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ADVISORY CIRCULAR

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DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: RECOMMENDED RADIATION SAFETY PRECAUTIONS FOR AIRBORNE WEATHER RADAR

1. PURPOSE. This circular sets forth recommended radiation safety precautions for ground operation of airborne weather radar. These general recommendations are, in some instances, based on past experience, but are not intended to be used in lieu of specific analysis by qualified personnel in each situation.

2. CANCELLATION. Advisory Circular 20-68, dated March 11, 1970, is cancelled.

3. REFERENCES. Barnes and Taylor: "Radiation Hazards and Protection," George Newnes Limited, London, 1963, page 211. Environmental Health Series: "Standards and Guides for Microwaves," U.S. Public Health Service, Health, Education and Welfare Agency, Consumer Protection Environmental Service, pages 56-57. Mumford, W.W.: "Some Technical Aspects of Microwave Radiation Hazards," Proceedings of the IRE, February 1961, pages 427-447.

4. BACKGROUND. Dangers from ground operation of airborne weather radar include the possibility of human body damage and ignition of combustible materials by radiated energy. Low tolerance parts of the body include the eyes and the testes. Since this possibility exists it is advisable to provide recommended practices.

5. PRECAUTIONS.

   a. General.

      (1) Installed airborne weather radar should be operated on the ground only by qualified, authorized personnel.

      (2) Installed airborne radar should not be operated while the aircraft is in a hangar or other enclosure unless the radar transmitter is deactivated, or the energy is directed toward an absorption sheild which dissipates the radio frequency (RF) energy.

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b. Body Damage.

(1) Personnel should never stand nearby and in front of a radar antenna which is transmitting, but not scanning.

(2) When the airborne radar is operating with the antenna scanning, a recommended safe distance should be specified indicating how far away personnel should remain, based on the type of radar, including parameters of average power output and antenna gain. A safe distance can be calculated using these variables in accordance with the equations in Appendix 1. This procedure is now accepted by many industrial organizations and is based on limiting exposure of humans to an average power density not greater than 10 milliwatts per square centimeter and is recommended for this purpose.

(3) Personnel should not be allowed at the end of an open waveguide unless the radar is turned off and will remain off. Radar should not be operated with an open waveguide unless a "dummy load" is connected to the portion which is connected to the transmitter.

(4) Personnel should not look into a waveguide, or into the open end of a coaxial connector or line connector to a radar transmitter output, unless necessary, and then only when it has been determined that the RF power is off. Severe eye damage may result from radiation.

(5) When high power radar transmitters are operated out of their protective cases, there may be X-rays emitted. Stray X-rays may emanate from the glass envelope type pulser, oscillator, clipper or rectifier tubes, as well as magnetrons. Although the likelihood of danger of X-rays with most airborne radars is small, the following precautions should be taken:

(a) Obtain data from the manufacturer indicating if their radar is a source of dangerous X-ray radiation and be guided by the manufacturer's recommendations.

(b) Make an engineering analysis of the possibility of X-ray emission and be guided by such findings.

c. Combustible Materials. Weather radar installed on aircraft should not be operated while that aircraft is being refueled or defueled.

R. P. SKULLY
Director, Flight Standards Service

APPENDIX 1. RADIATION SAFETY PRECAUTIONS FOR AIRBORNE RADAR

If more precise safety limits are desired, the following procedure can be used:

1. Safe Power Density Limit. Extensive experimental research into the hazard to humans from microwave radiation has been carried on since about 1942. Studies have been conducted to establish a safe exposure level for microwave fields and have shown that damage is likely to occur at power densities above 100 mw/cm^2 for whole body exposure for a time period of 6 minutes or longer. To provide a practical safety factor, the American National Standards Institute has specified a maximum level of 10 mw/cm^2 for personnel exposure for 6 minutes or longer.

2. Near Field Power Density. Power density within the near field of an antenna is oscillatory in nature and cannot be easily computed as a function of distance from the antenna. However, the maximum average power density that will occur in the near field may be calculated by:

$$W_{max} = \frac{4P}{A} \qquad (1)$$

where W_{max} = Maximum average power density (in watts/$meter^2$).
P = Transmitted average power (in watts).
A = Area of antenna (in square meters).

$$mw/cm^2 = \frac{watts/meter^2}{10} \qquad (2)$$

3. Near Field/Far Field Intersection. The distance to the near field/far field intersection can be computed by:

$$R_i = \frac{G\,\lambda}{8\,\pi} \qquad (3)$$

where R_i = Intersection distance from the antenna (in meters);
λ = Wave length (in meters).
G = Antenna gain (not db).

$$Feet = Meters\ (3.28) \qquad (4)$$

$$Frequency = \frac{3 \times 10^8}{\lambda} \qquad (5)$$

4. Far Field Power Density. Power density in the far field of the antenna varies as a function of range per the inverse square law. The far field power density may be calculated by:

$$W = \frac{GP}{4\pi R_a^2} \qquad (6)$$

where W = Power density (in watts/meter^2). (see equation 2)
G = Antenna gain (not db)
P = Transmitted average power (in watts).
R_a = Distance from the antenna (in meters).

5. Distance to 10 mw/cm^2 Safe Limit. For a far field power density of 10 mw/cm^2, the distance (in meters) from the antenna may be calculated by:

$$R_s = \sqrt{GP/400\pi} \qquad (7)$$

where R_s is the minimum safe distance in meters. (See equation 4.) An applicable graph is shown in figure 2.

6. Power Density Calculations. The above formulas or the graphs of figures 1 and 2 may be used. In either case the following procedures should be followed:

a. Determine if 10 mw/cm^2 density is exceeded in the near field (paragraph 2.)

b. If so, calculate the distance (R_s) to 10 mw/cm^2 density (paragraph 5.)

7. Example.

a. Data

Antenna Diameter	:	22 inches = 56 cm
Transmitter Frequency	:	9375 $\pm$ 30 MHz
Wave Length	:	3.2 cm = 3 x 10^8/frequency
Pulse Length	:	1.5 microseconds (search)
Pulse Repetition	:	400 Hz
Peak Power	:	40 kilowatts
Average Power	:	24 watts (search) = Peak Power x Pulse width x pulse repetition frequency
Antenna Gain	:	30 db = 1000 (db = 10 log G)

b. Calculations

(1) Maximum Near Field Power Density.

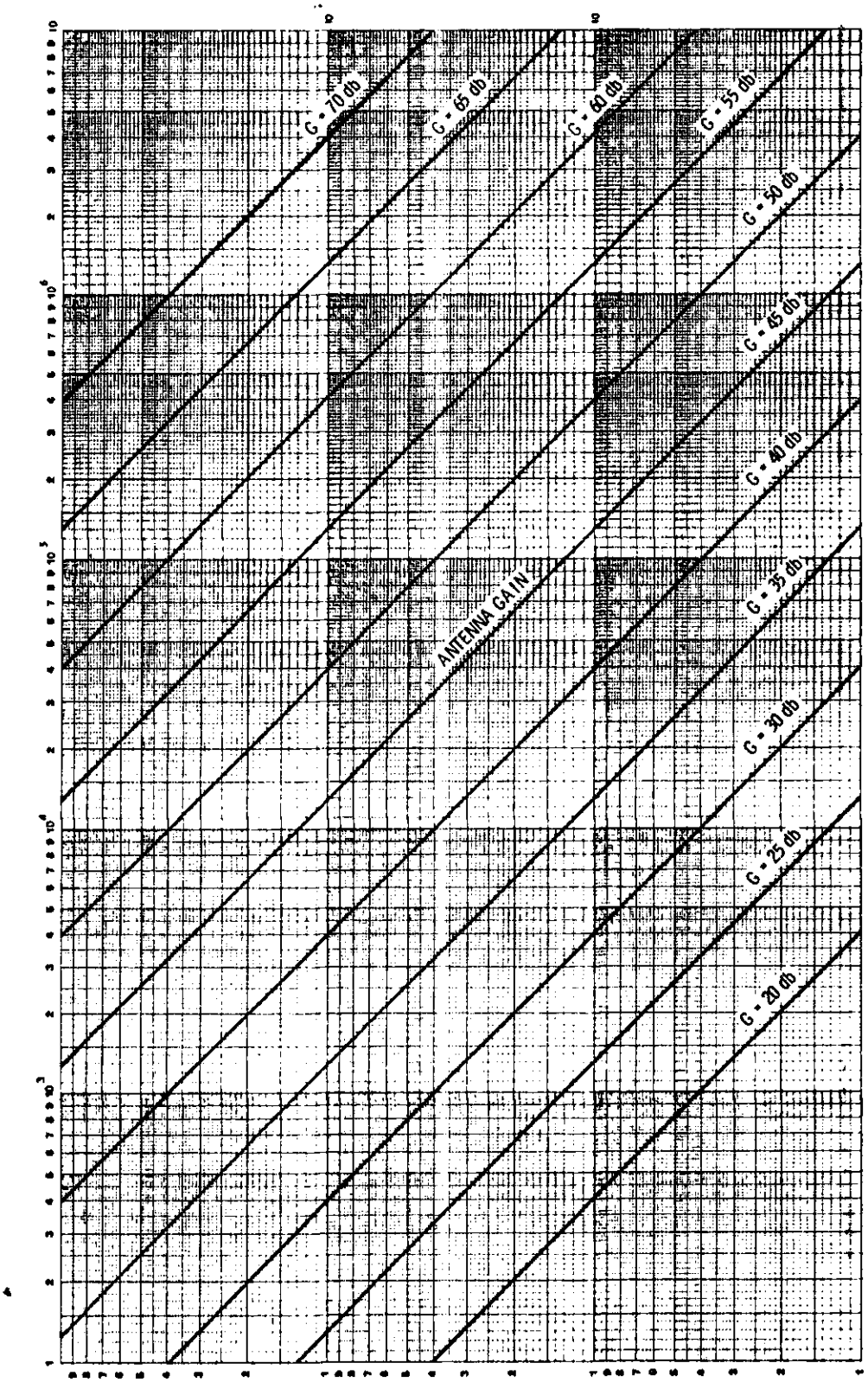
$W_{max} = \frac{4P}{A}$ (Antenna Area = π diameter^2/4 = 0.25 meters^2)
= 4 x 24/0.25
= 384 watts/meter^2
= 38.4 mw/cm^2
10 mw/cm^2 is exceeded in the near field.

(2) Distance (R_s) to 10 mw/cm^2 safe limit.

$$R_s = \sqrt{GP/400\pi}$$
$$= \sqrt{1000 \times 24/400\pi}$$
$$= 4.37 \text{ meters} = 14.3 \text{ feet}$$

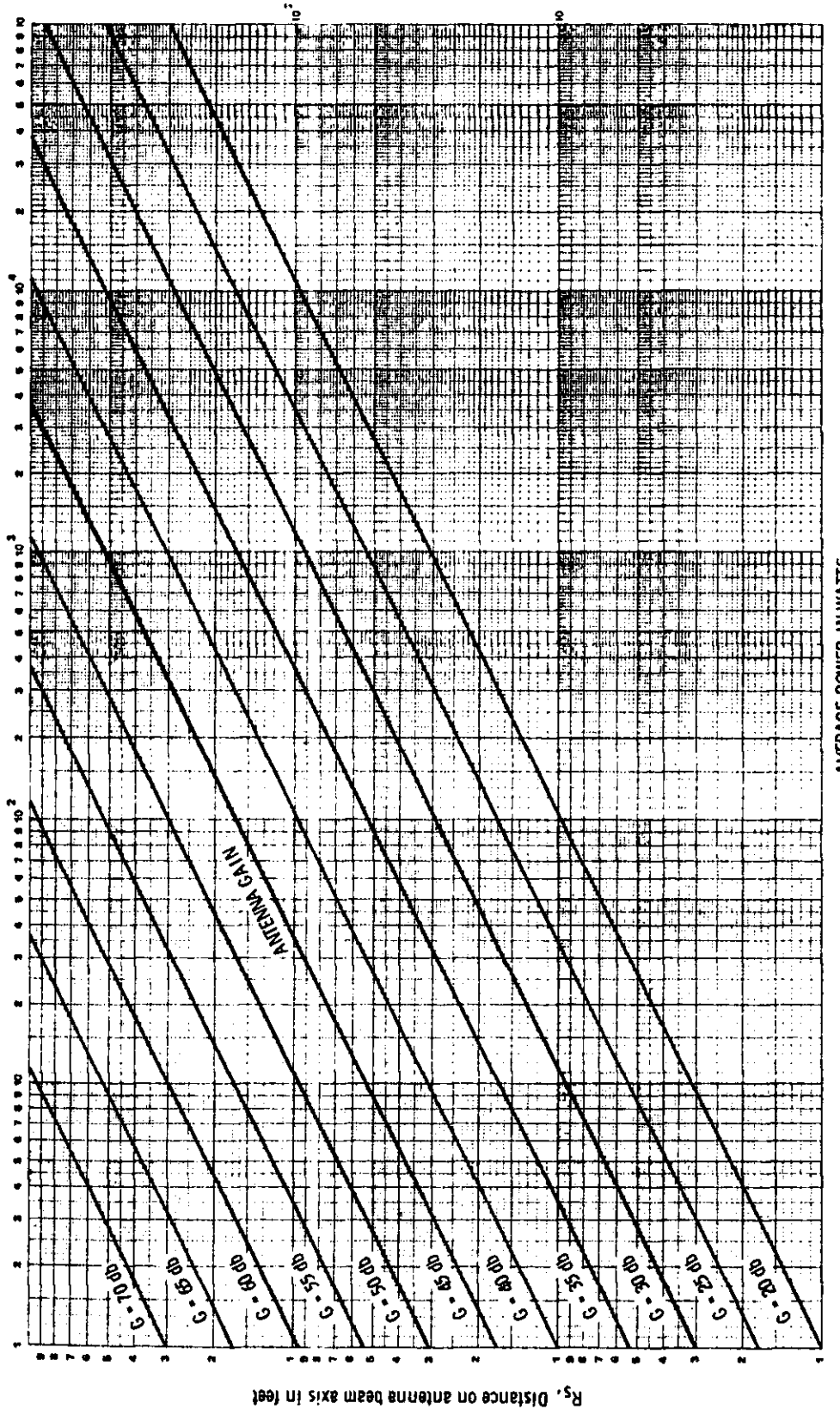
(3) Distance (R_i) to the near field/far field intersection.

$$R_i = G\lambda/8\pi$$
$$= 1000 \times 0.032/8\pi$$
$$= 1.27 \text{ meters} = 4.2 \text{ feet}$$



Distance to Intersection of Near and Far Fields

FIGURE 1



Distance on Antenna Beam Axis for Power Density = 10mw/cm2

FIGURE 2