class I	Foam Density 2 PCF Polystyrene	--	10^{16}	2.45 - 2.65 60 Hz	1/8" thick 500 - 700	0.03 - 0.05 (24 Hr. Immersion)	--	21	19	--	
16-3	Adhesvie	MMM-A-260 Class 2	--	--	--	--	--	--	--	--	--	9	
17	Support, Aft End	--	--	--	--	--	--	--	--	--	--	--	
17-1, 2,3,	Plastic Foam	MIL-P-60312 Class I	Foam Density 2 PCF Polystyrene	--	10^{16}	2.45 - 2.65 60 Hz	1/8" thick 500 - 700	0.03 - 0.05 (24 Hr. Immersion)	--	21	19	--	
17-4	Adhesvie	MMM-A-260 Class 2	--	--	--	--	--	--	--	--	--	9	
18	Backing, End, Support	PPP-F-320	Fiberboard, Type SF, Grade and Class Optional	--	--	--	--	--	--	10	--	--	
19	Backing, Cushioning Pad	PPP-F-320	Fiberboard, Type SF, Grade and Class Optional	--	--	--	--	--	--	10	--	--	
23	Nail, 8D	FF-N-105 Type II, Style 4	Steel, Cement Coated	--	$12x10^{-6}$	--	--	0	0.005	8	22	--	
24	Dessiccant, Bagged	MIL-D-3464	Unit Size 16	--	--	--	--	--	--	--	--	--	
25	Tape	MIL-T-21595 Type II	Pressure Sensitive Adhesive, Paper	--	--	--	--	--	--	--	--	--	
26	Strapping, Flat	QQ-S-781, Type I, CLB, GR Opt	Steel, Zinc Coated Galvanized	--	$12x10^{-6}$	--	--	0	0.005	8	22	--	
27	Ink, Stencil	TT-I-559	Color, Black	--	--	--	--	--	--	--	--	--	
28-29	Bag, Plastic	L-P-378, Type I	Plastic, Normal Polyethylene	10^{16}	--	2.3 60 Hz	1/8" thick 460 - 470	0.015 (24 Hr. Immersion)	--	21	19	--	
30	Tape	PPP-T-76	Pressure Sensitive Adhesive, Paper	--	--	--	--	--	--	--	--	--	

DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS-MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER I	II	III	ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
2,3 60 Hz	1/8" Thick 460 - 470	0,015 (24 Hr. Immersion)	--	21	19	--	--	Melts	1,5	Mat'l. MIL-B-131
--	--	--	--	10	--	--	--	--	1,2	Single wall, bursting strength 275 lbs/in^2 (dry)
--	--	--	--	--	--	--	--	--	--	--
2,45 - 2,65 60 Hz	1/8" thick 500 - 700	0,03 - 0,05 (24 Hr. Immersion)	--	21	19	--	--	--	1,5	Type 1 colored, class 1 anti-static coated, type 2 natural & unpigmented
--	--	--	--	--	--	9	--	--	1,2	H_2O emulsion adhesive, paper back
--	--	--	--	10	--	--	--	--	1,2	Single wall, bursting strength 275 lbs/in^2 (dry)
--	--	--	--	--	--	--	--	--	--	--
2,4 - 2,66 60 Hz	1/8" thick 500 - 700	0,03-0,05 (24 Hr. Immersion)	--	21	19	--	--	--	1,5	Type 1 colored - class 1 anti-static coated, type 2 natural and unpigmented
--	--	--	--	--	--	--	--	--	--	For porous surfaces, toluidine toner
--	--	--	--	--	--	9	--	--	1,2	H_2O emulsion adhesive, paper back
--	--	--	--	--	--	--	--	--	--	--
2,45 - 2,65 60 Hz	1/8" thick 500 - 700	0,03-0,05 (24 Hr. Immersion)	--	21	19	--	--	--	1,5	Type 1 colored - class 1 anti-static coated, type 2 natural and unpigmented
--	--	--	--	--	--	9	--	--	1,2	H_2O emulsion adhesive, paper back
--	--	--	--	--	--	--	--	--	--	--
2,45 - 2,65 60 Hz	1/8" thick 500 - 700	0,03 - 0,05 (24 Hr. Immersion)	--	21	19	--	--	--	1,5	Type 1 colored - class 1 anti-static coated, type 2 natural and unpigmented
--	--	--	--	--	--	9	--	--	1,2	H_2O emulsion adhesive, paper back
--	--	--	--	--	--	--	--	--	--	--
2,45 - 2,65 60 Hz	1/8" thick 500 - 700	0,03 - 0,05 (24 Hr. Immersion)	--	21	19	--	--	--	1,5	Type 1 colored - class 1 anti-static coated, type 2 natural and unpigmented
--	--	--	--	--	--	9	--	--	1,2	H_2O emulsion adhesive, paper back
--	--	--	--	10	--	--	--	--	1,2	Type and thickness optional
--	--	--	--	10	--	--	--	--	1,2	Type and thickness optional
--	--	0	0,005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
--	--	--	--	--	--	--	--	--	--	Static dehumidification, non-dusting, non-deliquescent
--	--	--	--	--	--	--	--	--	--	Masking tape on lacquer finish, flat type
--	--	0	0,005	8	22	--	--	--	1,2	--
--	--	--	--	--	--	--	--	--	--	Opaque, for porous surface, miscible with mineral spirits, should contain no benzol, aniline oil, chlorinated compounds or any other toxic materials.
2,3 60 Hz	1/8" thick 460 - 470	0,015 (24 Hr. Immersion)	--	21	19	--	--	Melts	1,5	Low and medium density
--	--	--	--	--	--	--	--	--	--	H_2O proof, 100% sulfate craft paper, range - 65 to 160°F, coated on 1 side with water resistant homogeneous adhesive

FOLDOUT FRAME I

Table 4-6. DL14-23-1886. Canister Cluster Assembly Chemi

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELE SERIES N I	II
1	Clip, Safety	MIL-A-10982	Phosphor Bronze	--	4.6×10^{-6}	--	--	0	0.00145	8	21
2	Adapter, Canister Cluster Assembly, XM43	--	--	--	--	--	--	--	--	--	--
3	Lanyard, XM15 Cluster	--	--	--	--	--	--	--	--	--	--
4	Canister Cluster, Chemical Agent XM15	--	--	--	--	--	--	--	--	--	--
5	Bolt, Explosive XM1	--	--	--	--	--	--	--	--	--	--
6	Bracket, Retaining Cluster	QQ-A-225/8 or QQ-A-200/8	Aluminum 6061, T6	--	2.828×10^{-6}	--	--	0	0.00446	8	11
7-8	Wiring Harness UH-1B Helicopter	--	--	--	--	--	--	--	--	--	--
7-8-1-2	Thermofit Tube No. RNF-100-3/8 Type 1	--	--	--	--	--	--	--	--	--	--
7-8-3-4	Coaxial Cable Plug, Series BNC	--	--	--	--	--	--	--	--	--	--
7-8-5	Cable Connecting Plug Assembly	--	--	--	--	--	--	--	--	--	--
7-8-6	Sleeve, Shield	--	--	--	--	--	--	--	--	--	--
7-8-7	Marking Foil	--	--	--	--	--	--	--	--	--	--
7-8-8	Awg #20 Gage 19 Strand Wire	MIL-W-16878	Copper Wire, Soft Annealed (QQ-W-473)	--	1.7241×10^{-6}	--	--	0	0.00393	8	21
7-8-9	Sealing Compound	MIL-1-16923 Type C	Insulating Compound, Electrical Imbedding	--	10^{12}	7.0, 23°C 60 CPS	275	1.0 Max	--	--	--
7-8-10	Solder, SN 60 WRAP	QQ-S-571	Solder, SN 60 WRAP	--	--	--	--	--	--	--	--
9	Label, Identification, XM165 Cluster Ass'y	MIL-P-19834	Metal Foil, Adhesive Backed Type II, Aluminum	--	2.828×10^{-6}	--	--	0	0.00446	--	--
10	Clamp Ass'y	--	--	--	--	--	--	--	--	--	--
10-1	Steel Strip	QQ-S-698	Steel Strip, 1/2 H, No. 2 Temper, 1008 - 1020	--	12×10^{-6}	--	--	0	0.005	8	--
10-2	Rivet	MS20427-406	Carbon Steel, Cadmium Plated	--	12×10^{-6}	--	--	0	0.005	8	--
10-3	Receptacle, Dimpled Rivet Hole	MIL-F-5591 Style 1, Size 5, Class B, Type III	Fastener, Ring Head Corr. Res. Steel	--	12×10^{-6}	--	--	0	0.005	8	--
10-4	Weld Pin	--	--	--	12×10^{-6}	--	--	0	0.005	8	--
11	Clamp, Safety	--	--	--	--	--	--	--	--	--	--
11-1	Steel Strip	QQ-S-698	Steel Strip, 1/2 H, No. 2 Temper, 1008 - 1020	--	12×10^{-6}	--	--	0	0.005	8	--
11-2	Weld Pin	--	--	--	12×10^{-6}	--	--	0	0.005	8	--
11-3	Ink, Stencil	TT-1-558	Color, Black	--	--	--	--	--	--	--	--
12	Wiring Harness 0-1 Aircraft	--	--	--	--	--	--	--	--	--	--
12-1-2	Insulation Tubing and Sleeving	--	--	--	--	--	--	--	--	--	--
12-3-4	Plug, Series BNC Coaxial Cable	--	--	--	--	--	--	--	--	--	--
12-5-6	STA-KON Terminal	--	--	--	--	--	--	--	--	--	--
12-7-8	Receptacle, Cable Connecting Plug, Quick Disconnect	--	--	--	--	--	--	--	--	--	--
12-9	Grommet	MIL-G-16491	Metallic No. 0, Type 1, Class 5, Aluminum	--	2.828×10^{-6}	--	--	0	0.00446	8	11

...TY (...M)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER I	II	III	ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
	--	--	0	0.00145	8	21	14	--	--	1,2	M.P. 1045 °C Composition D, 0.025" Thick, QQ-B-750 Temper
	--	--	--	--	--	--	--	--	--	--	See DL-14-23-1887
	--	--	--	--	--	--	--	--	--	--	See C-14-23-1904 of DL-14-23-1905
	--	--	--	--	--	--	--	--	--	--	See DL-14-23-1905
	--	--	--	--	--	--	--	--	--	--	See DL-14-23-1945
6	--	--	0	0.00446	8	11	8	--	--	1,2	M.P. 660 °C
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
-6	--	--	0	0.00393	8	21	14	--	--	1,2	--
	7.0, 23°C 60 CPS	275	1.0 Max	--	--	--	--	--	--	--	Type C - Thermal and Shock Resistant, to 130°C for short time operation, H_2O vapor permeability (Gm/Hr/Cm) 20×10^{-6} dissipation factor 23°C 60 cps 0.3 max.
	--	--	--	--	--	--	--	--	--	--	SN 60%, PB 40%
	--	--	0	0.00446	--	--	--	--	--	1,2	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	0	0.005	8	--	11	--	--	1,2	--
	--	--	0	0.005	8	--	11	--	--	1,2	--
	--	--	0	0.005	8	--	11	--	--	1,2	--
	--	--	0	0.005	8	--	11	--	--	1,2	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	0	0.005	8	--	11	--	--	1,2	--
	--	--	0	0.005	8	--	11	--	--	1,2	--
	--	--	--	--	--	--	--	--	--	--	Used on non-porous surface, weather resistant, Flat finish ink.
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	0	0.00446	8	11	8	--	--	1,2	--

FOLDOUT FRAME I

Table 4-6, DL14-23-1886, Canister Cluster Assembly, Chemical

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES N	
										I	II
12-10	Marking Foil	--	--	--	--	-	--	--	--	--	--
12-11	AWG #20 Gage 19 Strand Wire	MIL-W-16878	Copper Wire, Soft, Annealed (QQ-W-473)	--	$1.7241x10^{-6}$	--	--	0	0.00393	8	21
[illegible]	Solder	QQ-S-571	SN 60, WRAP, Solder	--	--	--	--	0	--	--	--
13	Wiring Harness UH-1E Helicopter	--	--	--	--	--	--	--	--	--	--
13-1	Connector, Plug, Electric, Straight	MS3106A14S-8P	--	--	--	--	--	--	--	--	--
13-2-3	Plug, Series BNC Coaxial Cable	--	--	--	--	--	--	--	--	--	--
13-4	Sleeve, Shield	--	--	--	--	--	--	--	--	--	--
13-5	Potting End Bell	--	--	--	--	--	--	--	--	--	--
13-6	Insulation Tubing	--	--	--	--	--	--	--	--	--	--
13-7	Marking Foil	--	--	--	--	--	--	--	--	--	--
13-8	AWG #20 Gage 19 Strand Wire	MIL-W-16878	Copper Wire, Soft, Annealed (QQ-W-473)	--	$1.7241x10^{-6}$	--	--	0	0.00393	8	21
13-9	Solder	QQ-S-571	SN 60, WRAP	--	--	--	--	0	--	--	--
13-10	Sealing Compound	MIL-I-16923, Type C	--	--	--	--	--	--	--	--	--
14	Key, Setting	FB55733	--	--	--	--	--	--	--	--	--
15	Washer	AN 960-PD-416L	Aluminum	--	$2.828x10^{-6}$	--	--	0	0.00446	8	11
16	Lug, Suspension	MS3314	Steel, 4340, Cadmium Plate	--	$12x10^{-6}$	--	--	0	0.005	8	23
17	Washer	MS15795-812	Stainless Steel	--	$12x10^{-6}$	--	--	0	0.005	8	22
18	Wire, Lock	MS20995-C47	Safety Wire, Corr. Res.	--	$12x10^{-6}$	--	--	0	0.005	--	--
19	Streamer Ass'y Warning	NAS 1091-30H	Nylon Cord with Cotton Duck Cloth Streamer	--	--	N=3.5 @ 23°C, 10^6 Hz	--	24 Hr. H_2O Immersion N=0.5-2.0 C=7 @ 70°F, 65% RH	--	--	N=5 C=12
20	Screw	NAS 1190-06PG	Carbon Steel, Cadmium Plated	--	$12x10^{-6}$	--	--	0	0.005	8	22
21	Screw	NAS 1190-4P10L	Carbon Steel, Cadmium Plated	--	$12x10^{-6}$	--	--	0	0.005	8	22
22	Fastener, Wing Head	MIL-F-5591 Style 1	Class B, Type III, Fastener, Wing Head, Corr. Res. Steel	--	$12x10^{-6}$	--	--	0	0.005	8	22
23	Nylon, Wear Washer	65-46-101-41	Nylon	--	--	3.5 @ 23°C 10^6 Hz	--	24 Hr. H_2O 0.5 - 2.0 70°F, 65% RH	--	--	5
24	Nut, Self Locking	29NU058	--	--	--	--	--	--	--	--	--
25	Technical Manual	DTM3-1325-231-12	--	--	--	--	--	--	--	--	--
26	Shield, End Clamp	QQ-A-25-/11	Aluminum Alloy 6061 Temper T6	--	$2.828x10^{-6}$	--	--	0	0.00446	8	11
27	Screw, Machine	MS35206-241	Steel, Carbon, Cadmium Plated	--	$12x10^{-6}$	--	--	0	0.005	8	22
28	Primer, Grade N, Form 2	MIL-S-22473	Surface Primer	--	--	--	--	--	--	--	--
29	Sealing, Compound, Grade CV	MIL-S-22473	Sealing Compound	--	--	--	--	--	--	--	--

[D]IELECTRIC [C]ONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER I	II	III	ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
--	--	--	--	--	--	--	--	--	—	--
--	--	0	0.00393	8	21	14	--	--	1,2	—
--	--	0	--	--	--	--	--	--	—	SN 60%, PB 40%
--	--	--	--	--	--	--	--	--	—	--
--	--	--	--	--	--	--	--	--	—	AN Type
--	--	--	--	--	--	--	--	--	—	--
--	--	--	--	--	--	--	--	--	—	--
--	--	--	--	--	--	--	--	--	—	--
--	--		--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	0	0.00393	8	21	14	--	--	1,2	--
--	--	0	--	--	--	--	--	--	--	SN 60%, PB 40%
--	--	--	--	--	--	--	--	--	—	--
--	--	--	--	--	--	--	--	--	—	--
--	--	0	0.00446	8	11	8	--	--	1,2	M.P. 660°C
--	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
--	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
--	--	0	0.005	--	--	--	--	--	--	--
[illegible].5 @ [illegible]°C, [illegible] Hz	--	24 Hr. H_2O Immersion N=0.5-2.0 C=7 @ 70°F, 65% RH	--	--	N=5 C=12	--	--	--	1,2	N is Thermoplastic
--	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
--	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
--	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
[illegible] @ 23°C [illegible] Hz	--	24 Hr. H_2O 0.5 - 2.0 70°F, 65% RH	--	--	5	--	--	--	1,2	Thermoplastic
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	0	0.00446	8	11	8	--	--	1,2	M.P. 660°C
--	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
--	--	--	--	--	--	--	--	--	--	Primer, Normal (Ready to use) Color - Green
--	--	--	--	--	--	--	--	--	--	Locking torque (inch-pounds) 40/100 Viscosity (centipoise) 100-250, Color code blue

FOLDOUT FRAME I

Table [illegible]

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELEC[TRIC] SERIES NUM[BER] I	II
1	Detonator and Holder Assembly	QQ-S-634	Steel C1010-C1020	--	12×10^{-6}	--	--	0	0.005	8	22
2	Bolt	MIL-S-500	Steel 4340	--	12×10^{-6}	--	--	0	0.005	8	22
3	Firing Pin	QQ-S-764	Stainless Steel 303 or 303 SF	--	12×10^{-6}	--	--	0	0.005	8	22
4	Lead Cup	MIL-C-21768	Copper, 210, Annealed	--	1.7241×10^{-6}	--	--	0	0.00393	8	22
5	Plug, Explosive Bolt	QQ-S-634	Steel C101-1020	--	12×10^{-6}	--	--	0	0.005	8	22
6	Detonator, Stab	M55 Assembly	--	--	--	--	--	--	--	--	--
7	Wire, Lock	MS20995 C32	Corrosion Resistant Steel	--	12×10^{-6}	--	--	0	0.005	8	22
8	Spring, Compression	MS24585-1046	Carbon Steel, Cadmium Plated	--	12×10^{-6}	--	--	0	0.005	8	22
9	Adhesive	--	Adhesive	--	--	--	--	--	--	--	--
10	Adhesive	--	Adhesive	--	--	--	--	--	--	--	--
11	Rubber, Silicone-RTV60	--	Silicone Rubber	1.3×10^{14}	--	3.70 60 Hz	0.040" Th 600 0.075" Thick 500	0.10	--	19	--
12	Catalyst 15	--	Catalyst	--	--	--	--	--	--	--	--
13	Sealant 2741	Stycast 2741	Epoxide Casting Resin	1.0×10^{14}	--	3.20 100 Hz	420	0.10 - 0.50	--	15	--
14	Primer	SS-4155	RTV Silicone Rubber Primer	--	--	--	--	--	--	--	--

RIC NT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER			ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
				I	II	III				
	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
	--	0	0.00393	8	22	14	--	--	1,2	M.P. 1063°C
	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
	--	--	--	--	--	--	--	--	--	--
	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
	--	0	0.005	8	22	--	--	--	1,2	M.P. 1300 - 1475°C
	--	--	--	--	--	--	--	--	35	Cure schedule 2 hrs. at 165°F Bond strength 2000 PSI
	--	--	--	--	--	--	--	--	35	Cure schedule 2 hrs. at 165°F Bond strength 2000 PSI
	0.040" Thick 600 0.075" Thick 500	0.10	--	19	--	--	--	--	1,3	Brittle point - 95°F, temperature range - 75°F to 600°F. Dissipation factor (elec.) 60 CPS = 0.020
	--	--	--	--	--	--	--	--	34	This catalyst used with stylcast 2741
	420	0.10 - 0.50	--	18	--	--	--	--	34	Temp. range -70°C to +150°C. Can cure in 8 hrs. at room temp. Rapid cure 112 hrs. at 70°C. Flexibility & hardness controlled by amount of catalyst.
	--	--	--	--	--	--	--	--	--	Used as a primer for 60 - 600 series RTV. Titanate curing mechanism.

FOLDOUT FRAME 1

Table 4-8. E146-1-149, Launcher and Cartridge Chemical Agent, TAC CS, Port

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECT SERIES NUMB	
										I	II
1	Harness Assembly	See C146-1-25 Sheet	--	--	--	--	--	--	--	--	--
2	Housing Cover Assembly	C146-1-72	--	--	--	--	--	--	--	--	--
2-1	Housing Cover	--	Royalite, No. 40-1211-RL, Solid HC/M Color Olive Drab, (Non Glare Surface) .062 ± .006 thk	--	2.9×10^{12}	5.9 60 Hz	389	0.4 - 0.5	--	14	--
2-2	Firing Tables Instr Plate	MIL-P-19834	Metal Foil, Adhesive Backed, Type 1	--	2.828×10^{6}	--	--	0	0.00446	8	11
2-3	Fastener, Pile Tape	MIL-F-21840	Nylon, Type II	--	10^{12}-10^{15}	3.5 @ 23°C 10^{6} Hz	--	0.5 - 2.0% (24 Hr.)	--	12	5
2-4	Methyl-Ethyl-Ketone	TT-M-261	Colorless Liquid	--	--	--	--	--	--	--	--
2-5	Cement	--	Bordens Cement No. SY-330	--	10^{11}-10^{15}	5 - 9 60 Hz	Short Time 300-1000 Step-by-Step 275-900	0.15 - 0.75	--	--	18
3	Module Assembly	D146-1-150	--	--	--	--	--	--	--	--	--
3-1	Module Loading	E146-1-153	--	--	--	--	--	--	--	--	--
3-1-1 thru 4	Cartridge, 35MM Riot Control, CS	--	See D146-1-49, 50, 51, and 53 Sheets	--	--	--	--	--	--	--	--
3-1-5	Filler Cap	MIL-P-40619	Plastic Material, Cellular Polystyrene Type 1, Class 2, Grade B	--	10^{16}	2.45 - 2.65 60 Hz	1/8" Thick 500 - 700	0.03 - 0.05 24 Hr.	--	20	--
3-1-6	Launcher Tube, Fuze & Case Assembly	--	See 146-1-154 Sheet	--	--	--	--	--	--	--	--
3-1-7	Disc Separator Disc Disc Cover	--	Manila Board, Finish No. 4, Coated Stock Manila Board, Aluminum Foil Lined	--	--	--	--	--	--	--	--
3-1-8	Flanged Cap Separator	L-P-390	Plastic Molding Material Polyethylene, Type I Class L	--	10^{16}	2.3 60 Hz	1/8" Thick 460 - 700	0.015 24 Hr.	--	21	19
3-1-9	Contoured Cap Separator	Same as 3-1-8									
3-1-10	Tape	--	Pressure Sensitive, Transparent Polyester Scotch Brand No. 850	--	--	4.4 - 8.1 60 Hz Step-by-Step 170	Short Time 250-400	0.50 - 2.5	--	--	17
3-1-11	Cover, Launch Tube	--	DN2626 DLM-P4	--	--	--	--	--	--	--	--
3-2	Rim	--	Same as 2-1								
3-3	Moisture Seal	MIL-A-148	Aluminum Foil, Type I	--	2.828×10^{-6}	--	--	0		8	11
3-4	Polyurethane Foam, Type II, Class 1	MIL-P-26514	--	--	--	1.05 60 Hz	--	4% by Wgt	--	11	17
3-5	Adhesive, Silicone Rubber	--	RTV-102	--	3×10^{15}	2.8 60 Hz	0.103 Thick 425	--	--	19	--
3-6	Cement	--	Borden's Cement No. SY-330	--	--	--	--	--	--	--	--
3-7	Fume	--	Bond #77	--	--	--	--	--	--	--	--
4	Module Cover	--	Same as 2-1								
5	Nameplate	MIL-D-8634	Decal, Elastomeric Pigmented Film, Type II	--	--	--	--	--	--	--	--

DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER			ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
				I	II	III				
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
.9 0 Hz	389	0.4 - 0.5	--	14	--	--	--	--	11	Slow Burning, ABS, Acrylonitrile-Butadiene-Styrene
--	--	0	0.00446	8	11	8	--	--	1,2	Aluminum Foil, Pressure Sensitive
.6 @ 23°C 0⁶ Hz	--	0.5 - 2.0% (24 Hr.)	--	12	5	--	--	--	1,2	Thermoplastic
--	--	--	--	--	--	--	--	--	--	CH_3 CO C_2H_5, Solvent
- 9 0 Hz	Short Time 300-1000 Step-by-Step 275-900	0.15 - 0.75	--	--	18	--	--	--	1,2 24	PVC, Co-Polymer Non-Conductive General Purpose Adhesive
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
45 - 2.65 Hz	1/8" Thick 500 - 700	0.03 - 0.05 24 Hr.	--	20	--	--	--	60 - 80	1,2	Slow Burning, Self-Extinguishing, High Density
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
3 Hz	1/8" Thick 460 - 700	0.015 24 Hr.	--	21	19	--	--	--	1,2	Low and Medium Density
										→
- 8.1 Hz p-by-Step	Short Time 250-400	0.50 - 2.5	--	--	17	--	--	135	1,2	--
--	--	--	--	--	--	--	--	--	--	--
										→
--	--	0		8	11	8	--	--	--	Aluminum Rolls, Uncoated
5 Hz	--	4% by Wgt	--	11	17	--	--	--	1,2	Dissipation Factor (Elec) 0.3-1.3 x 10^{-3} Temp. Range to 250°F Foam in Place, Rigid
Hz	0.103 Thick 425	--	--	19	--	--	--	--	1,4	Thixotropic, General Purpose
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	1,2,6 25	(Urethane Foam; Primer/Adhesive) Neoprene Rubber and Phenoil
										→
--	--	--	--	--	--	--	--	--	—	Use on Exterior Surface, Adhensive - Backed, Pressure Sensitive

Table 4-8

FOLDOUT FRAME I

Table 4-9. E146-1-154, Launcher Tube, Fuze and Case Assem

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELEC SERIES NUM I	II
1	Base Assembly	D146-1-85	--	--	--	--	--	--	--	--	--
1-1	Module Base (E146-1-86)	B146-1-131	Red Thread Molding Compound or Epoxy #2832	$5x10^{14}$ OHMS	$2x10^{14}$	4.0 60 Hz	1/8" Thick 450	0.10 - 0.50	--	15	--
1-2A 1-2B	Clip	QQ-A-250/11 or QQ-A-250/8	Aluminum Alloy Sheet 6061 Temper O, .032 Nom Stk Thk or Aluminum Alloy Sheet, 5052, H-32, .032 Nom.Stk.Thk.	--	$2.828x10^{-6}$	--	--	0	0.00446	8	11
1-3	Ring (Steel Only)	MS51925-2	DEE-Medium, Steel, Black Enamel Finish, 3/4 Size	--	$12x10^{-6}$	--	--	0	0.005	8	--
1-4	Base Pin	QQ-A-225/G	Aluminum Alloy Wire, Rolled; Drawn or Cold Finished, 2024, T4, No. 18 GA	--	$2.828 x10^{-6}$	--	--	0	0.00446	8	11
1-5	Rivet, Blind	--	Aluminum Alloy .156 Nom Diam .343 Lg.	--	$2.828x10^{-6}$	--	--	0	0.00446	8	11
2	Case, Assembly	E146-1-136	--	--	--	--	--	--	--	--	--
2-1	Drilled Case Assembly	E146-1-43	--	--	--	--	--	--	--	--	--
2-1-1	Case Body	--	Royalite, No. 40-1211-RL, Solid HC/M, Color Olive Drab, .062 ± .006 Thick	--	$2.9x10^{12}$	5.9 60 Hz	389	0.4-0.5	--	14	--
2-1-2	Housing	--	Same as 2-1-1								
2-1-3	Reinforcement Strip	--	Same as 2-1-1								
2-1-4	Royalite Solution	MIL-D-6998 B146-1-44	Dichloromethane, Technical Grade A or B CH_2 CL_2	--	--	--	--	--	--	--	--
2-1-5	Cement	--	Borden's Cement No. SY-330	--	10^{11}-10^{15}	5.9 60 Hz	Short Time 300-1000 Step-by-Step 275-900	0.15 - 0.75	--	--	18
2-2	Inc ometer Assembly	C146-1-20	--	--	--	--	--	--	--	--	--
2-2-1	Housing	MIL-P-21105	Plastic, Sheet, Acrylic, Heat Resistant, Utility Grade .312 Nom.Stk.Thk	--	10^{15}	3.5-4.5 60 Hz	Short Time 450-550 Step-by-Step 350-400	0.3 - 0.4	--	--	15
2-2-2	Housing	Same as 2-2-1									
2-2-3	Dial	--	Brilliant Opaque 60 Lb. Stock, Vellum Finish	--	--	--	--	--	--	--	--
2-2-4	End Plate	Same as 2-2-1									
2-2-5	Epoxy Mixture	--	Resin, Epoxy Part No. R9-2039 Hardener, Epoxy Part No. H2-3561	$5x10^{14}$	$2x10^{14}$	4.0	1/8" Thick	0.10 - 0.50	--	15	--
2-2-6	Ball, Bearing	MS19060-6	Ferrous, Cres, .21875 BAS DIA	--	$12x10^{-6}$	--	--	0	0.005	8	--
2-2-7	Cement	Same as 2-1-5	Borden's Cement No. SY-330	--	--	--	--	--	--	--	--
2-3	Guide, Lanyard	Same as 2-2-1									
2-4	Reel Assembly	C146-1-6	--	--	--	--	--	--	--	--	--
2-4-1	Reel	--	Same as 2-1-1								
2-4-2	Lanyard	MIL-C-5040	Nylon Cord, Type II, Color Olive Drab No. X34087	--	10^{12}-10^{15} 10^6 CPS	3.5 @ 23°C	--	At 24 Hr. H_2O Immersion 0.5 - 2.0%	--	--	5
2-4-3	Pull Pin	QQ-W-423	Wire, Steel, Cres, Form I Composition 302, Condition A, 1/16 Nom Stk Dia	--	$12x10^{-6}$	--	--	0	0.005	8	--
2-4-4	Patch Hook	MIL-F-21840	Nylon, Type II 1 In.	--	10^{12}-10^{15}	3.5 @ 23°C 10^6 Hz	--	At 24 Hr. H_2O Immersion 0.5 - 2.0	--	12	5
2.4.5	Cement	--	Same as 2-2-7								
2-5	Manual Activator Assembly	See C146-1-97	--	--	--	--	--	--	--	--	--
2-6	Activator Mounting Plate	QQ-A-250/11	Same As 1-2A								

uncher Tube, Fuze and Case Assembly

FOLDOUT FRAME II

R-052

DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER I	II	III	ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
--	--	--	--	--	--	--	--	--	--
1/8" Thick 450	0.10 - 0.50	--	15	--	--	--	90	1, 8	--
--	0	0.00446	8	11	8	--	--	1, 2	--
--	0	0.005	8	--	--	--	--	1, 4	--
--	0	0.00446	8	11	8	--	--	1, 2	--
--	0	0.00446	8	11	8	--	--	1, 2	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
389	0.4-0.5	--	14	--	--	--	--	11	Slow Burning, ABS, Acrylonitrile - Butadiene - Styrene
--	--	--	--	--	--	--	--	1, 2	Methylene Chlorine, CH_2Cl_2, Solvent
Short Time 300-1000 Step-by-Step 275-900	0.15 - 0.75	--	--	18	--	--	--	1, 2, 24	PVC - Co-Polymer, Non-Conductive, General Purpose Adhesive
--	--	--	--	--	--	--	--	--	--
Short Time 450-550 Step-by-Step 350-400	0.3 - 0.4	--	--	15	--	--	No Track	1, 2	Slow Burning Rate
--	--	--	--	--	--	--	--	--	--
1/8" Thick	0.10 - 0.80	--	15	--	--	--	90	1, 8	--
--	0	0.005	8	--	--	--	--	1, 2	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	At 24 Hr. H_2O Immersion 0.5 - 2.0%	--	--	5	--	--	--	1, 2	--
--	0	0.005	8	--	--	--	--	1, 2	--
--	At 24 Hr. H_2O Immersion 0.5 - 2.0	--	12	5	--	--	--	1, 2	--
--	--	--	--	--	--	--	--	--	--

FOLDOUT FRAME I

Table 4-9. E146-1-154, Launcher Tube, Fuze and Case Ass

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBO SERIES I	TRIBO SERIES I
2-7	Nut, Slotted	QQ-S-637	Steel Bar, Carbon, Cold Finished, CD, 121.14, .500 Nom. Stk. Hex.	--	$12x10^{-6}$	--	--	0	0.005	8	-
2-8	Primer Fuze Assembly	E146-1-140	--	--	--	--	--	--	--	--	-
2-8-1	Frame	QQ-A-250/8	Same as 1-2B								
2-8-2 thru 4	Tape Double Coated	--	Pressure Sensitive Tape, No. 410 Double Coated Tissue, 1/2 wide 2 Mil.	--	--	--	--	--	--	--	-
2-8-5 thru 8	Tape, Electrical	MIL-I-15126	Insulation Tape, Electrical, Type Aft	--	$10^{11}-10^{15}$	4 - 5	--	2 - 7	--	13	1
2-8-9 thru 12	Fuse Strip	--	See C146-1-169	--	--	--	--	--	--	--	-
2-8-13 & 14	Sponge	MIL-P-26514	Polyurethane Foam, Elastic, Type 1, Class 2	--	--	1.05	--	4% by Wgt	--	11	1
2-8-15	Tape, Electrical	--	No. 11 Pressure Sensitive, 008 inc. Scotch Brand, 3M	--	$10^{11}-10^{15}$	4 - 5	--	2 - 7	--	13	1
2-8-16	Ignitor Cord	--	Thermalite Ignitor Cord, Type B, Burn Rate 16-20 Sec/Ft	--	--	--	--	--	--	--	--
2-9	Royalite Solution	Same as 2-1-4	Same as 2-1-4								
2-10	Tape, Electrical	Same as 2-8-5	Same as 2-8-5								
2-11	Washer, Flat Round	MS15795-706	Aluminum Alloy	--	$2.828x10^{-6}$	--	--	0	0.00446	8	11
2-12	Washer, Lock-Spring	MS35338-41	Stl. Cad. Plated	--	$12x10^{-6}$	--	--	0	0.005	8	--
2-13	Nut, Plain, Hex	MS35649-262	No. 6-32NC-2B	--	--	--	--	--	--	--	--
2-14	Packing "O" Ring	AN6227-2 MIL-P-5516	High Flexibility Syn. Rubber	10^{17} OHM	--	2.3 (10^3 Hz)	600	--	--	14	--
2-15	Packing "O" Ring	AN6227-7 MIL-P-5516	High Flexibility Syn. Rubber	10^{17} OHM	--	2.3 (10^3 Hz)	600	--	--	14	--
2-16	Screw	MS24621-18	Steel, Cadmium Plated	--	$12x10^{-6}$	--	--	0	0.005	8	--
2-17	Fastener Tape Hook	MIL-F-21840	Nylon, Type II	--	$10^{12}-10^{15}$	3.5 @ 23°C 10^6 Hz	--	24 Hour Immersion 0.5 - 2.0%	--	12	5
2-18	Hookup Wire MW-C-18-(16)-J-0	MIL-W-76	Wire, Cu	--	$1.7241x10^{-6}$	--	--	0	0.00393	8	21
2-19	Wire Type S, Solid No. 16 AWG	--	Wire, Cu	--	$1.7241x10^{-6}$	--	--	0	0.00393	8	21
2-20	Same as 2-17										
2-21	Post Binding, Waterproof Type PB08NA01	MIL-P-55149/8	Rubber Cap, Body Brass - Nickel Plated, "O" Ring Silicone Rubber, Nylon Insulated	--	--	--	--	--	--	--	--
2-22	Cement	--	Same as 2-1-5								
2-23	Bear Weather Adhesive	--	Part No. 4513818	--	--	--	--	--	--	--	--
2-24	Tape, Electrical	--	Same as 2-8-15								
2-25	Solder	QQ-S-571	Lead-Tin Alloy, SN60 WRAP 2	--	--	--	--	--	--	--	--
2-26	Toluene, Grade B	JAN-T-171	$CH_3 C_6 H_5$ Colorless Liquid	--	--	--	--	--	--	--	--
2-27	Sealant (B146-1-129)	--	Lexan No. 131 Clear, Granular Polycarbonate Resin, Chemical	--	$2.1x10^{16}$	3.17 60 Hz 23°C 50% R.H.	Short Time 400 Step-by-Step 364 1/8" Thick	0.15 (24 Hour) 73°F	--	--	--
	--	MIL-D-6998	Dichloromethane, $CH_2 CL_2$ Technical Grade A or B								

Launcher Tube, Fuze and Case Assembly (cont'd)

FOLDOUT FRAME II

R-052

…ECTRIC …STANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER			ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
				I	II	III				
--	--	0	0.005	8	--	--	--	--	1, 2	--
--	--	--	--	--	--	--	--	--	--	--
										→
--	--	--	--	--	--	--	--	--	21	Paper Tape, Non-Conductive, Crude Rubber Adhesive
	--	2 - 7	--	13	14	--	--	180 - 200	1, 2, 21	Thermosetting, Cellulose Acetate, Rubber Adhesive
--	--	--	--	--	--	--	--	--	--	--
	--	47 by Wgt	--	11	17	--	--	--	6	Dissipation Factor (Elec) $0.3-1.3 \times 10^{-3}$ Temp. Range to 250°F
	--	2 - 7	--	13	14	--	--	180 - 200	1, 2, 31	Black Acetate, Thermosetting, Rubber Adhesive
--	--	--	--	--	--	--	--	--	31	Ignition Compound is Red Lead Silicate, Cord is very light Steel/Stranded Wire.
										→
										→
--	--	0	0.00446	8	11	8	--	--	1, 2	--
--	--	0	0.005	8	--	--	--	--	1, 2	--
--	--	--	--	--	--	--	--	--	--	--
…21)	600	--	--	14	--	17	--	--	1, 2	Dash Number, Ref. Size -2 O.L 9/32", I.D. 5/32"
…2)	600	--	--	14	--	17	--	--	1, 2	Dash Number, Ref. Size -7 O.D. 1/2", I.D. 3/8"
--	--	0	0.005	8	--	--	--	--	1, 2	--
…23°C	--	24 Hour Immersion 0.5 - 2.0%	--	12	5	--	--	--	1, 2	--
--	--	0	0.00393	8	21	14	--	--	1, 2	--
--	--	0	0.00393	8	21	14	--	--	1, 2	--
										→
--	--	--	--	--	--	--	--	--	--	--
										→
--	--	--	--	--	--	--	--	--	--	--
										→
--	--	--	--	--	--	--	--	--	--	SN 60%, PB 40%
--	--	--	--	--	--	--	--	--	--	Solvent, Insoluble in Water, Pure Comm. Grade
	Short Time 400 Step-by-Step 364 1/8" Thick	0.15 (24 Hour) 73°F	--	--	--	--	--	10 - 120	5	Polycarbonate
									1	Methylene Chloride CH_2Cl_2, Solvent

FOLDOUT FRAME I

Table 4-9. E146-1-154, Launcher Tube, Fuze and Case Assembl

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBE		
										I	II	III
3	Tube and Fuze Assembly	E146-1-155	--	--	--	--	--	--	--	--	--	
3-1	Launcher Tube	--	Tube - 22 Point Semi-Bleached Rotoform Board No. 97440, Sorg	--	--	--	--	--	--	--	--	
		--	Tube wrapped with tape, reinforced, permacel, Type No. 162, 1 in.	--	--	--	--	--	--	--	--	
3-2	Distribution Fuze Train	E146-1-147	--	--	--	--	--	--	--	--	--	
3-2-1 thru 3	Tape, Electrical	Same as 2-8-5										
3-2-4 thru 7	Fuse Strip	--	Same as 2-8-9									
3-2-8	Sponge	Same as 2-8-13										
3-2-9	Stiffener	--	Nickel, Grade A 1/4 Hard	--	7.8×10^{-6}	--	--	0	0.006	--	21	
3-2-10	Squib Shield	QQ-A-250/8	Aluminum Alloy Sheet, 5052 Temper H-32	--	2.828×10^{-6}	--	--	0	0.00440	8	11	
3-2-11	Sponge	--	Same as 2-8-13									
3-2-12	Tape, Electrical	--	Fiberglass 210	--	--	--	--	--	--	--	--	
3-2-13	Igniter Cord	Same as 2-8-16										
3-3	Squib Assembly	C146-1-163	--	--	--	--	--	--	--	--	--	
3-3-1	Squib, Electric, M2, Assembly	MIL-S-46428	--	--	--	--	--	--	--	--	--	
3-3-2	Insulation Tubing	MIL-I-23053	Heat Shrinkable Class I	--	$10^{11}-10^{15}$	5 - 9 60 CPS	Short Time 300-1000 Step-by-Step 275 - 900	0.15 - 0.75	--	--	18	
3-4 thru 7 & 11	Tape, Electrical	--	Same as 2-8-15									
3-8	Fuse Strip	--	Same as 2-8-9									
3-9	Sponge Strip	--	Same as 2-8-13									
3-10	Baffle	Same as 3-2-10										
4, 5, & 7	Tape, Electrical	--	Same as 2-8-15									
6	Epoxy Mixture	Same as 2-2-5										

Launcher Tube. Fuze and Case Assembly (cont'd)

FOLDOUT FRAME II

R-052

IC T	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER I	II	III	ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	32	Polyester Backing, Glass Strands (Lengthwise), Beta Adhesive
	--	--	--	--	--	--	--	--	--	--
										→
										→
										→
	--	0	0.006	--	21	14	--	--	1, 2	--
	--	0	0.00446	6	11	6	--	--	1, 2	--
										→
	--	--	--	--	--	--	--	--	32	Glass Cloth, Rubber Base Adhesive
										→
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	Electrical Initiation Device
	Short Time 300-1000 Step-by-Step 275 - 900	0.15 - 0.75	--	--	18	--	--	--	1, 2	Polyvinyl Chloride
										→
										→
										→
										→
										→
										→

FOLDOUT FRAME 1

Table 4-10. DL146-1-49, Cartridge 35mm Riot Control, CS E23 "A" (

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TH SE
1	Propellant Cup, 13 Gram	C146-1-53	--	--	--	--	--	--	--	--
1-1	Cup and Delay Fuse	C146-1-57	--	--	--	--	--	--	--	--
1-1-i	Propellant Cup	--	Lexan, Type 131	--	2.1×10^{16}	23^{0}C, 50 RH, 3.17 60 Hz	1/8" Thick 400 Short Time Step-by-Step 364	0.15 @ 73^{0}F 24 Hour	--	--
1-1-5	Delay Fuze and 1st Fire	C146-1-58	--	--	--	--	--	--	--	--
1-1-5-1	Clamp Ring	MIL-T-8606	Tubing, Steel Cres, 304 Annealed, Type 1, Seamless	--	12×10^{-6}	--	--	0	0.005	6
1-1-5-2	Quick Match	MIL-Q-378	Quickmatch, Type II Class A	--	--	--	--	--	--	-
1-1-5-3	Delay Fuse	--	Light Core double tape, 22 grains per foot, .250 ± .015 dia. 90 sec/yard (std.atmo)	--	--	--	--	--	--	--
1-1-5-4	First Fire Slurry	--	First Fire Power (B146-1-165 See 1-1-5-5) Tap Water	--	--	--	--	--	--	--
1-1-5-5	First Fire Powder	MIL-P-223	Black Powder, Class 8	--	--	--	--	--	--	--
		--	Boron, Amorphous, 92% Grade, 325 Mesh	--	--	--	--	--	--	--
		--	Acacia (Fine Powder)	--	--	--	--	--	--	--
1-1-6	Quick Match	Same as 1-1-5-2								
1-1-7	Ignition Coating (Spark-Sensitive)	--	Ignition Power B146-1-166	--	--	--	--	--	--	--
		--	Silicon	--	--	--	--	--	--	--
		--	Red Lead	--	--	--	--	--	--	--
		--	Titanium	--	--	--	--	--	--	--
		--	Acacia	--	--	--	--	--	--	--
		--	Tap Water	--	--	--	--	--	--	--
1-1-8	Sealant	B146-1-129	Lexan No. 131 Same as 1-1-1							
		MIL-D-6998	Dichloromethane Grade A or B	--	--	--	--	--	--	--
1-2	Diaphragm	--	Chemical Fiber 100%	--	--	--	--	--	--	--
1-3	Lacquer	B146-1-130	Same as 1-1-8 Except % of Mixture							
1-4	Black Powder	MIL-P-223	Class 4, 13 ± 1/2 Grains	--	--	--	--	--	--	--
2	Loaded Canister	D146-1-59	--	--	--	--	--	--	--	--
2-1	Canister and Fill	MIL-A-12545	Aluminum Alloy Impact 1100-F	--	2.828×10^{-6}	--	--	0	0.00446	8
		B143-14-7	Mixture, CS	--	--	--	--	--	--	--
		JJJ-S-791	Sugar Type (b) (2)	--	--	--	--	--	--	--
		MIL-P-150	Potassium Chlorate GR. B, CL 7	--	--	--	--	--	--	--
		MIL-C-51-29	Chemical Agent CS	--	--	--	--	--	--	--
		MIL-M-11361	Magnesium Carbonate Gr. B	--	--	--	--	--	--	--
		MIL-N-244	Nitro Cellulose Gr. D	--	--	--	--	--	--	--
		O-A-51	Acetone	--	--	--	--	--	--	--
2-2	Retainer	QQ-A-200/3	Aluminum Alloy Rod, 2024, Temper T4	--	2.828×10^{-6}	--	--	0	0.00446	8
3	Extensible Diaphragm (See 12ô-131-853)	--	Polyacrylate Rubber Type 1402	10^{17} OHM	--	2.3 (10^{3} Hz)	600	--	--	14
			Part No. L-2416 or	--	--	--	--	--	--	--
			Part No. 206107A	--	--	--	--	--	--	--

FOLDOUT FRAME II

...dge 35mm Riot Control, CS E23 "A" (also serves as DL146-1-50, 51 ... R-052

DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER			ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
				I	II	III				
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
23°C, 50' RH, 3.17 60 Hz	1/8" Thick 400 Short Time Step-by-Step 364	0.15 @ 73°F 24 Hour	--	--	--	--	--	10 - 120	1,5	Polycarbonate
--	--	--	--	--	--	--	--	--	--	--
--	--	0	0,005	8	--	--	--	--	1,2	--
--	--	--	--	--	--	--	--	--	--	Fast burning fuse made from a cord impregnated with black powder.
--	--	--	--	--	--	--	--	--	31	Black powder, double paper wrapped, jute fibers then rayon cord
--	--	--	--	--	--	--	--	--	--	--
--		--	--	--	--	--	--	--	--	Made from potassium or sodium nitrate, charcoal, sulfur
--			--	--	--	--	--	--	--	B, fuel
--	--	--	--	--	--	--	--	--	--	Thickening agent and colloidal stabilizer
										→
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	Si, fuel
--	--	--	--	--	--	--	--	--	--	PB_3O_4, oxidant
--	--	--	--	--	--	--	--	--	--	Ti, fuel
--	--	--	--	--	--	--	--	--	--	Thickening agent and colloidal stabilizer
--	--	--	--	--	--	--	--	--	--	
										→
--	--	--	--	--	--	--	--	--	--	Colorless liquid; $CH_3C_6H_5$, solvent
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	0	0,00446	8	11	8	--	--	1,2	--
--	--	--	--	--	--	--	--	--	--	-
--	--	--	--	--	--	--	--	--	--	$C_{12}H_{22}O_{11}$, fuel
--	--	--	--	--	--	--	--	--	--	$KClO_3$, oxidant
--	--	--	--	--	--	--	--	--	--	O - chlorobenzalmalononitrile
--	--	--	--	--	--	--	--	--	--	$MgCO_3$, binder or retardant
--	--	--	--	--	--	--	--	--	--	Explosive
--	--	--	--	--	--	--	--	--	--	CH_3COCH_3, solvent
--	--	0	0.00446	8	11	8	--	--	1,2	--
.3 (10^3 Hz)	600	--	--	14	--	17	--	--	1,2	Resistant to fuel and petroleum oil
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--

FOLDOUT FRAME I

Table 4-10. DL146-1-49, Cartridge 35 mm Riot Control, CS E23 "A" (also s

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELE SERIES I	TRIBOELE SERIES II
4	Fuse Strip	--	Same as 2-8-9 on E146-1-154								
5	Disc	Naval Ord OS8935	Paper, Z-2, Class 5 Type 1-XII	--	--	--	--	--	--	--	--
6	Pad	B146-1-84	--	--	--	--	--	--	--	--	--
6-1	Paper	--	Same as 5								
6-2	First Fire Paint	--	Lacquer Thinner	--	--	--	--	--	--	--	--
			Collodion Merck	--	--	--	--	--	--	--	--
			First Fire Power Same as 1-1-5-5								
7	Sealant	Same as 1-1-8	Same as 1-1-8								
8	Twine	MIL-T-2520	Linen, Type I 6 Plies per strand	--	--	--	--	--	--	--	--
9	Tape	Scotch Brand #Y-9183	Lead Foil Tape Silicone/Paper Liner Crude Rubber Adhesive	--	--	--	--	--	--	--	--
10	Adhesive	--	RTV-102	--	$3x10^{15}$	2.8 60 Hz	0.103 Thick 425	--	--	19	--

mm Riot Control, CS E23 "A" (also serves as DL146-1-50, 51 and 52)(c FOLDOUT FRAME II 052

...CTRIC ...TANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER			ELECTRICAL ENERGY FOR IG NITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
				I	II	III				
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	Solvent
	--	--	--	--	--	--	--	--	--	Suspending agent
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	21	--
Hz	0.103 Thick 425	--	--	19	--	--	--	--	1,4	Thixotropic, general purpose. This product no longer manufactured by 3M Company.

FOLDOUT FRAME I

Table 4-11. DL146-1-97, Manual Activator Assembly

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELEC SERIES NUM I	II
1	Striker Housing Assembly	C146-1-98	--	--	--	--	--	--	--	--	--
1-1	Primer Cup	MIL-B-994	Brass, Naval, Composition B	--	$6.9x10^{-6}$	--	--	0	0.00098	--	22
1-2	Striker Housing	QQ-S-766	Steel, Sheet, Corrosion Resisting, Class 302, Annealed, No. 2B Finish	--	$12x10^{-6}$	--	--	0	0.005	8	--
1-3	Screw	MS51957-29	Machine, Cres #6-32UNC	--	$12x10^{-6}$	--	--	0	0.005	8	--
1-4	Solder	QQ-S-561	Silver, Class 4	--	--	--	--	0	--	--	--
2	Striker Assembly	QQ-S-766	Same as 1-2								
		QQ-S-763	Steel Bar, Corrosion Resisting, Class 302 Condition A	--	$12x10^{-6}$	--	--	0	0.005	8	--
3	Latch	Same as 1-2	Same as 1-2								
4	Striker Spring	QQ-W-423	Steel Wire, Corrosion Resisting, Form I Composition 302 Condition B	--	$12x10^{-6}$	--	--	0	0.005	8	--
5	Latch Hinge Pin	Same as 1-2 or 4	--	--	$12x10^{-6}$	--	--	0	0.005	8	--
6	Striker Hinge Pin	Same as 4	--	--	$12x10^{-6}$	--	--	0	0.005	8	--
7	Igniter Powder		Same as 1-1-7 DL146-1-49								
8	Ring	QQ-W-470	Wire, Steel, Carbon,	--	$12x10^{-6}$	--	--	0	0.005	8	--
9	Primer Percussion M42C	B8849126	Potassium Chlorate	--	--	--	--	--	--	--	--
			Lead Sulfocyanate Type Mixture No. 530G, .32 to .35 Grain	--	--	--	--	--	--	--	--
10	Cotter Pin	MS24665-155	Type 3, Corrosion Resisting Steel, Passivated	--	$12x10^{-6}$	--	--	0	0.005	8	--
11	Sealing & Locking Compound Grade A	MIL-S-22473	Single Component Sealing and Locking Compound	--	--	--	--	--	--	--	--
12	Tape	Scotch Brand #Y-9183	Lead Foil Tape Silicone/Paper Liner Crude Rubber Adhesive	--	--	--	--	--	--	--	--
	Primer, Coating; Phenolic	MIL-P-12742	--	--	--	--	--	--	--	--	--
	Cleaning Methods and Pretreatment	TT-C-490	--	--	--	--	--	--	--	--	--
	Enamel, Phenolic, Lusterless	TT-E-522	--	--	--	--	--	--	--	--	--

DL146-1-97, Manual Activator Assembly

DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER I	TRIBOELECTRIC SERIES NUMBER II	TRIBOELECTRIC SERIES NUMBER III	ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
--	--	--	--	--	--	--	--	--	--	--
--	--	0	0.00098	--	22	14	--	--	1,2	Free machining
--	--	0	0.005	8	--	--	--	--	1,2	--
--	--	0	0.005	8	--	--	--	--	1,2	--
--	--	0	--	--	--	--	--	--	--	Ag 49-51%, Cu 14.5-16.5%, Zn 14.5-18.5%, Cd 17.0-19.0%
--	--	0	0.005	8	--	--	--	--	1,2	--
--	--	0	0.005	8	--	--	--	--	1,2	--
--	--	0	0.005	8	--	--	--	--	1,2	--
--	--	0	0.005	8	--	--	--	--	1,2	--
--	--	0	0.005	8	--	--	--	--	1,2	--
--	--	--	--	--	--	--	--	--	--	$KClO_3$, Oxidant
--	--	--	--	--	--	--	--	--	--	$PB(SCN)_2$, ingredient of priming mixture.
--	--	0	0.005	8	--	--	--	--	1,2	--
--	--	--	--	--	--	--	--	--	--	Locking torque (3/8 bolt) 100/250 in/lbs. Viscosity - centpoise 10-25 color red, explosive compatable
--	--	--	--	--	--	--	--	--	21	This product no longer being manufactured by 3M Company.
--	--	--	--	--	--	--	--	--	--	Primer coating, phenolic, water immersible.
--	--	--	--	--	--	--	--	--	--	Treatment of ferrous surfaces for organic coating.
--	--	--	--	--	--	--	--	--	--	Outside paint, for steel and wood surfaces.

FOLDOUT FRAME I

Table 4-12. DL146-1-117, Launching Platform Assembl

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELEC SERIES NUM I	II
1	Tether Assembly	D146-1-15	--	--	--	--	--	--	--	--	--
1-1	Strap Assembly	MIL-W-005625	Nylon Textile Webbing	--	10^{12}-10^{15}	3.5 @ 23°C 10^6 Hz	--	at 24 Hr. H_2O Immersion 0.5-2.0%	--	12	5
1-2	Stake	MIL-P-17549	Plastic Laminate, Fibrous Glass Reinforced Marine Stru., Grade 1	--	10^{14}	5.3 - 7.30 60 Hz	Short Time 345-420 Step-by-Step 275-390	0.06 - 0.28	--	--	17
1-3	Bracket	QQ-A-250/11	Aluminum Alloy 6061, Temper 0	--	2.828×10^{-6}	--	--	0	0.00446	5	11
2	Tee Bar & Back Rest Assembly	E146-1-76	--	--	--	--	--	--	--	--	--
2-1	Tee Bar Assembly	B146-1-71	Laminated Plastic	--	--	--	--	--	--	--	--
		MIL-R-7575	Resin, Polyester, Low-Pressure Laminating	--	10^{14}	5.3 - 7.30 60 Hz	Short Time 345 - 420 Step-by-Step 275 - 390	0.06 - 0.28	--	--	17
		ASTM D-1529-58T Type II	Random Chopped - Glass Fiber Mats for Reinforced Plastics	--	--	--	--	--	--	--	--
2-2	Backrest Assembly	D146-1-45	--	--	--	--	--	--	--	--	--
2-2-1	Backrest, Cover End	MIL-C-7219	Nylon Duck Cloth, Type III	--	10^{12}-10^{15}	3.5 @ 23°C 10^6 Hz	--	At 24 Hr. H_2O Immersion 0.5 - 2.0%	--	12	5
2-2-2	Backrest, Cover	Same as 2-2-1	Same as 2-2-1								
2-2-3	Backrest Filler	MIL-P-26514	Polyurethane Foam, Type 1, Class 2	--	--	1.05, 60 Hz	--	4% by Wgt	--	--	--
2-2-4	Stiffener	MIL-P-15035	Plastic Sheet, Laminated Type FBE	--	10^{12}-10^{13}	6.5 - 7.5 60 Hz	Short Time 350 - 400 Step-by-Step 250 - 300	0.3 - 0.4 24 Hr. Immersion	--	--	--
2-2-5	Pad	--	Neoprene Coated Nylon, Style A-330, Goodyear	--	10^{12}-10^{15}	3.5 @ 23°C 10^6 Hz	--	At 24 Hr. H_2O Immersion 0.5-2.0%	--	12	5
2-3	Latch	Same as 2-1	Same as 2-1								
2-4	Tee Bar Spring	QQ-W-470	Wire, Steel, Carbon Spring, Music	--	12×10^{-6}	--	--	0	0.005	8	--
2-5	Latch Bracket	Same as 2-1	Same as 2-1								
2-6	Pin	--	Conform to Aeronautical Material Spec 5643C	--	--	--	--	--	--	--	--
3	Base and Side Panel, Assm.	E146-1-88	--	--	--	--	--	--	--	--	--
3-1	Base	Same as 2-1	Same as 2-1								
3-2	Side Panel	Same as 2-1	Same as 2-1								
3-3 & 4	Guide Block	B146-1-96	Polyester Premix Fibercore #4010 Molding Compound	--	10^{14}	3 - 4.36 60 Hz	Short Time 380 - 500 Step-by-Step 280 - 420	0.15 - 0.60	--	--	17
3-5 & 6	Bracket	Same as 2-1	Same as 2-1								
3-7	Shim	Same as 2-1	Same as 2-1								
3-8	Spacer	Same as 2-1	Same as 2-1								
4 & 5	Trail Leg Assembly	Same as 2-1	Same as 2-1								

...RIC ...ST	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER I	II	III	ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
	--	--	--	--	--	--	--	--	--	--
C	--	at 24 Hr. H_2O Immersion 0.5-2.0%	--	12	5	--	--	--	1,2	Thermoplastic
0	Short Time 346-420 Step-by-Step 275-390	0.06 - 0.28	--	--	17	--	--	120 - 240	1,2	Fiberglass Reinforced Polyester
	-	0	0.00446	8	11	8	--	--	1,2	--
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
	Short Time 346 - 420 Step-by-Step 275 - 390	0.06 - 0.28	--	--	17	--	--	120 - 240	1,2	Fiberglass Reinforced Polyester
	--	--	--	--	--	--	--	--	--	Fiberglass Filler for Reinforcing Plastic Material
	--	--	--	--	--	--	--	--	--	--
	--	At 24 Hr. H_2O Immersion 0.5 - 2.0%	--	12	5	--	--	--	--	Thermoplastic
→										→
	--	4% by Wgt	--	--	--	--	--	--	6	Dissipation Factor (Elec) 0.3-1.3x10^{-3} Temp. Range to 250°F
	Short Time 350 - 400 Step-by-Step 250 - 300	0.3 - 0.4 24 Hr. Immersion	--	--	--	--	--	--	1,2	Thermosetting
	--	At 24 Hr. H_2O Immersion 0.5-2.0%	--	12	5	--	--	--	1,2	Thermoplastic
→										→
	--	0	0.005	8	--	--	--	--	1,2	--
→										→
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	- --	--	--	--
→										→
→										→
	Short Time 380 - 500 Step-by-Step 280 - 420	0.15 - 0.60	--	--	17	--	--	125	1,2	--
→										→
→										→
→										→
→										→
→										→

FOLDOUT FRAME I

Table 4-13. DL146-1-25, Harness Assembly

LINE NO.	DESCRIPTION	SPECIFICATION	MATERIAL	SURFACE RESISTIVITY (OHMS)	VOLUME RESISTIVITY (OHMS-CM)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOEL… SERIES N… I	II
1	Harness Assembly (Only nylon is considered since it is the prime material) DL146-1-25	MIL-W-5625	Nylon, Textile Webbing	--	10^{12}-10^{15}	3.5 @ 23°C 10^{6} Hz	--	At 24 Hr. 0.5 - 2.0	--	12	5
		MIL-W-5038	Nylon, Textile Tape	--			--		--		
		MIL-W-4088	Nylon, Woven, Textile Webbing	--			--		--		
		MIL-C-7219	Nylon, Cloth, Duck, Parachute Pack	--			--		--		

FOLDOUT FRAME II

ble 4-13. DL146-1-25, Harness Assembly

...Y ...)	DIELECTRIC CONSTANT	DIELECTRIC STRENGTH (VOLTS/MIL)	WATER ABSORPTION (PERCENT)	TEMPERATURE COEFFICIENT OF RESISTIVITY PER °C	TRIBOELECTRIC SERIES NUMBER			ELECTRICAL ENERGY FOR IGNITIONS (JOULES)	ARC RESISTANCE (SECONDS)	REFERENCE	REMARKS
					I	II	III				
	3.5 @ 23°C 10^6 Hz	--	At 24 Hr. 0.5 - 2.0	--	12	5	--	--	--	1, 2	Thermoplastic
		--		--			--	--	--		
		--		--			--	--	--		
		--		--			--	--	--		

SECTION 5
POTENTIAL ELECTROSTATIC HAZARDS

5.1 GENERAL

The identification of locations and operations where electrostatic potentials may be generated and the evaluation of the process equipment and procedures are presented in this section.

Each manufacturing facility (E8 and XM15/XM165) was visited as scheduled.

An XM15/XM165 manufacturing plant was visited a week after it had a malfunction of an XM15 cluster during the manufacturing process. The results of this investigation and plant visit were submitted as Report No. GE-MTSD-R-047, "Inadvertent Functioning of an XM15 Cluster During Manufacturing," dated October 29, 1970. However, the information contained in paragraphs 5.2.2 to 5.2.7 of this report reflect the investigation/findings by reviewing the manufacturing procedures and related technical manuals of an additional XM15/XM165 cluster manufacturing facility.

A report on the results of the E8 plant visit is included in paragraph 5.3.3. The manufacturing procedure for the E8 was not available for this report, because the manufacturer considered the procedures to be company proprietary information.

5.2 XM15/XM165 CLUSTER

5.2.1 GENERAL

The XM15/XM165 tactical CS canister cluster appears to be vulnerable to premature activation by electrostatic charge. This assumption is based on the general design features of the unit (i.e., use of nonconductive plastics and other nonconductive materials) and on two premature activations of the XM165 during unloading operations. However, as the result of Edgewood's ignition tests and the initial Phase II XM15 fuse train tests, changes have been incorporated to make the fusing system relatively safe from premature activation by electrostatic charge.

The following documents were used as references for this study:

- Assembly Procedure for Canister Cluster Assembly, Chemical Agent, XM165
- DTM 3-1325-231-12; Draft Technical Manual; Operation and Organization Maintenance Manual; Canister Cluster Assembly, Chemical Agent, XM165; and Canister Cluster, Chemical Agent, XM15; May 1969
- DTM 3-1325-234-12; Draft Technical Manual; Operator's and Organization Maintenance Manual; Canister Cluster, Riot Control Agent, CS, XM15; May 1970
- XM15/XM165 Drawings

The following paragraphs describe the operations involved in handling the weapon at the manufacturing facility and transporting it to combat aircraft as well as potential hazards for premature activation from electrostatic sources. Table 5-1 summarizes locations and operations where electrostatic potentials could exist.

5.2.2 MANUFACTURING

The "Assembly Procedure for Canister Cluster Assembly, Chemical Agent, XM165" was used as a reference in evaluating the process of manufacturing the clusters. It was determined during review of this procedure that most of the hazardous manufacturing conditions have been negated by implementation of techniques of electrostatic suppression and personnel safety. The following procedure changes, however, should decrease the likelihood of activation from electrostatic discharge:

- Expulsion Charge Assembly - During the heat sealing of the black powder expulsion charges, cotton gloves are worn while handling the polyethylene bags. These two materials are separated by a number of other materials on the triboelectric series of material. It is recommended that an anti-static aerosol be used during this operation to eliminate the possibility of accidental generation and discharge of static electricity, or that the cotton gloves not be used. A further improvement would be the use of a conductive material for the powder bags. However, if the black powder bags are made of a conductive material, provisions must be made to electrically connect the bags to the conductive part of the fuse train. If electrical contact is not made, then an electrostatic hazard would exist.
- Assembly XM721 Time Fuze - During the assembly of the time fuze, the igniter pellets, and fuses, there is a possibility of electrostatic discharge from personnel to the pyrotechnic material. It is recommended that grounding bracelets be worn during this operation.

5.2.3 PACKAGING AND UNPACKING

The XM165 is packed in a fiberboard box containing desiccants and supported by filler pads. This box is sealed in a moisture proof bag which is enclosed by several layers of fiberboard. The entire assembly is then placed inside a cleated plywood container cushion-lined with filler pads. Through contact and friction during packaging, these materials generate static electricity which may accumulate to sufficient size to spark. To prevent these discharges, it is recommended that antistatic aerosols be used liberally. Also, where possible, the nonconductive packaging material should be replaced by a conductive type and a grounding system should be employed.

Table 5-1. XM15/XM165 Locations and Operations With Electrostatic Potentials

OPERATIONS	POSSIBLE SOURCE	REMEDIAL ACTION	REFERENCE
1. Manufacturing a. Fuse, Orifice Assembly	Mixing and packing of ignition material in the XM16 fuse assembly	Manufacturing procedure techniques of electrostatic suppression and personnel safety appear adequate	Assembly Procedure XM165
b. C/S Pyrotechnic Mixture	Mixing and handling of C/S materials	Manufacturing procedure techniques of electrostatic suppression and personnel safety appear adequate	Assembly Procedure XM165
c. Loading XM16	Handling of C/S pyrotechnic mixture and live XM16 fuse assembly	Manufacturing procedure techniques of electrostatic suppression and personnel safety appear adequate	Assembly Procedure XM165
d. Expulsion Charge Assembly	Handling of polyethylene powder bags with cotton gloves	Use of a conductive material for powder bag or use of an aerosol antistatic electricity compound	Assembly Procedure XM165
e. Slide Assembly	Handling of stab detonators in assembly of the time fuse slide mechanism	Manufacturing procedure techniques appear adequate	Assembly Procedure XM165
f. Fuse Igniter Pellet	Handling of fuse igniter material during pellet consolidation	Manufacturing procedure techniques of electrostatic suppression and personnel safety appear adequate	Assembly Procedure XM165
g. Assembly XM721 Time Fuse	Handling of fuses and fuse igniter material during time fuse assembly	It would seem desirable for personnel to wear ground bracelets during this operation	Assembly Procedure XM165

Table 5-1. XM15/XM165 Locations and Operations With Electrostatic Potentials (cont'd)

OPERATIONS	POSSIBLE SOURCE	REMEDIAL ACTION	REFERENCE
h. Assembly of Black Powder Igniter Assembly	Handling and packing of igniter composition	Manufacturing procedure techniques of electrostatic suppression and personnel safety appear adequate	Assembly Procedure XM165
i. Junction Block Igniter Pellet	Handling of igniter material during pellet consolidation	Manufacturing procedure techniques of electrostatic suppression and personnel safety appear adequate	Assembly Procedure XM165
j. Heat Sealing Operations, Canister Cluster	Handling of XM16 canister during cluster assembly and heat sealing operations and handling of expulsion charges	Manufacturing procedure appears adequate; however, use of anti-static aerosol or conductive materials on powder bags should further reduce dangers	Assembly Procedure XM165
k. Fuse, Igniter Assembly and Component Installation of XM15	Handling of plastic covered canister clusters or handling of igniter pellets	Manufacturing procedure techniques of electrostatic suppression and personnel safety appear adequate	Assembly Procedure XM165
2. Packaging	Contact and friction between plastic outer case (surlyn) of XM15/XM165 and polystyrene box, filler material (polyurethane), moisture proof bag and plywood container during packaging	Use of conductive packaging materials with grounding and use of antistatic electric aerosols during packaging	DTM 3-1325-234-12 DTM3-1325-231-12
3. Shipping a. Loading	Contact and friction between XM15/XM165 and various packaging materials as a result of container motions during loading	Use of conductive packaging materials and positive grounding of vehicles during loading	
b. Trans-portation	Contact and friction between XM15/XM165 various packaging materials as a result of container motions in transit	Use of conductive padding materials and positive grounding of shipping box to vehicle body plus a drag ground strap for ground transportation vehicles	

Table 5-1. XM15/XM165 Locations and Operations With Electrostatic Potentials (cont'd)

OPERATION	POSSIBLE SOURCE	REMEDIAL ACTION	REFERENCE
c. Unloading	Contract and friction between XM15/XM165 and various packaging materials as a result of container motions during unloading	Grounding of vehicle and use of conductive packaging materials	
4. Unpacking	Contact and friction between plastic outer case (surlyn) of XM15/XM165 and polystyrene, or fiberboard box filler material (polyurethane), moisture proof bag and plywood container during unpacking	Use of conductive packaging materials with grounding during unpackaging operations and use of antistatic electricity aerosol compound	
5. Delivery to Aircraft	Contact and friction between surlyn outer case, padding and delivery vehicle floor during loading and in transit	Maintain positive grounding between XM15/XM165 transporting vehicle and between vehicle and earth ground	
6. Loading Aboard Aircraft	Contact and friction between surlyn outer case and padding during unloading and contact with aircraft during loading operations	Assure aircraft is properly grounded and that ground crew has come into contact with a ground point before handling of the weapon is attempted	
7. Atmospheric Electrical Discharges	Atmospheric discharges of static electricity (lightning) within close proximity to the XM15/XM165 inducing static electric accumulations within the weapon	Use of conductive materials in manufacture and packaging, and liberal use of antistatic aerosols in packaging operations	

The same problems associated with packaging will be encountered during unpacking. Therefore, the same solutions can be applied; i.e., use of conductive packaging materials and maintaining a ground and/or antistatic aerosols.

The desiccant will maintain a low humidity within the fiberboard box which will tend to increase the possibility of generating static electricity. However, it is not recommended that the desiccant be removed.

The second premature activation at Dugway occurred during the unpacking operation. The fact that the personnel were grounded increased the ignition possibility since the unit was not grounded and a bleed-off path was not available for any charge that had accumulated; however, the application of an antistatic aerosol could have dispersed the charge.

5.2.4 SHIPPING

During loading, transportation, and unloading operations, container motion will generate static electric charges as a result of contact and friction between the various nonconducting materials previously described. As mentioned previously, use of conductive packaging materials, ground and/or antistatic aerosols are recommended to reduce or eliminate some of the electrostatic hazards. It may also be desirable to provide electrostatic bleed-off of the transport vehicles through a drag ground strap, although this technique has been questioned by authorities in recent years.

5.2.5 DELIVERY TO AIRCRAFT

The XM165/XM15 is normally transported to the aircraft uncrated and with all outer packaging materials removed. At the time of the first premature activation at Dugway, the unit had been transported from a storage building to the aircraft on a layer of polyurethane insulation. Apparently this insulation material was in part responsible for the accident.

It is recommended that, in the future, conductive padding and insulating materials be used for this operation. A drag ground strap should be provided for all vehicles transporting these units, and positive contact should be maintained between the unit and the vehicle body.

5.2.6 LOADING ABOARD AIRCRAFT

Grounding of the aircraft should be maintained at all times while loading the XM15/XM165 to prevent static potential differences between the weapon and the aircraft from causing an activation discharge. This precaution assumes that steps mentioned previously have been taken to assure minimum static charge accumulations.

5.2.7 ATMOSPHERIC ELECTRICAL DISCHARGES

Lightning strikes in close proximity to the weapon could possible induce static electric charges sufficient to activate the weapon. Although the likelihood of this particular type of accident occuring is extremely remote, it is recommended that precautions be taken to prevent it.

As mentioned, use of conductive packaging materials and antistatic aerosols would be of considerable value in this regard.

5.3 E8 CLUSTER

5.3.1 GENERAL

The E8 tactical CS backpack appears to be vulnerable to premature activation by electrostatic charge. This assumption is based on the general design features of the unit (i.e., use of nonconductive plastics and other nonconductive materials) and a premature activation and ensuing fire at a production facility.

The following documents were used as references for this study:

- TB 3-1310-255-10, Launcher and 35-MM Cartridges; Tactical CS, 16-Tube, E8; August 1966
- E8 Drawing System

The following paragraphs describe the operations involved in handling the weapon at the manufacturing facility and transporting it to the GI engaged in combat as well as the potential hazards for premature activation from electrostatic sources.

5.3.2 MANUFACTURING

The manufacturing operations of the E8 cluster assembly have been terminated. Because the company would not release their manufacturing procedures which were classified as "company confidential," the discussion of the manufacturing procedures that are involved is limited to the possible hazardous operations involved in the assembly of the E8 cluster.

The operations involved in handling the CS cartridges with the propellant charges attached can be hazardous if personnel involved are not properly grounded. Electrostatic buildup on clothing could easily be discharged to the explosive and pyrotechnic materials within the canisters. A similar situation exists in the attachment of the fuse train and the squib.

The foaming operations could very well be the most hazardous since the fire at a manufacturing facility started as a result of this operation. Although not conclusively proved, it is possible that the expansion of the nonconductive urethane generated a static charge sufficient to ignite the fusing system. (A foaming test will be conducted during Phase II at the manufacturing facility to determine the static charges generated during this operation.

5.3.3 RESULTS OF VISIT TO E8 MANUFACTURING FACILITY

The party touring the Brunswick E8 manufacturing facility at Sugar Grove, Virginia, was given a general briefing of the plant's facilities and safety precautions prior to visiting the assembly lines. Each member of the party was given safety glasses and conducting leg straps to wear through the manufacturing facilities. The party toured the E8 launcher assembly building and then the mix plant building where the tactical CS is prepared and loaded into the canisters.

5.3.3.1 Launcher Assembly Building

The operations observed at the Brunswick launcher assembly building included:

- Fuses - The fuses are cut to the dimensions prescribed on the drawings, each end is drilled out, and quick match is installed. A stitching machine applies a stitch to each end of the fuse that goes into the canister. The stitching machine and all of the tables associated with this procedure are grounded, the conductive concrete floor is grounded, and all grounds are tied back to a single point. After the fuses leave the stitching machine the propellant cup is installed and quick match is applied; then the propellant cups are loaded with a class 6 or class 4 black powder charge, depending upon the color coding of the particular cartridge. Four different cartridge loads are installed in the launcher, depending upon the dispersion requirements. The black powder charge is installed and wafers are installed on the bottom of the propellant cups, the propellant cups are mated with the CS canister, and then the fusing material is installed around the canister and the metal foil tape is installed.

- Launch Tubes - The base plate and the foil-like case of the launcher are mated and the launch tubes are inserted in the launch tube and fuse assembly subsystem. The launch tube and fuse assembly are then moved to a different area and the cartridges are installed.

- Main Fuse Train - The main fuse train is made up according to the drawings (manufacturing) and inserted in the top of the launcher assembly. The fuse cloth that the fuse train is made of is purchased in sheets and shipped and cut in the wet condition. (There is a critical point between the wet and dry condition for handling the fuse cloth material because if the fuse cloth becomes too dry (dries out) it will ignite spontaneously.) The fuse train is then installed in the launcher assembly, all the work benches are grounded, and, when the fuse train and the cases are handled, a ground strap is wrapped around the case and "Statikil" spray is used to dissipate any charge buildup on the plastic material. The Statikil spray is used to dissipate charge buildup at several points during the assembly operation. Charge buildup is monitored by the use of a static meter manufactured by Custom Material, Inc. Just before the launcher assembly is taken into the foaming booth, the main fuse train is bent over to make contact with the top canisters and the polystyrene discs are installed in the tops of the launching tube.

- Foaming (two-step operation) - The foaming operation takes place in a specially constructed area where the floor and walls are covered with grounded aluminum sheeting. It has been ascertained by the manufacturer that, when required, it is more economical to periodically replace this aluminum sheeting than to clean it.

After the first foaming operation is completed, a vapor barrier, which is made of aluminum foil, is installed in the top of the launcher assembly, and the second foaming operation takes place. The manufacturer has detected by use of a static charge gun that quite a large electrostatic charge does build up during this operation. (Electrostatic measurements of this operation will be made during Phase II.) After the completed launch assembly is removed from the foaming room, it is sprayed again with "Statikil" spray and the case is grounded by the operator handling the unit for the final packaging.

- Final Assembly - The final assemblies are placed on a grounded roller assembly where the launch assembly is then mated with the platform for final packaging. The platform and launch assembly is then inserted in a foil-backed bag, horsehair is inserted around the bag, and a vacuum is drawn on the bag containing the entire assembly.

5.3.3.2 Mixing Plant

The mixing plant where the CS is prepared is located several hundred yards away from the launcher assembly building. The mixer building, of monolithic construction, is divided into various individual storage, weigh-in, and mixing areas that are designed specifically for handling the various types of chemicals used in the preparation of the tactical CS.

5.3.3.3 Conclusions

The following conclusions were reached concerning the Brunswick manufacturing operations:

- One of the main differences between this operation (Brunswick) and the operations of the other manufacturer is the foaming process. Individual foaming kits were utilized by the previous manufacturer and a preformed piece of foam was inserted during the second foaming step.
- The manufacturing facilities did not utilize very efficient control or control procedures for their humidity, forced air, and environmental systems.
- The only charge dissipating system was the grounding of all the work tables and the floor, the use of static spray, and the wiping of the outer case with a wet cloth.
- All the people involved in the manufacturing processes wear conductive shoes and cotton type clothing, and the whole operation is a hand operation requiring a lot of manual manipulations with a limited use of various machines.
- It did appear that sufficient electrostatic preventive measures were used in all phases of the manufacturing operation.

5.3.4 PACKAGING AND UNPACKING

The E8 is packaged with a one-inch layer of cushioning material, sealed in a foil-backed bag, enclosed in a fiberboard box, and crated in a plywood shipping container wrapped with steel bands. According to classical electrostatic theory, contact or friction between these materials is adequate to generate potentials of several thousand volts, which may be sufficient to set off the squib, the fuse, or black powder charges. (Ignition energy levels will be determined during Phase II.) It would seem desirable to make the unit less capable of generating static electricity by the use of conductive packaging materials, maintaining a ground and/or antistatic aerosols.

5.3.5 TRANSPORTATION

The major contributor to static electric charges during transportation is again the contact and friction between the various materials. Use of conducting packaging materials and/or antistatic aerosols and positive grounding of vehicles would eliminate this hazard.

5.3.6 FIELD TRANSPORTATION

Assuming use of the E8 exclusively in Southeast Asia, generation and storage of electrostatic surface charge associated with field transportation would be reduced by the conditions of high humidity and perspiration from GIs handling the unit. These conditions increase the air and body contact conductivity, hence they would tend to bleed off any static electricity generated by friction between the unit and personnel clothing. In dry climates, however, this would become a problem which should be eliminated by use of an antistatic aerosol. Elimination of surface charge may not increase the systems safety level. On the contrary, internal unbled charge could conceivably induce a larger electric field after removal of the surface charge. This phenomena deserves further study.

The E8 can be fired electrically; a shorting wire is provided across the terminals of the squib to prevent premature firing from stray voltages. During the process of connecting the electrical firing unit to the squib, personnel may make electrical contact with terminals. Any accumulation of electrostatic charge on their bodies will then be discharged through this terminal, possibly prematurely initiating the unit. (Refer to Section 6 for further information.) However, as previously mentioned, if deployment is made in Southeast Asia it is highly unlikely that such accumulations could occur because of the high humidity.

Lightning striking in close proximity to the weapon could induce static electric charges by ion collection of capacitive or inductive effects sufficient to activate the weapon if the electrical activation mode is being employed. This can be prevented by completely shielding the connecting wires.

SECTION 6

EQUIVALENT ELECTRICAL CIRCUITS

6.1 GENERAL

The purpose of an equivalent electrical circuit is to provide a simplified and idealized presentation of a complex mechanical system such that the system can be evaluated by classical electrical techniques. In presenting a system as an equivalent electrical circuit it is not always feasible to consider every aspect of the system. In many cases the number of components and the equivalent electrical circuit for those components would produce a circuit that would not be useful for understanding the behavior of the system. Therefore, it is necessary to define the rationale for the circuit, the assumptions and conditions, and the analysis technique. Another point to consider is the level of effort required to obtain the objective. This type of analysis or endeavor can vary from a simple circuit considering only the basic DC components to very complex networks showing every possible combination.

The scope of the total project only permitted the simple approach in the formulation of the equivalent electrical circuits. However, these circuits will be refined and analyzed from the standpoint of assigning values to the circuit components during Phase II as defined in Section 7 of this report.

6.2 EQUIVALENT ELECTROSTATIC CIRCUITS FOR XM165

6.2.1 GENERAL

The CS gas disseminating equipment XM165 has been found to be subject to accidental firing as a result of the presence of electrostatic potentials or charges. Voltages and currents (motion of charges) are commonly described in terms of electric circuits. It is the purpose of this report to present the XM165 as a circuit which will represent the electrical properties of the equipment so as to facilitate studying the behavior of the equipment in the presence of various configurations of electrostatic fields or applied electrostatic charges.

Though the complete XM165 assembly contains two XM15 clusters, only one of the XM15 clusters is shown in the diagrams, it being understood that the other is identical.

6.2.2 CONDUCTORS AND INSULATORS

In general, the various materials in the equipment may be classed as either conductors or insulators. Metallic parts are conductors; most others are insulators. However, the flow of charge across and through materials ordinarily considered as insulators plays a very important part in electrostatics; therefore, insulators must be considered as resistors having values in the range of 10^8 to 10^{12} ohms. By comparison, the resistance of metallic parts, on the order of hundredths or tenths of an ohm, may be neglected and metal parts considered as perfect conductors.

6.2.3 CONDUCTING PARTS

A simplified diagram of the significant conducting parts of the equipment is shown in Figure 6-1. The adapter assembly XM43, or strongback, contains a hole which passes the time fuze XM721, through which passes a section of lead-jacketed delay fuse. The various fuse sections and the line igniter terminate in aluminum junction blocks.

Twelve copper sealing wires are embedded in the plastic parts. The three of these which are of particular significance are shown on Figure 6-1, as are two CS canisters, representative of the 264 canisters contained in each XM15 cluster.

6.2.4 CONTACT BETWEEN CONDUCTING PARTS

Where metal parts are welded together or bolted or clamped together in such a way as to create substantial pressure at the contact area, they may be considered to be a continuous conducting piece. In a number of places, however, contact between pieces is light and the degree of electrical connection is uncertain. Clean metal parts touching lightly may have a low resistance connection between them, but if a particle of dust or a thin film of surface oxide or contamination interferes with contact, an ohmmeter (using a low test voltage) may show a very high resistance connection. Since the insulating gap is short, a modest voltage would break down the gap, thus forming a lower resistance path. Such points are important to consider when they occur near inflammable materials because the arc across such a gap generates heat. Junctions of this nature in the XM165 equipment are shown in Figure 6-2.

The strongback assembly XM43 contains light-contact points between the adapter and tie rod assembly, adapter and clamps, arming wire and arming wire tube, and other places. These are usually extended regions of contact with many points of contact connected in parallel. Similarly, there are a number of connection points between the strongback and the time fuze XM721. The strongback touches screw heads on the timer, and other connections exist via the arming wire and the safety wire. None of these light-contact points is exposed to any pyrotechnic material. The entire adapter assembly along with the time fuze are therefore considered to be a single conducting body, and this body is one of the points at which connection may be made to an external circuit.

The center section of delay fuse passes through a hole in the time fuze and also through a hole in an ignition pellet within the housing. This light-contact point is shown as resistor R_1 in Figure 6-2.

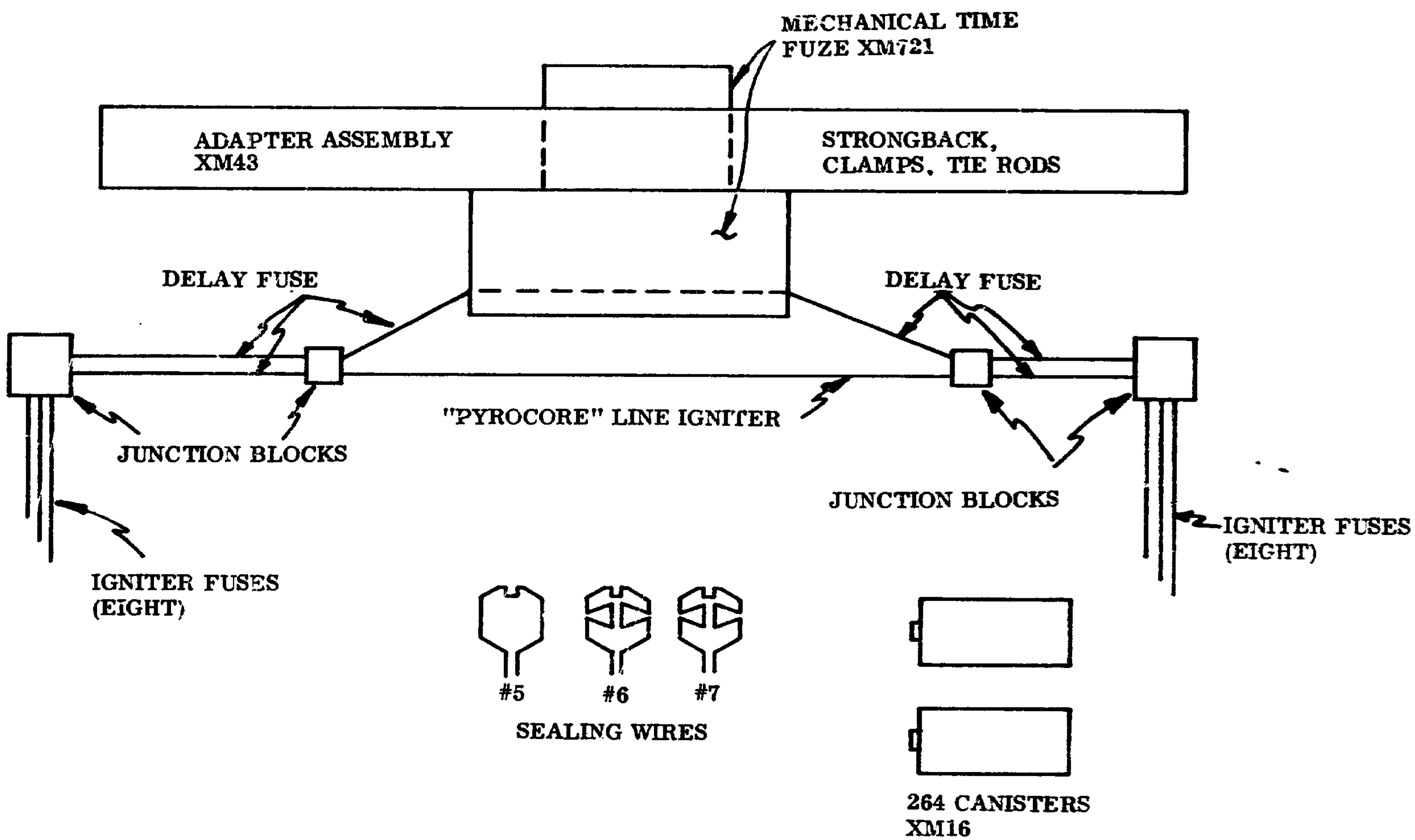


Figure 6-1. Conducting Parts in Chemical Agent Canister Cluster XM15

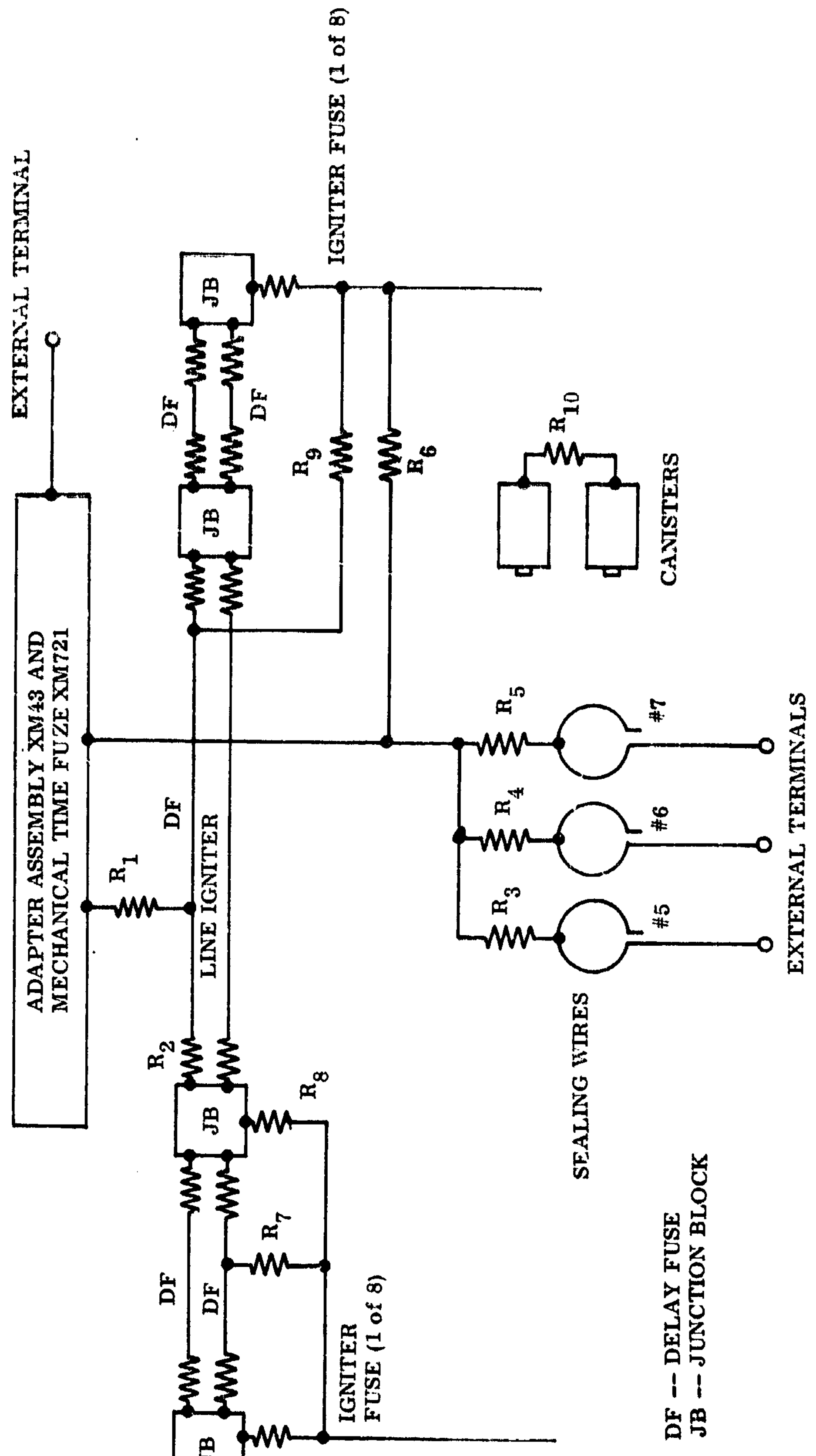


Figure 6-2. Points of Possible Contact Between Conducting Parts

Each point where a section of fuse or Pyrocore igniter enters a junction block is a possible arcing point and is adjacent to an igniter pellet. R_2 is an example of such a point.

If the 12 sealing wires are numbered 1 through 12 from left to right (viewed as in Figure 6-2), wire number 5 is between the overlapping shells of the third and fourth clusters, and wires numbers 6 and 7 are on each side of the central plate between the fourth and fifth clusters. The time fuze, XM721, is attached to the clusters by hooking a clip over the edge of the fourth cluster shell and inserting a single mounting screw through the base of the time fuze and into the edge of the central plate. The tolerances on the length of the clip and the location of wire number 5 are such that the clip may or may not contact the sealing wire when the time fuze is in position. If the mounting screw is exactly centered it is separated from sealing wires numbers 6 and 7 by .024 inches each; however, because the sealing wire melts itself into the plastic plate, it could easily touch the screw. These three possible connections between the time fuze and the sealing wires are shown as R_3, R_4, and R_5 in Figure 6-2. Because the ends of the wires come out of the bottom of the cluster, they are possible connection terminals to external circuits.

Sections of delay fuse leading to expulsion charge igniters in clusters 3 and 4 may touch the time fuze mounting plate where they pass through notches in the plate. It has been shown that a sufficiently strong arc is capable of igniting the delay fuse through the lead jacket; therefore, these points are included in Figure 6-2 as R_6. Similarly, certain igniter fuses may touch delay fuse sections between junction blocks (R_7 in Figure 6-2) or the small junction blocks themselves (R_8 in Figure 6-2); and the igniter fuse to module 5 may touch the center delay fuse (R_9 in Figure 6-2).

Finally, there may be contact between some of the individual canisters, while others will be separated. The canister diameter is 1.250 inches and the center-to-center spacing is 1.275 inches so that they would all be separated if all were perfectly placed. However, the diameter of the locating fingers is such as to permit contact between them. Three canisters in contact form a three-sided opening which will contain a 0.194-inch cylinder; the locating fingers have a nominal 0.188-inch diameter. Many light-contact points may therefore exist, one of which is shown as R_{10} on Figure 6-2.

Several features of Figure 6-2 should be especially noted:

- The resistors shown are not conventional ones, but represent points where the resistance is unpredictable and may be either essentially zero or moderately high, and in the latter case subject to breakdown when voltage is applied.
- Not all potential arcing points are represented--only those where there could be metallic contact.

- This is not a complete equivalent circuit; leakage paths across insulating materials and capacitances have yet to be considered.

6.2.5 ANALYSIS TECHNIQUE

It is not suggested that the circuit of Figure 6-2 be analyzed in the form shown, as it contains too many unknown resistances. This diagram is intended only to show the various points of uncertain contact and the conducting paths between them and to the outside world. It is suggested that the circuit be used in the following manner. Assume that the possibility of ignition due to arcing at one of the points indicated in Figure 6-2 is to be investigated. The resistor at that point is replaced by the leakage resistance and capacitance that would exist across the assumed gap. Most of the other resistors would be replaced by short circuits, a few by open circuits. The conducting parts (exluding the canisters) would thereby be separated into two sections with only capacitance, leakage conductance paths, and an arc gap between the two sections. There may be several ways of dividing the conductors into two sections, depending on which uncertain contact points are assumed open and which are assumed shorted. It would probably be necessary to determine the worst case by investigating several configurations. The equivalent circuit finally analyzed, then, would contain none of the resistors of Figure 6-2, but would contain high leakage resistances and capacitors provided by the insulating materials in the structure.

6.2.6 LEAKAGE RESISTANCE AND CAPACITANCE

There is a possibility of a small current flow between each pair of conducting parts in the canister assembly if the two parts are at different potential. This current path is represented by a high-value resistor. In addition, an electric field is present in the intervening region due to the potential difference, and charges of opposite signs are stored on the two parts. The circuit element which has these properties is the capacitor. Each such pair of conducting parts, therfore, is joined by a parallel RC combination.

Figure 6-2 indicates a total of 30 conducting parts, including all 16 of the igniter fuses (but excluding the canisters). Therefore, a complete representation of all of the circuit elements associated with these parts would contain 435 parallel RC combinations. Through it might be possible to show all of these in a single diagram, the diagram in this form would not be useful for understanding the behavior of the equipment. If all 264 canisters were included as well as the remaining 9 isolated sealing wires and a number of small parts not heretofore considered such as the spring pads and fuse retainer tabs, it would no longer be possible to represent the complete circuit of nearly 10^5 components. Fortunately, this sort of representation is not necessary with the analysis technique suggested in paragraph 6.2.7.

6.2.7 FORMATION OF THE EQUIVALENT CIRCUIT

It has been suggested in the preceeding paragraphs that the gaps between conducting parts should not all be considered to exist simultaneously but should be considered one at a time with most of the other parts connected so as to form two sections separated by the gap under consideration. In addition to the two sections connected to the arc gap, there will generally be other metal parts which are floating. These would include the CS canisters and the isolated sealing wires plus other small parts. The grouping of the parts into connected sections greatly reduces the number of circuit components that must be included and makes it possible to draw a circuit which can be analyzed. A generalized circuit is shown in Figure 6-3. The particular parts of the device that are represented by each component of the generalized equivalent circuit will depend on where the potential arcing point is assumed to be.

External terminals are associated with the strongback and the sealing wires and therefore may exist on one or both sides of the gap, depending on the particular configuration. They will exist on some of the floating parts.

Floating parts which have external terminals, or to which arcing may occur, should be included in the circuit. All other floating parts, it is assumed, may be omitted as the effect of their presence is included in the other circuit components.

6.2.8 A SPECIFIC EXAMPLE

The example included in this paragraph will better illustrate the construction of an equivalent circuit. Assume that it is desired to investigate the possibility of an arc occurring between the central delay fuse section and the left small junction block. This is the contact point labeled R_2 in Figure 6-2. This point is open-circuited, and all of the others in Figure 6-2 are shorted. In this case, there is no possibility of an arc since the two sides of the gap are still connected together, and no voltage can exist across the gap. It is necessary also for at least one other point to be open in order to have an arc at point R_2. There are several ways to make an arc at R_2 possible, and for this example it is assumed that the line igniter also fails to make contact with the same junction block.

The conducting parts have now been divided into two groups, as follows:

Group 1	Group 2
Left large junction block	Right large and small junction blocks
Left small junction block	Center and two right delay fuse sections
Left two sections of delay fuse	Line igniter
Left eight igniter fuses	Right eight igniter fuses
	Strongback and timer
	Sealing wires numbers 5, 6, and 7

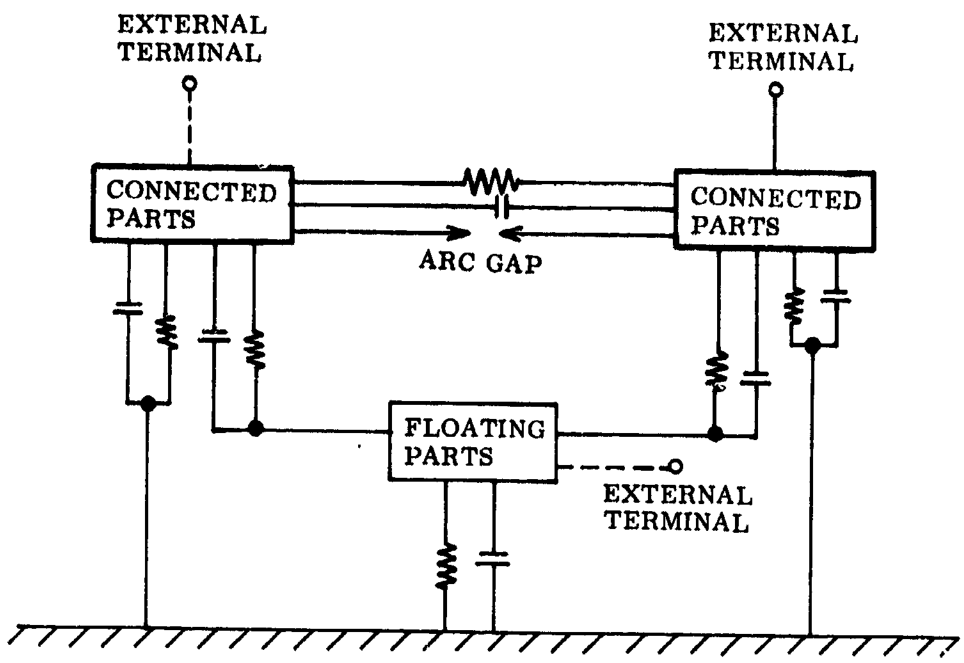


Figure 6-3. Generalized Equivalent Circuit

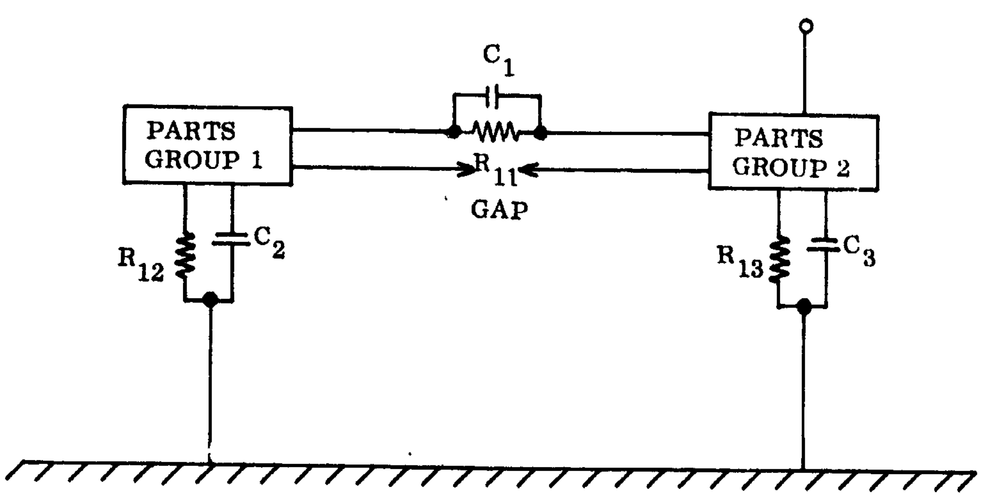


Figure 6-4. Example of Equivalent Circuit

Figure 6-4 shows the equivalent circuit that results when these two conducting groups and the ground plane are joined by the assumed admittance paths.

It is essential to understand that the boxes in Figure 6-4 each represent a number of physical parts, but in the equivalent circuit they are merely junction points--such as big dots. They do not contain any components of the equivalent circuit.

Parts group 2, because it contains both the strongback and the sealing wires, has external terminals. It is only necessary to indicate one terminal, but contact with this point in the circuit may be made either through the strongback or the stubs of the sealing wires. (By shorting R_3, R_4, and R_5, we have assumed that the sealing wires are in contact with the timer.)

Capacitor C_1 represents the stray capacitance between all the parts of group 1 and all the parts of group 2. Physically, most of this capacitance would probably be between the junction block and the two fuse sections which do not quite make contact with it.

R_{11} is the resistance between the same groups of parts. The grease on the fuse parts entering the junction block (or whatever is preventing solid contact) would contribute to R_{11}; there may also be longer leakage paths that are significant, such as through the silicone rubber material in which the fuse parts are potted.

C_2 represents the capacitance between the parts of group 1 and the surrounding walls, floor and other surfaces at ground potential. R_{12} is the leakage resistance from these parts to ground. C_3 and R_{13} are corresponding values for parts group 2. If the whole XM15 assembly is well insulated (for example, resting on a mat of good insulating material), R_{12} and R_{13} could be omitted.

Canisters and isolated sealing wires are not included because, in the present example, any arcing involving these parts and any charge entering or leaving the circuit via the sealing wire ends are not considered. These parts do, of course, influence the values of certain circuit components, especially the capacitors C_1, C_2, and C_3.

6.2.9 ANALYSIS OF EQUIVALENT CIRCUIT

Using the example of an equivalent circuit, its use is illustrated in this paragraph. Suppose someone wishes to investigate what happens when a man carrying an electrostatic charge touches the strongback. The equipment is assumed to be initially neutral and well insulated from ground. The charged man can be represented by a capacitor C_o in series with a resistance R_o. C_o is the ratio of the charge on the man to the voltage between his body and ground. These quantities may all vary as the man moves about; the values used would be those existing at the instant he touches the equipment. R_o represents the resistance to the flow of current between the man and the equipment.

The circuit may now be drawn as shown in Figure 6-5. Closure of the switch represents contact between the charged man and the strongback. It is desired to determine the voltage variation across the gap, as the charge initially on C_o redistributes itself to the other capacitors in the circuit.

If R_o is much smaller than R_{11}, which is likely to be the case, R_{11} may be neglected during the charging of C_1. All three capacitors, C_1 through C_3, receive some of the charge from C_o. The time constant of this charging phase is $R_p C_{net}$, where C_{net} is the net capacitance of the circuit as seen from the terminals of R_o:

$$C_{net} = \frac{C_o \left[C_3 \ (C_1 + C_2) + C_1 \ C_2 \right]}{(C_o + C_3) \ (C_1 + C_2) + C_1 \ C_2}$$

The voltage on C_1 rises initially at a rate determined by this time constant. A curve of V_1 (the voltage across C_1 and the gap) versus time is shown in Figure 6-6. The peak value reached by V_1 (if no breakdown occurs) can be found to be:

$$V_{1(max)} = V_o \ \frac{C_o \ C_2}{(C_o + C_3) \ (C_1 + C_2) + C_1 \ C_2}$$

where V_o is the voltage to which the man, C_o, was initially charged.

Eventually, C_1 will discharge through R_{11}, but this phase of the charge redistribution is not of great interest for purposes of this study.

The voltage $V_{1(max)}$ may be compared with the expected breakdown voltage of the gap. Since the gap is small, breakdown is quite likely to occur before $V_{1(max)}$ is reached. At the time of breakdown, the open circuit gap is replaced by a low resistance and charging of C_2 continues (now at a new time constant) with the charging current crossing the gap. C_1 also discharges through the gap. The energy dissipated in the arc may then be calculated as a function of the circuit component values and the initial and breakdown voltages.

The energy initially stored on C_o is not all dissipated in the arc; some of it is dissipated in R_o. The relative amounts depend on the resistance of the arc after breakdown. As a practical matter some of the energy will also be dissipated in another arc which forms at the switch during its closing; i.e., between the hand of the man and the strongback as he approaches.

In this example the gap has been assumed to be a good open circuit: R_{11} is large compared to R_o. If this assumption were not made, the maximum voltage across the gap would not be as great. (The circuit equations would also be more complex.) Therefore, it can be seen that if good contact cannot be guaranteed between fuse sections and the blocks, some sort of partial conducting path will aid in reducing hazards due to arcing at this point.

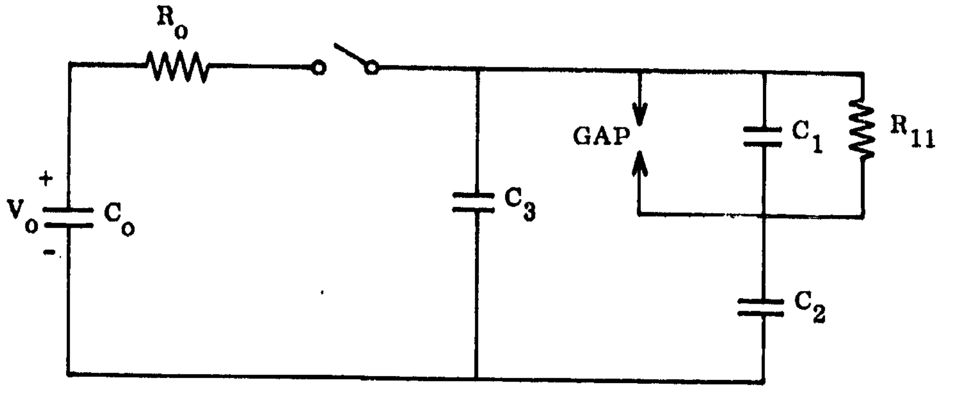


Figure 6-5. Circuit for Analysis of Redistribution of Charge

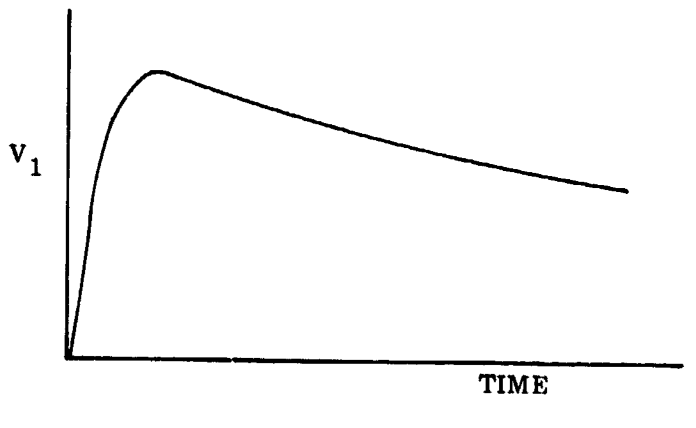


Figure 6-6. Voltage Across Gap

6.3 EQUIVALENT ELECTROSTATIC CIRCUITS FOR THE E8 LAUNCHER

6.3.1 GENERAL

From the electrical conception standpoint the E8 launcher is constructed differently than the XM165. The E8 launcher is completely encased in insulation material. Within this housing are sixteen tubes and within each tube are four metal cartridges (E23) containing the propulsion material for launching and the gas to be disseminated. Each of the metal cartridges is linked to the remaining cartridges by a fuse strip. In addition, the E8 launcher contains support material, igniter chord, and a system provided for ignition by manual or electrical means from outside the housing.

The housing itself represents a multiple layer dielectric insulator surrounding all critical parts of the system. The existence of such an insulator around the critical "circuits" would appear to be a good safety measure; however, there are conditions that can occur whereby this insulator is a detriment and possibly an energy source for providing undesired ignition of the system. This condition is described further in succeeding paragraphs of this report.

The prime area of investigation described in this report is the circuit that is present allowing an electrostatic charge or transient electrical energy to enter the critical "circuit" area from outside housing. This circuit is initiated at the firing well. A secondary circuit not described at this time is the direct capacitive effect existing between the housing and the E23 cartridge and fusing system.

6.3.2 MANUAL ACTIVATOR - PRIMER FUSE ASSEMBLY

6.3.2.1 Equivalent Circuit

The manual activator-primer fuse assembly is constructed in a manner that may allow electrostatic and possibly certain types of electromagnetic energy to be transferred to areas within the E8 launcher. The path begins at the firing well which becomes visibly or physically accessible when the cover is removed for purposes of manual or electrical preparation for firing. Removal of the cover is not necessarily required for exposing the system to electromagnetic fields.

Figure 6-7 shows the fundamental circuit present beginning with the manual activator system. This fundamental circuit contains all major equivalent circuit components which may be reduced to a simplified circuit. The resistors indicated as R_1 through R_4 (Figure 6-7) are not considered as insulator or semi-insulator type resistances as defined earlier in this report but are resistances occurring between conducting surfaces. Their values may range from a few tenths of an ohm to several hundred ohms depending upon the condition of the conducting or metal surfaces (see paragraph 6.2.4). One of the "inputs" to the circuit is the metal ring used for direct activation of the system. This ring, which is attached to a cotter pin of

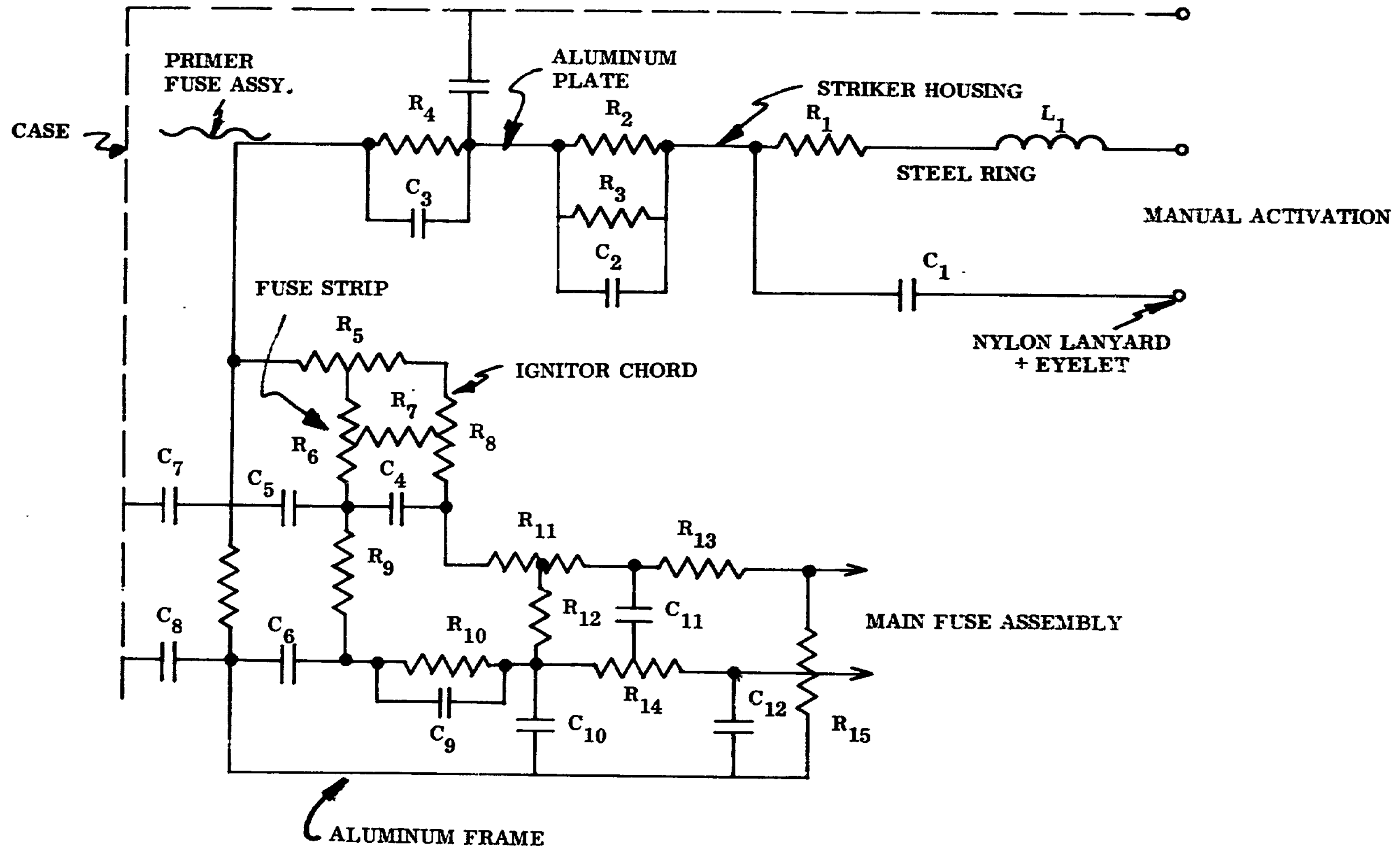


Figure 6-7. Manual Activator-Primer Fuse Assembly Equivalent Circuit

the manual activator, allows manual removal (personal contact) of the cotter pin to activate the striker assembly which in turn strikes the percussion primer and initiates activation of the system. In Figure 6-7, L_1 represents the inductance of the ring and R_1 represents the contact resistance between the ring and the cotter pin and also the resistance between the cotter pin and the striker housing assembly.

A second input to the circuit is the manual remote activation system. This input in itself requires further investigation to identify the extent of transfer or generation of an electrical charge to the striker housing. The prime area of concern is the metal eyelet through which the nylon lanyard is pulled. This circuit is represented by C_1 (Figure 6-7).

Again referencing Figure 6-7, the striker housing is electrically coupled to an aluminum mounting plate by an equivalent capacitance, C_2, which contains a multiple layered dielectric. In addition, it is directly coupled by a machine screw with contact resistance, R_2, and the primer cup, R_3. The primer cup is made of 90 percent copper and 10 percent zinc and is brased to the striker housing. Its contact resistance is expected to be quite low in value so that the major contribution to the resistance essentially is formed by a nut attached to it and touching the mounting plate by pressure. This same nut is slotted and attaches to the aluminum frame of the primer fuse assembly. The contact resistance is represented by R_4. (The equivalent circuit of Figure 6-7 has been simplified to some extent when considering this part of the circuit.) C_3 in parallel with R_4 represents the capacitance of the mounting plate to the primer fuse assembly frame.

As mentioned earlier the resistances just described are not normally considered representative of dielectric or semi-dielectric material but are metal-to-metal contact resistance. Their values should range, in this case, between a few tenths of an ohm to (at most) several hundred ohms. In contrast to this condition, the primer fuse assembly can have equivalent resistivity circuits of semi-dielectric material.

The primer fuse assembly consists of sandwiched layers of dielectric material (electrical tape and sponges), fuse strips and igniter cord (possibly semi-dielectric material) and an aluminum frame. A simplified cross-section of this assembly is shown in Figure 6-8. The aluminum frame of the assembly is connected through the resistor, R_4 (Figure 6-7), to the conductive circuits described. According to the system drawings, the igniter cord is taped to this end of the aluminum frame. It appears to be touching the frame for a reasonable length for contact considerations and R_5 of Figure 6-7 represents the condition. There is some indication that the end of the fuse cloth (or fuse strip) also touches the frame. However, the fuse strip and igniter cord are pressed together for a considerable distance, thus providing the tap in R_5 as well as R_7, C_4, R_{12} and C_{11}. The resistors R_6, R_9, R_{14}, and R_8, R_{11} and R_{13} represent the resistivity of the fuse strip and igniter cord material, respectively. In addition, R_{10} and C_9

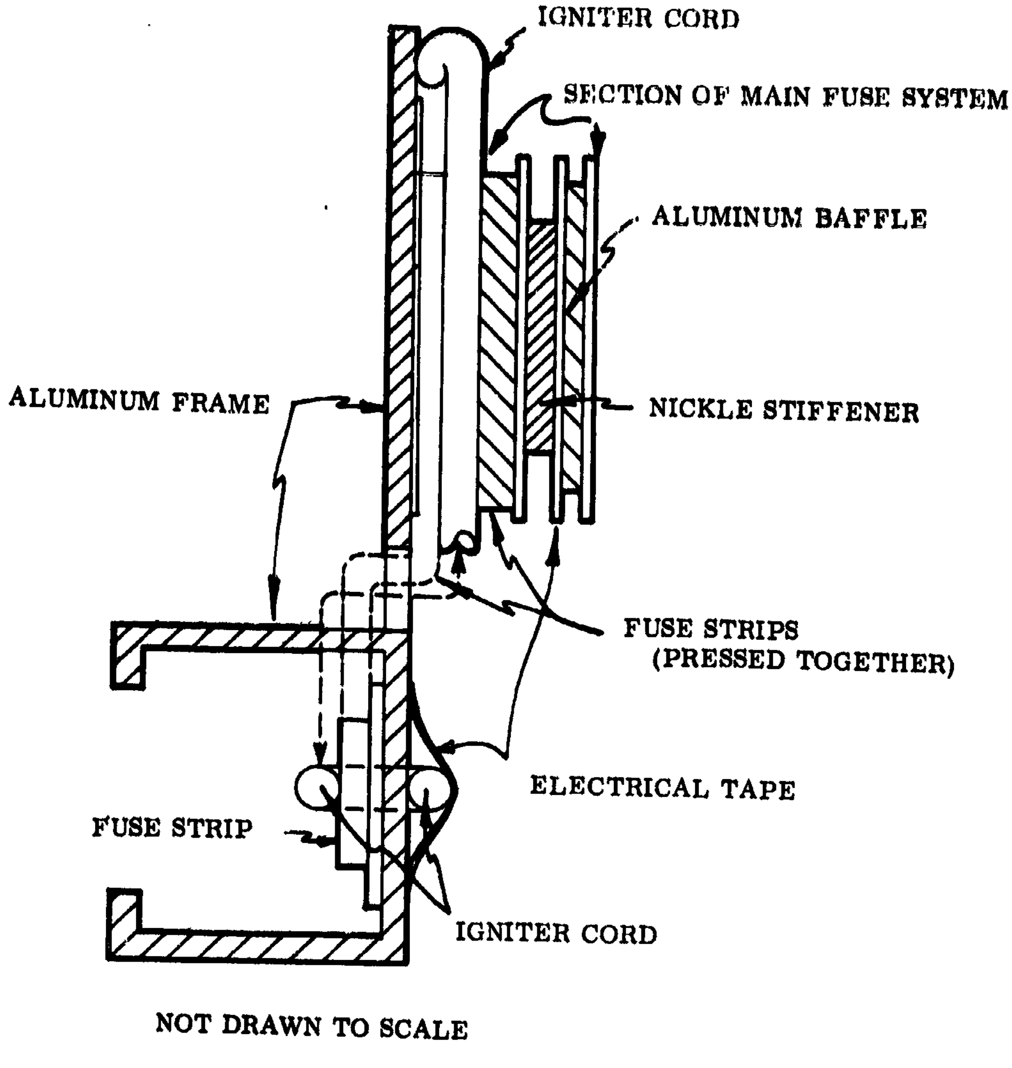


Figure 6-8. Partial Cross-Sectional View of Primer Fuse Assembly Pressed Against Main Fuse System

represent the coupling resistivity and capacity of the vertical and horizontal fuse strips as they are overlapped within the assembly (Figure 6-8). The primer fuse assembly is approximately shaped like the letter "L". Two overlapping fuse strips are used in this configuration. The fuse strip is pressed against the aluminum frame throughout the full length of the assembly separated by a sheet of electrical tape. The resulting capacity coupling is indicated by C_5, C_6, C_{10} and C_{12}. The igniter chord also apparently touches the aluminum frame at the other end of the assembly and, because it also is pressed against the fuse strip, the configuration is represented by R_{15} in Figure 6-7.

The nature of the construction of the primer fuse assembly (that is, the sandwich construction of the frame, fuse strip, igniter chord and the tape and sponge dielectric) results in the equivalent electrical characteristics to be distributed throughout the assembly. Thus, the primer fuse assembly equivalent circuit shown in Figure 6-7 is actually a type of distributed transmission line. The values of resistances and capacitances are a function of the fuse strip and igniter chord dimensions and effective area in respect to the frame. The resistivity and permittivity are distributed continuously; exceptions to this condition are R_5, C_9, R_{10} and R_{15}. It is expected that this circuit will have a characteristic pulse response as well as an electromagnetic transmission response. In addition, there is, to some extent, capacitive coupling to the launcher housing. This capacitance is represented by C_4, C_7 and C_8.

The far end of the primer fuse assembly (Figure 6-7) attaches to some degree (electrically) to the main fuse assembly and igniter chord. The details of these parts of the system are beyond the scope of this report. It is noted, however, that direct conductive coupling from the manual activator is terminated at this point as is indicated in respect to the frame in Figures 6-7 and 6-8.

6.3.2.2 Simplified Equivalent Circuit

A simplified version of the equivalent circuit is shown in Figure 6-9. The components C_o and R_o represent the internal impedance and energy storage capability of the energy source. In this case, consider a man who may generate or transfer an energy charge from a source. R_o and C_o may be replaced by other types of sources as would appear when considering the electromagnetic case. The components R_A and C_A represent the equivalent circuit values of the "metal to metal" contact resistances R_1 through R_4 and the corresponding capacitance of the previously described configuration. The simplified distributed circuit "transmission line" is represented by R_B, R_C, R_D, C_B, and C_C. The components C_D, C_E and C_F are simplified circuit capacitances of the aluminum frame, fuse strip, and igniter chord to the case. The component representation of this part of the equivalent circuit is incomplete due to the scope of the report; the prime concern here is that of the manual activator and primer fuse assembly. However, it is necessary to estimate to some extent the remainder of the circuit because of its functional influences upon the manual activator and primer fuse assembly circuits.

6.3.2.3 Analysis of Simplified Equivalent Circuit

Considering the electrostatic case in respect to Figure 6-9 the final steady state condition involves C_o, C_D, C_E and C_F. The final steady state voltage, E_F, is:

$$E_F = \frac{E_o C_o - E_1 (C_D + C_E + C_F)}{C_T}$$

(Equation 6-1)

where $C_T = C_o + C_D + C_E + C_F$

E_o = initial voltage across C_o

E_1 = initial voltage across C_D, C_E and C_F

The value of E_o may be of the order of 5,000 to 10,000 volts if a man is the means of energy transfer or source and the humidity is not excessive.

The transient condition of Figure 6-9 is somewhat complex as a function of time and depends upon the relative values of R_A, R_5, R_B, R_D and R_C. R_A is expected to be of relatively small resistance. The time constant of the initial instant of the charging phase may be expected to approximate R_o C net where:

$$\frac{1}{C_{net}} = \frac{1}{C_o} + \frac{1}{C_D} + \frac{1}{C_A}$$

(Equation 6-2)

This will be a relatively fast charging rate and the larger portion of the distribution of the charge will appear across C_D, considering the expected value of R_A. With this occurrence the "transmission line" will possess most of the charge of C_D across its terminals. If the contact resistance of the fuse strip and igniter chord is considerably higher than its distributed resistance, this is where such breakdown points will occur (point Y or Z) if the voltage is high enough; if they are not, the charge will be redistributed as time increases with the longer time constant provided by the distributed transmission line and C_E and C_F. It is difficult to ascertain the characteristics of the potential breakdown regions until relative values of the equivalent circuit are determined. In fact, the values of R_o, C_A, R_A and C_D could be high enough in respect to the distributed transmission line and C_E and C_F to reduce the breakdown region to a non-hazardous condition.

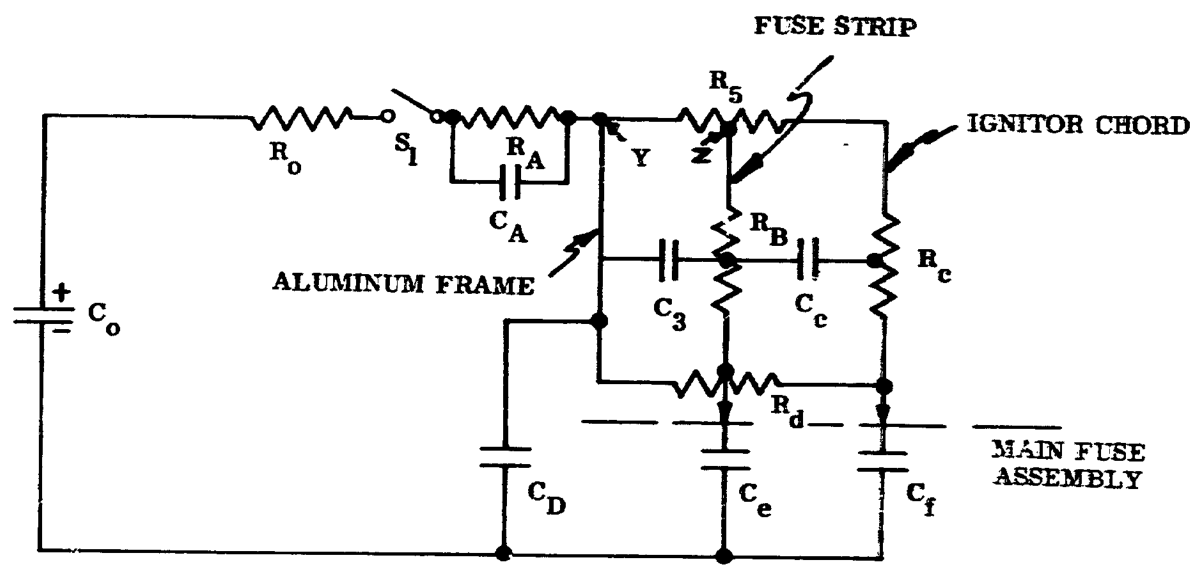


Figure 6-9. Simplified Equivalent Circuit of Manual Activator-Primer Fuse Assembly

It is also noted that because of the configuration construction the system analyzed may be quite immune to pulse type energy or high frequency electromagnetic sources. The aluminum frame together with C_A and C_D may provide a low bypass type impedance essentially isolating the critical areas from such problems. This would depend, among other things, upon the conductivity and dielectric factors of the case itself.

6.3.3 POTENTIAL SOURCE OF ELECTROSTATIC CHARGE

The E8 launcher housing or case, as it is sometines called, is constructed of Royalite, identified as type number 40-1211-RL. This material is part of the plastics family. It is approximately .062 inches thick, and with the polyfoam existing directly beneath it, the material completely surrounds all of the critical components of the system. This construction represents a multiple layer dielectric insulator. Normal use of the E8 launcher is expected to include considerable amounts of movement and rubbing of the Royalite against other material. A larger percentage of this action might occur against material worn by a man and some would occur against his skin as he prepares the launcher for use. It would also be expected that the same man could be involved in preparing the launcher for firing, which includes removing the firing well cover and touching parts of the manual activator assembly or squib input leads.

The agitation occurring between the man and the E8 launcher can provide an electrostatic charge. The potential that would result between the man and launcher would be expected to be caused by a negative charge or electron excess on the Royalite and a depletion of electrons or a positive charge on the man. The extent of the charge depends upon the material on the man (and also the Royalite), the extent of agitation, the length of time after the agitation that the charge is "utilized," and the existing humidity. When the man removes the firing well cover and touches any part of the manual activator assembly, he will transfer his charge depletion to the igniter chord and fuse strip critical area. If no breakdown occurs (see Figure 6-9 and discussion related to it), the charge originally generated between the man and the case will be distributed to C_D, C_E, and C_F as indicated by Equation 6-1.

The length of time the charge remains across the capacitors is a function of the conductivity of the imperfect dielectric. It may be possible to accumulate the charge or under certain circumstances have it oppositely charged from that described. When two charge accumulations occur which are of opposite polarity the transient breakdown conditions can increase considerably.

The precise susceptibility of the E8 launcher to electrostatic charges can only be determined by measuring some of the equivalent circuit values. It is evident from the preceding discussions that some of the construction design is beneficial to the reduction of possible electrostatic ignition; however, there are other considerations that should be taken into account such as the case and conductive cement used with the fuse strip and igniter chord. Changes required to improve immunity to electrostatic charge problems appear quite minimal.

SECTION 7
PHASE II TEST PLAN

7.1 GENERAL

This plan represents the scope of work to be performed during the second phase of the two-phase investigation of the electrostatic vulnerability of the E8 and XM15/XM165 clusters. The objectives of this phase are to:

- Conduct electrostatic spark ignition and triboelectrification tests on subsystems and components of the E8 and XM15/XM165 clusters.
- Evaluate prior incidents of the E8 and XM15/XM165 clusters from an electrostatic viewpoint.
- Refine the equivalent electrical circuits generated in Phase I.
- Recommend measures to eliminate or neutralize hazard areas.
- Propose a future system test program.

To accomplish these objectives, Phase II will be divided into five tasks, one for each objective. The tasks will be implemented as shown in the Phase II logic diagrams, Figures 7-1 through 7-5.

7.2 PHASE II TESTING

7.2.1 GENERAL

There is sufficient evidence to suggest that the E8 and XM15 tactical CS dispersion weapons are vulnerable to premature activation by electrostatic accumulation and discharge. Results of an investigation into an accident involving an XM165/XM15 at Dugway gives credence to suspicions that an electrostatic discharge prematurely activated the weapon. Similarly, a fire at a facility manufacturing the E8 appears to have resulted from the same type of malfunction.

The series of tests comprising Phase II should prove or disprove suspicions that the E8 and XM15 are indeed sensitive to electrostatic energy. These tests will be conducted under laboratory conditions to assure control of the test environment, and the test configurations will be simplified as much as possible.

7.2.2 TEST OBJECTIVE

The objectives of these tests will be to determine the electrostatic sensitivity of the E8 and XM15, to isolate sources of electrostatic generation either internally or externally, and to determine ways of decreasing or eliminating the possibility of premature ignition.

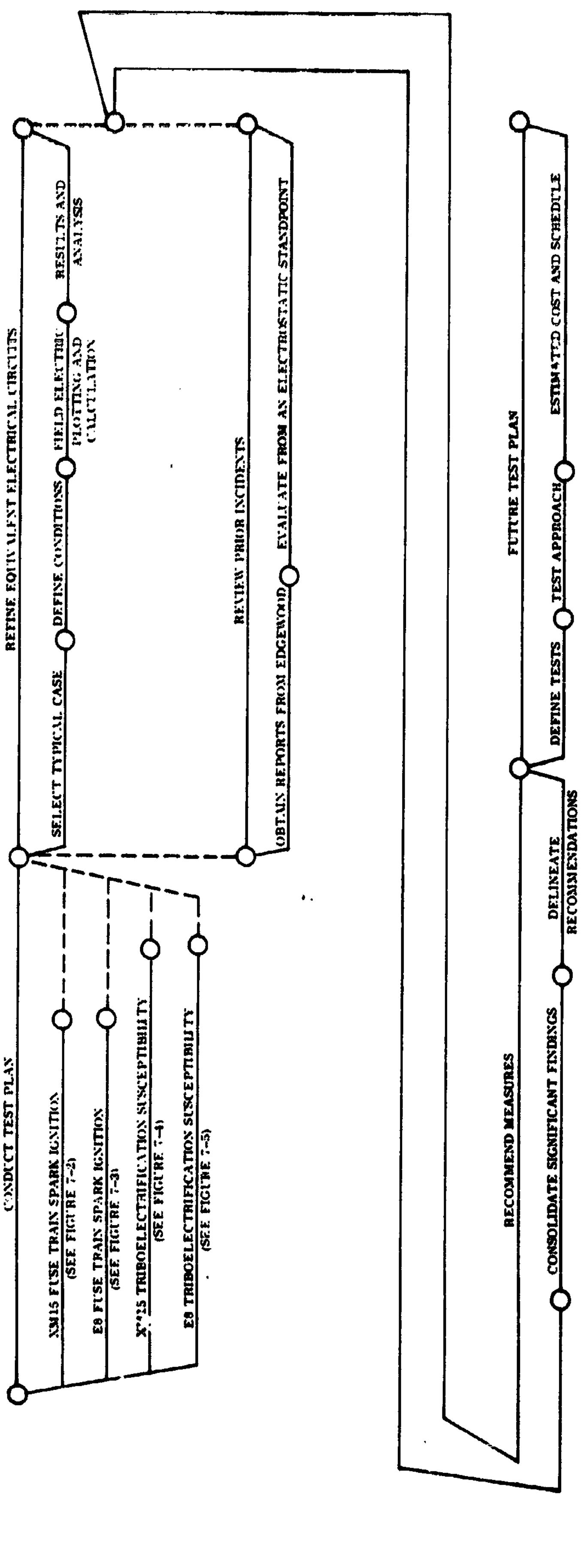


Figure 7-1. Phase II Logic Diagram

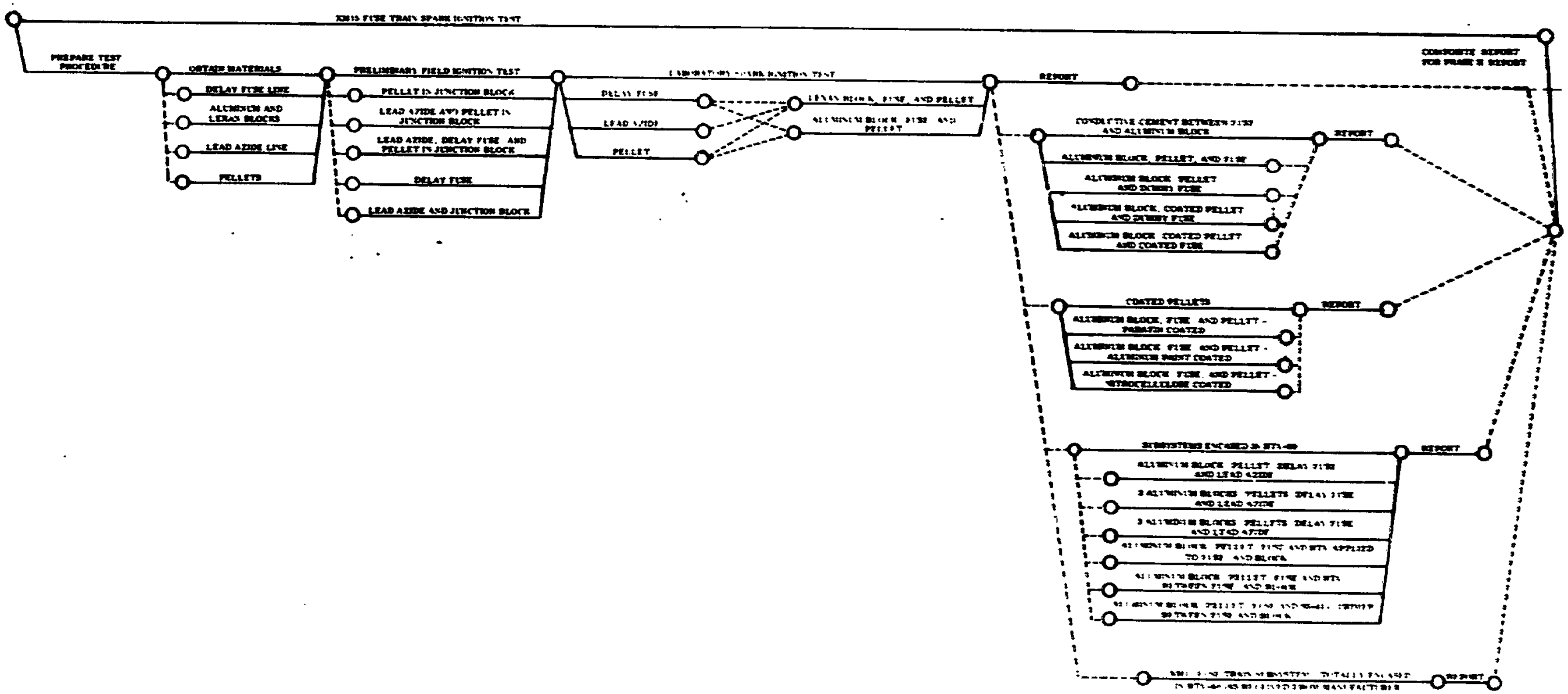


Figure 7-2. XM15 Fuse Train Spark Ignition Tests

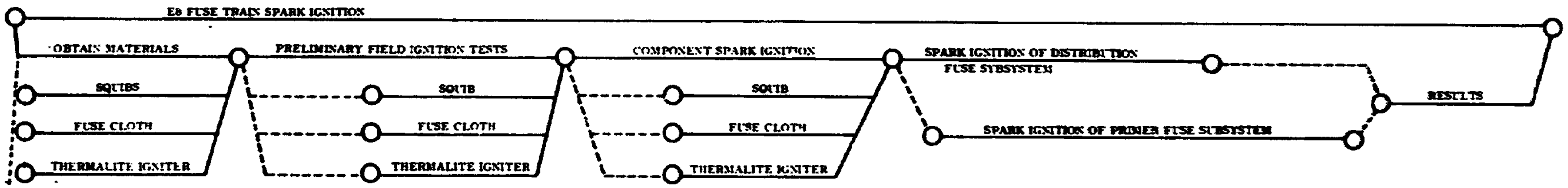


Figure 7-3. E8 Fuse Train Spark Ignition Tests

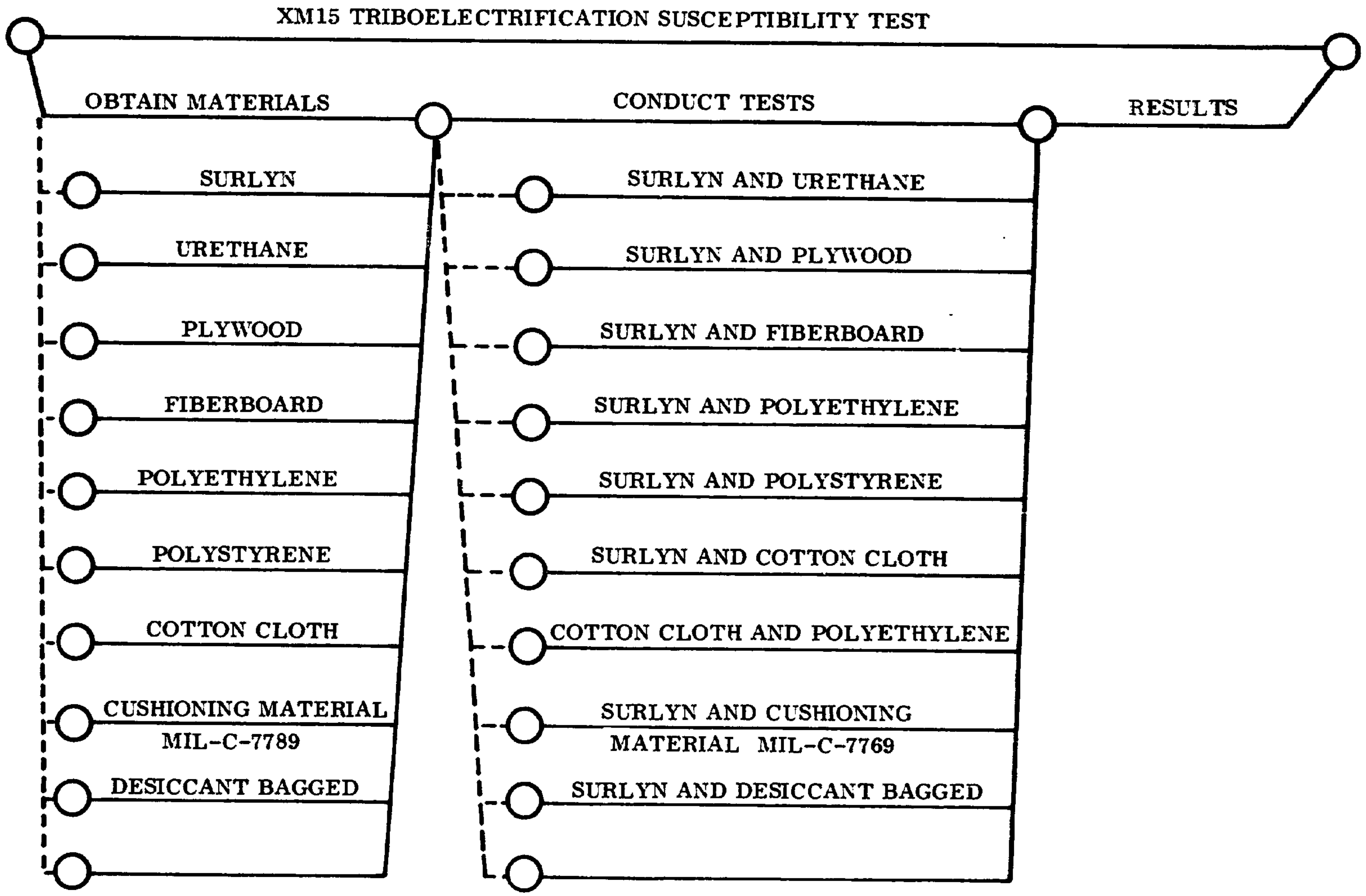


Figure 7-4. XM15 Triboelectrification Susceptibility Test

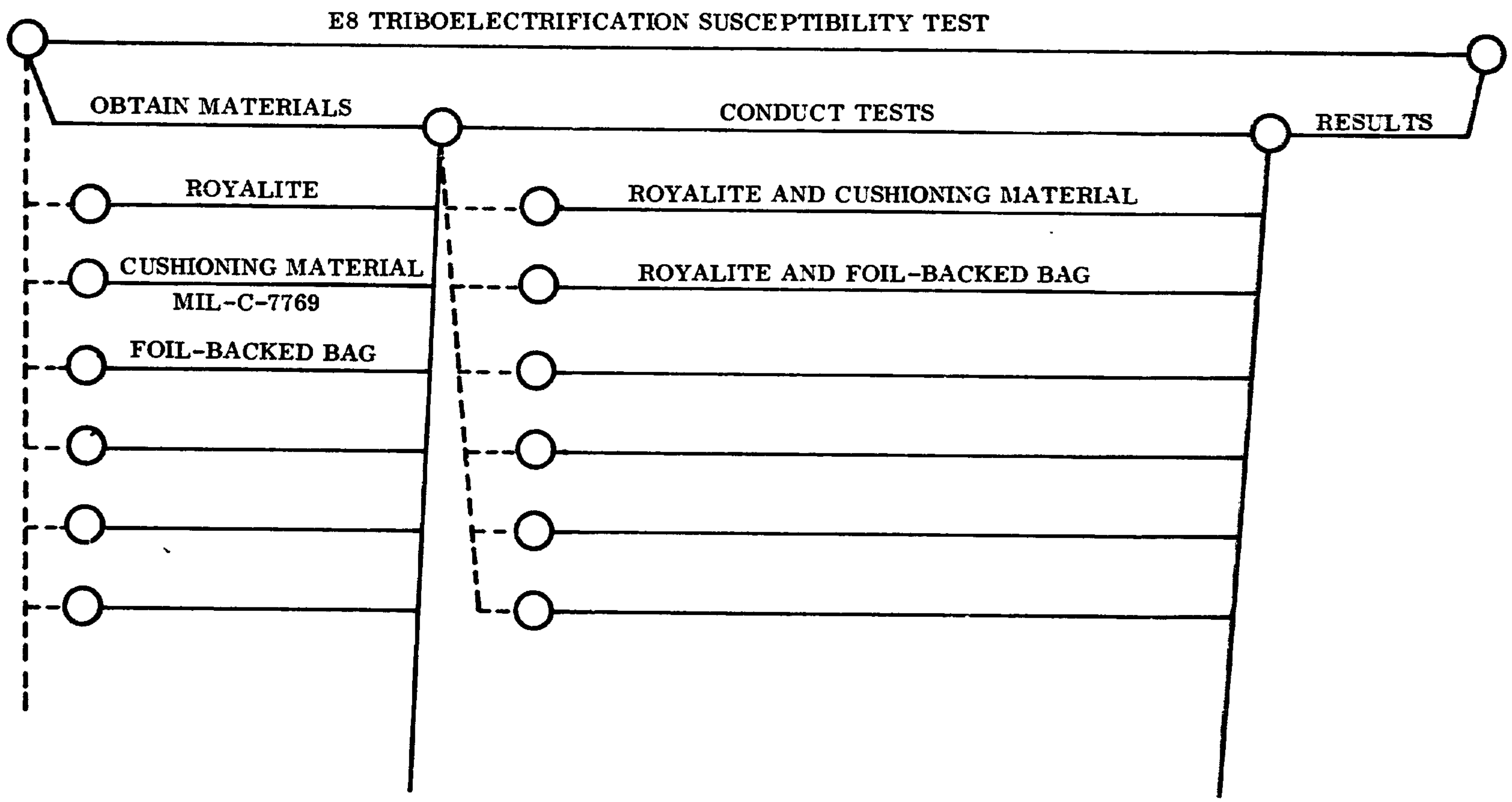


Figure 7-5. Triboelectrification Susceptibility Test

7.2.3 TEST SCOPE

During Phase II, testing will be confined to two general areas:

- Susceptibility of E8 and XM15 pyrotechnic materials to electrostatic ignition
- Susceptibility of E8 and XM15 structural materials to triboelectrification

The ignition tests will be limited to components and subsystem configurations of the E8 and XM15 fuse systems. The triboelectrification tests will include only those structural materials of the E8 and XM15 which are good insulators and consequently possible static electric accumulation points.

7.2.4 TEST APPROACH

7.2.4.1 Electrostatic Spark Ignition Susceptibility

An obvious conclusion concerning the electrostatic problems associated with pyrotechnic materials is that sparking and the resultant heat are responsible for ignition of the material. These tests should answer the question that arises from this conclusion of whether or not an energy threshold exists which governs the susceptibility of a material to ignition by electrostatic sparking.

A sample or an assembly will be placed in a test fixture and subjected to sparks of various energy levels until ignition is obtained or until it becomes obvious that the material is insensitive. Careful observations will be made to determine the exact cause of ignition and to identify the "weak points" in the fusing system.

Based on these test results, recommendations can be made for design changes to reduce or eliminate the premature ignition hazard.

7.2.4.2 Triboelectrification Susceptibility

In conjunction with the electrostatic ignition tests, triboelectrification susceptibility tests will be performed on the nonconducting structural components of the E8 and XM15.

It is known that when two different insulating materials are brought into contact with each other and then separated a positive charge will be found on one and a negative charge found on the other. This phenomenon is known as triboelectrification or electrification by touch. Frictional contact between these materials produces the same results.

Samples of the various materials will be subjected to contact and friction with materials which would normally be adjacent to them during either manufacturing, shipping, or handling. The frequency and duration of the contact or friction will be selected so as to simulate as closely as possible the actual triboelectric conditions encountered by the E8 and XM15.

By this method, a determination can be made of which materials, under what conditions, are likely to produce charges of magnitudes sufficient to prematurely activate these weapons.

7.2.5 TESTS TO BE CONDUCTED

The tests that will be conducted during Phase II are identified in Tables 7-1 through 7-4. These tables are divided into the two major groups, Electrostatic Spark Ignition Susceptibility, and Triboelectrification Susceptibility. Due to the urgency of the XM15/XM165 production schedule, some of the XM15 electrostatic spark ignition tests have been completed and reports submitted. However, those reports will be presented more concisely in the Phase II report.

7.2.6 ELECTROSTATIC SPARK IGNITION SUSCEPTIBILITY TEST PROCEDURE

7.2.6.1 Purpose

The purpose of the electrostatic spark ignition susceptibility tests is to determine the electrostatic sensitivity of various components of the XM15 and the E8 pyrotechnic fuse trains.

7.2.6.2 Description

Various materials and assemblies of materials will be subjected to electrostatic discharges of various energy levels to determine their sensitivity to electrostatic energy. Capacitance values and voltage levels will be varied to attain these various energy levels; capacitive discharge will be the mechanism by which the samples will be tested.

7.2.6.3 Scope

This procedure will be used for the investigation of the following items (in a subsystem configuration):

- Delay fuse line (XM15)
- Lead azide line (XM15)
- Small junction blocks (aluminum and lexan) (XM15)
- Large junction blocks (aluminum and lexan) (XM15)
- Ignition pellets (small and large) (XM15)
- Main fuse train (E8)
- Electrical squib (E8)
- Auxiliary fuse train (E8)
- E23 fuse train (E8)

7.2.6.4 References

The following sources were utilized in preparing this procedure:

- U.S. Army Draft Technical Manual 3-1325-234-12
- U.S. Army Draft Technical Manual 3-1325-231-12

Table 7-1. Electrostatic Spark Ignition Susceptibility Test for XM15

TEST	TEST OBJECTIVE	REASON FOR TEST
Field test of pellet in junction block	To observe reaction	To determine laboratory test precautions
Field test of lead azide and pellet in junction block	To observe reaction	To determine laboratory test precautions
Field test of lead azide, delay fuse and pellet	To observe reaction	To determine laboratory test precuations
Field test of delay fuse	To observe reaction	To determine laboratory test precautions
Field test of lead azide and junction block	To observe reaction	To determine laboratory test precautions
Preliminary lab test with pellet material	To ignite the material with a spark	To familiarize personnel with the materials and test methods
Preliminary lab test with delay fuse	To ignite the material with a spark	To familiarize personnel with the materials and test methods
Spark ignition of pellets	To determine ignition energy level	To obtain data for analysis and evaluation of subsystem and system ignition tests
Spark ignition of delay fuse	To determine ignition energy level	To obtain data for analysis and evaluation of subsystem and system ignition tests
Spark ignition of lead azide	To determine ignition energy level	To obtain data for analysis and evaluation of subsystem and system ignition tests
Delay fuse, pellet and lexan junction block	To determine ignition energy level	To provide data to compare ignition energy levels between lexan and aluminum junction blocks
Delay fuse, pellet and aluminum junction block	To determine ignition energy level	To provide data to compare ignition energy levels between lexan and aluminum junction blocks
Conductive cement between fuse and aluminum block with pellet	To determine ignition level with positive electrical contact between fuse and aluminum block	To obtain data for analysis and evaluation of subsystem and system tests
Conductive cement between dummy fuse and aluminum block with pellet	To determine ignition level of pellet only with positive contact of fuse and aluminum block	To obtain data for analysis and evaluation of subsystem and system tests

Table 7-1. Electrostatic Spark Ignition Susceptibility Test for XM15 (cont'd)

TEST	TEST OBJECTIVE	REASON FOR TEST
Pellet (with conductive coating) in aluminum block and dummy fuse	To determine ignition level of a coated pellet	To test concept of coating the pellets
Pellet (with conductive coating) in aluminum block and fuse	To determine ignition level of a coated pellet	To test concept of coating the pellets
Pellet coated with parafin - aluminum block and fuse	To determine ignition level of a coated pellet	To test concept of coating the pellets
Pellet coated with aluminum paint - aluminum block and fuse	To determine ignition level of a coated pellet	To test concept of coating the pellets
Pellet coated with nitrocelluicse - aluminum block and fuse	To determine ignition level of a coated pellet	To test concept of coating the pellets
Aluminum block, pellet, fuse and lead azide encased in RTV-60	To detetermine ignition of subsystem encased in RTV-60	To obtain data for analysis and evaluation of system test
2 aluminum blocks, pellets, connecting fuse and lead azide encased in RTV-60	To determine ignition of subsystem encased in RTV-60	To obtain data for analysis and evaluation of system test
3 aluminum blocks, pellets, connecting fuse and lead azide encased in RTV-60	To determine ignition of subsystem encased in RTV-60	To obtain data for analysis and evaluation of system test
RTV applied to fuse and aluminum block with pellet	To determine if RTV will ingress between fuse and block	To obtain data for analysis and evaluation of system test
RTV between fuse and aluminum block with pellet	To determine ignition level if RTV-60 insulates the fuse and block	To obtain data for analysis and evaluation of system test
SS-4155 RTV primer between fuse and aluminum block with pellet	To determine ignition level if primer ingresses between fuse and block	To obtain data for analysis and evaluation of system tests
XM15 fuse train encased in RTV-60	To determine ignition level of XM15 fuse train	To determine if electrostatic energy can ignite the XM15 fuse train

Table 7-2. Electrostatic Spark Ignition Susceptibility Test for E8

TEST	TEST OBJECTIVE	REASON FOR TEST
Squib	To determine ignition level of squib	To obtain data for analysis and evaluation of subsystem tests
Fuse Strip (Cloth)	To determine ignition level of fuse strip	To obtain data for analysis and evaluation of subsystem tests
Thermalite Igniter	To determine ignition level of thermolite igniter	To obtain data for analysis and evaluation of subsystem tests
Distribution fuse subsystem	To determine ignition level of subsystem	To obtain data for analysis and evaluation of system tests
Primer fuse subsystem	To determine ignition level of subsystem	To obtain data for analysis and evaluation of system tests

Table 7-3. Triboelectrification Susceptibility Test for XM15

TEST	SITUATION TESTED
Surlyn and urethane	
Surlyn and plywood	In contact during packing, shipping and unpacking
Surlyn and fiberboard	In contact during packing, shipping and unpacking
Surlyn and polyethylene	In contact during packing, shipping and unpacking
Surlyn and polystyrene	In contact during packing, shipping and unpacking
Surlyn and cotton cloth	In contact during packing, shipping and unpacking
Cotton and polyethylene	In contact during the filling operation of expulsion charge bags with black powder
Surlyn and cushioning material (hair) MIL-C-7769	In contact during packing, shipping and unpacking
Surlyn and desiccant bagged	In contact during packing, shipping and unpacking

Table 7-4. Triboelectrification Susceptibility Test for E8

TEST	SITUATION TESTED
Royalite and cushioning material MIL-C-7769	In contact during packing, shipping and unpacking
Royalite and foil-backed bag	

- "Pyrotechnic Materials: Their Resistivity, Charge Generation, and Sensitivity to Spark Discharge" by Arthur D. Little, Jr.
- Assembly Procedure for Canister Cluster Assembly, Chemical Agent, XM165
- Assembly Drawings E8 and XM15
- U.S. Army Technical Bulletin 3-1310-255-10

7.2.6.5 Definitions and Abbreviations

None

7.2.6.6 Responsibilities

7.2.6.6.1 Test Conductor

The test conductor will be responsible for the performance of the test per procedure.

7.2.6.6.2 Safety

The safety representative will monitor the operation, render safety advice, and assure that the test is conducted in a safe manner.

7.2.6.7 Support Requirements

7.2.6.7.1 Special Tools/Test Equipment

The following tools/test equipment will be utilized for testing for electrostatic ignition susceptibility:

- Technician's tool box
- Fluke, Model 410B, high voltage P/S
- HV probe
- Spark gap test fixture
- Rule, calipers, or other instrument for measuring gaps

7.2.6.7.2 Equipment/Materials

The equipment/materials required for this testing activity are:

- Assorted capacitors,0.002-1.0 mfd, with voltage ratings to 10kv
- Aluminum buss with 8-32 mounting holes
- Assorted test leads
- Freon cleaning agent

7.2.6.8 <u>Prerequisites</u>

A CO_2 fire extinguisher must be available during testing, and all personnel engaged in the testing activity must wear safety glasses or face shields.

7.2.6.9 <u>Test Procedure</u>

7.2.6.9.1 Preparation

Preparations for testing will be as follows:

a. Assemble the test equipment into the configuration shown in Figure 7-6.

b. Secure the specimen or components to be tested.

c. Ensure that all personnel within ten feet of the pyrotechnic test specimens are wearing safety glasses.

7.2.6.9.2 Test

Actual testing will proceed as follows:

a. Verify that the high voltage power supply is off.

b. Place the test specimen in the test fixture (see Figure 7-6).

c. Ground the specimen as directed by the test conductor. <u>Record</u> the test configuration on the data sheet (Figure 7-7).

d. Turn on the high voltage power supply.

<u>CAUTION</u>

HIGH VOLTAGE. During the remaining steps high voltages will be present. Use extreme caution to prevent accidental contact with points of high voltage.

e. With all output voltage switches to zero, turn the high voltage power switch on.

f. In the approximately five seconds between steps, advance the output voltage switches to the test voltage specified by the test conductor. Record the final voltage on the data sheet.

g. Using the control knob, lower the spark gap test aid probe to the sample until a spark occurs.

h. Return the spark gap test aid probe to its original position.

i. Return the power supply high voltage output switches to zero.

j. Record observations and comments concerning the results of the test on the data sheet.

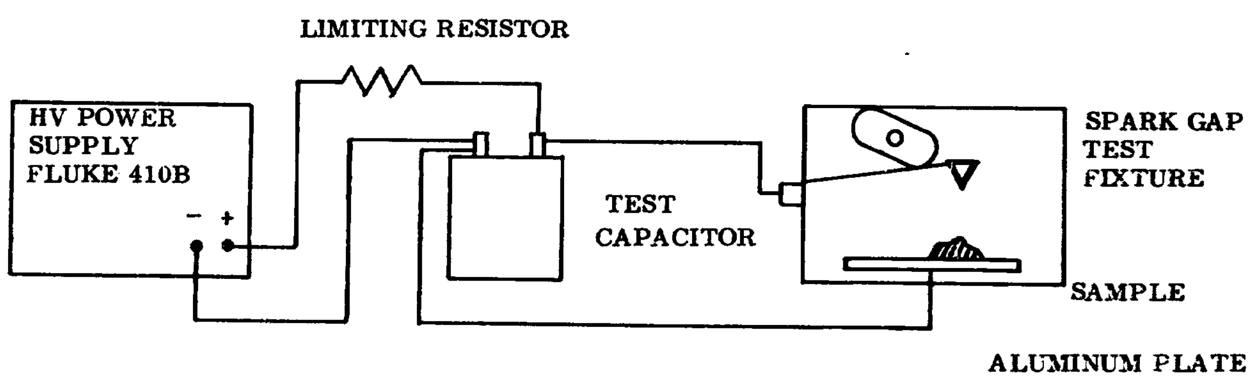


Figure 7-6. Electrostatic Ignition Susceptibility Test Setup

DATA SHEET

TEST NO.	TEST CONFIGURATION	VALUE OF CAPACITANCE (μf)	VOLTAGE LEVEL (VOLTS)	ENERGY $1/2CV^2$ (JOULES)	TEMPERATURE	HUMIDITY	DATE
					OBSERVATIONS AND COMMENTS		

Figure 7-7. Electrostatic Ignition Susceptibility Test Data Sheet

k. Clean the test surface and place the next specimen on the test fixture.

l. Repeat step 7.2.6.9.2.c.

m. Repeat steps 7.2.6.9.2.e and k.

n. Upon completion of the test series, turn off the high voltage power supply.

o. Make the necessary calculations and complete the data sheet.

7.2.7 TRIBOELECTRIFICATION SUSCEPTIBILITY TEST PROCEDURE

7.2.7.1 Purpose

The purpose of the triboelectrification susceptibility test to determine the susceptibility of various components of the E8 and XM165/XM15 weapons to triboelectrification.

7.2.7.2 Description

Various materials will be placed in contact with each other and then separated, and the triboelectric potential will be measured. Frictional contact will also be made, and the resulting potentials will be measured.

7.2.7.3 Scope

This procedure will be used only for the investigation of the triboelectric effects of the E8 and XM15 pyrotechnic fuse train.

7.2.7.4 References

The following sources were utilized in preparing this procedure:

- U.S. Army Draft Technical Manual 3-1325-234-12
- U.S. Army Draft Technical Manual 3-1325-231-12
- Assembly Drawings E8 and XM15

7.2.7.5 Definitions and Abbreviations

None

7.2.7.6 Responsibilities

7.2.7.6.1 Test Conductor

The test conductor will be responsible for the performance of the test per procedure.

7.2.7.6.2 Safety

The safety will monitor the operation, render safety advice, and assure that the test is conducted in a safe manner.

7.2.7.7 Support Requirements

7.2.7.7.1 Special Tools/Test Equipment

The following tools/test equipment will be utilized for testing for triboelectrification susceptibility:

- Technician's tool box
- Keithley Model 610B or 610C electrometer and Model 2501 head
- Statitrol Corporation Model M-1001 static meter
- Customer Materials, Inc., Model CM 1-7777 static meter
- Temperature/humidity recorder

7.2.7.7.2 Equipment/Materials

Equipment/materials required for this testing activity are:

- Glass sheet, 18 inches x 18 inches x .125 inch (6 pieces)
- Rubber gloves (2 sets)
- Freon cleaning agent

7.2.7.8 Prerequisites

Prior to initiation of the test activity, the test conductor will select the material pairs to be tested.

7.2.7.9 Test Procedure

7.2.7.9.1 Preparation

Preparations for testing will be as follows:

a. Clean the rubber gloves thoroughly with Freon after they have been placed on hands (do not rub Freon).

b. Clean the sheets of Plexiglas thoroughly with poured Freon.

c. Place the pieces of Plexiglas into two stacks of three each, using clean gloves or paper towels to prevent contamination.

d. Clean the samples with Freon when possible, being careful not to touch them with the hands.

NOTE

Some samples may react with Freon.

7.2.7.9.2 Test

7.2.7.9.2.1 Contact Electrification. Contact electrification testing will be conducted as follows:

a. Wearing cleaned rubber gloves, grasp the two samples, bring them into gentle contact, then separate them. Record the samples on the data sheet (Figure 7-8).

b. Place each sample on a Plexiglas sheet.

c. Using the Keithley Model 610C electrometer, measure the electrostatic potential of each material. Record on the data sheet.

7.2.7.9.2.2 Friction Electrification. Friction electrification testing will be conducted as follows:

a. Wearing cleaned rubber gloves, grasp the two samples and rub the surfaces together (back and forth) for 10 strokes.

b. Place each sample on a Plexiglas sheet.

c. Using the Keithley Model 610B or 610C electrometer, measure the electrostatic potential of each material. Record on the data sheet.

d. Repeat steps of 7.2.7.9.2.1 and 2 for each pair of materials.

7.3 OTHER TESTS

7.3.1 GENERAL

In addition to the electrostatic ignition and the triboelectrification tests as defined in paragraph 7.2.3, special tests relatir, to the electrostatic vulnerability of the E8 and XM15/XM165 will be conducted. The results of the planned tests may yield data or information which will dictate additional or special tests or tests in lieu of the planned tests. Also, due to system design changes or unknown events, Edgewood may require other tests in lieu of some of the planned tests. Presently two tests fall in this category: the XM15 fuse train subsystem test and the the E8 foaming test.

7.3.2 XM15 FUSE TRAIN SUBSYSTEM TEST

This test is very similar to the electrostatic ignition test defined in paragraph 7.2.3 and the same test procedure will be used. However, instead of applying a spark, energy will be applied directly to the fuse train as shown in Figure 7-9. This will simulate an electrostatic voltage being applied to the fuse train. The spark gap test fixture as defined in paragraph 7.2.3 will be used to discharge the fuse train potential. Various voltages and capacitors will be used to yield energies up to 50 joules. This test method will simulate, in a subsystem mode, realistic situations to which the fuse train is exposed. A total of six fuse trains will be tested, three

DATA SHEET

MATERIAL A MATERIAL B	CONTACT VOLTAGE	FRICTION VOLTAGE	COMMENTS

Figure 7-8. Triboelectrification Susceptibility Test Data Sheet

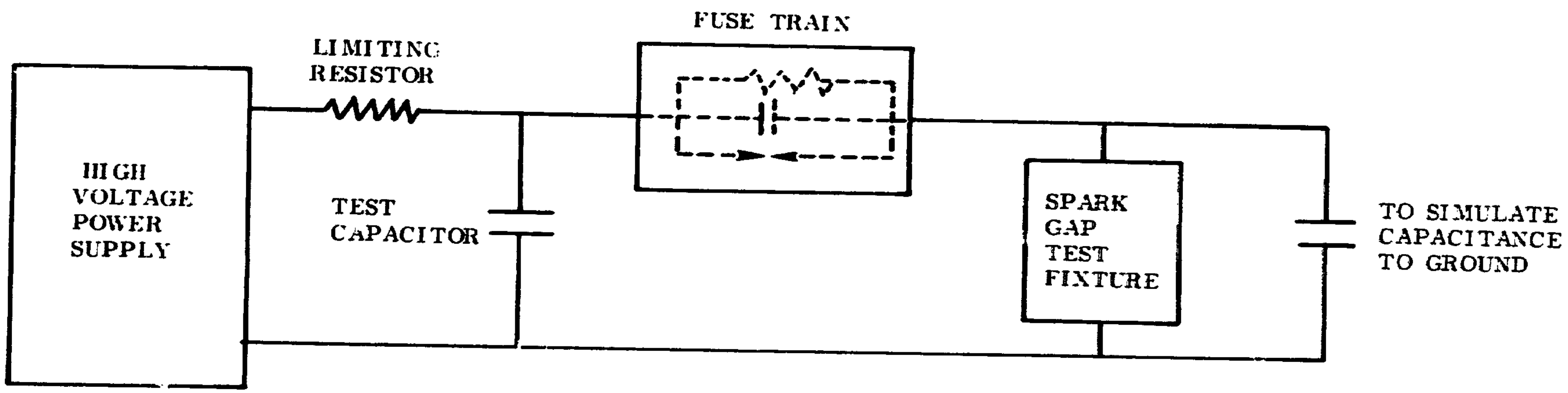


Figure 7-9. XM15 Fuse Train Subsystem Test Setup

from each of the two XM15 manufacturers. This will ensure that true samples are tested and will eliminate the possibility of inducing manufacturing errors from an independent source.

7.3.3 E8 FOAMING TEST

7.3.3.1 General

The source of two fires in the E8 production facilities has been traced to the polyurethane plastic foaming operations. Static electric ignition is the prime suspect since polyurethane foaming is a low exothermic chemical process and consequently produces insignificant heat.

It is theorized that the foamed plastic generates static electricity as it expands against the other nonconductive materials inside the E8. The aluminum foil vapor barrier placed across the top of the foamed area could provide an excellent charge collection point for this static electricity. The fuse train could be in contact with this foil barrier and easily pick up the charge. If the fuse is sensitive enough and the charge is of sufficient magnitude, ignition is possible. Ignition tests will be conducted during Phase II.

To investigate this potential hazard, a visit to the production facility will be made. During this visit the manufacturer will conduct foaming operations of an E8 to simulate as closely as possible the conditions encountered during this portion of the production process. (Refer to Figures 7-10 through 7-13 for the locations of the measuring points.)

7.3.3.2 Test Approach

The E8 foaming tests will encompass the following:

- Prefoaming Tests - Prior to initiation of foaming operations the E8 shell and other components will be measured for electrostatic accumulations. The locations and magnitudes of any charges will be noted.
- Foaming Tests - During the foaming operations the E8 will be constantly measured to determine if any changes have occurred in the location and the magnitude of any electrostatic accumulations. Any changes will be noted.
- Post Foaming Tests - Immediately upon completion of the foaming operations measurements will be made to determine the location and the magnitude of any electrostatic accumulations. Notes will be made and compared to information obtained from prefoaming and foaming tests.
- Visual Inspections - After all electrostatic measurements have been made a visual inspection of the E8 will be made to determine the:
    - Physical location of the vapor barrier with respect to the launch tubes, the foam and the top cover.

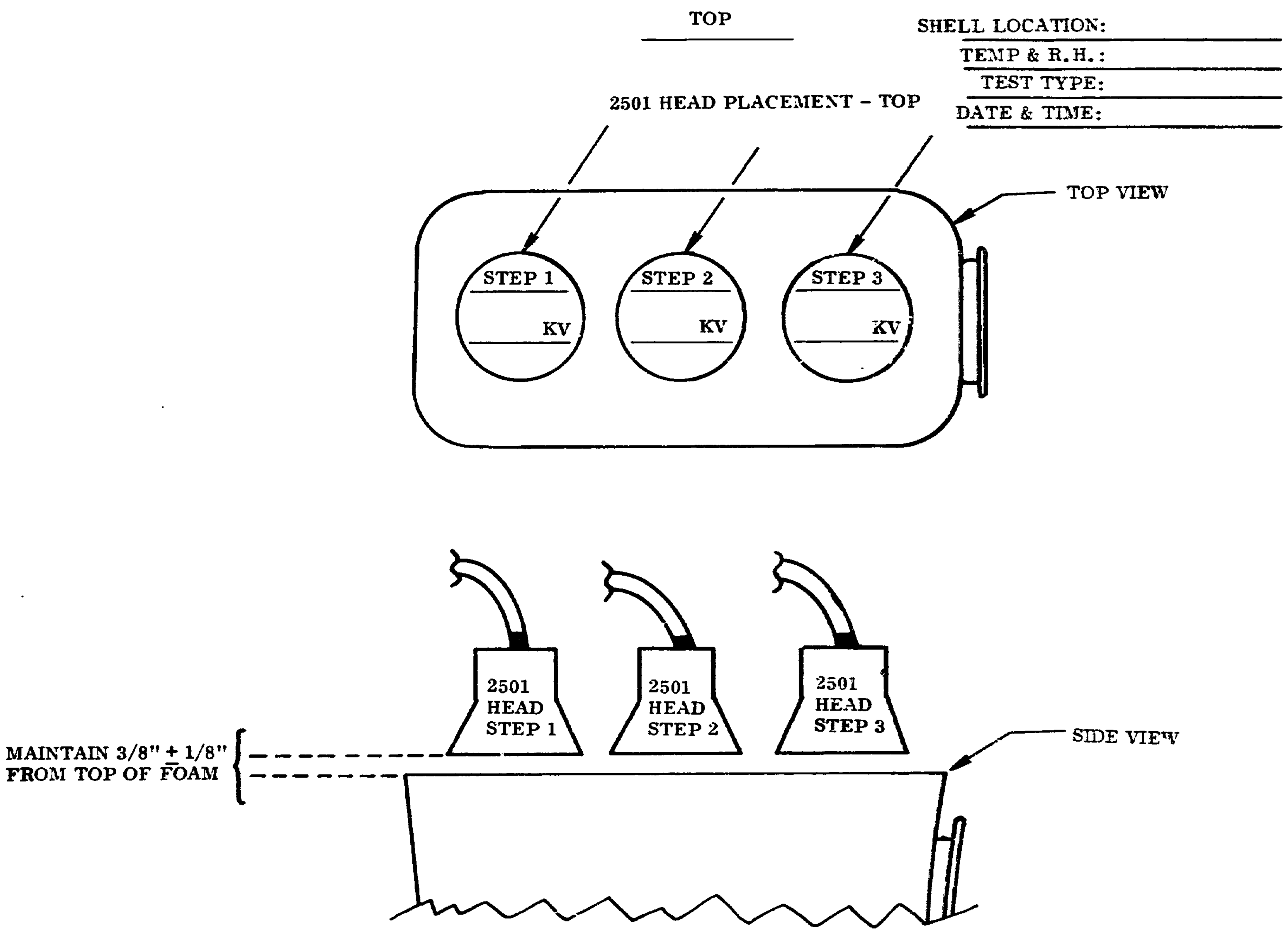


Figure 7-10. E8 Foaming Test Top Measurements

FRONT

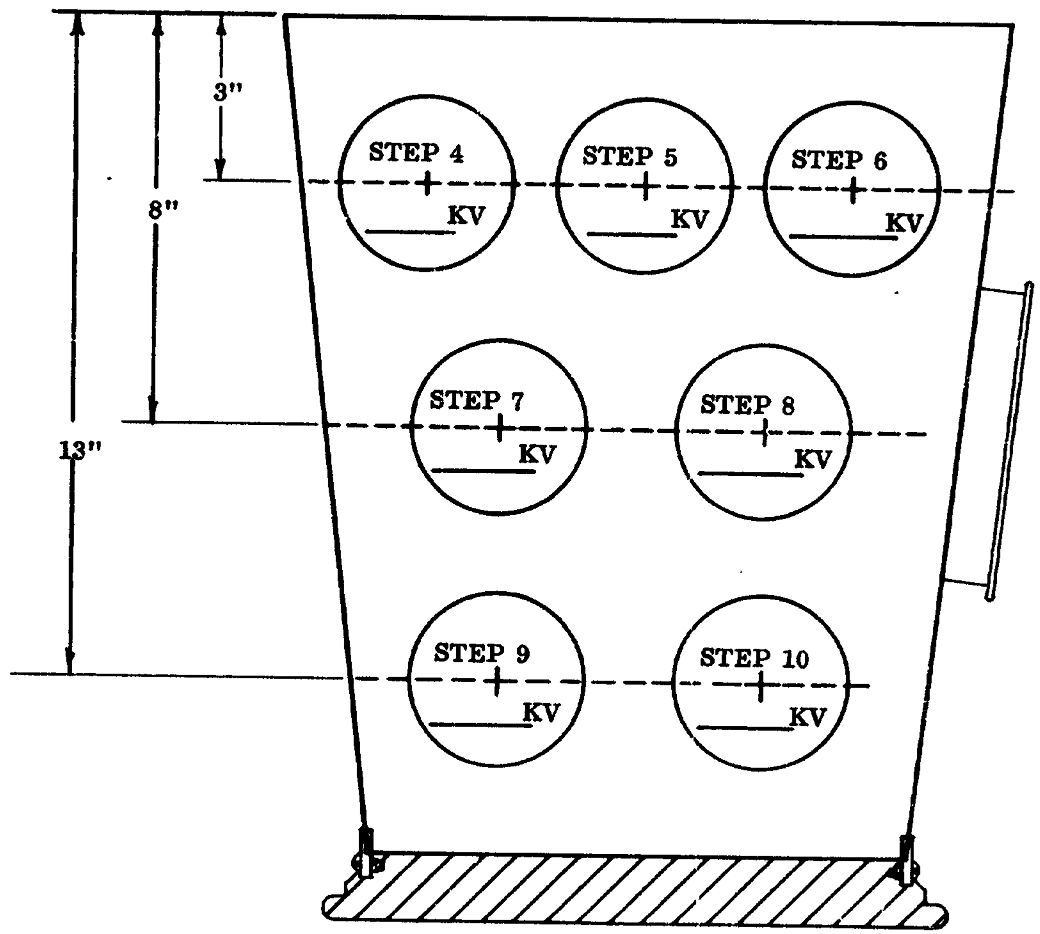


Figure 7-11. E8 Foaming Test Front Measurements

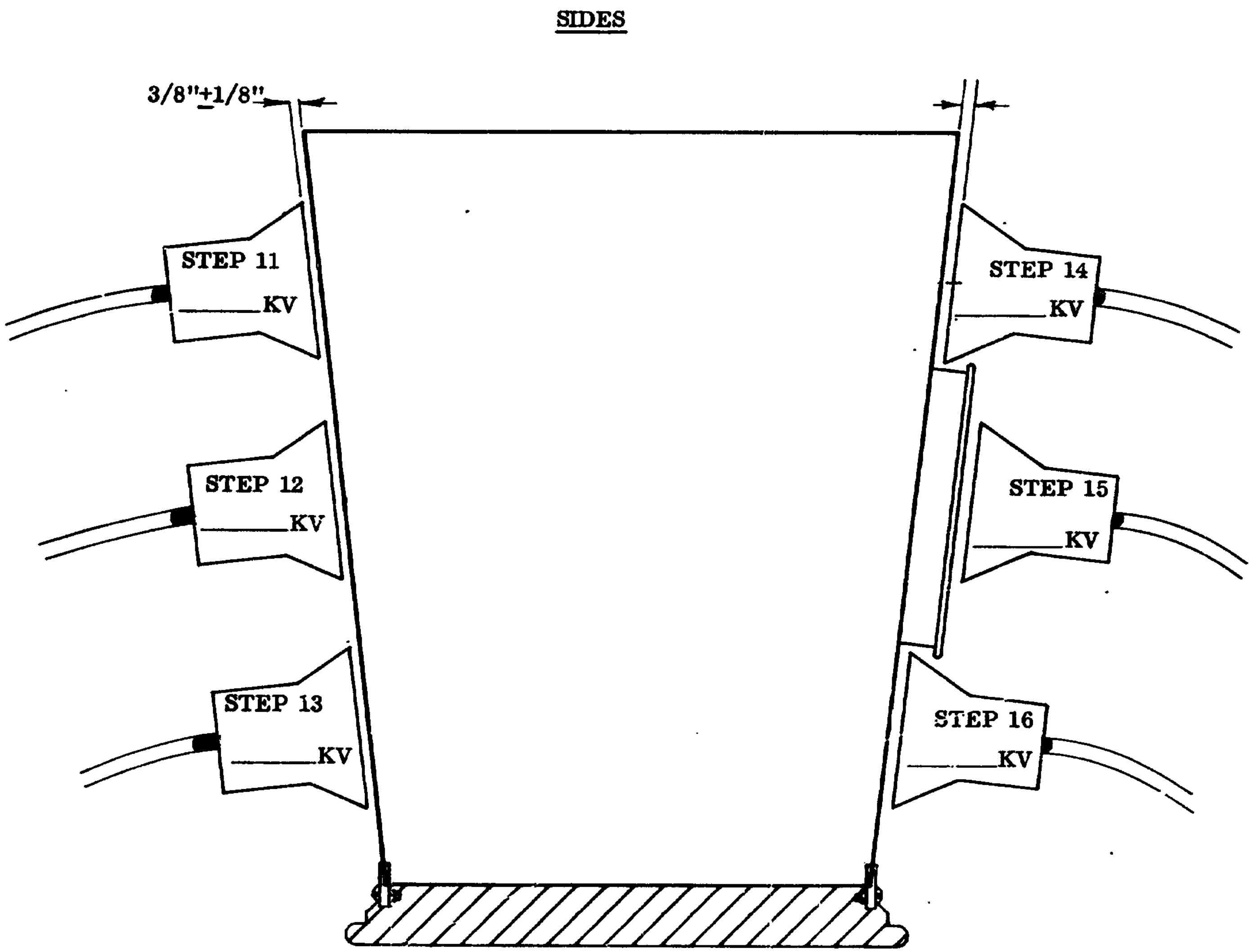


Figure 7-12. E8 Foaming Test Side Measurements

BACK

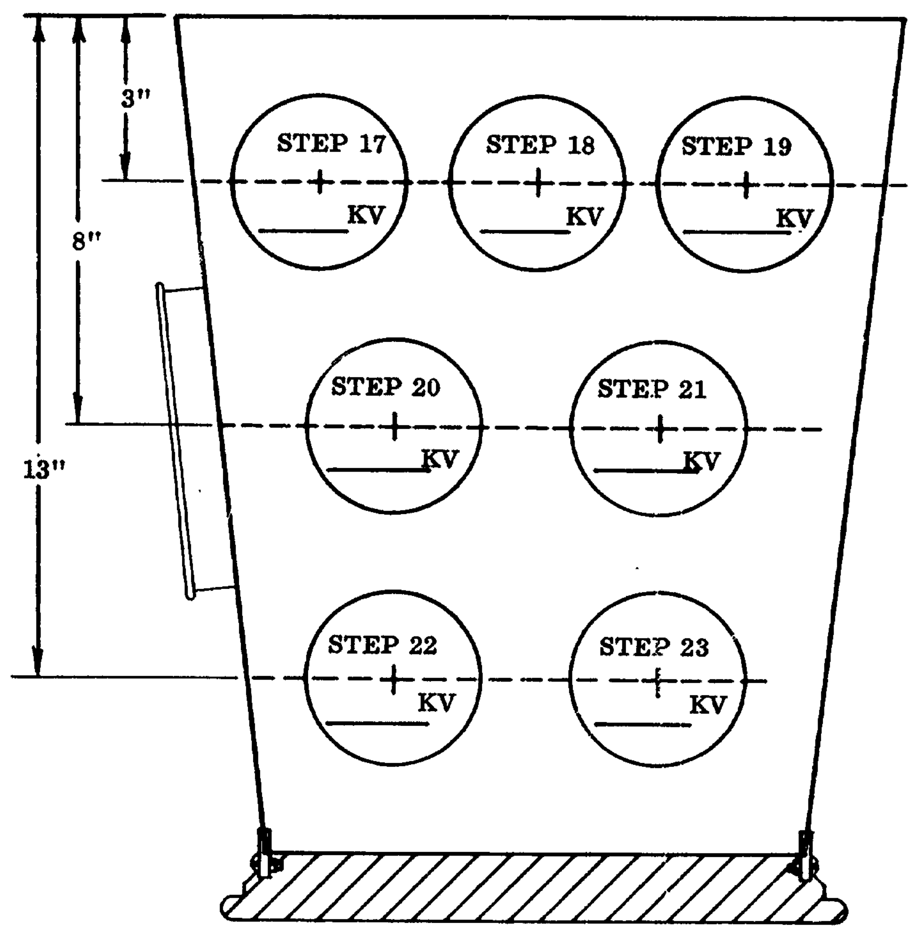


Figure 7-13. E8 Foaming Test Back Measurements

- Physical location of the fuse train with respect to the vapor barrier, foam and any metal components in close proximity.

7.3.3.3 Data Evaluation

Data acquired during the foaming operation will be thoroughly reviewed and evaluated. Laboratory tests will be conducted as required to substantiate or refute conclusions reached from the field data. Upon completion of this evaluation, a report will be prepared containing the results of the tests, conclusions reached, and recommendations for remedial action.

7.4 EVALUATE PRIOR INCIDENTS

This task will consist of evaluating prior mishaps, accidents and malfunctions involving the E8 launchers and the XM15/XM165 cluster. Success of the effort will depend on the availability of the incident reports and the details contained therein. The reports will be evaluated only from an electrostatic standpoint.

7.5 REFINE EQUIVALENT ELECTRICAL CIRCUITS

The equivalent electrical circuits will be refined and analyzed from the standpoint of assigning values to the circuit components. It is not feasible to analyze or assign values to all possible circuit components. A typical case will be considered, component values will be assigned, and the typical case will be analyzed.

Two unique techniques will be employed by the General Electric Electronics Laboratory as a part of the analysis--electrostatic field plotting and analysis of transmission lines with arbitrary boundaries.

7.5.1 ELECTROSTATIC FIELD PLOTTING

7.5.1.1 Introduction

Electrostatic field plotting is a technique for plotting equipotential contours of a two-dimensional electrostatic field. This display technique provides a visual display of electric fields and field gradients as a function of position. Thus an easily interpreted pictorial representation of the parameter (electric field) which induces discharge is obtained. The electrostatic field is generated by painting conductive lines or surfaces on a sheet of resistance paper and applying voltage potentials to the conductive lines. The resistance paper is placed on an X-Y plotter whose pen is used as a voltage probe. The voltage is fed to an analog computer where it is compared with the voltage of the desired equipotential line to generate an error signal. The error signal is amplified, filtered, and resolved into sine and cosine components which are used to drive the X-Y plotter pen in Y and X directions, respectively. This completes a servo feedback loop which effectively guides the X-Y plotter pen along a fixed voltage contour generated by the electrostatic field. A second X-Y plotter, which is driven by the same X and Y control signals as the first, traces the voltage contours in ink on a sheet of graph paper.

7.5.1.2 Servo Loop Description (See Figure 7-14)

The voltage potential at a given set of X-Y coordinates is detected by using the X-Y plotter pen to make contact with the resistance paper. The pen is connected to the input of an FET type operational amplifier used as a voltage follower. This op amp has a very high input impedance (about 10^{11} ohms) and as a result measures the voltage on the resistance paper very well.

The op amp output is trunked to the analog computers where it is subtracted from a reference voltage. The reference voltage is adjusted to the value of the equipotential contour which is to be plotted. The resulting error signal is fed through a gain and compensation circuit and then through a low-pass filter to reduce 60Hz and higher noise components. The filter output is applied to the input of a simulated rate resolver.

The rate resolver is initialized to an angle of zero degrees. This makes the initial sine output zero and the initial cosine output +100 volts. Both the cosine and sine are outputs multiplied by a constant velocity magnitude (V) to generate the velocity component in the X and Y directions. Each velocity component is fed to an integrator which generates X and Y drive voltages for the plotters. Initial pen position is determined by setting initial conditions on these integrators.

7.5.1.3 Operation

The initial values of X and Y are adjusted manually such that the error signal is zero at the start of each contour line plot. The pen is located somewhere within the parallel plate part of the field (see Figure 7-15).

When the analog computer is placed in the COMPUTE mode, the integrators become active and the plotters move in the positive X direction. If the error signal becomes positive, this means the potential at that point of the field is too small and the plotter pen must be directed in the positive Y direction to reduce the error. This means that angle must increase from zero to some positive value. This will point the velocity vector along the equipotential contour while keeping the magnitude of the velocity vector a constant.

The equipotential line is traced to within 0.5 inches of the edge of the graph paper grid. The computer is then placed in the HOLD mode which keeps the X-Y plotter pens from moving. The pens are lifted from the resistance paper and graph paper, respectively, and the computer is placed in the INITIAL CONDITION mode which drives the plotter pens back to their starting positions.

Two switches are thrown on the analog computer which changes the rate resolver initial angle from 0° to 180° and inverts the sign of rate resolver input. When placed in the COMPUTE mode, the plotter pens now move in the negative X direction and correct as before to reduce the error voltage. Due to the inversion of the sign of the rate resolver input, a positive error will now

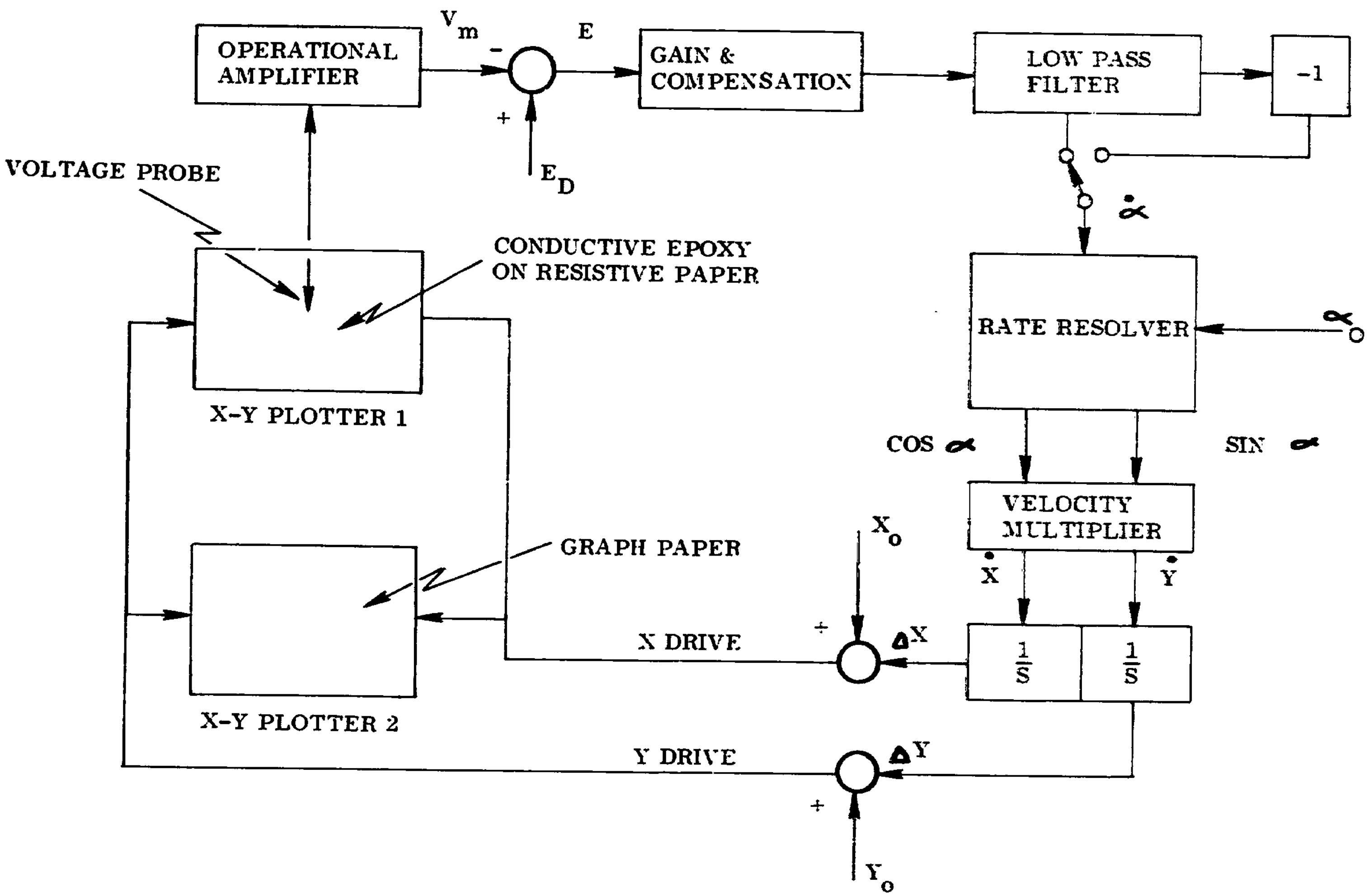


Figure 7-14. Electrostatic Field Plotter - Servo Loop

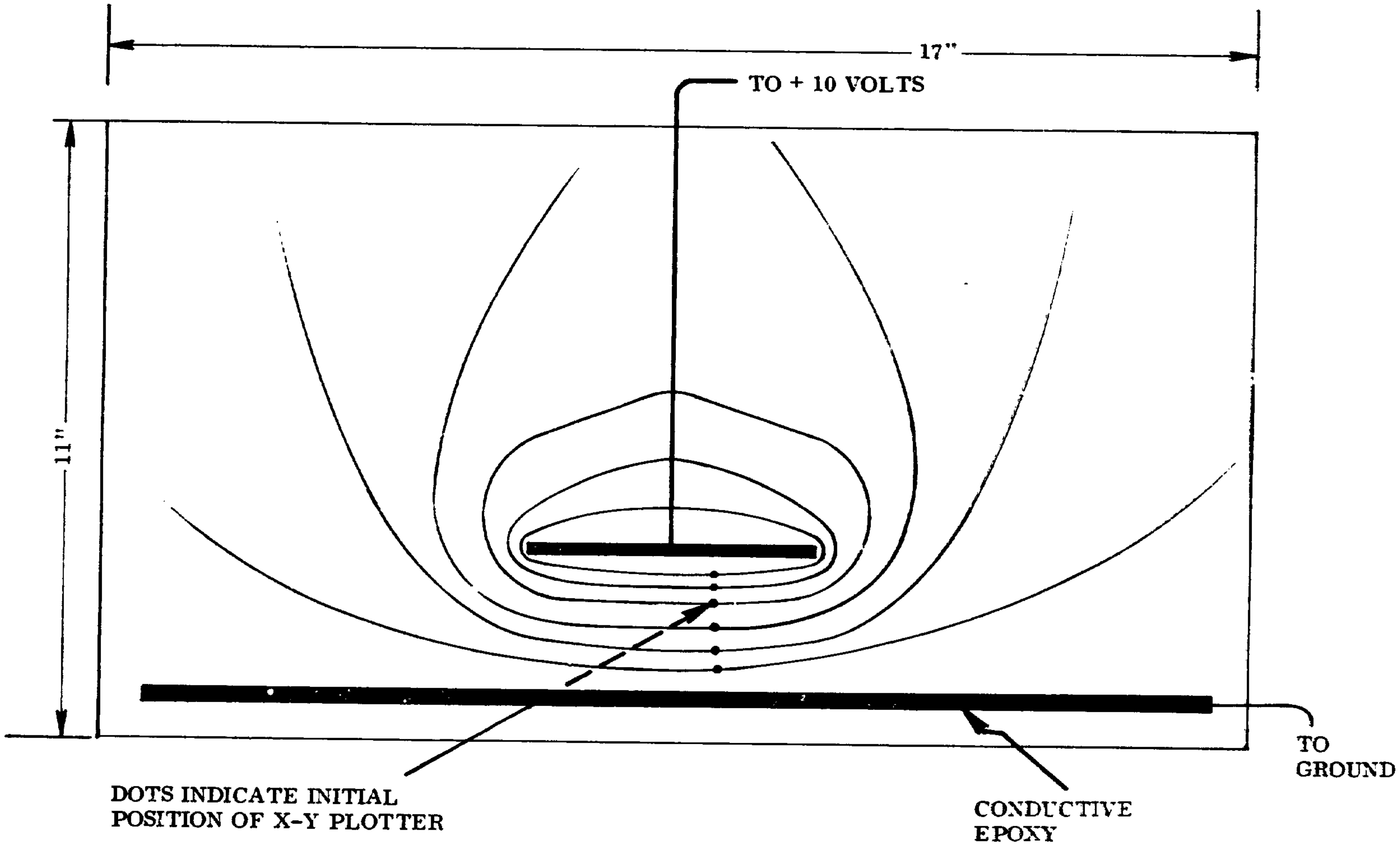


Figure 7-15. Sample Field Plot

decrease the rate resolver angle from 180^0 but will still cause a positive velocity component in the Y direction since the sine of the rate resolver angle is increasing. The greatest deviation from the equipotential contour occurs when passing close to the end of a constant voltage conductor.

7.5.1.4 Field Model

The model of the field pattern has been constructed by scaling down the physical dimensions of the real world situation to fit on a piece of 11" x 17" graph paper while preserving relative sizes. Provisions must be made to keep the areas of interest toward the center of the paper where the boundary effects are not important. The edges of the resistance paper will cause the equipotential lines to be perpendicular to the edge at the point of intersection.

The model on the resistance paper is constructed by applying conductive epoxy strips wherever conductors are supposed to be. Wires can be attached to the conductive strips by cementing them in place with the same conductive epoxy. Masking tape is used to assure reasonably straight lines with smooth edges. It is possible to get dimensional accuracies to less than 0.1 inches using this approach.

7.5.2 APPLICATION OF THE ATLAB COMPUTER PROGRAM

The Analysis of Transmission Lines with Arbitrary Boundaries (ATLAB) program is capable of analyzing virtually any mechanical configuration in terms of its electrostatic properties. The versatility of this computer program accrues from the fact that no apriori assumptions about the geometry to be analyzed are built into the program. It can thus evaluate numerically configurations that are not amenable to conventional analysis--a structure that heretofore required tedious special-purpose computer programs.

ATLAB is capable of analyzing any configuration that can be represented by X-Y segments in a plane. The structure may have multiple conductors, several different dielectrics, inner shields, etc. No matter how complicated the structure (within reason), ATLAB can determine the equivalent capacitance between conductors and the potential that any floating conductor will rise to when other conductors are excited. By use of the impedance-resistance analogy, the equivalent resistance between any two conductors can also be determined, even if the space between those conductors contains several materials of different bulk resistivities.

The following examples will illustrate the use of ATLAB in electrostatic problems similar to the present fusing problem.

Figure 7-16 represents a metallic box located within an outer shielding box. The space between the two boxes contains a plastic material on the bottom and a different plastic foam on the sides. The odd shape of the inner box would make conventional analysis difficult, if not impossible. ATLAB, by using numerical techniques, can determine the effective capacitance between the boxes directly.

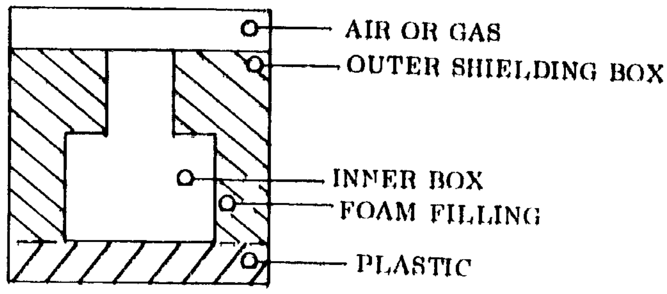


Figure 7-16. Metallic Box Within Outer Shielding Box

Figure 7-17 illustrates an electronic device normally installed inside a shielding cover. ATLAB can be used to calculate the resistance and capacitance (the equivalent circuit) present if the cover inadvertently made a poor contact with the base. The amount of current that would flow due to the application of a voltage to the outside shield and the time-constant of the object, its susceptibility to external pluses, could then be determined.

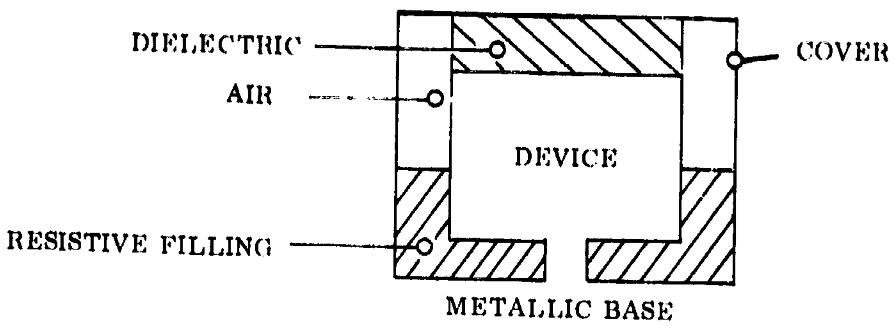


Figure 7-17. Electronic Device Normally Installed Inside Shielding Cover

Figure 7-18 illustrates another electronic problem, that of two isolated devices located within a metallic enclosure. If a potential were applied between points A and B, ATLAB could calculate the capacitively-induced potential which the other nonconnected box attains. This calculation would be necessary to check for the possibility of sparking between the box and the case.

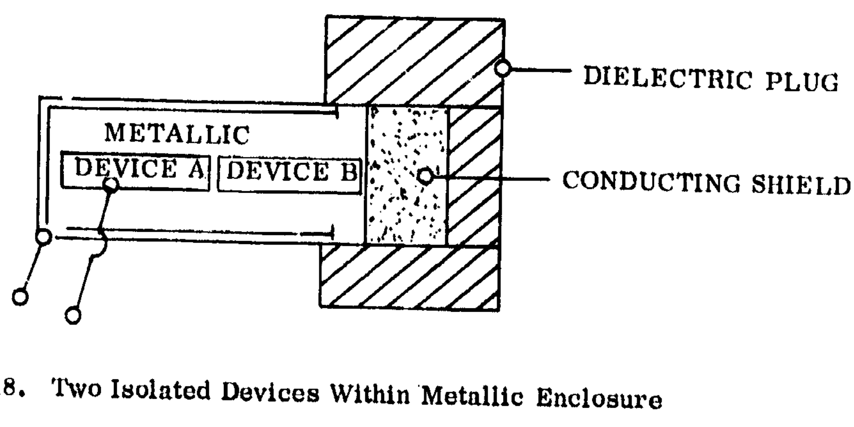


Figure 7-18. Two Isolated Devices Within Metallic Enclosure

7.6 RECOMMEND MEASURES

This task will consist of reviewing all efforts expended in Phase I and Phase II of this program and compiling all recommendations resulting from the tasks. Recommendations will be based on the results, findings, and assumptions generated during Phase I and Phase II.

7.7 FUTURE TEST PLAN

Because this program has considered only the E8 and XM15/XM165 clusters in subsystem configurations it is necessary to conduct system tests to verify the findings/assumptions resulting from Phase I and Phase II. The tests should be conducted with completely assembled inert and/or agent-loaded XM15/XM165 and/or E8 canisters which incorporate those changes deemed necessary. The same tests should also be conducted with units which have not incorporated changes. This will provide for a "before and after" type test.

The future test plan will identify recommended tests, time required to conduct those tests, and cost estimates.