HAZARD EVALUATION AND TECHNICAL ASSISTANCE REPORT
HETA 89-284-L2029
TECHNICAL ASSISTANCE TO THE FEDERAL EMPLOYEES OCCUPATIONAL HEALTH
SEATTLE, WASHINGTON
APRIL 1990

Hazard Evaluations and Technical Assistance Branch
Division of Surveillance, Hazard Evaluations and Field Studies
National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, Ohio 45226

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NIOSH INVESTIGATOR:
C. Eugene Moss

BACKGROUND

On July 21-26, 1989 the National Institute for Occupational Safety and Health (NIOSH) made occupational microwave (MW) radiation measurements at two facilities of the U. S. Army Corps of Engineers located in the state of Washington in response to your request for technical assistance (HETA 89-284). These measurements were performed to document potential occupational MW exposure to Corps of Engineer (COE) personnel from marine radar systems on a variety of water craft. COE personnel were concerned that they were subject to excessive MW exposure from these radar systems. The Corps facilities at the Hiram M. Chittenden Locks in Seattle and the Ice Harbor Lock and Dam near Pasco were selected for these evaluations based on magnitude and type of traffic expected.

Source Characteristics:

Marine radar systems are used on both pleasure and commercial vessels to detect and display the location of navigational hazards, fixed and moving. Such information is useful for coastal and harbor navigation, coastal charting, and harbor surveillance. The systems typically operate in a pulsed mode within the frequency band from 9300 to 9800 Megahertz (MHz). Typically, the peak power of such systems are in the 3 to 35 kilowatt (kW) range. While these radar systems do not need to be activated during the passage through the locks, they often are left on either by mistake or forgetfulness.

Facility Descriptions

The Hiram M. Chittenden Locks located in northwestern Seattle link Puget Sound and Shilshole Bay with the fresh waters of Salmon Bay and Lakes Union and Washington. Two locks are controlled by valves which raise and lower water levels, permitting the water crafts to pass through the system. The locks are in service year-round, 24 hours a day. An average passage through the locks takes from 10 to 25 minutes depending upon volume of traffic and water levels in the lakes and canal. One of the locks is used by ocean-going vessels. Approximately 100,000 commercial and pleasure vessels navigate the locks annually. Lock personnel are stationed along the lock walls to assist boaters during transit. The lockmaster is stationed in a tower between the two locks.

Ice Harbor Lock and Dam is located about 10 miles upstream from the mouth of the Snake River (near Pasco) in southeastern Washington. Ice Harbor is one of several water resource projects operated by the U.S. Army Corps of Engineers that provide hydroelectric power, navigational, recreational, and irrigation opportunities along the Columbia and Snake Rivers in Washington. Without the navigation lock, boats would not be able to pass through the dam because the water level behind the dam is about 100 feet higher than the level in front of the dam. The lock operates on the principle of water seeking its own level. Boats enter the lock, the gates are closed, and the lock is either filled or emptied. It takes about 15 minutes to fill, 12 minutes to empty and holds about 43 million gallons of water. The volume of traffic in Ice Harbor is much less than Chittenden Locks; however, the same type of marine radar systems are used at both locations.

Evaluation Design and Methods

Since these radar systems use pulsed microwave radiation energy, it was necessary to use a measurement system that would respond to extremely low level, short burst fields. The measurement system consisted of a calibrated Narda Electromagnetic Radiation Monitor Model 8616 connected to either a Narda H-field isotropic probe model 8633 (10 to 300 MHz), or a E-field isotropic probe model 8621B (0.3 to 40 Gigahertz (GHz). Both the E- and H-field probes, when connected to the monitor system, measure field intensities in units of milliwatt per square centimeter (mW/cm^2) over their respective frequency region. The lowest meter indication level (LMIL) for the 8616/8633 system is 0.05 mW/cm^2 and for the 8616/8621B system is 0.01 mW/cm^2.

In addition, a Holiday HI-3320 data logger was connected to the radiation monitor to log exposure data detected by the microwave measurement system as a function of time. The logged exposure data were uploaded via a special serial communication program to a portable computer, which was located in the lockmaster control facility, for analysis within minutes after being recorded.

All instruments used in this evaluation had been calibrated within 6 months of use by their manufacturer using appropriate calibration techniques and procedures. Due to the nature of the rotating radiation source, it was necessary to hold the detecting system fixed for a time period to allow the system to properly respond (i.e. time constant of meter). We calculated this time to have been a few seconds when the meter was placed in the maximum hold mode.

Radiation measurements were made around the lock walls and aboard vessels at varying distances from the marine radar systems. In many cases, it was necessary to move the detecting probe so that it would intercept the

small beam produced by the radar system. In general, measurements were obtained at the positions where lock personnel normally stand in performing their duties within the locks. Since the boats and ships would rise or drop in the locks as a function of the water movement, radiation levels were measured over time to determine the maximum radiation exposure level.

Evaluation Criteria [1-5]

Absorption of MW energy can adversely affect a worker's health. Human and animal studies indicate that this type of radiation can cause harmful biological effects due to excessive heating of body tissues. Absorption of MW energy may also result in "non-thermal" effects on cells or tissues, which occur without a measurable increase in tissue or body temperature. Such effects are reported to occur from exposure to MW energy at levels lower than those sufficient to cause thermal effects. MW radiation can penetrate the body and cause heating of internal tissues. The body's heat sensors are located in the skin and do not readily sense heating deep within the body. Therefore, workers may absorb large amounts of radiation without being immediately aware of the presence of such energy. There have been reports that personnel exposed to MW fields from radar equipment, MW heaters and sealers, and radio/TV towers have experienced a warming sensation some time after being exposed.

Exposure of pregnant animals to high thermal levels of MW energy can cause birth defects and kill the fetus. MW radiation exposures have also been associated with human miscarriages, irregular menstrual cycles, and decreased lactation in nursing mothers. Testicular damage and sterility in male animals have been produced at high intensities of MW radiation. Sterility, decreased sperm production, decreased sperm motility, and decreased libido have been reported in workers exposed to MW. MW radiation induced heating can damage the brain, spinal cord, muscles, blood, liver, kidneys, and skin. Such effects have generally been attributed to cellular damage resulting from excessive temperature increases.

There is little supportable evidence that MW radiation can cause cancer. However, recent evidence suggests that it may act as a cancer promoter in animals. In addition, there is no consensus on the potential hazard of low-level chronic MW radiation exposure, but biological changes definitely occur during or following relatively low intensity exposure.

There is general agreement that the incidence and severity of MW biological effects are related to the magnitude of radiation power absorbed by the body. This absorption depends strongly upon the frequency and intensity of the radiation, the size and shape of the exposed worker, and the worker's orientation in the radiation field. The human body absorbs maximally in the frequency range of 30 to 300 MHz. Outside this range, much less energy is absorbed by the body from the radiation field.

The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value and the Occupational Safety and Health Administration (OSHA) Permissible Exposure for MW radiation in this frequency range is 10 mW/cm^2. Power density levels exceeding these limits are allowed providing the power density, when averaged over any 6-minute period, does not exceed 10 mW/cm^2.

Results

Data was collected in two different formats. The first type was considered to be area exposure data and was obtained from measuring incident field intensity at various locations within the facilities. Approximately 100 different measurement conditions of this format were documented at the two facilities. The second type of data collected was denoted data-logged results and consisted of 13 different events at selected sites.

Power density levels were measured as the craft approached the locks, passed through the locks, while anchored to the lock walls, and leaving the locks. These measurements accounted for both single and multiple craft scenarios, low and high power radar systems, commercial and private vessels, time of day (from 6 AM to 10 PM), locations along the lock walls, different lock worker tasks, and distance from the lock walls. In all situations at both facilities, except one, the results obtained from the area exposure format were below the LMIL, which is well below both the ACGIH and OSHA criteria for this particular frequency region.

The single situation where higher levels were recorded occurred aboard the Corps of Engineer vessel at the Seattle facility. Measurements were purposely made next to the radar system in such a manner as to simulate a worst case condition, i.e. moving the detector so that it followed the antenna as it rotated. While this exposure situation would not be duplicated by any COE worker the NIOSH investigators made these measurements for comparative purposes. The measurements were made fairly rapid and were not repeated due to the potential exposure of the investigators. The measured levels were in excess of 4 mW/cm^2.

Table 1 shows the data-logged exposure levels recorded at various locations. The major purpose of collecting data-logged data was to demonstrate the pattern of exposure over time. Since the levels documented with the survey meters were below the LMIL, the pattern of exposure was not always clear or understandable.

Conclusions and Recommendations

It was observed by the NIOSH investigators during these evaluations that most pleasure boats either turned off their marine radar systems or put them into standby as they entered the locks. In fact, we had to ask many of the boat captains to turn on their radar system while in the locks. It was also observed that COE personnel moved around a lot in their job

duties and were not found to occupy a given spot for a long period of time. This is important since direct exposure to these systems is limited to a narrow beam of microwave radiation. As a result, measurement at worker sites may be on the order of microwatts per square centimeters for a few seconds. The only exception to this generalization would be the condition where workers are located a few feet either from a non-rotating antenna or moving with the rotating antenna. These situations, however, are considered as extremely unlikely. Moreover, such situations are easily resolved by administrative control measures.

In conclusion, electric and magnetic field intensities, measured on the day of this survey, do not represent a health hazard to lock personnel. This conclusion, based on these measurements, is in agreement with previous findings [6]. Those results state "...it seems unlikely that personnel would normally be exposed to average power densities approaching 1 mW/cm^2 due to the radiation from a small-craft radar having a rotating antenna." In that same reference the following sentence is found, "Care should, therefore, be exercised to limit the unnecessary use of marine radar in areas of high population density (e.g., when docked in harbors)."

The following two recommendations are offered to further reduce the potential to any future MW exposure from these systems:

1. Official US Army Corps of Engineer signs should be posted at both ends of all locks to remind incoming water crafts to turn off (or put into standby) their marine radar systems.

2. Commercially available radar detector system could be installed in the lockmaster station to monitor any non-adherence to recommendation 1 above.

REFERENCES

1. Occupational Diseases: A Guide to Their Recognition, USPHS CDC NIOSH Publication #77-181, Revised June 1977.

2. Biological Effects of Radiofrequency Radiation, US Environmental Protection Agency Publication EPA-600/8-83-026F, September 1984.

3. CRC Handbook of Biological Effects of Electromagnetic Fields, edited by C. Polk and E. Postow. CRC Press, Inc., Boca Raton, Florida 1986.

4. American Conference of Governmental Industrial Hygienists (ACGIH). 1989-1990 (Second Printing). Threshold Limit Values and Biological Exposure Indices for 1989-1990, Cincinnati, Ohio.

5. American National Standards Institute, Safety Levels with Respect to Human Exposure to Radiofrequency Electromagnetic Fields, 300 kHz to 100 GHz. The Institute of Electrical and Electronic Engineers, New York, N.Y. 10017, ANSI Committee C. 95.1

6. Measurement of Power Density from Marine Radar, DHEW Publication (FDA) 76-8004, November 1975.

TABLE I

ESTIMATED MAXIMUM MICROWAVE POWER DENSITY
FOR DATA LOGGED EVENTS

U.S. ARMY CORPS OF ENGINEER
WASHINGTON STATE REGION
HETA 89-284
JULY 21-26, 1989

EVENT NUMBER	DESCRIPTION OF EVENT	MAXIMUM POWER DENSITY (Microwatts/cm^2)
1.	Tug boat in Seattle locks, 3 kW system (maximum range), 30 feet from system while boat was raised.	33
2.	Background run, no radar system.	1
3.	Pleasure craft in Seattle locks, 5 kW system (various ranges), 8 feet away	33
4.	Measurement made at end of lock for 40 minutes. Little boat activity in area.	1
5.	Pleasure craft in Seattle locks, 3 kW system (standby and maximum range), measurements made for 5 minutes at 8 feet.	11
6.	Same system as #5, measurements made for 5 minutes with system off and at maximum.	18
7.	Pleasure craft in Seattle locks, 5 kW system (maximum range), at 8 feet.	53
8.	Same system as #7 but with system off (i.e. background run).	1
9.	Large tug boat with 10 kW system, radar system mounted on tallest part of tug-could not detect in Seattle locks.	1
10.	COE vessel, 3 kW system, used various ranges, measured at 4.5 feet.	250
11.	Same system as #11, measurements made at end on antenna.	59
12.	Tug boat entering at Ice Harbor, 6kW on maximum range.	3
13.	Same as #12, Tug being lowered in locks	8
EVALUATION CRITERIA: OSHA PEL/ACGIH TLV		10,000