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Materiel Test Procedure 3-2-616*
Aberdeen Proving Ground

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

RADIO FREQUENCY RADIATION HAZARDS TO PERSONNEL

1. OBJECTIVE

The objective of this MTP is to determine the distance from the test item at which radio frequency radiation is no longer harmful to personnel.

2. BACKGROUND

Potentially serious safety hazards exist to personnel when operating electronic equipment capable of transmitting and generating radio frequency (RF) at high power levels. Biological injurious radiations are produced by the equipment in two forms, radiated R-F energy in the microwave region and ionizing radiation varying from x-rays to gamma rays.

3. REQUIRED EQUIPMENT

a. Broadband power density meter BA-157
b. RF pick-up probe 200 MC to 800 MC PR-1-157
c. RF pick-up probe 750 MC to 3800 MC PR-2-157
d. RF pick-up probe 3750 MC to 10 GHZ PR-3-157
e. RF pick-up probe 10 GHZ to 40 GHZ
f. RF divider as required
g. Attenuater as required
h. Impedence matching network as required
i. RF cable CBA-157
j. Carrying case AC-157
k. Operating battery BTA-157

4. REFERENCES

A. AR 40-583, Control of Potential Hazards to Health from Microwave Energy, 1 October 1962
B. Mumford, W.W., Some Technical Aspects of Microwave Radiation Hazards, Proc. IRE, Vol. 49, No. 2, February 1961.
C. Daily, L. E., Clinical Study of Results of Exposure of Laboratory Personnel to Radar and High Frequency Radio, U.S. Naval Med Bull., Vol. 41, July 1943
D. Clark, J. W., Effects of Intense Microwave Radiation on Living Organisms, Proc. IRE Vol. 38, September 1950.
E. Schwan, H. P., and Li, K., The Mechanism of Absorption of Ultra-high Frequency Electromagnetic Energy in Tissues, as Related to the Problem of Tolerance Dosage, Proc. IRE, Vol. 44, November 1956.

* Supersedes Interim Pamphlet 35-112

5. SCOPE

5.1. SUMMARY

This document discusses the characteristics of electromagnetic radiation hazards and the safety procedures required in the protection of personnel from R-F energy in the spectrum from 100 MHZ to 40 GHZ, and gives the general procedures for measuring and evaluating electromagnetic radiation hazards. (See Appendix A)

5.2. LIMITATIONS

Not considered in this document are the biological effects of exposure to ionizing radiations such as x-ray and gamma rays. Psychological stresses, neurological effects, and long-term genetic effects are also excluded. The term "biological effect" as used herein refers specifically to the destructive heating of tissue caused by the absorption of R-F energy.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 Pre-Test Preparation

a. Record the following:

1) Nomenclature of the test item
2) Serial number and model number
3) Manufacturer of test item
4) Identification of and any modification to equipment

b. Select test equipment having an accuracy of at least 3 times that of the function to be measured and record nomenclature, serial number, accuracy tolerances, calibration requirements, and last date calibrated of test equipment selected for the tests.

c. Assure that all test personnel are familiar with the required technical and operational characteristics of the item under test, such as stipulated in Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), Technical Characteristics (TC), and general safety requirements.

d. Review all instructional materiel issued with the test item by the manufacturer, contractor, or government, as well as reports of previous similar tests conducted on the same type of test item, and familiarize all test personnel with the contents of such documents. These documents shall be kept readily available for reference.

e. Arrange the test item for operation, and test requirements.

f. Prepare record forms for systematic entry of data, chronology of test, and analysis in final evaluation.

g. Obtain design data concerning the boundry of the potentially hazardous zone as well as data on the average power frequency, direction, and polarization of the transmitted energy.

6.1.2 Safety Preparation

a. Ensure that danger zones are adequately posted with warning signs and devices.

b. Inform all personnel of the nature of the potential radiation hazards and the necessary precautions to be taken to avoid biological injury during the test.

c. Assure that safety interlocks are installed on all access points.

d. Ensure that all personnel are excluded from the danger areas.

e. Establish a system of periodically checking all interlocks, limiting devices and warning devices.

f. Schedule periodic medical examinations of all personnel exposed to electromagnetic radiation environment.

g. Assure that qualified safety personnel maintain a continuous observation of the test item and procedures through the entire test of the item.

6.1.3 Pre-Test Operation

a. Determine the distance from the radar at which the power density is estimated to be 10 mw/cm^2 using the following formula:

$$D \approx \sqrt{\frac{P_T G}{4 \pi Pd}}$$

D = Distance from radar in meters
P_T = Transmitter power in watts
G = Antenna gain
Pd = Power density at D in mw/cm^2

b. Record the transmitted power of the radar.

6.2 TEST CONDUCT

6.2.1 Power Density Measurements

a. Emplace the test equipment at 1.5 times the distance determined in 6.1.3.

b. Apply power to the radar and measure the power density level at the point determined in step a.

c. Decrease the distance in 10 meter intervals along the axial line and repeat the power measurements until the point is found where the power density level is found to be 10 mw/cm^2.

NOTE: During the power density measurement test the antenna is not scanning.

d. Repeat the above procedures for 24 axial lines equally spaced about the radar in 15° increments.

6.3 TEST DATA

6.3.1 Preparation for Test

Data to be recorded prior to testing shall include but not be limited to:

a. Nomenclature of test item
b. Serial number of test item
c. Manufacturer of test item
d. Identification of and any modification to equipment
e. Nomenclature, serial number, accuracy tolerances, calibration requirements and last data calibrated of the test equipment selected for the tests.
f. Radar transmitter power

6.3.2 Test Conduct

Data to be recorded during test conduct shall include the following:

a. An engineering log book containing in chronological order, pertinent remarks, and observations that consist of temperature, humidity and other appropriate environmental data, or other description of equipment or component and functions and deficiencies.

6.4 DATA REDUCTION AND PRESENTATION

The data reduction and presentation shall consist of plotting the instrument indications and measurements into polar coordinates of 24 axial lines equally spaced about the radar.

APPENDIX A

BIOLOGICAL EFFECTS OF RADIATED R-F ENERGY

The biological effects of radiated R-F energy are frequency dependent between 100 MHZ to 10 GHZ. The frequencies below 1000 MHZ, particularly in the region around 500 MHZ are considered to be extremely dangerous to personnel. In this spectrum, radiation penetrating the interior of body may be near 40% producing a deep heating of tissue and vital organs. The heat sensors of the body are located in the skin therefore personnel exposed to radiation below 1000 MHZ will absorb this energy without being aware that destructive heating is taking place.

For frequencies between 1000 MC and 3000 MC the biological effects are not entirely predictable. The radiated energy is absorbed in body and surface tissues in a ratio determined by a number of electrical and physiological variables. The percentage of radiation absorbed can approach 100 percent depending upon the thickness of skin and subcutaneous fat. Radiated energy above 3000 MC is absorbed in the surface tissue and results in only superficial heating. Discomfort resulting from a general rise in body temperature may be perceived by the heat sensors at the surface of the body and serve as a warning to the individual.

The danger of excessive amounts of radiation to the sensitive areas of the body are of prime importance. The brain, eyes, and testes are the areas most affected. The viscous material of the eye (lens) may be permanently damaged by the formation of cataracts, in such cases the process is an irreversible one. The testes are also sensitive to heat the the irradiated subject may experience a degree of temporary sterility although an energy level high enough to cause total sterility usually results in death.

Although human tolerances for absorbed energy are variable and biological injury is dependent upon frequency, a limit of 10 mw/cm^2 is considered to provide a safety factor that is adequate for all personnel under all conditions where the irradiated body is at equilibrium with the average power of the microwave power field. For a fixed radar antenna the criterion for biological injury is the average power density level incident upon the subject. For a scanning antenna the power absorbed by a subject fixed in this field depends upon the thermal time constant of the subject, assuming the time constant is long compared with the scanning period, the hazardous distance is reduced by the square root of the ratio of the beamwidth to the scanned angle.

Table A-1, shows approximate safe distances for a representative number of typical radar system.

TABLE A-1
COMMON RADAR SYSTEMS
SAFE DISTANCE IN FEET FROM RADAR ANTENNA TO BOUNDARY
OF POTENTIALLY HAZARDOUS ZONE

RADAR TYPE	Safe distance in feet for power density level of 10 mw/cm^2
AN/FPS-16	
SIG C MOD	1020
Standard model	1590
HERC, IMP, ACQ, HIPAR (fixed)	550
HERC, MTR (Ajax)	270
AN/TPS-16 (40' x 11')	150
HAWK	
(High power illuminator radar)	350
(Range-only radar)	145
(CW acquisition radar)	60
(Pulse acquisition radar)	50

NOTE: The above data is based upon the following assumptions:

a. Transmissions are in free space.

b. There are no ground reflections (reflections could double the distance).

c. Calculations apply to the axis of the beam, i.e., where the power density is maximum.

d. The beam is considered fixed in space, i.e., not scanning.