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19 ABSTRACT (Continue on reverse if necessary and identify by block number)
This TOP describes methods for determining the explosive hazard classification of vehicle applique armor titles and for reaching a conclusion of insensitive munition if possible. A secondary objective is to determine the tile-to-tile detonation propagation effects by initiating the center tile of a matrix and observing the reaction of the surrounding tiles.

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

AMSTE-RP-702-10
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AD No.

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TYPICAL REACTIVE ARMOR SAFETY TESTS

1. SCOPE. This TOP describes methods for determining the explosive hazard classification, as defined in TB 700-2[1*], of vehicle applique armor tiles and for reaching a conclusion of insensitive munition if possible. A secondary objective is to determine the tile-to-tile detonation propagation effects by initiating the center tile of a matrix and observing the reaction of surrounding tiles. Tests described in this document are useful for determining tile sensitivity to various threats; i.e., small arms, overhead artillery, etc. Subtests which include tank-fired high-explosive anti-tank (HEAT) rounds and anti-tank missiles may be useful to gather performance data as well. Not all subtests may be required for a safety assessment or release. Likewise, additional subtests may be required based on supporting documents such as the Independent Evaluation Plan/Test Design Plan (IEP/TDP), Test and Evaluation Master Plan (TEMP), etc. In short, safety test requirements need to be assessed on specific tile design parameters, proposed vehicle doctrine, and various user concerns. Other subtests which may be required for a safety release/assessment may include vibration, climatic storage, rough handling tests, etc., which are already well documented in other TOPs.

*Superscript numbers/letters match those in Appendix B.

It is not the intent of this TOP to describe all tests required for qualification of a reactive armor system or for a safety assessment/release, but rather to describe typical safety/performance tests used to characterize reactive tile designs. Detailed guidance on tests required for specific systems should be obtained from user specification/requirements documents. If required, contact the U.S. Army Technical Center for Explosives Safety (TCES), Development and Production Explosives Safety Division (SMCAC-ESP), at DSN 585-8876/8808 (Comm 815-273-8876/8808) for detailed advice on selection of tests which will result in a valid determination of "insensitive munition" for the item under test.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities. Only the facilities required by particular subtest(s) to be conducted need to be provided.

Item	Requirement
Fragmentation arena	Constructed as described in Appendix A to suit test requirements
Protective shelters	Bombproofs, barricades, etc., to protect personnel and cameras from fragmentation and blast effects
Fragment recovery equipment	As needed to separate fragments from bulk recovery media (e.g., metal detector, etc.)
Timing device	As needed to control test events (e.g., starting cameras, firing flashbulbs, detonation, etc.)
Electronic detonators	As needed to remotely detonate the test item
Cradle or mounting	As needed for various threats
Fire-fighting equipment	To protect facilities and instrumentation
Drop tower test facility	For drops 12 m (40 ft) or less for unimpeded falls
Temperature chambers	To condition tiles to required temperatures for testing
225-kg (500-lb) block	Used to drop on a tile, from a specified height, during impact testing, to create a shearing, crushing, or punching action
1134-kg (2500-lb) block	Used to drop from 12 m to simulate vehicle collision

Item	Requirement
High-voltage source such as an arc welder	20 kV, 300 A for power line contact test with carbon probe
Lightning simulation test facility	Capable of simulating lightning strikes of 1.5 MV with current magnitude and duration similar to those in Appendix A or as specified
High-heat source	Capable of heating tile(s) above 121°C
Remote area	To accommodate fragmentation of tiles or threat in an open area
Drill and bits	3-, 6-, 13-, and 19-mm bits to be used for drilling tiles at various speeds
Boom	To suspend a threat over a tile
Projectiles and weapons	As indicated by test directive
Rail	As required to launch missile threats
Cutting torch	To be used for cutting tile
High-speed cameras (8,000 to 10,000 frames/sec)	To obtain records of test events, as needed
Still-photograph camera	To photograph test item(s) and test area before and after test conducted
Video cameras and video recorders	To document test procedures and obtain records of test events, e.g., tile reactions

2.2 Instrumentation. Only the instrumentation required by particular subtest(s) to be conducted need to be provided.

Devices for Measuring:	Permissible Error of Measuring Device:
Velocity	±0.5% of reading
Blast	±3% of reading
Radiosonde and meteorological data	±1% air pressure (measured in mm of Hg)

Devices for Measuring:	Permissible Error of Measuring Device:
	±1°C air temperature ±1.5 m/s wind velocity ±5% relative humidity
Weight of test item and component weights	±0.1% of reading
Fragment mass	±1% of reading
Tile temperatures*	±1°C
Release height for weight	±5% of reading
Impact angle of weight	±10°
High voltage and current	±5% of reading

*Actual values for temperature ranges depend upon proposed usage, or doctrine for armor application.

3. REQUIRED TEST CONDITIONS.

3.1 Inspection. Inspect each test item for damage and defective or missing parts, using visual and nondestructive procedures. Test item configuration will dictate the method of inspection. Record a description of the test item and all defects and modifications, including the following:

a. Nomenclature, including model number.

b. Manufacturer and manufacturer's lot number.

c. Evidence of defective parts.

d. Any missing parts.

e. Evidence of voids or fissures with n the explosive fill.

f. Any discrepancies from applicable drawings.

g. Physical dimensions.

h. Weight.

i. Notes on workmanship.

3.2 Test Planning.

a. Review all instructional materials (including system support packages) issued with the test item, and review reports of previous tests of similar items.

b. Review the safety assessment report (SAR) provided by the developer to determine whether all hazards have been identified; write the test plan to include subtests suitable for evaluating them.

c. Select the tests applicable to the test item from paragraph 4

d. Select applicable pretest and post-test nondestructive inspection (as described in para 3.1).

e. Prepare an operational checklist for the specific test item and situation.

f. Make sure pertinent Standing Operating Procedures (SOPs), Test Operations Procedures (TOPs), and detailed test plan are at the test site. Observe all applicable SOPs during testing.

3.3 Test Preparation.

3.3.1 Fragmentation Hazard Classification (in accordance with TB 700-2 and TOP 4-2-813*).

a. This TOP covers test procedures that will allow for estimation of surface danger areas occurring from tile fragmentation. The procedures presented here assume that all fragmentation will have ballistic properties similar to those of naturally-formed steel fragments (in accordance with TB 700-2). If this is not the case, then fragment velocities will have to be measured. Methods to accomplish this are covered in TOP 4-2-813.

b. Construct a fragmentation test arena similar to Figure A-1, Appendix A. This setup requires the recovery packs to be placed at a distance from the array approximately equal to $10 \times w^{1/3}$ feet, where w is the TNT equivalent weight of the reacting explosive, in pounds (TB 700-2, para 6-3). Depending on the distance used, that dimension will be accounted for in the data analysis. This distance may be varied to minimize the blast damage to the recovery packs. Depending on test requirements, fragment recovery packs may be constructed of alternate layers of thin mild steel panels and 25-mm styrofoam, or of consecutive layers of 13-mm Celotex fiberboard.

c. Prepare a sketch of the test arena and record the distances established between the test munition center and recovery panels.

d. Position appropriate personnel safety shelters for remote observation and detonation of the test item.

e. Inspect item in accordance with paragraph 3.1.

f. Record the appropriate data listed in paragraph 3.1 for test items and major components (i.e., fuze, explosive charge, etc.).

g. Photograph test item and test setup; note any variations from the TOP - proposed setup.

h. Modify the test item, as required, to accommodate an electric detonator for remote detonation. If multiple layers of explosive are contained within a single armor tile, or if detonation interrupters are contained within the tile, a small shaped charge will be required to initiate the test item. Preferably, the shaped charge should have a cone diameter of 42-mm or less; the 1.5-inch, M42 charge has been a popular munition for this purpose.

i. Assemble tile array symmetrically in an arrangement as shown by Figure A-1, Appendix A with its longitudinal axis in the horizontal plane described by the centers of the recovery panels. The tile array is typically positioned so that the test munition center (target tile) is at approximately the same height as the center of each recovery pack. Precise positioning is accomplished using geodetics instrumentation. The armor tile array should be mounted in a configuration that closely resembles the actual mounting hardware of the vehicle application or intended use, including angle of obliquity.

3.3.2 External Fire Effects (Bonfire).

a. Position appropriate personnel safety shelters for remote observation.

b. Conduct inspection and record the appropriate data listed in paragraph 3.1.

c. Stack five packages of tiles on top of one another and place on a steel platform about 1 meter from ground level. The length and width of the platform should be approximately the same as the tile packages. The packages will be steel banded (strapped together). Pile kindling or other air-dried wood not thicker than 30 mm around and beneath the tiles to provide at least 0.5 meter of kindling wood in every direction.

3.3.3 Small Arms Test.

NOTE: Calibers to be fired, engagement ranges, sizes of automatic bursts, and number of engagements will be selected, in accordance with user requirements, based on the intended mission areas of the vehicle, projected battlefield scenarios, etc.

a. Prepare a sketch of the test site.

b. Position appropriate personnel safety shelters for remote observation.

c. Protect instrumentation, monitoring equipment, and recording equipment with an appropriate shelter

d. Position gun behind shield, only allowing the muzzle to extend beyond it.

e. Prepare and position armor plate, appropriate to the application and obliquity, for mounting of temperature-conditioned tile.

f. Inspect item in accordance with paragraph 3.1.

g. Record the appropriate data listed in paragraph 3.1 for the test item and major components.

h. Photograph test item and test setup; note any variations from the TOP - proposed setup.

i. If fragmentation must be controlled to minimize hazards, ensure that the test item is shielded on the sides and overhead with a backstop in the rear.

j. Install thermocouples or temperature sensors in and on the tile, as required.

k. Provide a means for recording firing bursts on film or video for use as "zero" time.

l. Install a sequencing device, as required, to control test events such as starting the cameras, firing the weapon, etc.

3.3.4 Impact Testing.

a. Ensure adequate shielding of personnel and equipment.

b. Inspect and record the appropriate data listed in paragraph 3.1.

c. Photograph test item and test setup; note any variations from the TOP - proposed setup.

d. Position armor plate, to be used for the mounting of the temperature-conditioned tile(s), at the base of the drop facility. The impact area of the drop facility should consist of concrete faced with steel plate having a foundation effectively 20 times the mass of the weight dropped. Further guidance on the drop facility can be obtained in ITOP 4-2-601[b].

e. Install thermocouples or temperature sensors in and on the tile, as needed, to accurately determine tile temperature prior to test.

f. Raise a 225-kg block to a specified height with a remote control release holding the block.

g. Provide a means for recording the release of the block on film or video for use as "zero" time.

h. Install a sequencing device, as required, to control test events such as starting cameras and so forth.

3.3.5 High Voltage Effects.

a. Position appropriate personnel safety shelters for remote observation.

b. Inspect and record the appropriate data listed in paragraph 3.1.

c. Photograph test item and test setup; note any variations from the TOP - proposed setup.

d. Position a tile that has been mounted to a 76-mm baseplate under a high-voltage source with a carbon probe in contact with the tile and the baseplate grounded (see app A, fig. A-2 for typical circuit). Waveforms will be selected based on user concerns (contact of tile with downed powe line, etc.).

e. Provide a means for recording when the high voltage is applied to the tile on film or video for use as "zero" time (arcing of current from voltage source to tile will be visible).

f. Install a sequencing device, as required, to control test events such as starting cameras and so forth.

3.3.6 Lightning Effects.

a. Position appropriate personnel safety shelters for remote observation.

b. Record the appropriate data listed in paragraph 3.1.

c Photograph test item and test setup; note any variations from the TOP - proposed setup.

d. Position tile(s) 1 m under the lightning simulator probe and ground the base of the tile(s). An example schematic of the setup is in Appendix A, Figure A-3.

e. Provide a means for recording the initial lightning strike on film or video for use as "zero" time (arcing of lightning from probe to test item will be visible).

f. Install a sequencing device, as required, to control test events such as starting cameras and so forth.

3.3.7 Overhead Artillery.

a. Ensure adequate shielding of personnel and equipment.

b. Record the appropriate data listed in paragraph 3.1.

c. Photograph test item and test setup; note any variations from the TOP - proposed setup.

d. Position tile(s) under a boom, from which the threat round will be suspended.

e. Position threat 10 m overhead or as required by sponsor.

f. Provide a means for recording the detonation of the threat on film or video for use as "zero" time, if needed.

g. Install a sequencing device, as required, to control test events such as starting cameras, detonating the threat, etc.

3.3.8 Drill Test.

a. Position appropriate personnel safety shelters for remote observation.

b. Record the appropriate data listed in paragraph 3.1.

c. Photograph test item and test setup; note any variations from TOP - proposed setup.

d. Position a stand to be used for mounting the temperature-conditioned tile(s).

e. Position a remote-controlled drill, that can be moved towards and away from the tile, perpendicular to the tile face mounting position.

f. Provide a means for recording the contact of the drill bit on the tile on film or video for use as "zero" time, if needed.

g. Install a sequencing device, as required, to control test events such as starting cameras and so forth.

h. Install thermocouples or temperature sensors in and on the tile, if required.

3.3.9 Flechette Impact.

a. Prepare a sketch of the test site.

b. Ensure adequate protection for all personnel and equipment.

c. Prepare and position tile(s) or armor plate, appropriate to the application and obliquity, at the appropriate distance from the gun tube. The orientation of the threat to the tile will depend on the mechanics of the flechette ejection. Distances between the gun tube and the tile will depend on the threat fuze.

d. Inspect item in accordance with paragraph 3.1.

e. Record the appropriate data listed in paragraph 3.1 for the test item and major components.

f. Photograph test item and test setup; note any variations from the TOP - proposed setup.

g. If fragmentation must be controlled to minimize hazards, ensure that the test item is shielded on the sides and overhead with a backstop in the rear.

h. Provide a means for recording firing of a flechette round on film or video for use as "zero" time, if needed.

i. Install a sequencing device, as required, to control test events such as starting cameras, firing the round, etc.

j. Although various threats can be used a popular one has been the 105-mm APERS-T, M494.

3.3.10 Vehicle Exhaust.

a. Position appropriate personnel safety shelters for remote observation.

b Record the appropriate data listed in paragraph 3.1.

c. Photograph test item and test setup; note any variations from the TOP - proposed setup.

d. Position a stand to be used for mounting tile(s) in an area where high heat or detonation of tile would not create a hazard.

e. Position the heat source (typically one or more kerosene "torpedo" heaters) at the specified distance from the tile mounting stand.

f. Install thermocouples or temperature sensors in and on the tile.

3.3.11 Vulnerability to Tank-Fired HEAT Round/Anti-Tank Missile.

a. Adequately shield personnel and equipment.

b. Record the appropriate data listed in paragraph 3.1

c. Photograph test item and test setup; note any variations from the TOP - proposed setup.

d. For dynamic testing, position a tile array at the end of the ballistic rail, used to launch missiles, so that the missile will be aimed to impact the center of the tile array. For static testing, position the HEAT round at the exact desired impact point (center of array). Mount the tile array on representative vehicle backup armor. Place rolled homogenous armor (RHA) witness approximately 50 mm behind the armor configuration.

e. Provide a means for recording the ignition or detonation of the threat on film or video for use as "zero" time.

f. Install a sequencing device, as required, to control test events such as starting cameras, statically detonating rounds, igniting rockets during rail launching, etc.

3.3.12 Cutting Torch.

a. Position appropriate personnel safety shelters for remote observation.

b. Record the appropriate data listed in paragraph 3.1.

c. Photograph test item and test setup; note any variations from the TOP - proposed setup.

d. Mount a tile on a test fixture or stand.

e. For the first test, position a remote-controlled cutting torch so that the cutting torch flame is perpendicular to the tile frontal surface and in contact with the tile sidewall. For the second test, the flame is in contact with the center of the tile.

f. Provide a means for recording the contact of the cutting flame on the tile on film or video for use as "zero" time, if needed.

3.4 Test Controls.

3.4.1 Fragmentation Hazard Classification (In accordance with TOP 4-2-813).

a. Make sure all personnel exposed to hazardous noise or blast levels wear hearing protection as required. Earplugs are required to be worn when impulse noise levels are in the range of 140-165 dB. Impulse noise greater than 165 dB requires additional hearing protection. Consult TB MED 501[c] for guidance.

b. Ensure adequate shielding/protection for all personnel.

c. Do not conduct tests under adverse weather conditions (i.e., winds in excess of 18.5 km/hr (10 knots), heavy precipitation, severe restrictions to visibility or lightning within 35 km of the test site).

d. Ensure that all guidelines and/or supports for test projectiles are non-metallic materials so that only metal fragments produced from the test item are entrapped in the test arena.

e. Record meteorological data for each detonation (air temperature, humidity, etc.).

f. Ensure that all instrumentation is in a proper state of calibration.

3.4.2 External Fire Effects (Bonfire.

a. Same as described in paragraph 3.4.1 pertaining to personnel.

b. Ensure that all instrumentation is in a proper state of calibration.

3.4.3 Small Arms Test.

a. Same as described in paragraph 3.4.1 pertaining to personnel.

b. Ensure that test items are conditioned to required temperatures, as determined by user requirements.

c. Allow sufficient temperature conditioning time to ensure complete temperature stabilization (uniformity).

d. Ensure that all instrumentation is in a proper state of calibration.

3.4.4 Impact Testing. Same as described in paragraph 3.4.3.

3.4.5 High Voltage Effects.

a. Same as described in paragraph 3.4.1 pertaining to personnel.

b. Ensure that all instrumentation is in a proper state of calibration.

c. Ensure that the electric current of the high-voltage source is sustained during the duration of the test interval.

3.4.6 Lightning Effects.

a. Same as described in paragraph 3.4.1 pertaining to personnel.

b. Ensure that all instrumentation is in a proper state of calibration.

c. Ensure that the lightning waveform is correct; this may require a pretest strike into a dummy test item.

3.4.7 Overhead Artillery.

a. Same as described in paragraph 3.4.1 pertaining to personnel.

b. Ensure that all instrumentation is in a proper state of calibration.

c. Modify the threat fuze, as required, to accommodate an electric detonator for remote detonation.

3.4.8 Drill Test. Same as described in paragraph 3.4.3.

3.4.9 Flechette Impact.

a. Same as described in paragraph 3.4.1 pertaining to personnel.

b. Ensure that all instrumentation is in a proper state of calibration.

3.4.10 Vehicle Exhaust.

a. Same as described in paragraph 3.4.1 pertaining to personnel.

b. Ensure that all instrumentation is in a proper state of calibration.

c. Do not conduct tests under adverse weather conditions (i.e., winds in excess of 18.5 km/hr (10 knots), heavy precipitation, severe restrictions to visibility or when lightning is within 35 km of the test site).

3.4.11 Vulnerability to Tank-Fired HEAT Round/Anti-Tank Missile.

a. Same as described in paragraph 3.4.1 pertaining to personnel.

b. Ensure that all instrumentation is in a proper state of calibration.

c. Modify the threat fuze, as required, to accommodate an electric detonator for remote detonation. For dynamic tests, design a method to initiate the threat detonator at the desired position on the rail.

3.4.12 Cutting Torch.

a. Same as described in paragraph 3.4.1 pertaining to personnel.

b. Ensure that the cutting speed, torch gas mixture, and distance of the torch from the tile surface remain constant throughout the test.

c. Ensure that all instrumentation is in a proper state of calibration.

4. TEST PROCEDURES.

4.1 Fragmentation Hazard Classification.

4.1.1 Method.

a. If blast measurements are required, see TOP 4-2-822[4] for specific guidance.

b. For direct pressure measurements, align blast gages with the plane of the sensitive element passing through the axis of the tiles. The intent is to measure the side-on pressure from the primary wave and any secondary explosion. This technique will tend to minimize the arrival of shock waves at transducer incidence angles between 0° and 90° where overshoot and ringing occur. Place 8 to 12 blast gages in two or three concentric circles (four to a circle, one at each 90° interval) around the tiles at distances where overpressures of interest are expected. (When personnel or fragile material are of concern, overpressures of interest are usually in the 0.2 to 69 kPa (0.03 to 10 psi) range.)

c. For shock wave velocity, use two velocity gages instead of one blast gage as described above. Mount the gages 60 cm apart with the first one 30 cm in front of the blast gage they are replacing, and the second one 30 cm behind it. Separate the velocity gages by 8 cm vertically so that the front gage does not disturb the shock wave for the rear gage. The velocity gages should be placed either 15 cm above or below the blast gage when the blast gage is left in place.

d. If the target tile is to be initiated by an electric detonator, connect the center tile by inserting a blasting cap/detonator, from the front, into the center, using qualified demolition personnel. If the tile is to be initiated by a shaped charge, support the charge on a suitable support and position it against the tile at the proper standoff and obliquity.

e. Connect the firing circuit to the recording instruments.

f. Start the timer to initiate the data acquisition system and to perform the test events leading to initiation of the tile.

g. After detonation, locate and recover the fragments lodged in the recovery panels and record the zone of recovery (location of the recovery pack) for each fragment 13 mm or larger in diameter (or length/width if fragment is noncircular).

h. Clean and separate the recovered fragments.

i. Weigh and record the weight of each fragment, greater than the specified cutoff weight, in each zone of recovery. The cutoff weight is 0.03 gram (0.5 grain) unless otherwise specified by the test plan. If it is impractical to weigh fragments individually, they may be segregated with sieves of the following standard square mesh sizes: 13, 16, 19, 22, 32, 51, and 76 mm, and the average weight of fragments on each sieve determined. The average weight of the fragments on each sieve is determined by weighing and counting a representative sample. Only the total weight of fragments passing through the 13-mm sieve is determined; an actual count of these fragments is not required (Guidance in TB 700-2, para 6-3).

j. Perform the procedure for a minimum of five tile arrays of the same design.

4.1.2 Data Required.

a. Round number.

b. Weight of each fragment weighing more than the cutoff weight or average weight passing through each sieve tabulated according to recovery zone.

c. Total weight of all fragments which have been recovered which weigh less than the cutoff weight for each recovery zone.

d. Film or video record of detonation.

e. All applicable items as described in paragraph 3.1.

f. Test site ambient conditions of atmospheric pressure, temperature, wind velocity and direction at each firing time (some of these may be deleted, depending on test requirements).

g. Location, height, and orientation of each pressure gage (if they are used).

h. Still photographs of typical test setups.

i. Typical pressure-time traces, with an exact description of how peak pressure values were obtained.

j. Photographs of tiles before and after the test.

4.2 External Fire Effects (Bonfire)

4.2.1 Method.

a. Drench the dry wood (described in para 3.3.2c) with 57 liters of diesel fuel or kerosene and ignite simultaneously from two sides (by means of electric squibs).

b. Conduct the firing procedure as described in paragraph 4.1.1 with exception of starting the sequence when the squibs are ignited and not inserting a firing cap in the center tile.

c. Minimize the fire hazard.

d. Perform the procedure for a minimum of three tile stacks of the same design.

e. If fragmentation hazard is of interest, construct a fragmentation arena around the tile stack, as described in paragraph 3.3.1b.

4.2.2 Data Required. The data required are the same as described in paragraph 4.1.2 (if fragment hazard analyses are not required, items b and c may be deleted).

4.3 Small Arms Impact Effects

4.3.1 Method.

a. Perform the procedure at three different temperatures, -46°C, ambient or +21°C, and +63°C, for a minimum of three tiles of the same design at each of the three temperatures.

b. After a tile has been temperature conditioned, mount it on the armor plate described in paragraph 3.3.3e.

c. Connect the tile thermocouples or temperature sensors to the recording equipment (complete circuit necessary to obtain temperature measurements).

d. Start sequencing device to initiate cameras, etc.

e. Fire an adequate burst of rounds (usually 5-round) of a specific type ammunition into a single tile, or an array of tiles, to explore the reaction of the tile(s). Repeat firings until the tile receives three (5-round) bursts of ammunition or the tile detonates, deflagrates, shatters, or otherwise fails to remain substantially intact.

f. After the test is complete, note the condition of the tile and photograph it.

4.3.2 Data Required.

a. All applicable items as described in paragraph 3.1.

b. Projectile striking velocities.

c. Description of the tile reaction (i.e., detonation, deflagration, shatter, etc.).

d. Photographs of tile before and after the test.

e. Film or video record of test.

4.4 Impact Testing

4.4.1 Method.

a. Perform the procedure at three different temperatures, -46°C, ambient or +21°C, and +63°C, for a minimum of one tile of the same design at each of the three temperatures.

b. After a tile has been temperature conditioned, position it on the armor plate described in paragraph 3.3.4d. Tiles will be positioned in a horizontal (rear face down) orientation, unless otherwise specified in user requirements.

c. Connect the tile thermocouples or temperature sensors to the recording equipment.

d. Start sequencing device to start cameras, etc. when weight is released.

e. Raise the 225-kg (500-lb) block to the appropriate height and drop it on the tile using a quick-release mechanism. Detailed drop test procedures can be found in ITOP 4-2-601.

f. After the test is complete, note the condition of the tile and photograph it.

g. Conduct a total of nine drop tests (three each from a 3-meter height, three each from a 9-meter height, and three each from a 12-meter height). For each drop height, test one tile at each temperature. The variance in drop distances demonstrates the effect of various shearing rates and various degrees of tile damage. Depending on test requirements, the impacting surface of the block can be designed to represent shearing, crushing, or punching actions with the tile.

NOTE: The 225-kg block was chosen as a "generic" item which may represent a variety of collision situations. Other items may be used in lieu of the 225-kg block to address specific user concerns. For example, a piece of an actual gun tube could be dropped to simulate the impact of a vehicle-mounted gun tube into a turret tile. A wedge-shaped 1134-kg (2500-lb) block is often used to simulate hull-to-hull collisions (dropping this block from a height of 12 meters (40 ft) simulates a crash at 40 km/hr (25 mph)).

4.4.2 Data Required.

a. All applicable items as described in paragraph 3.1.

b. Description of the tile reaction (i.e., detonation, deflagration, shatter, etc.).

c. Photographs of tile before and after the test.

d. Film or video record of test.

4.5 High Voltage Effects (in accordance with MIL-STD-1757A[2]).

4.5.1 Method.

a. Perform this procedure on a minimum of three tiles of each design.

b. To ensure that the high-voltage source will sustain the current and voltage during the test, apply the source to a dummy test item while monitoring the source for six seconds.

c. When the high-voltage source is ready to be applied to the tile, start the sequencing device which controls test events (if one is used).

d. Apply the high-voltage source to the tile. The applied voltage duration and waveform will be dictated by test procedures (i.e., designed to simulate armor contact with severed power lines, etc.). Detailed procedures are given in Test Method TO2 of MIL-STD-1757A.

e. After test is complete, note condition of tile and photograph.

4.5.2 Data Required.

a. Same as described in paragraph 4.4.2.

b. Record of the test voltage waveforms.

c. Description of the tile reaction (i.e., tile completely destroyed, tile damaged in a particular way, etc.).

d. Record if the tile smoked, burned, and/or detonated during the test.

4.6 Lightning Effects (in accordance with MIL-STD-1757A).

4.6.1 Method.

a. Perform this procedure on a minimum of three tiles of each design.

b. To ensure that the waveform will be accurate, fire a lightning strike into a dummy test item while monitoring the waveform (see app A, fig. A-4) for typical waveform.

c. When the lightning generator is prepared to fire a discharge, start the sequencing device which controls test events (if one is used).

. Fire discharge(s). See Test Method TO2 of MIL-STD-1757A for detailed procedures.

e. After test is complete, note condition of tile and photograph.

4.6.2 Data Required.

a. Same as described in paragraph 4.4.2.

b. Record of the test voltage waveforms.

c. Description of the tile reaction (i.e., tile completely destroyed, tile damaged in a particular way, etc.).

d. Record if the tile smoked, burned, and/or detonated during the test.

4.7 Overhead Artillery.

4.7.1 Method.

a. Connect the firing circuit to the recording instruments.

b. Start the sequencing device to perform the test events leading to detonation of the threat.

c. After threat detonation, locate and highlight location of fragment hits on tile(s) with a color marker, if tile did not detonate.

d. Photograph tile(s).

e. Perform this procedure twice for each tile design at each threat position (height) specified in test plan.

4.7.2 Data Required.

a. Same as described in paragraph 4.4.2.

b. Record the number of artillery round fragment hits and penetrations.

c. Record if the tile(s) detonated or burned.

4.8 Drill Test.

4.8.1 Method.

a. Perform the procedure at three different temperatures, -46°C, ambient or +21°C, and +63°C, for a minimum of two tiles of each design at each of the three temperatures.

b. Drill each tile with four different size drill bits, 3-, 6-, 13-, and 19-mm, if the tile does not detonate.

c. Divide the tile face into four equal areas and mark the center of each area.

d. After a tile has been temperature conditioned, mount it on a test stand with the drill bit positioned over the center of a marked area.

e. Connect the tile thermocouples or temperature sensors to the recording equipment.

f. Start drilling at 300 rpm (or at rpm specified in test plan).

g. Start sequencing device which controls test events, if one is used, when drill bit makes contact with tile.

h. Drill completely through tile (or as deep into tile that drill will penetrate), if tile does not detonate.

i. After the test is complete, note damage to tile and photograph it.

j. Repeat this procedure on the three remaining marked points on the tile face, using each of the three remaining drill bit sizes.

k. Repeat the entire procedure at 600 rpm (or at rpm specified in test plan) on a virgin tile.

l. Conduct each test three times (requiring a total of six tiles, two at each tile temperature).

m. In cases where minimum damage occurs, repeat the test at higher speeds (if attainable).

4.8.2 Data Required.

a. Same as described in paragraph 4.4.2.

b. Record if the tile(s) smoked, burned, and/or detonated during the test (also drill bit size and drill speed used when reaction occurred).

4.9 Flechette Impact.

4.9.1 Method.

a. Set weapon so that round will detonate at some predetermined location before it would impact the tile (or pass overhead, depending on the orientation of the threat to the tile); or statically detonate the round (if flechette ejection will function properly)

b. Start sequencing device which controls test events, if one is used, when firing begins.

c. After firing, if tile(s) did not detonate, locate and mark location of flechette impacts on tile(s) with a color marker.

d. Photograph tile(s) and note tile damage.

e. Perform this procedure twice for each tile design at each specified threat position.

4.9.2 Data Required.

a. Same as described in paragraph 4.4.2.

b. Record whether or not the tile(s) detonated or burned, the condition of the tile(s), and whether or not the tile(s) was penetrated and/or impacted by flechettes.

4.10 Vehicle Exhaust.

4.10.1 Method.

a. Perform this procedure on a minimum of three tiles of each design.

b. Place tile in mounting stand and connect tile thermocouples or temperature sensors to recording equipment.

c. Set heat source at 1 m away from the tile.

d. Start sequencing device which controls test events, if one is used, when tile temperature reaches 120°C ± 6°C.

e. Apply heat to tile until the temperature is 120°C ± 6°C. Hold tile at this temperature for approximately one hour.

f. After test is completed, allow the tile to cool to near ambient temperature, visually inspect the tile and photograph if damage is apparent.

g. If no damage is apparent, the heat source can be moved closer to the tile (usually, at intervals of approximately 0.3 m) and the procedure can be repeated as many times as necessary to address user concerns.

4.10.2 Data Required.

a. Same as described in paragraph 4.4.2.

b. Record the tile temperatures, heat source distances, elapsed times, and type of tile damage or explosive reactions.

c. Record if the tile(s) smoked, burned, and/or detonated during the test.

4.11 Vulnerability to Tank-Fired HEAT Round/Anti-Tank Missil .

4.11.1 Method.

a. Perform the procedure at three different temperatures, -46°C, ambient or +21°C, and +63°C, using fresh armor and virgin tiles for each test shot.

b. Connect the firing circuit to the recording instruments.

c. Start the sequencer to perform the test events leading to ignition or detonation of the threat.

d. Photograph the tile array after the test has been completed.

e. Perform three test shots, dynamic or static, for each tile design at each specified threat position and at each required temperature.

4.11.2 Data Required.

a. Same as described in paragraph 4.4.2.

b. Description of the tile arr (i.e., which tiles were completely destroyed, which tiles were damaged in a particular way, etc.).

c. Penetration measurements into the backup armor of the dynamic or static rounds (i.e., partial or comple e penetration, depth of penetration, etc.), and depth of penetration into RHA witness.

4.12 Cutting Torch.

4.12.1 Method.

a. Ignite torch and adjust cutting flame to the appropriate intensity.

b. Start sequencer, to control test events, when torch flame makes contact with the tile.

c. Always hold the cutting flame perpendicular to the outward surface of the tile. For the first test, start with cutting flame in contact with the tile sidewall and proceed to cut across the tile until it is cut in half or until some type of reaction or detonation occurs. For the second test, begin cutting in the center of the tile. Hold the torch in place until a hole is burned through the center or until some type of reaction or detonation occurs. Use a virgin tile for the second test.

d. Photograph tile after each test is completed.

e. Perform this procedure twice for each tile design or as required.

4.12.2 Data Required.

a. Same as described in paragraph 4.4.2.

b. Record the tile type, cutting time, tile condition, and reaction for each of the two cutting tests (i.e , smoked, burned, detonated, and so forth during the test).

5. PRESENTATION OF DATA.

5.1 Fragmentation Hazard Clas i' ation. Correlate the number of collected fragments retained on each siev eavier than a given fragment weight with the angular position of the appropriate zone of recovery. Relate fragment weights to impact energy. Fragments with kinetic energy above 79 joules (58 ft-lb) are generally considered hazardous to personnel. Procedures for data analyses and presentation are detailed in TB 700-2, paragraph 6-3.

5.2 External Fire Effects (Bonfire). In cases where detonation or explosion of tiles occurs, provide information as described in paragraph 4.1.2. In cases where only fire propagation occurs, give analysis of tile condition (i.e., tile completely destroyed, tile intact with explosive melted, etc.).

5.3 Small Arms Impact Effects.

a. Use still photographs (with scale) and film/video coverage to analyze the results of each test.

b. Use a visual inspection of the tile and description of tile reactions to assess results of testing.

5.4 Impact Testing. Same as described in paragraph 5.3

5.5 High-Voltage Effects.

a. Same as described in paragraph 5.3.

b. It is desired to have no explosive reaction when the tile(s) are subjected to the high-voltage source. However, there will be no pass-fail decision based on the results of this test, unless test requirements dictate accordingly.

c. Tabulate the test results for each tile design according to the observed reaction of the tiles under the test conditions.

5.6 Lightning Effects.

a. Same as described in paragraph 5.3

b. It is desired to have no explosive reaction when the tile(s) are subjected to the simulated lightning. However, there will be no pass-fail decision based on the results of this test, unless test requirements dictate accordingly.

c. Tabulate the test results for each tile design according to the observed reaction of the tiles under the test conditions.

5.7 Artillery Impact Effects.

a. Use still photographs (with scale) when target vehicle applique armor takes a hit by an artillery shell. In addition, film or take video coverage of the event to record the results of each test.

b. In cases where burning and detonation occur, give an analysis of the tile condition (i.e., tile completely destroyed, tile intact with melted explosive, etc.). Additionally, analyze tiles penetrated or struck by fragments (i.e., number of hits, position of threat, depths of penetrations, etc.).

5.8 Drill Test.

a. Same as described in paragraph 5.3.

b. Make an analysis of each tile to determine the effects of drilling on the condition of the tiles.

5.9 Flechette Impact.

a. Same as described in paragraph 5.3.

b. In cases where burning and detonation occur, give an analysis of the tile condition (i.e., tile completely destroyed, tile intact with melted explosive, etc.). Additionally, analyze tiles penetrated or struck by flechettes (i.e., number of hits, position of threat, depths of penetrations, etc.).

5.10 Vehicle Exhaust. Same as described in paragraph 5.3.

5.11 Vulnerability to Tank-Fired HEAT Round/Anti-Tank Missile.

a. Same as described in paragraph 5.3.

b. Note and analyze the tile design type and damage incurred for each tile array. Include any type of tile damage or reaction.

5.12 Cutting Torch. Same as described in paragraph 5.3.

APPENDIX A.

SCHEMATICS

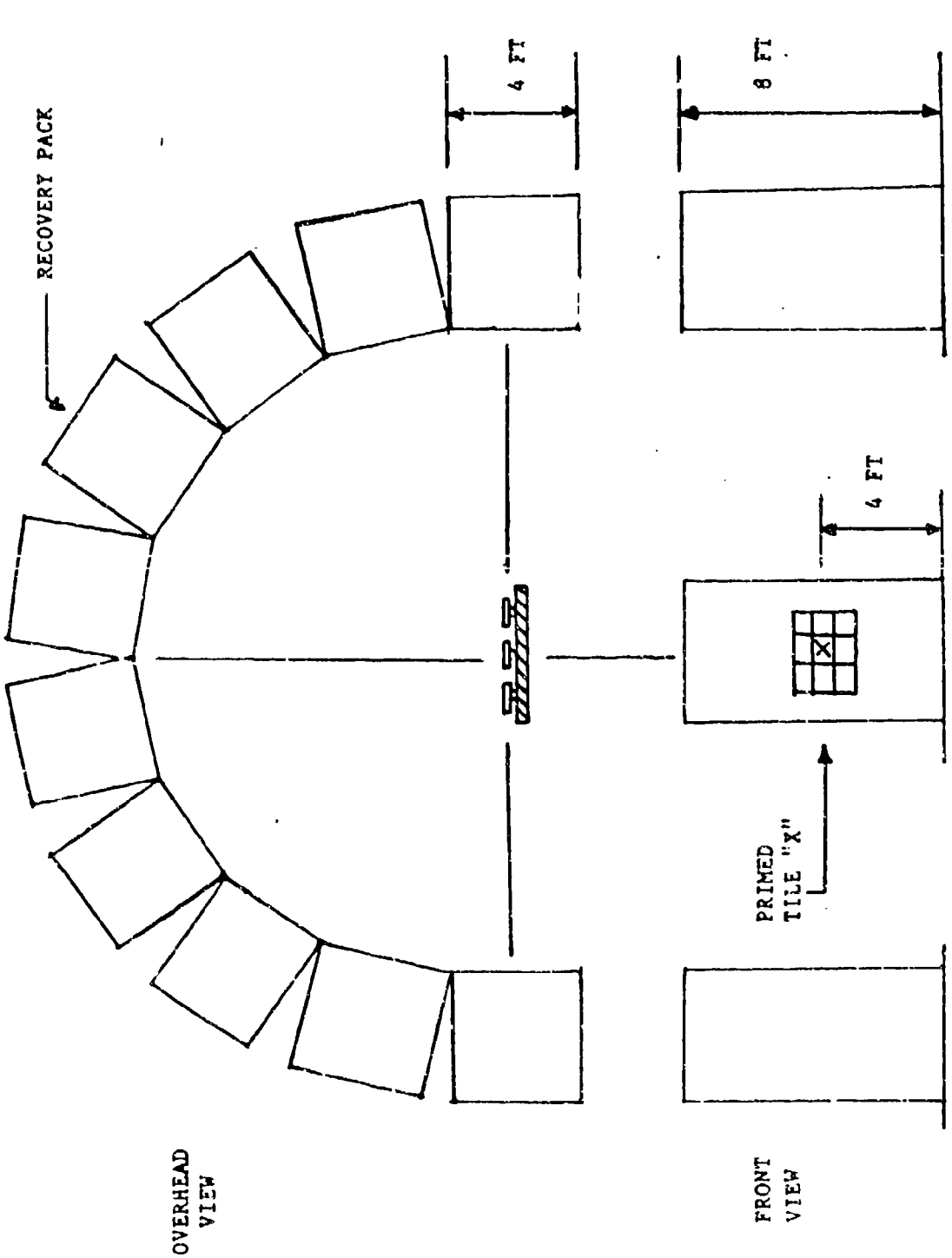


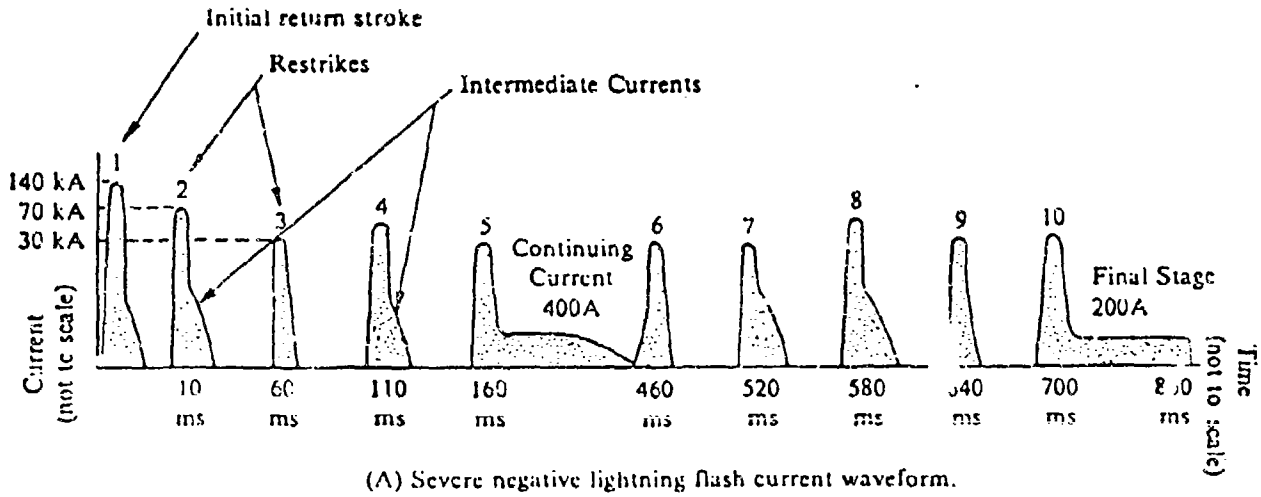
Figure A-1. Typical setup for fragment recovery.

For each stroke:

Time to peak current = 1.2 μs
Time to half value = 50 μs

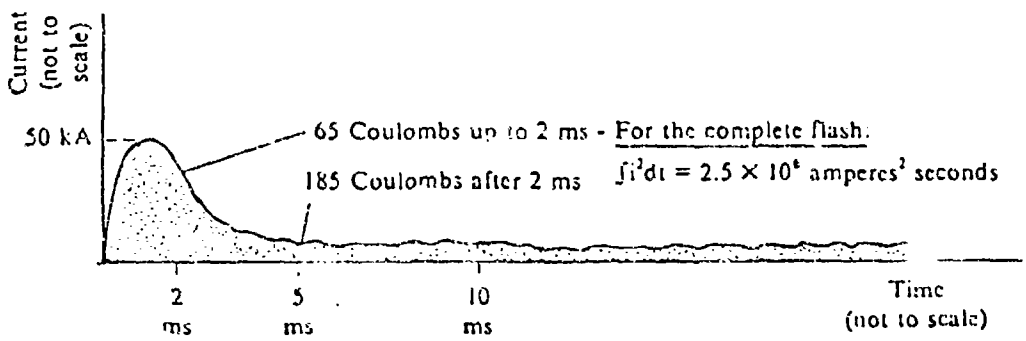
For the complete flash:

$\int i^2 dt = 1.9 \times 10^6$ amperes^2 seconds



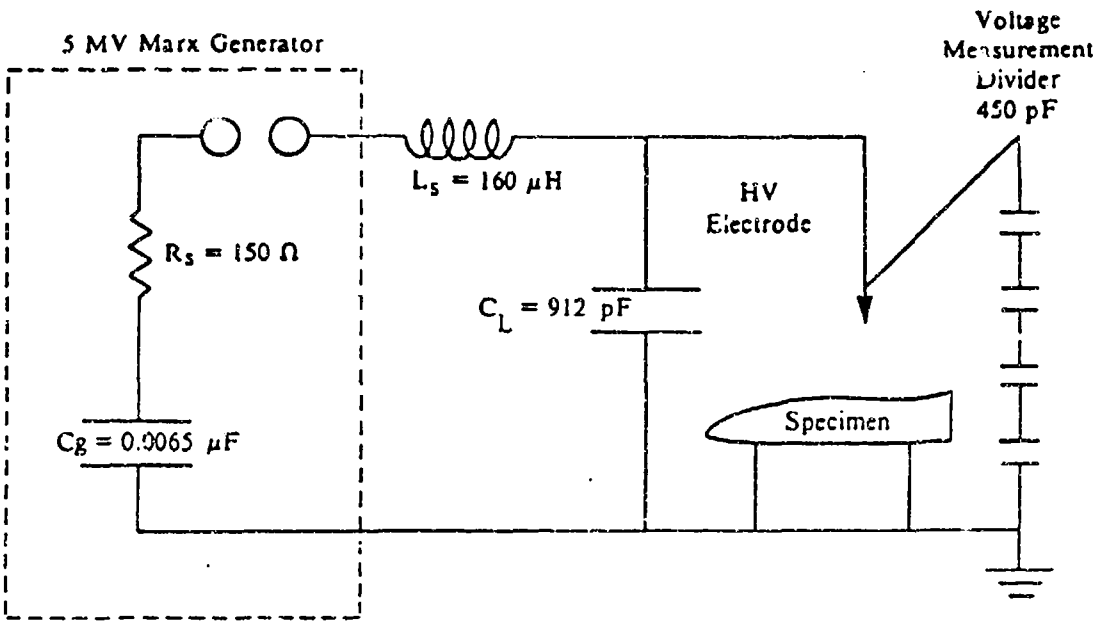
(A) Severe negative lightning flash current waveform.

(From "A Ground-Lightning Environment for Engineering Usage" by Cianos & Pierce)



(B) Moderate positive lightning flash current waveform.

Figure A-2 Typical high voltage test circuit (without load capacitor).



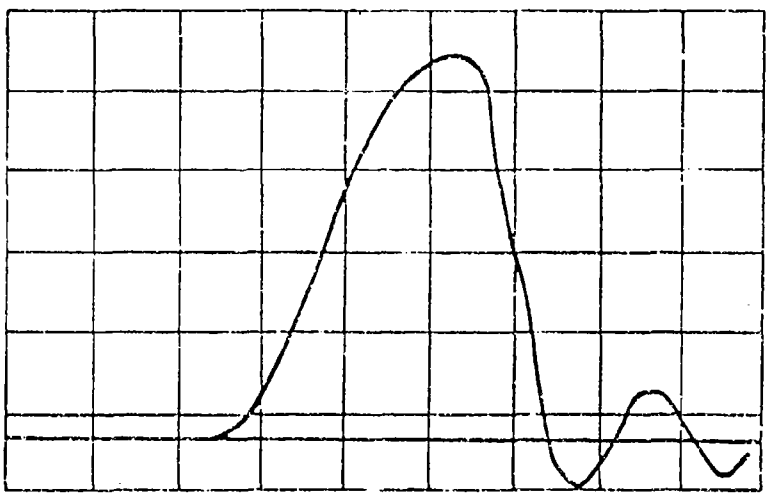
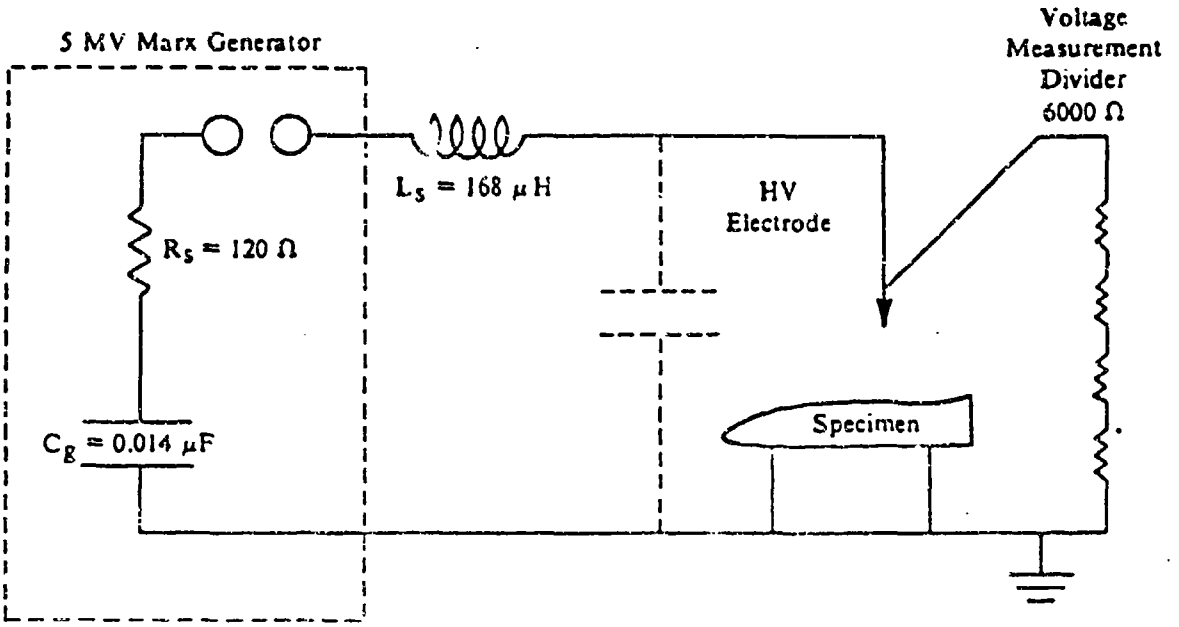
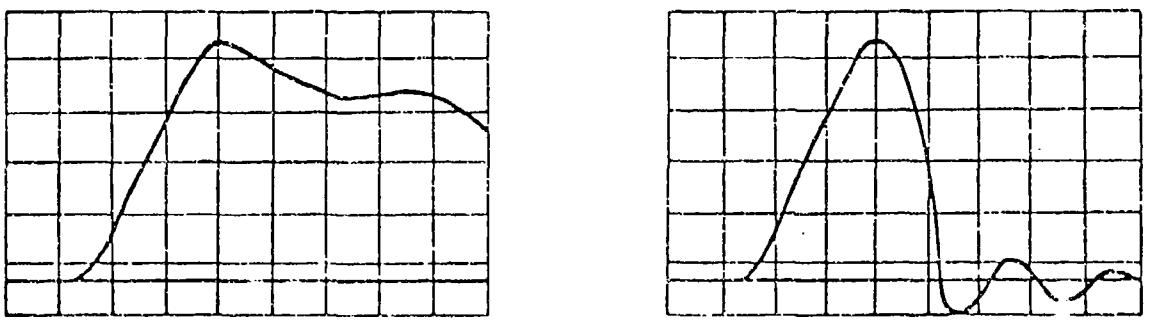


Figure A-3. Typical circuit and applied voltage waveform for simulated lightning strike attachment tests.



High Voltage Test Circuit



Crest is 1530 kV
without test object
in place

Flashover to test
object at 1115 kV
on rise

Voltage Waveforms
(Sweep is 0.5 μs/div)

Figure A-4. Lightning flash current waveforms.

APPENDIX B

REFERENCES

Required References

1. TB 700-2, NAVSEAINST 8020.8, TO 11A-1-47, DLAR 8220.1, Department of Defense Explosives Hazard Classification Procedures, September 1982.

2. MIL-STD-1757A, Lightning Qualification Test Techniques for Aerospace Vehicles and Hardware, 20 July 1983.

References for Information Only

a. GE/UK/US ITOP 4-2-813, Static Testing of High-Explosive Munitions for Obtaining Fragment Spatial Distribution, 30 March 1993.

b. GE/US ITOP 4-2-601, Drop Tower Tests for Munitions, 10 December 1984, C1, 29 July 1986, C2, 22 September 1987.

c. TB MED 501, March 1980.

d. US TOP 4-2-822, Electronic Measurement of Airblast Overpressure, 28 September 1981.