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HAZARDS of High Frequency Radiation

By LT T. Moslak, USNR-R

SINCE high frequency radiation cannot be readily detected by the human senses, a few reports and rumors of fearsome side effects on persons exposed to radar beams have more than once found an interested audience. We often ask ourselves "Just how dangerous is radar radiation?" It is recognized that radio frequency radiation is a personnel hazard, but it is not a phenomenon meriting unreasonable fear. It is, rather, a hazard to be regarded respectfully, much as one might regard fire: very useful when properly used, but potentially dangerous when treated carelessly.

Advanced communications and radar systems incorporating high powered transmitting tubes and high gain antennas are the source of hazard to both personnel and equipment. The nature of the hazard is the creation of radio frequency electromagnetic fields of sufficient intensity to produce harmful biological effects in humans, cause spark ignition of volatile combustibles, or actuate electroexplosive devices contained in ordnance systems.

Carefully controlled experiments and studies have been made over a period of several years to detect any possible harmful effects upon personnel working with or near high powered airborne radar. Medical experiments with test animals have established that a hazard may exist under certain conditions. But, proper precautions can prevent adverse effects just as they do in other potentially dangerous situations.

Let's briefly review the radar wave itself, then examine the findings from controlled medical tests and from the surveillance of persons working with airborne radar. Safety precautions from both the physiological and physical standpoints will also be discussed for personnel working with radar, particularly systems in the S-3A and F-14A aircraft.

The Radar Beam. *What it is:* Radar waves originate as electromagnetic impulses in a high frequency oscillator tube called the magnetron. These impulses are generally referred to as microwaves, because of their relatively short wavelength. They are carried through a waveguide to a transmitting antenna which projects the waves into space at the speed of light. Upon striking an object which they cannot penetrate, the waves are reflected back to the antenna and waveguide. These reflected waves are similar in frequency and wavelength, but are of considerably less power than the original projected waves. A receiver translates the reflected wave into the visual presentation of range and bearing that appears on the radar screen.

How it affects us: The biological effects of radar are, to a great extent, associated with the radar's frequency and wavelength as well as its average field intensity (power). It is the nature of microwave radiation that at lower frequencies, below one gigahertz (giga – one billion), the electromagnetic energy will penetrate to the deep body tissues; whereas, at higher frequencies, above three gigahertz, maximum heating effects occur at skin level, where it is most easily felt and dissipated. At frequencies between one and three gigahertz, the percentage of energy absorbed ranges from 20 to 100 percent because of varying degrees of penetration. The heat produced by microwave radiation is capable of adversely affecting living tissue if the organism cannot dissipate the heat as rapidly as it is produced.

This type of exposure may be especially undesirable in that a high degree of heat is generated below the nerve endings that generally serve as heat detectors. It is, therefore, possible for this type of radiation to produce relatively high heat levels in the body without any warning to the person exposed. This situation is difficult to understand. As an analogy, however, it is true that if a slab of butter approximately ¾-inch thick was placed upon a cut of beef, then exposed to 10 centimeter S-band radar, the butter would first melt at the butter and meat junction, rather than at the top level of the butter as one might expect.

Effects on Operating Personnel: The consensus among military and civilian medical investigators is that the primary danger to the body from radar radiation is due to the heating effect. Injury does not occur instantaneously, but must be applied for various periods of time at certain intensities of power. There is essentially no radiation danger from the reflected wave since this is greatly reduced in power at the time of visual display. Radar-equipped aircraft in flight offer no hazards to the flightcrews as the radar waves are usually absorbed or reflected by the shielding of the transmitters. And at the present time, there is certainly no reason for carrier or maintenance personnel to fear exposure if standard operating procedures are adhered to and personnel remain outside minimum safe distances from operating radar.

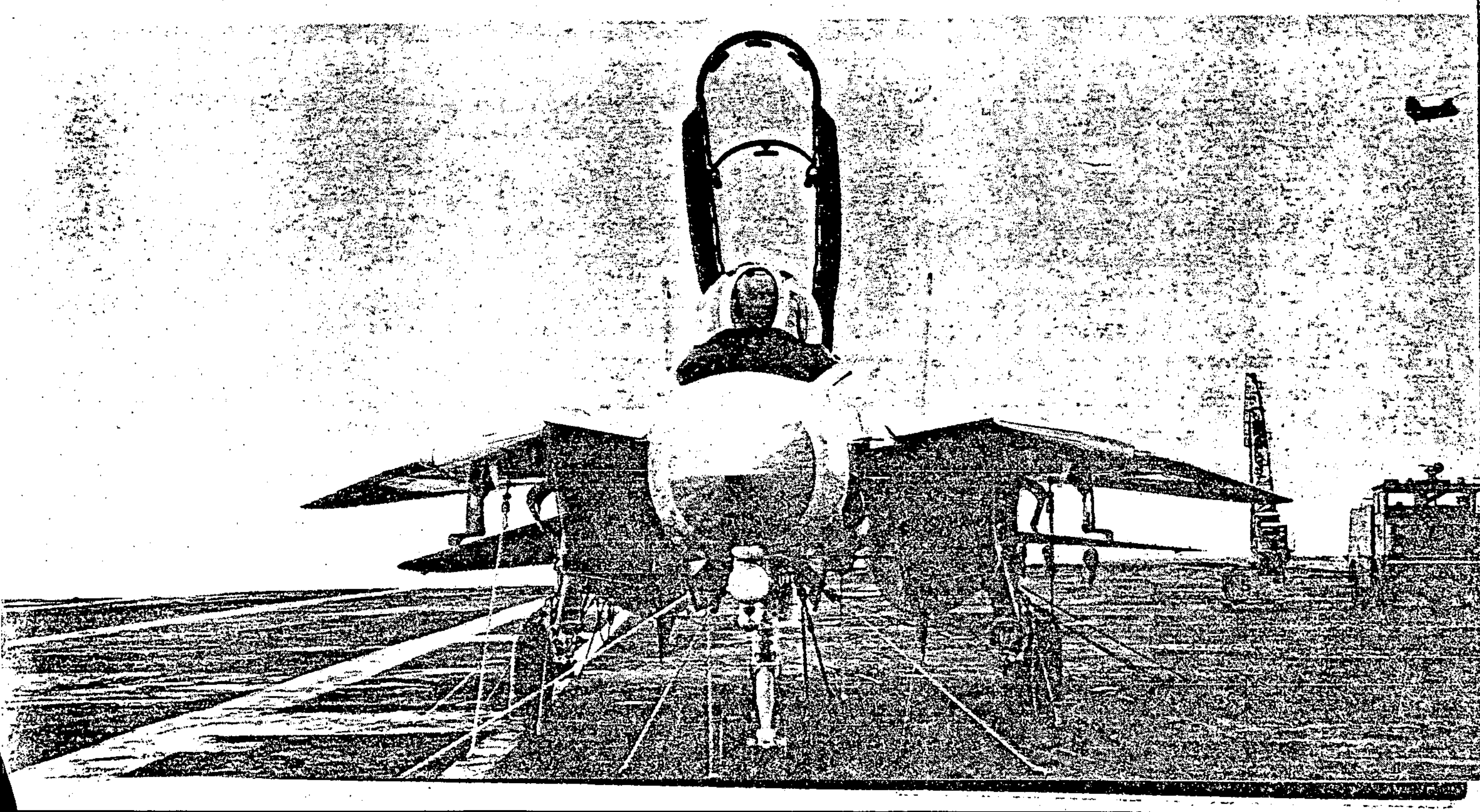
Medical Studies and Findings. Particular attention must be paid to the eye. The transparent lens of the eye appears to be easily damaged by intense radiation energy, whether ionizing, infrared, or microwave. The lens is especially susceptible to thermal damage since it lacks a blood supply to dissipate heat. Temperature elevations within the eye may alter the metabolic processes of the lens cells and lead to damage or cellular death. Since damaged cells cannot be shed or replaced, a permanent opacity results. If this opacity is large enough to measurably interfere with vision, it is termed a cataract. The damaged cells may lose their transparency slowly, and as a result, depending upon the extent of damage, the individual suffers impaired vision. Lens opacities or other changes can be identified promptly and their development investigated without need for anesthesia by use of the slit lamp. The slit lamp is an instrument which projects a narrow beam of light into the eye and provides sufficient magnification to enable the visual study of the various layers in the eye lens. It takes power levels 10 times the now permitted exposure levels to produce cataracts in experimental animals.

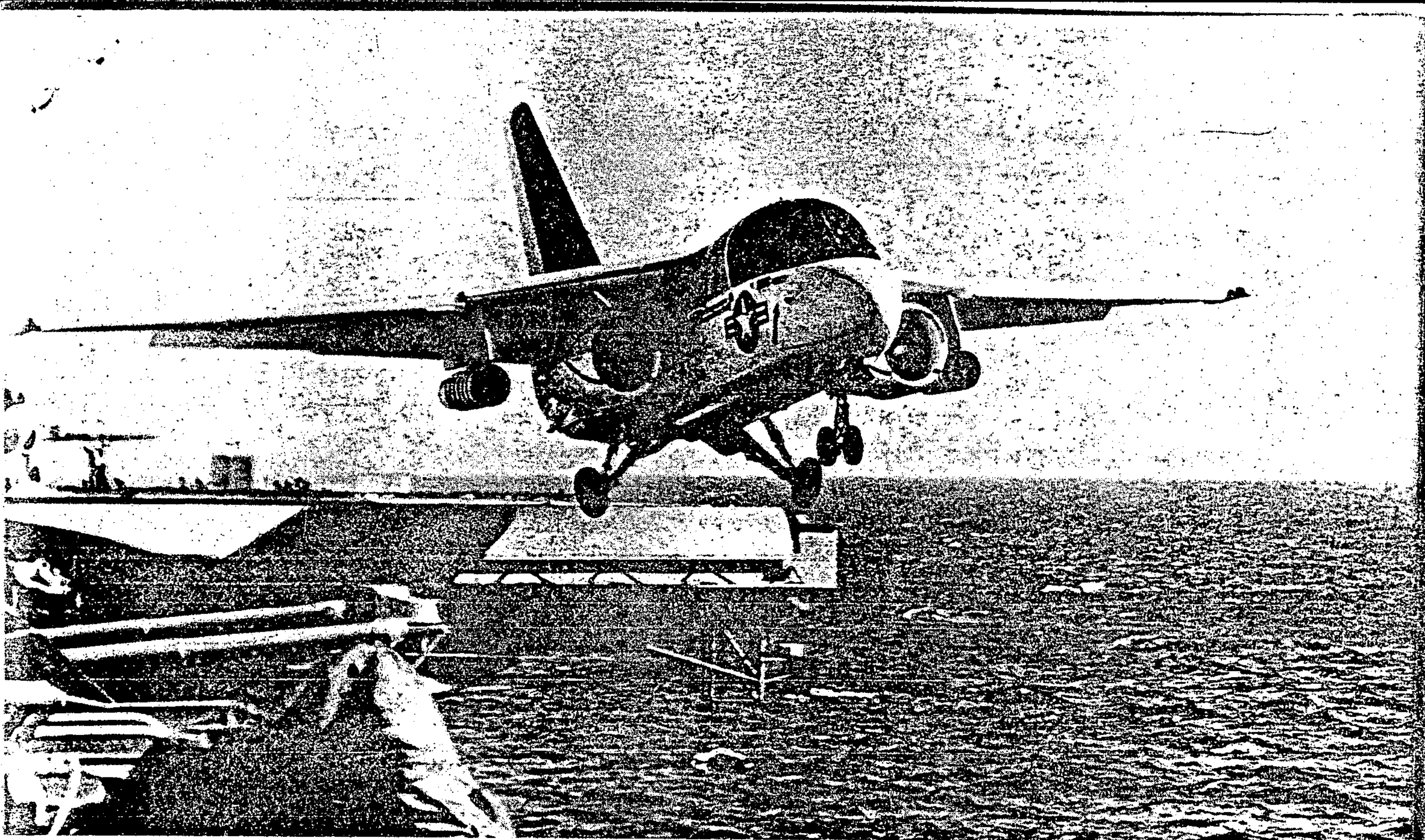
Testicular reaction to heat injury resulting from microwave radiation appears to be the same as would result from a very hot bath. Although a condition of temporary sterility and damage to seminiferous tubules may occur, the condition does not appear to be of a permanent nature and will ultimately correct itself.

A good deal of discussion and controversy exists in current literature regarding the question of "nonthermal" or "specific" effects; i.e., effects caused by mechanisms other than thermal action. These effects include disturbances of the central nervous system, sensory perception, and various cardiovascular changes. A variety of activity and behavioral changes have been noted, including changes in alertness and endurance. There have also been reports of general loss of strength, memory disturbance, tiredness, headache, irritability, and loss of appetite. A conclusive answer to the "nonthermal" effects question is not currently available.

There are two additional, unexplained temporary responses of man to microwaves which have been reported. One of the responses is nausea. The effect is purported to occur within the frequency range from 9-12 gigahertz. Also, certain people can perceive an auditory response in the form of a "buzz" when exposed to frequencies between 0.2 and 3.0 gigahertz which are in a pulse-modulated format within the audio frequency range.

To guarantee the safety of persons who work with airborne radar, additional and extensive medical research is continuing in military and civilian research centers. In the meantime, high-power radar transmitters are to be treated with full respect and in accordance with the necessary precautions outlined in flight manuals and





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supplements. Such documents provide limiting radiation hazard distances (minimum safe distances) and maximum allowable exposure times for personnel working around radars.

Hazard Prediction. The Bureau of Medicine and Surgery has established safe limits based on the power density of the radiated beam and the exposure time of the human body in the radiation field. These maximum personnel exposure levels are as follows:

In the frequency range between 100 megahertz and 100 gigahertz, personnel exposure shall not exceed the following:

- For continuous exposure, the average power density is not to exceed 10 milliwatts per square centimeter.
- For intermittent exposure, the incident energy level is not to exceed 300 milijoules per square centimeter per 30-second interval.

All areas in which the energy levels exceed the above limits shall be considered hazardous. Accordingly, admittance to areas where the exposure levels exceed the above limits shall be restricted, and warning signs shall be posted.

The Electromagnetic Survey Group of the Naval Ship Engineering Center is responsible for determining hazardous areas and ensuring that the possibility of biological injury to personnel from radio frequency radiation is minimized or nonexistent. Theoretical calculations and power density measurements are used to establish the distances from radar antennas within which it is not biologically safe for personnel to enter. Shipboard power density surveys may be routinely conducted by qualified personnel using the thermistor type power meters, usually the Hewlett-Packard 431 series or the AN/USM-177 power meters. Techniques for the general operation of these instruments may be obtained by referring to the Technical Manual for Radio Frequency Radiation Hazards (NAVSHIPS 0900-005-8000).

Awareness of the potential dangers of high-powered radar has led to refinement of hazard prediction techniques so that it is possible to predict, during the early design stages of an aircraft, the presence and degree of hazard to be anticipated and to incorporate safety provisions that do not detract from the aircraft's primary mission. For example, cam cutouts (trigger kills), system safety devices, and interlocks prevent accidental ground operation of radar with weight-on-wheels in modern aircraft such as the F-14A *Tomcat.* Also, explicitly written operating procedures ensure clearly defined responsibilities to flightcrews and maintenance personnel when ground testing is being performed. Such procedures and survey data are incorporated in flight manuals and supplements. Two examples of survey data pertaining to hazardous ground operations involving RADHAZ are shown in Fig. 1 (S-3) and Fig. 2 (E-2C). This information was taken from each aircraft's flight manual.

WARNING

- OPERATING AT FULL POWER, RADAR IS HAZARDOUS TO FUELING EQUIPMENT WITHIN 235 FT RADIUS.
- AT FULL POWER, RADAR IS HAZARDOUS TO PERSONNEL WITHIN 200 FT. AT LOWEST POWER HAZARDOUS AREA IS REDUCED TO 40 FT.

RADAR TRANSMISSION DANGER AREAS

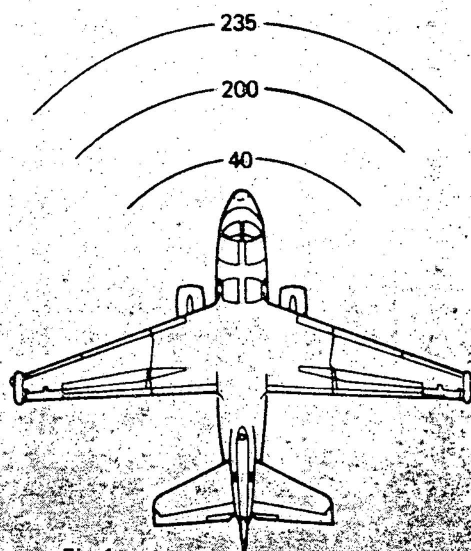

Fig. 1

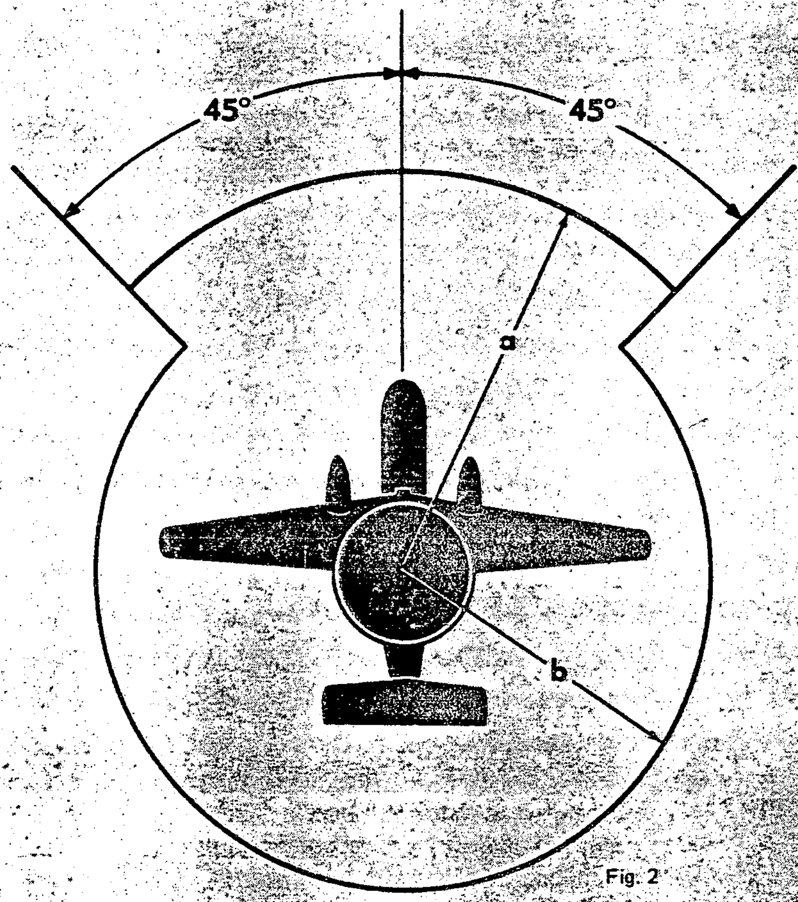

Fig. 2

MAIN BEAM AXIS
(ANTENNA IN FIXED POSITION)

WARNING

- RADIATION MAY CAUSE STEEL WOOL TO BE SET AFIRE OR METALLIC CHIPS TO PRODUCE SPARKS, WHICH IN TURN MAY IGNITE SPILLED OILS OR FUELS AROUND AIRCRAFT AND BUILDINGS.
- UNAUTHORIZED TRANSMISSION ABOARD SHIP IS PROHIBITED. 9

NOTE

THE TABULAR INFORMATION IS APPLICABLE TO FIXED ANTENNA POSITIONS. IF THE ANTENNA IS ROTATED, THE (a) SECTOR MUST MOVE ACCORDINGLY.

THE DISTANCES INDICATED FOR PERSONNEL SAFETY ARE BASED ON A LEVEL OF .01 WATTS/CM^2

MINIMUM DISTANCE (FEET) TO BE MAINTAINED FROM OPERATING RADAR

DANGER AREAS	PERSONNEL	VEHICLES	FUELING	EXPLOSIVES
SECTOR a (MAIN LOBE)	170 FT	255 FT	1000 FT	1500 FT
SECTOR b (SIDE LOBE)	20 FT	30 FT	150 FT	300 FT