Number of Pages: 19

Word Count: Approx. 2496

Number of Tables and Figures: 3

Number of References: 10

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TITLE:

MINIMIZING THE EFFECTS OF ELECTROMAGNETIC PULSE (EMP) ON FIELD MEDICAL EQUIPMENT

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KEY WORDS:

EMP, Medical Equipment, Nuclear Weapons Effects, EMC, EMI

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IN REPLY REFER TO:

June 6, 1991

Bioengineering Branch

Editor
MILITARY MEDICINE
9320 Old Georgetown Rd.
Bethesda, MD 20814

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Sincerely,

ROBERT H. VANDRE
LTC, DC
Chief, Bioengineering Section

Enclosures

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
1991, Jun, 7

3. REPORT TYPE AND DATES COVERED
Final 6/86 to 6/88

4. TITLE AND SUBTITLE
"Minimizing the Effects of Electromagnetic Pulse (EMP) on Field Medical Equipment" (Unclassified)

5. FUNDING NUMBERS

6. AUTHOR(S)
Vandre, Robert H., LTC, DC
Blanchard, J.P., MS
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Klebers, J., BSEE

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Submitted as a journal article to Military Medicine

12a. DISTRIBUTION/AVAILABILITY STATEMENT
UNCLASSIFIED/UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

14. SUBJECT TERMS
EMP (Electromagnetic Pulse) EMI (Electromagnetic Interference)
EMP protection
Pulse burnout

15. NUMBER OF PAGES
19

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

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ABSTRACT

Electromagnetic Pulse (EMP) simulator testing and computer simulations show that a field commander can expect approximately 65% of his unprotected electronic medical equipment to be damaged by a single nuclear detonation as far as 2200 Km away. Ways that a field commander can minimize these effects are to keep wiring near the ground. Keep wiring short. Unplug unused equipment. Run power cabling and tents in a magnetic North-South direction. Avoid running power cabling in the East-West direction. Place sensitive equipment in ISO (International Organization for Standardization) shelters.

INTRODUCTION

High altitude electromagnetic pulse (EMP) is a radiated electromagnetic (EM) wave caused by the detonation of a nuclear weapon above the earth's atmosphere. A one megaton nuclear weapon, detonated 400 km above the ground, produces an EMP with an electric field strength of 20,000 to 50,000 volts/meter (1-5). At this altitude, the burst point is sufficiently distant that no blast, thermal, or ionizing radiation is present at ground level. A single high altitude burst can produce EMP radiation over the entire United States or over large portions of Europe. Thus, field medical treatment facilities and all other military systems in the area of coverage would be exposed to EMP as a result of the burst.

Retrofitting of critical electronic equipment to protect against EMP at the equipment level is usually a costly process. The electronic design of the equipment must be modified by the addition of electronic protection circuitry and/or by the incorporation of an electromagnetically shielded chassis box or enclosure.

This type of EMP protection has not been feasible for most medical equipment due to the wide diversity of equipment types, ages and suppliers for the equipment in field medical treatment facilities. Deployable Medical Systems (DEPMEDS) hospitals currently have over 145 different items of electronic equipment in them. Most, if not all, are off-the-shelf items, with no EMP protection incorporated.

Although field-expedient methods of mitigating the effects of EMP cannot be expected to protect exposed equipment from damage in all cases, methods such as those listed below can, however, be employed to increase equipment survivability during an EMP event.

EFFECTS OF EMP ON MEDICAL EQUIPMENT

A previous article in Military Medicine showed that EMP could potentially damage medical equipment, but did not predict the actual amount of damage that a typical EMP pulse might cause (6).

In our EMP simulator testing and computer simulations, we found that a field commander can expect an average of 65% of his unprotected electronic medical equipment to be damaged by a single high altitude nuclear detonation (7).

Electronic damage caused by EMP to medical equipment is very similar to the damage that can be produced by lightning. The energy from the EMP electric field is coupled, or led into, medical equipment by any attached wire or metallic surface, such as power cords, patient leads, or metal chassis.

The principal effect of EMP is to deposit damaging energy into circuit components sufficient to cause semiconductor burnout. That is, a critical junction in a transistor or an integrated circuit literally melts and is permanently damaged. Thus, service provided by equipment with affected components stops instantly.

Measurements of the response of a 100 meter power cable when exposed to a simulated EMP coupled with calculations of the electromagnetic response of a typical field medical treatment facility's power grid indicate that one can expect currents and voltages as great as 120 amps and 12,000 volts, respectively to pass through equipment that is plugged into the power cable (8).

Currents and voltages of such magnitude can burn out unprotected components. This type of damage was evidenced during tests of medical equipment conducted in the Army's AESOP (Army EMP Simulator Operations) EMP simulator facility at the Harry Diamond Laboratories (HDL), located in Woodbridge, Virginia. [HDL has been the Army's lead laboratory for nuclear effects studies and testing.]

The medical equipment tested was configured with a 50 meter power cable made up of components from the DISE (Distribution, Illumination System, Electrical) cabling system which is the power distribution system used in the military's DEPMEDS hospitals. The cable was aligned parallel to the electric field of the simulator to maximize EMP effects. A 60 KW generator was placed at the opposite end of the cable to allow the equipment to be tested under power. Equipment tested with this configuration were:

X-Ray Processor,

Spectrophotometer,

Blood Gas Analyzer,

Respirator,

Electrocardiograph, and an

Electrosurgical Apparatus.

Of these, the Electrocardiograph and Electrosurgical Apparatus experienced permanent circuit damage. As an indication of the extent of damage possible, Figure 1 shows a damaged circuit board from the Electrosurgical Apparatus. In addition to the test program, a computer simulation study analyzed the effects of EMP on the circuits of 17 pieces of medical equipment typically deployed in Army field hospitals. This computer simulation study used proven analysis methods developed in the nuclear effects community for the prediction of EMP effects on electronics (7).

The results of these studies indicated that EMP exposure would damage 11 of the 17 units at sensor/control or power cord interfaces with the electronics. As a verification of the analytical techniques used, the Electrocardiograph and the Electrosurgical Apparatus that were damaged in the previous test were studied in detail by the same analytical techniques. The results of the analytical model accurately predicted the failure levels for the two devices as they actually occurred. Indications of damage were also found for the following additional items of equipment:

Electrocardiograph (different manufacturer)
Resuscitator
Ultrasonic Generator
X-Ray Apparatus (two units, different manufacturer)
Blood Gas Analyzer
Endoscopic Light Source
Ophthalmic Diathermy
Flame Photometer

These studies demonstrated that selected items of otherwise unprotected medical equipment will suffer damage from EMP. Since the coupling of EMP to complex electrical and electronic systems is statistical in nature, not all of the equipment listed above may necessarily be damaged by a particular burst. However, the probability of damage to many medical items deployed in field medical treatment facilities is significant, and mitigation measures should be employed to enhance survivability.

FIELD-EXPEDIENT METHODS OF REDUCING EMP EFFECTS ON MEDICAL EQUIPMENT

To find methods of reducing EMP effects on medical equipment, a computer code was utilized. This code, called "FMPLIN," was developed to calculate the pick-up of EMP energy in overhead power cables (9). This code approximates the values of current and voltage generated in real power cables and is especially accurate at comparing the relative effects that come from changes in the length, height, or orientation of the power cables.

The EMP spectrum used for this calculation is that recently developed by Longmire which calculates the EMP output for a hypothetical 3.3 Megaton detonation at an altitude of 400 km over the central United States (5).

EMPLIN calculated the response of a 100 meter long cable lying one cm above the ground with a resistance of 500 ohms to ground on each end. The EMP response was calculated for cables (polar coordinates) at ranges of 0, 200, 500, 1000, 1500, and 2000 km and azimuths from 0-360 degrees in 22.5 degree increments. At each position on the ground, the cable response was calculated as the cable was rotated in 10 degree increments from 0-360 degrees. From these calculations it was found that the maximum cable response occurs at a distance of 1000 km due East or West from the point of detonation with the cable lying in the E-W direction. The effects of cable height and length were calculated at a position 1000 km due East of ground zero with the cable in an East-West direction. Results of these calculations are discussed below.

Although EMP is certain to damage some unprotected electronic equipment, the field medical treatment facility commander has many options within his control which will greatly reduce EMP induced damage to his equipment. Based on the results of this study some of these are:

1. Keep All Wiring As Short As Possible. In field deployments, the electrical cables available to the medical treatment facility come in standard lengths. Often cables are longer than necessary. The extra length of the cable should be coiled tightly in loops of diameter no greater than one foot. This coil does two things. First, it effectively shortens the cable as far as its antenna-like properties are concerned. Second, it acts as a choke or inductor to slow the rate of rise of the induced EMP pulse and thereby reduces its amplitude. If the coil has a diameter of greater than one foot, it will start to pick up significant amounts of energy.

Any power cable that cannot be coiled tightly enough to make the coil diameter small enough should be looped upon itself in a long "S-curve" as demonstrated in Figure 2.

2. Unplug Unused Equipment. Less than 10% of unplugged equipment will be damaged by EMP exposure. Eliminating the long power cable, which is the major EMP collection path, reduces the possibility of a large EMP power surge entering the equipment.

3. Keep All Wiring Low to the Ground. Both calculations and experiments have shown that EMP coupling to cables and wires increases with cable height above ground, and/or with increasing cable length (4). Thus, it is important to deploy cables as close to the ground as possible, and to minimize their length by coiling unused sections.

Power cables entering TEMPER (Tent, Extendable, Modular, Personnel) tents and shelters are typically run along the wall, near the ceiling, approximately seven feet off the ground, with drop-downs for wall power receptacles. Such deployment causes a large EMP-collecting loop to be formed between the cable and the ground. Relatively inexpensive cable deployment modifications, such as running power cables on the floor near the wall, with receptacle leads going up (the reverse of the present practice), would reduce EMP coupling to these cables by a factor of 8 or more.

Communications cables are often strung on poles and in trees to keep them out of the way, but a cable 13 feet above the ground will collect almost 20 times more energy than if it were placed on the ground.

4. Align Long Cables In A North-South Direction With Generators On The North End. Calculations show that the average peak voltage and energy coupled from EMP is at a minimum for cables lying in the North-South direction. In the Northern Hemisphere it is also slightly better to have the generator on the North end of the line and the equipment on the South end. A piece of equipment on the South end of a power cable is likely to receive 2.4 times less EMP energy than if it were on either end of an East-West cable. This is dramatically illustrated in Figure 3. Note that not only is the maximum value of the energy greater for the East-West cable, the area on the ground where the energy is greater than 10 mJ is much larger. 10 mJ was the threat energy used in the computer simulation above which predicted that 65% of the equipment would be damaged.

5. Place Sensitive Equipment in ISO Shelters. Because expandable shelters are made of metal, they offer some intrinsic shielding from EMP. Tests performed at the Army's REPS (Repetitive EMP Simulator) at HDL on the ISO (International Organization for Standardization) Shelter showed EMP magnetic field reduction inside by a factor of 13 for doors closed, and a reduction of the magnetic field by a factor of 7 with doors open (10). Note that to maximize shielding effectiveness of the shelter, the doors must be kept closed. Metallized fabric tents may also offer some protection from EMP (11).

SUMMARY

The studies described here demonstrate that without taking the protective measures outlined above, a field commander can expect that approximately 65% of his electronic equipment will be damaged by high altitude EMP. The only hint that the field commander will have that a nuclear weapon has been detonated will most likely be the sudden shutdown of his equipment.

Rather than ignore this EMP threat, the simple methods discussed in this paper are within the commander's disposal to give some protection to his equipment from possible EMP damage.

REFERENCES

1. Glastone S, Dolan PJ:The Effects of Nuclear Weapons, XI: The Electromagnetic Pulse and Its Effects. Washington, Department of the Army Pamphlet 50-3, 1977.

2. Dittmer P, Clark S, et al: DNA EMP Course Study Guide, Volume II. Defense Nuclear Agency, DNA-H-86-68-V1, 1986.

3. Sherman R, De Moss RA, et al: EMP Engineering and Design Principles. Whippany, NJ, Bell Telephone Laboratories, 1975.

4. Ricketts LW, Bridges JE, Miletta J: EMP Radiation and Protective Techniques. New York, John Wiley & Sons, 1976.

5. Longmire CL, Hamilton RM, Hahn JM: A Nominal Set of High-Altitude EMP Environments. Oak Ridge National Laboratory, ORNL/Sub/86-18417/1, 1987.

6. Oliva SA, Stromberg LWR: Medical Electronic Equipment: Aan it 144:28-30, 1979.

7. Klebers J: Protection of Medical Equipment Against Electromagnetic Pulse (EMP), Phase I: Vienna, VA, IRT Corporation, DTIC No. ADA 177443, 1986.

8. De Pringer VA: Electromagnetic Pulse (EMP) Threat Specification for Army Medical Equipment. Vienna, VA, IRT Corporation Report No. 11055.07, 1987.

9. Tesche FM, Barnes PR: Development of a New, High Altitude Electromagnetic Pulse (HEMP) Environment and Resulting Overhead Line Responses. Electromagnetics 8:2-4, 1988.

10. Boswell GT, Bock TJ, Patrick EL: HEMP Shielding Effectiveness Tests on Tactical Mobile Shelters. HDL- TR-2039. Harry Diamond Laboratories. July 1984.

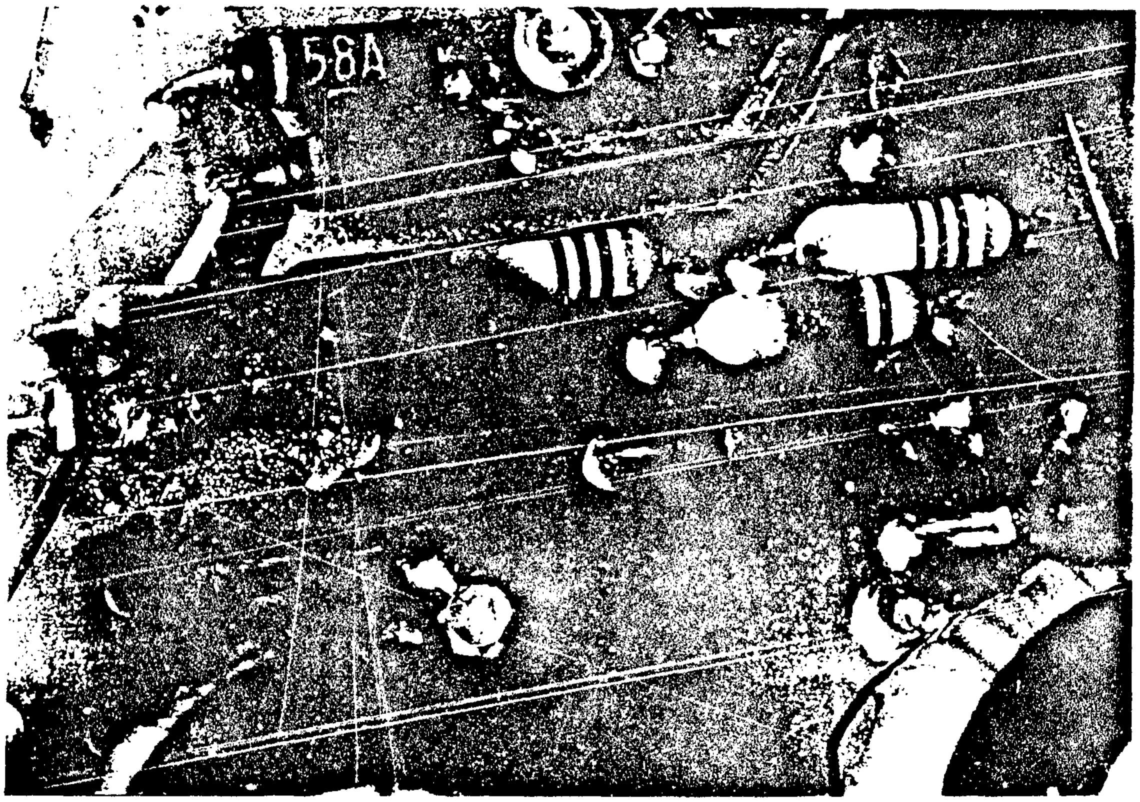
11. Blanchard JP, Tesche FM, Sands SH, Vandre RH: Electromagnetic Shielding by Metallized Fabric Enclosure: Theory and Experiment. IEEE Trans. on EMC 30:282-288, 1988.

FIGURE CAPTIONS

Figure 1. Circuit board from the Electrosurgical Apparatus burned out by an EMP pulse from the Army's AESOP EMP Simulator.

Figure 2. A high-power cable coiled in an "S" curve to minimize EMP pickup. Equal sections of cable running parallel to each other, but in different directions produce voltages and currents that tend to cancel each other out.

Figure 3. Comparison of the energy (in milli-Joules) deposited to the load of a 100 meter long wire lying on the ground with respect to a weapon detonated over the central United States. The left graph shows the ground coverage for cables oriented North-South (equipment on South end). The right graph shows larger area of coverage and energy deposited for a cable oriented East-West (equipment on East end).



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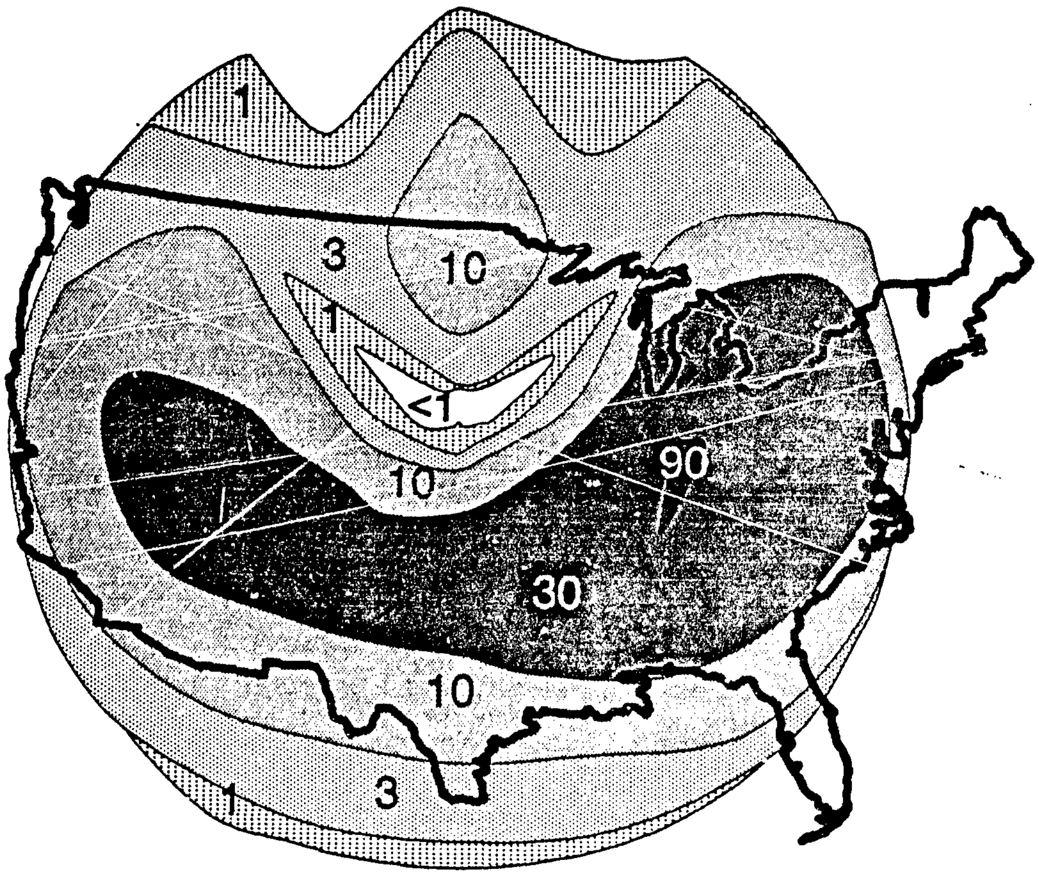
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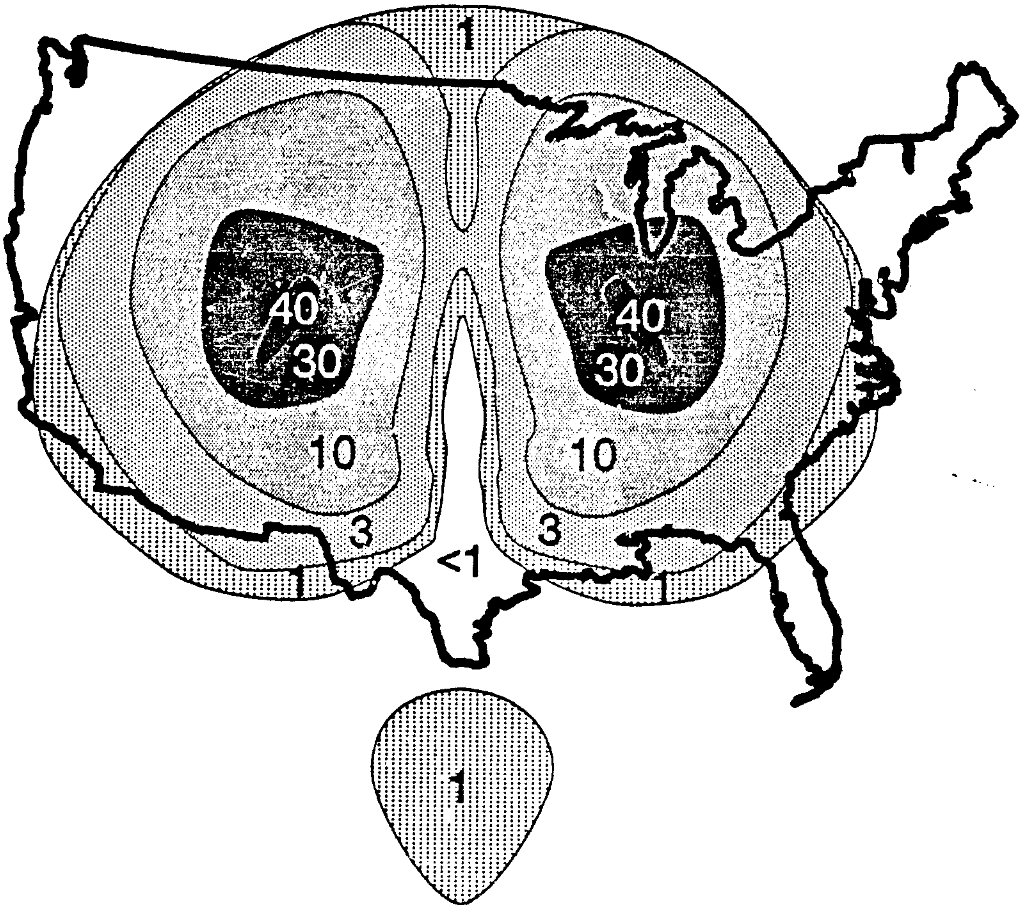
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