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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Provides procedures for performing nuclear weapon blast effects tests on Army weapon systems and combat support materiel. Discusses types of blast facilities used to simulate the nuclear weapon blast environment. Covers test procedures, safety, and instrumentation. Applies to vehicles (land, amphibious, tracked, wheeled), missile systems, self-propelled or towed guns, and electronic equipment.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-100
*Test Operations Procedure 1-2-613 9 November 1978
AD No.

NUCLEAR EFFECTS TESTS OF ARMY MATERIEL (BLAST)

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1. SCOPE. This test operations procedure (TOP) describes procedures for testing and evaluating the blast effects from a nuclear weapon on Army materiel. The materiel tested includes such basic Army vehicles as land, amphibious, tracked, wheeled, or special purpose vehicles; fixed or rotary wing aircraft, missile systems, self-propelled or towed guns, and electronic equipment. This TOP adheres to single integrated development test cycle principles that result in valid data for evaluation. It is limited to test procedures for planning, conducting, and reporting of nuclear tests which may be conducted within the provisions of the Nuclear Test Ban Treaty, such as those tests conducted in laboratory simulated nuclear weapon environments. These include blast tests conducted as large-scale, high-explosive events in the field or in shock tube and laboratory blast test facilities.

2. FACILITIES AND INSTRUMENTATION

2.1 FACILITIES

a. The two types of blast facilities used to simulate blast effects from a nuclear weapon are:

(1) Large-scale, high-explosive field tests

(2) Shock tube blast test facilities

*This TOP supersedes the blast and shock subtests of MTP 5-2-522, 31 October 1969 and MTP 2-2-618, November 1966.

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b. The type of facility to be used is determined:

(1) By the size of the item to be tested

(2) Whether soil, trees, snow, or other natural environment are required as an integral part of the test

(3) Whether the air blast parameters can be provided

TYPICAL RANGE OF BLAST WAVE PARAMETERS

CHARACTERISTICS	REQUIREMENTS
Peak overpressure	134,860 dynes/cm^2 (2 psi) to 3.37 X 10^6 dynes/cm^2 (50 psi)
Peak dynamic pressure	6.743 X 10^4 dynes/cm^2 (1 psi) to 6.74 X 10^5 dynes/cm^2 (10 psi)
Arrival time	200 to 1700 msec
Overpressure impulse	2.03 X 10^3 dynes sec/cm^2 (0.3 psi-sec) to 6.743 X 10^4 dynes sec/cm^2 (1 psi-sec)
Dynamic pressure impulse	1.01 X 10^3 dynes sec/cm^2 (15 psi-sec) to 3.3715 X 10^4 dynes sec/cm^2 (0.5 psi-sec)
Positive duration	200 msec to 400 msec

c. Computer programs to simulate blast environment may be useful in supplementing laboratory and/or field test data. These programs are available through the Defense Nuclear Agency.

2.1.1 Large-Scale, High-Explosive Field Tests

a. Large-scale blast tests performed in the field require:

(1) The detonation of large quantities of high explosives. Approximately 20 to 600 tons of explosives have been used.

(2) A large area of from 4 to 10 km radius

(3) Extensive support activities: secure storage area for the explosives prior to emplacement in the area, security, command and control, communications, safety, electrical power, construction of bunkers and instrumentation sites.

Such a facility is presently available near Stallion Site at White Sands Missile Range, New Mexico.

b. Advantages

(1) Large items can be tested.

(2) Complete systems may be emplaced in a near natural environment.

(3) Several items of an identical type can be subjected to different pressure levels of the same blast wave and can be placed in different orientations and configurations.

(4) A number of different projects can share the cost of the support activities. When several projects share the cost, this type of blast test can be comparable in cost to tests on the shock tube facilities.

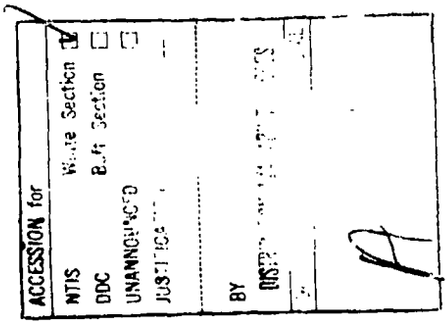
c. Disadvantages

(1) Long lead time

(2) Lack of flexibility of test dates

(3) Remote location

(4) Field instrumentation



(5) The fact that the time pressure curve of the blast wave is equivalent to a nuclear weapon blast wave of only 1 kt or less. A peak overpressure of up to 60 psi is available, but the positive phase duration of the wave is limited to a 1 kt weapon equivalent or less.

2.1.2 Shock Tube Blast Test Facilities

a. The DOD operates several shock tube facilities. Several sizes and types of these facilities are available at the Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland. Blast effects testing can be performed in a laboratory environment using air at high pressure in a shock tube. The peak overpressure and the shape of the time pressure curve of the blast wave produced are governed by the shock tube design. Although the peak overpressures are limited to approximately 2 to 20 psi, the positive phase duration can be made to simulate a nuclear weapon of approximately 1 MT. Positive overpressure, pulse durations, and pulse shapes vary with the methods used to produce the environment. Explosive charges in shock tubes can produce overpressures with flow durations in the order of milliseconds. Rocket motors can provide flow durations in the order of seconds. Pressure-diaphragm systems provide flat-topped pressure waves as contrasted with some shock tubes which provide the required exponential decay of pressure after passage of

the shock wave. In some facilities, it may be necessary to exceed the criteria peak pressure in order to meet the impulse criteria if the required pulse duration cannot be obtained.

b. Advantages

(1) Ability to produce successive tests of gradually increasing intensity

(2) Laboratory instrumentation

(3) The ability to produce the long duration blast waves that simulate the larger nuclear weapons

c. Disadvantages

(1) Limited size of the test items

(2) Inability to obtain high peak overpressures

(3) Inability of the test item to incorporate natural environment such as ground effects

2.2 INSTRUMENTATION

a. Blast effects instrumentation must provide data for both the environment to which the test item was exposed and the response of the test item to the environment.

TEST INSTRUMENTATION	REQUIREMENTS
Blast overpressure and dynamic pressure transducers	6.743×10^4 dynes/cm^2 (1 psi) to 3.37×10^6 dynes/cm^2 (50 psi), maximum
One- and three-axis accelerometers	5g to 100g ± 10%
Magnetic tape recorders	Capable of recording from b to 240 KHz maximum error of measurement ± 10% of full scale
High speed cameras	200 to 600 frames per second ± 10%

b. Data acquisition and recording instrumentation and associated test support equipment will vary according to the specific test item. Primary consideration should be given to instrumentation responsiveness, detection, measurement of expected test signals, and measurement of facility environmental output parameters. Instrumentation safety aspects and

calibration standards current with acceptable and recognized sources must be addressed.

3. PREPARATION FOR TEST

3.1 Planning

a. Integrated tests usually involve more than one agency and/or contractors; therefore, extensive informal and formal planning or coordination must be accomplished to positively identify scope, responsibilities, objectives, subtests, test material, funding, schedules, critical issues, test criteria, personnel, facilities, data, documentation, reporting, and any other test related requirements that are prerequisite for preparation of a formal test plan for performance of tests and other operations interacting with overall project execution.

b. Prepare environmental impact evaluations, schedules and/or check lists of initial milestone related to critical events for examination, that could reveal potential significant areas for special observations throughout the performance of the test project.

c. Present briefing material to familiarize test personnel with technical, operational characteristics of test items. Provide such reference materials as technical manuals, safety and physical security requirements documents, and any other pertinent information relevant to the test project.

d. Determine atmospheric conditions that must prevail for the detonation of high explosives so that focusing of the blast wave at distant locations outside the blast area does not occur.

3.2 Facilities

a. Potential test facilities and commitment procedures required, including scheduling priorities, etc., must be identified.

b. Special static or dynamic tests requiring the firing of live weapons, missiles, or the detonation of warheads will be performed in an area which must provide physical protection and the safety of all personnel. Administrative controls may supplement physical requirements for personnel safety, physical security, and environmental quality.

c. Test plans involving the testing of warheads or other hazardous materials must specify storage procedures and accountability. In addition, plans for testing flammable, toxic, radioactive or other hazardous materials must be reviewed and approved by a safety committee at the test facility prior to test execution.

d. All materials that may have previously been exposed to neutron radiation, especially gases and liquids, are potential radioactive contaminants. Activation of materials is common. In accordance with Title 10, Code of Federal Regulations, Part 30, Section 30.3, it is mandatory that a valid license exists in order to receive, own, and possess radioactive by-product materials. Therefore, it may be necessary to assure that previously exposed test items are covered by appropriate licenses.

3.3 Equipment and Test Item(s)

a. Inspect each piece of equipment and test item(s) for damage, defective or missing parts, etc., and validate inventory requirements for test (spare parts, film, recorder tape, etc.).

b. Prepare list of equipment and test item requirements acceptable for testing and record the following as applicable:

(1) Nomenclature, including model number

(2) Manufacturer and manufacturer's lot number

(3) Evidence of defective parts

(4) Missing parts, if any

(5) Discrepancies from applicable drawings, if any

(6) Length

(7) Outside diameters

(8) Weight

(9) Weight and composition of explosive or other hazardous materials

(10) Design standoff (notable differences from original design)

(11) Operating characteristics

(12) Conformance to calibration requirements

(13) Acceptable to test standards

3.4 Instrumentation. Confirm availability and prepare a list of instruments detailing type, nomenclature, accuracy, date of last calibration and its conformace to acceptable calibration standards, and any other applicable details relevant to test requirements.

3.5 Data Requirements. Record of instrumentation and test item nomenclature, manufacturer, identification, serial numbers, model numbers, calibration certification, etc. Data acquisition records, including details of test item performance, time and response, test location environmental characteristics, etc., including specific test objective requirements.

4. TEST CONTROLS

a. Test items are to be tested in the configuration(s) and condition(s) that have been designated for field deployment and operations.

b. Safety evaluation will be planned, conducted, and reported by qualified personnel for the specific test item(s).

c. Precautions must be taken to insure highest degree of safety for personnel and equipment.

d. In addition to material requirement documents criteria, all available threat information should be considered for effective test accomplishment.

5. PERFORMANCE TESTS

5.1 Method

5.1.1 The prescribed methodology is essentially a laboratory test; however, during field blast tests, special procedures apply such as consideration of meteorological data which include temperature, wind velocity profiles, and barometric pressures recorded and correlated with blast data.

5.1.2 Perform an initial evaluation of all potential hazards to personnel and equipment. Continue these observations throughout test operations.

5.1.3 Locate and orient the item(s) under test within the blast test volume in allocation consistent with the designated parameters for static or dynamic pressures and test objectives.

5.1.4 Perform a complete dynamic and/or static performance test on test items as near to the time of the blast test as is practicable. These final tests should be performed at the blast test location and under the same environmental conditions as those expected during the test.

5.1.5 Check all power cables and instrumentation wires to and from blast gages, accelerometers, and high speed cameras to assure that wires have enough flexibility to allow motion but will not be torn loose or broken by the blast wave.

5.1.6 Load film and magnetic tape.

5.1.7 Perform full frequency, full power dry runs prior to blast test to determine noise levels and whether interference occurs.

5.1.8 Develop test strips of film to assure proper field of view and focus of cameras.

5.1.9 Play back magnetic tape to assure proper calibration and instrumentation ranges.

5.1.10 Perform pretest documentary photography showing test item configuration, location, and orientation. Photograph each blast gage and accelerometer installation location on the test item.

5.1.11 Correlate each accelerometer axis and each blast gage with polarity of each recorded instrumentation channel.

5.1.12 Notify blast facility personnel of status of project.

5.1.13 Immediately after the blast test, check tape recorders and cameras to determine whether proper operation occurred.

5.1.14 Remove data film and data magnetic tape from cameras and tape recorders. Load cameras and recorders with additional film and tape.

5.1.15 Inspect all power cables and instrumentation wires to and from blast gages, accelerometers, and cameras to determine whether wires have been torn loose or broken by the blast wave.

5.1.16 Perform a complete instrumentation calibration after the blast test.

5.1.17 Perform post-test documentary photography showing test item condition and displacement. Photograph each blast gage and accelerometer installation location on the test item.

5.1.18 Perform a complete post-test dynamic and/or static performance test on the test item. Data from these tests are recorded and correlated with the pretest data.

5.2 Data Required

5.2.1 Nomenclature, description, serial and model numbers of test item(s) under test

5.2.2 Location and orientation of the item under test in relation to the blast source

5.2.3 All instrumentation calibration data

5.2.4 Description of the test environment, including peak dynamic and static pressures and static and dynamic pressure pulsewidths

5.2.5 Photographs of damage to the test item(s) under test and high speed photography sequences showing system response to the test environment

5.2.6 All performance data for item(s) under test

6. DATA REDUCTION AND PRESENTATION

6.1.1 Describe test item and give nomenclature, serial and model numbers.

6.1.2 Display photographs or diagrams showing the test item location in the test volume with respect to the blast.

6.1.3 Tabulate overpressure and dynamic pressure gage data, displacement of test item due to blast, and location of each gage on the test item.

6.1.4 Display still photographs and sequences of high-speed photographs showing effects during and after passage of blast wave.

6.1.5 Tabulate pre- and post-exposure performance data.

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APPENDIX A

SAMPLE DATA SHEET

BLAST TEST*

1. Test missile, description:

   a. Nomenclature:

   b. Model and serial numbers:

   c. Dimensions:

   (1) Length:

   (2) Width:

   (3) Height:

   (4) Weight:

2. Location of test item with respect to blast source:

3. Orientation of test item with respect to the blast source:

4. Blast wave parameters:

   a. Peak dynamic pressure (dynes cm^{-2})

   b. Dynamic pressure pulsewidth (sec)

   c. Peak static overpressure (dynes cm^{-2})

   d. Static pressure pulsewidth (sec)

5. Pre- and post-exposure performance results:

*A data sheet should be provided for each exposure.

APPENDIX B

CHARACTERISTICS OF NUCLEAR PHENOMENA

1. BLAST AND SHOCK

1.1 Blast

a. Most of the physical damage to materiel due to a nuclear weapon detonation will develop as a result of blast. The blast wave produces both overpressure (the pressure above atmospheric that acts from all sides and tends to crush inwardly) and dynamic pressure (the drag force, associated with the strong winds, that tends to overturn, tumble, or tear apart materiel). Most materiel targets are damaged primarily by dynamic pressure; they are referred to as "drag-sensitive targets."

b. Impulse, another important blast damage parameter, takes into account the duration of the positive pressure phase and the variation of pressure with time. Impulse may be defined as the total area under the pressure-time curve.

c. Blast damage will increase with an increase in any of the above parameters. For a given peak pressure level, large-yield weapons, because of their long positive blast phases, will produce impulses many times greater than those produced by small-yield weapons. A typical blast wave is shown in Figure B-1.

d. The relationship between the peak dynamic pressure and the peak overpressure is expressed by the Rankine-Hugoniot equation, which reduces to the following:

$$q = \frac{5}{2} \times \frac{p^2}{7p_o + p}$$

where

q = dynamic pressure

p = overpressure

p_o = ambient pressure

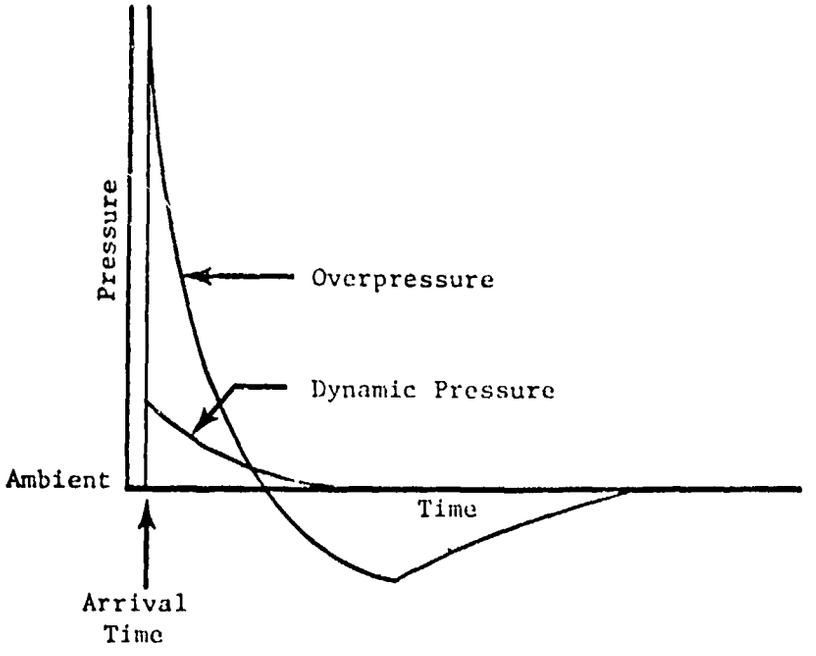


Fig. B-1. Variation of Overpressure and Dynamic Pressure with Time at a Fixed Location

e. The extent to which materiel must be invulnerable to nuclear blast is dependent upon its tactical employment and the location and relative vulnerability of the personnel operating the materiel. Requirements for invulnerability of materiel in storage is another consideration. Some classes of materiel need to be blast resistant only up to the point where members of the crew become casualties as a result of one or more of the damage mechanisms from a nuclear blast. For initial radiation for "unwarned, exposed" personnel (standing in open), it is considered that 5000 rads will produce immediate casualties, 3000 rads will produce casualties within an hour or "prompt casualties," and 650 rads will produce casualties within a few hours or "delayed casualties." Some investigators use a further criterion - 10,000 rads for 5-minute casualties. If it is assumed that personnel will be "warned, protected," they will be afforded considerable radiation protection by crouching in a foxhole. It is generally accepted that foxholes provide transmission factors of 1:5 for gamma rays and 1:3.3 for neutrons. In such instances, if prompt casualties are used as a criterion, materiel in the open may be required to withstand blast levels at points where 10,000 to 15,000 rads of initial radiation would develop. As weapon yield increases, the importance of

initial radiation effects on personnel decreases relative to blast and thermal radiation effects. For large yields, the governing mechanism for personnel incapacitation would be blast or thermal radiation, or a combination of these, rather than initial radiation.

f. The 3000-rad point corresponds to different blast levels, depending upon the yield of the weapon and the fission-to-fusion ratio of the particular weapon. In general, a given radiation level will be accompanied by a lesser blast level for small weapons than for large weapons. This is shown in Table B-1.

TABLE B-1

APPROXIMATE BLAST LEVELS AT THE 3000-RAD POINT FOR FISSION NUCLEAR WEAPONS

Weapon Yield	Distance of 3000-Rad Point From Low Air Burst (meters)	Blast Levels at 3000-Rad Point*	
		Peak Overpressure (psi)	Peak Dynamic Pressure (psi)
1 KT	550	3.7	0.3
20 KT	980	7.5	1.2
100 KT	1270	13	3.4
1 MT	2000	25	12

*For surface burst. Air blast would be slightly higher.

1.2 Ground Shock

A nuclear detonation, particularly a burst that occurs under or near the surface, will transmit a shock wave through the surrounding earth. Ground shock is important in damaging underground targets and shelters, but its effect on materiel targets located on the surface is insignificant in comparison to the effects of blast. Thus, ground shock is not normally considered in the evaluation of vulnerability of materiel.

2. THERMAL RADIATION

a. Thermal (heat) radiation is composed of ultraviolet, visible, and infrared radiation originating in the fireball. It has very little penetrating power and can readily be absorbed or reflected. Any solid, opaque material (e.g., a wall of a vehicle or a tarpaulin) between a given object and the fireball will provide protection from thermal radiation. Conversely, transparent materials, such as glass, provide almost no protection.

b. The duration of the effective thermal pulse increases with the nuclear weapon yield. For example, the thermal pulse duration from a 10-megaton air burst is about 30 seconds, whereas from a 1-kiloton weapon it is roughly 0.3 second.

c. The requirements for resistance to thermal radiation will normally be expressed in units of calories per squre centimeter which describe the area under the curve of thermal radiation versus time. Ignition of materials, however, is dependent upon peak intensity as well as upon the area under the curve. Thus, a 20 cal/cm^2 exposure from a 20-kiloton weapon, with its short duration pulse and high peak, will have much more ability to ignite than a 20 cal/cm^2 exposure from a 10-megaton weapon, with its long duration pulse and low peak. As an example, 4 cal/cm^2 from a 1-kiloton weapon is required to ignite dead grass, whereas 12 cal/cm^2 from a 10-megaton weapon is required.

d. Some typical ignition conditions are shown in Table B-II; others may be found in numerous documents.

TABLE B-II

APPROXIMATE RADIANT EXPOSURES
CAUSING DAMAGE TO MATERIALS

Material	Radiant Exposure (cal/cm^2)	Effect
Cotton Shirting (tan)	*7	Ignition
Cotton awning canvas (green)	*8	Ignition
Burlap, heavy (brown)	*8	Ignition
Rubberized canvas auto top (gray)	*16	Temporary ignition
Plexiglas	16 to 70	Surface melting or darkening
Teflon	60 to 70	Surface melting or darkening
Bakelite	60 to 70	Surface melting
Hardwood, unpainted	10 to 15	Charring
Leather, thin (brown)	15	Charring
Newspaper, single sheet	*3	Ignition

*Based on a 20-kiloton weapon. Greater exposures would be required for larger weapons.

e. To evaluate the resistance of an item of materiel to thermal radiation, the evaluator first examines the item to determine potential trouble areas. These are usually associated with materials such as plastics, fabrics, rubber, and wood. Charring of paint is of no consequence, nor is the charring or discoloration of any material, provided that such damage does not interfere with the operation of the equipment. The fact that gasoline may spill out when motorized equipment is overturned should not be interpreted as suggesting that it will be ignited by thermal radiation, because the thermal pulse from most weapons will have passed by the time the spilling occurs.

f. Adequate resistance to thermal radiation can sometimes be confirmed by a visual examination that proves the item free of heat-sensitive areas. At other times, it may be necessary to expose the item to devices which simulate the thermal pulse. One such device is the White Sands Solar Furnace.

g. Typical of problems that may be associated with thermal radiation are: destruction of insulation on wires, distortion of plastic moving parts, burning of rubber on tires and tracks, blackening of optical devices, ignition of exposed propellants, burning of tarpaulins and other fabrics, and ignition of oil and rags that are present through poor housekeeping. Thermal damage is, of course, of no consequence when an item will suffer severe damage from blast.

3. INITIAL NUCLEAR RADIATION

a. Initial nuclear radiation is defined as that nuclear radiation which is emitted by a nuclear explosion within the first minute after the burst. Initial nuclear radiation tests are concerned only with gamma radiation and neutrons. Alpha and beta particles that are also produced have very short ranges and are of no consequence.

b. Initial radiation shielding tests involve the exposure of materiel to neutron and gamma radiation sources to measure the protection afforded to the crew and the most vulnerable components by the walls of the vehicle. The radiation sources must have spectra that collectively approximate the spectra from nuclear weapons. The distance from radiation source to vehicle must be as great as practicable, and the angle of the source from the horizontal should be realistic.

c. Some vehicles, such as radiologically protected vehicles, are designed specifically to provide a certain level of protection against initial radiation. Such vehicles will contain composite armor made up of such layers as:

(1) An armor material, presumably steel armor, to provide ballistic protection against conventional weapons

(2) Thermal neutron absorbers

(3) Fast neutron moderators, such as a plastic high in hydrogen atoms

(4) A high-density material efficient in gamma absorption

d. Resistance of materiel to initial radiation is of importance only up to that point where some other damaging mechanism of a nuclear detonation becomes dominant. Additionally, with materiel manned by a crew, the vulnerability of the crew must be considered and is, in fact, often the limiting factor. Because of these considerations, requirements for radiation resistance are appropriately tempered. The result is that only the more radiation-sensitive materials have a possibility of being affected. This, in effect, means that usually only electronic items need be tested for radiation resistance. Occasionally, other components will have to be evaluated. Damage thresholds for the items most sensitive to transient radiation doses are shown in Table B-III.

e. When certain materials are exposed to neutron bombardment, they become radioactive. This process is called activation. Since activated materiel may be dangerous, under some circumstances it may be desirable to know to what extent materiel will become radioactive when exposed to a nuclear blast. This can be done by mathematical techniques if the exact chemical compositions of all components are known. A better method is to expose the item to a reactor, following this with measurements of radiation versus time. Standard activation analysis techniques can uncover any offending element. Cobalt and manganese, with long half-lives, and aluminum, with a short half-life, are among the elements easily activated. When activation is very serious, it may be necessary to change the composition of the item, provide shielding, or place a thermal neutron absorber over the offending component.

f. Because of rate effects, the only suitable means of irradiating materiel to evaluate nuclear weapon effects is by pulses of radiation. The pulsewidth must be short enough to simulate a nuclear weapon radiation burst.

g. Initial gamma radiation can be simulated either with the reactors used to obtain the fission neutron spectrum or by using very large gamma sources, such as cobalt-60.

TABLE B-III

DAMAGE THRESHOLDS FOR ITEMS SENSITIVE TO TRANSIENT NUCLEAR RADIATION

	Thresholds for Damage (n/cm^2)			
	Highly Sensitive Items		Moderately Sensitive Items	
Item	Mild Damage	Severe Damage	Mild Damage	Severe Damage
Electronic components*	**10^8	10^{12}	10^{13}	10^{15}
Power transistors	10^{10}	10^{11}		
Power diodes			10^{11}	10^{14}
Diode detectors	10^{12}	10^{13}		
Integrated circuits	10^{12}	10^{13}	10^{13}	10^{14}
Rubber and plastics	10^{13}	10^{15}	10^{15}	10^{16}
Glass	***10^{15}	10^{16}	10^{17}	10^{18}
Greases and lubricants	10^{15}	10^{16}	10^{17}	10^{18}
Explosives	Classified			

*Damage may be of a very fleeting (though disruptive) nature.

**For silicon-controlled rectifiers; 10^{10} n/cm^2 otherwise.

***Coloration of some glasses may occur as low as 10^{13} n/cm^2.

4. ELECTROMAGNETIC PULSE

a. The electromagnetic pulse consists of low-radio-frequency electromagnetic radiation emitted isotropically from the point of detonation. There are indications that this phenomenon is similar in energy content to a lightning discharge.

b. Although the electronic and electrical equipment is found in systems that are vulnerable to the EMP phenomenon, they must be tested as parts of the whole system, because the EMP effects are dependent on configuration and orientation with respect to the radiating source.

5. RESIDUAL RADIATION

a. Residual radiation is principally the radiation emitted by fallout deposited on the ground and equipment as a result of a nuclear detonation. To a lesser extent, it is also radiation from induced contamination, such as soil (often referred to as activated soil) which has been made radioactive by the neutron bombardment. Fallout may be deposited over very large areas, including locations where little or no other effect from a nuclear detonation is felt. Induced radioactivity, on the other hand, will be found only close to ground zero. Residual radiation consists of alpha, beta, and gamma radiation.

b. Only gamma radiation is of concern in providing shielding against residual radiation. Both alpha and beta radiations may be stopped by thin layers of materials.

c. Most of the residual radiation received by personnel in a vehicle is transmitted directly through the walls and floor of the vehicle, but a significant amount arrives through the roof. This latter radiation is the result of scattering in the air and is called "skyshine."

d. Combat vehicles, particularly tanks and armored personnel carriers, because of their armor and massive metal parts, inherently provide a considerable amount of shielding against residual radiation. The amount of shielding provided is almost a direct function of the mass of material between the individual and the radiation source. The effectiveness of material in attenuating radiation may be represented by its "half-value thickness," the thickness of the particular material which absorbs half of the gamma radiation falling upon it.

e. The amount of shielding provided for each crew member is expressed in terms of "protection factor," defined as follows:

$$\text{Protection factor} = \frac{\text{Radiation level 3 feet above the ground in the free field}}{\text{Radiation level where crew member is located}}$$

f. In other words, the protection factor is the ratio of the radiation dose a person would receive if he were standing in the open in a fallout field to the dose he would receive in the vehicle at the same location. Some tanks may provide protection factors against residual radiation as high as 20, whereas a ¼-ton truck may provide a protection factor of 1.25.

g. The term "transmission factor" is also used. It is essentially the inverse of the protection factor and is defined as:

$$\text{Transmission factor} = \frac{\text{Dose inside}}{\text{Dose outside}}$$

Typical transmission factors for initial and residual radiation are contained in Table B-IV.

h. With a detailed analysis of the design of a vehicle, it is theoretically possible to compute protection factors, but this is difficult to do accurately. The preferred method is to send the vehicle to the Nuclear Defense Laboratory at Edgewood Arsenal, Maryland, where protection factors can be determined experimentally.

TABLE B-IV

TYPICAL TRANSMISSION FACTORS

FOR NUCLEAR RADIATION

Item	Initial Radiation		Residual Radiation
	Neutrons	Gamma	
Armored personnel carrier	1:1.4(0.7)	1:1.4(0.7)	1:1.7(0.6)
Foxholes	1:3.3(0.3)	1:5 (0.2)	1:10 (0.1)
Tank, light	1:3.3(0.3)	1:5 (0.2)	1:5 (0.2)
Tank, medium	1:3.3(0.3)	1:10 (0.1)	1:10 (0.1)
Truck, ¼-ton	1:1 (1.0)	1:1 (1.0)	1:1.3(0.8)
Truck, 3/4-ton	1:1 (1.0)	1:1 (1.0)	1:1.4(0.7)
Truck, 2½-ton	1:1 (1.0)	1:1 (1.0)	1:1.7(0.6)
Truck, 4- to 7-ton	1:1 (1.0)	1:1 (1.0)	1:2.0(0.5)