MR 714

AUTHORS: Frey AH:

DATE: 1963

TITLE: Human response to very low-frequency electromagnetic energy.

SOURCE: Naval Research Reviews 16:1-4

MAIN SUBJECT HEADING:

AN	HU	AT	IH	M
ANALYTICS	HUMAN EFFECTS	ANIMAL TOXICITY	WORKPLACE PRACTICES-ENGINEERING CONTROLS	MISCELLANEOUS

SECONDARY SUBJECT HEADINGS: AN HU AT IH M

Physical/Chemical Properties

Review

Animal Toxicology

Non-occupational Human Exposure

Occupational Exposure

Epidemiology

Standards

Manufacturing

Uses

Reactions

Sampling/Analytical Methods

Reported Ambient Levels

Measured Methods

Work Practices

Engineering Controls

Biological Monitoring

Methods of Analysis

Treatment

Transportation/Handling/Storage/Labelling

MR 714

Human Response to Very-Low-Frequency Electromagnetic Energy

Allan H. Frey
Institute for Research
State College, Pennsylvania

The sailor, pilot, meteorologist, and workers in other fields have for many years relied on low-frequency radio services, such as are provided by marine and aeronautical radio beacons and by aeronautical range stations. Although these services are no less valuable now than they have been in the past, much other low-frequency broadcasting has diminished in value, and some of it has been discontinued. This apparent trend away from low-frequency broadcasting has now been reversed, however. Today, low-frequency transmissions are very much in use again, and they are serving some highly important purposes.

There are several reasons for renewed interest in the low-frequency bands (VLF: 3-30 kc; and LF: 30-300 kc). First, a need now exists for extremely high accuracy in frequency and time measurement. Because VLF and LF transmissions avoid the significant, though small, errors that occur in the higher frequency transmissions, they are well suited for this job. Second, for security reasons, we have to do everything possible to keep our communications networks from breaking down as the result of ionospheric disturbances. Through transmissions in the lower frequencies most of these breakdowns can be avoided. Another reason is the far better communication that can be maintained with submerged submarines by means of VLF and LF transmissions.

To make the kind of broadcasts that are needed in the low-frequency ranges, a number of very powerful broadcasting stations have been constructed. One is the National Bureau of Standards station (WWLV) located in Boulder, Colo., which delivers 10 kw to the antenna. Another is the Navy's Jim Creek, Washington, station (NPG), which is said to deliver a megawatt into its antenna. Other powerful Navy stations are NAA at Cutler, Maine, and NBA in Panama. Some of the strong English stations are GYC at Whitehall and GBR at Rugby.

As the number and power of such stations increased, the question of the danger of radiation to the men who operate and maintain the stations was raised, particularly those workers who have to climb the towers periodically. Some workers had complained of unpleasant sensations, but as little was known about the physiological and behavioral effects of electromagnetic energy in the low-frequency range, no one could say for sure how dangerous these experiences were. Therefore, to determine if hazards did exist, and to obtain the data the Navy would need to establish hazard limits, a contract to study the problem was awarded to the writer by the Office of Naval Research. A portion of the investigation is reported in this paper.

"Pins and Needles"

The study began with visits to the NAA site by a physician, an engineer, a field-measurements specialist, and an experimental psychologist. The plan was to interview the men working with the tower equipment and to observe the radiation effects at first hand.

Interviews were conducted as informally as possible. In each of these talks we were told about an itching or "pins-and-needles" sensation on the skin of the face and forearms, experienced while a worker climbed or stood on towers of an energized array, or on towers of an unenergized array when the wind blew toward him from the energized array. There was also agreement that the effect was strongest on the upper platform, or "roof" of the tower.

Electromagnetic Field Strengths

Evaluation of the physiological and behavioral effects of VLF energy requires measurement of the fields which produce those effects, from threshold level to the maximum strength which is routinely encountered. We began with the antenna.

The strength of the "near" field of a dipole antenna—the field within five wavelengths—is the sum of the strength of the radiation field (the electromagnetic field which breaks away from the antenna and travels outward into space as electromagnetic waves) and the strength of the induction field (the electromagnetic field which acts as though it were permanently associated with the antenna). At NAA's frequency—14.7 kc—a wavelength is about 12 miles, so the near field extends approximately 60 miles. Within five wavelengths the strength of the radiation field is negligible compared to that of the induction field. Within one wavelength, the electrical component of the induction field is dominant over the magnetic component. Therefore, the measurement of the field at Cutler became a task of measuring an alternating electric field at 14.7 kc/sec.

The measurements were made with two mutually calibrated commercial field-strength meters, a large one for use on the ground and a smaller one that could be carried up the towers. The readings were taken on a warm, clear day when the humidity was low and the wind speed, measured at a point half way up the tower, was 20 miles per hour. NAA's north antenna array, where the measurements were made, was operating at the time, radiating 1100 kw of power.

At the 470-Foot Level

Above-ground measurements were made at the 470-foot level of tower N-4, where the first noticeable effect occurred. On the outside surface of the tower framework at points where the paint had chipped off the metal, a mild, tingling electric sensation was produced when the skin of the inner forearm touched the bare metal. The ac field in the space about 12 inches outside the framework at this point was measured as 30,000 volts per meter. The ac field measured at the center of the framework at this level was 1000 volts per meter. No behavioral effects were observed inside the framework.

At the 470-foot level, an aluminum hard hat drew a small spark when touched to the bare metal on the outside of the framework at the same point where the forearm felt a tingle. No unusual sensation occurred at the palm of the hand when touching this point. The rigger who was present at the time these observations were made remarked that the spark from the hard hat was often used by the workers as a test for "shocking" conditions.

At the Top of Tower N-4

Measurements were made again at the top of tower N-4 (980 feet). The weather and radiating conditions were the same as at the 470-foot level. At the center of the tower framework just below the flat, triangular roof of the tower, the ac field was 30,000 volts per meter. Touching the framework with the inner forearm sometimes produced the tingling sensation where the metal was painted, always where the metal was bare. The grill-work floor, ten feet under the roof was comfortable to stand or sit on—at least no noticeable sensations were produced there by radiation.

At the top of the ladder, which protrudes about two feet above the roof, the ac field was measured as 989,000 volts per meter. All metal parts, painted or unpainted, produced a strong and unpleasant electric shock when touched—comparable to that which occurs when one touches a live power line of 115 volts ac. The metal case of the portable meter produced similar shocks. Although the shocks caused a strong reflex withdrawal of the hand and arm, no tetany, or "freezing" of the muscles, was observed. Bare hands could not be used to mount the ladder near the top of the tower (the last five feet); climbing was done with feet and safety belt only. A lifting of the hair of the eyebrows and backs of the hands was observed.

The Static Field

In addition to the alternating field, caused by the transmitter, is a large static field, caused by atmospheric electricity. In fine weather the atmosphere is ordinarily positive with respect to the earth. At ground level the static potential gradient may vary from 80 to 300 volts per meter at different locations and times, the average being about 130 volts per meter. Since the tower is at ground potential and its height is approximately 300 meters, it is a discharge point of significance for it protrudes into a region of the atmosphere which would otherwise be at 27,000 volts dc. Thus there will be corona or dc discharge. The strong static field was not measured on the tower, but is undoubtedly present outside the framework near the top.

The Hazards

Through the interviews and field measurements we learned that a distinct physical hazard exists on the upper parts of certain towers at the NAA site, primarily because of the electric-shock potential created by the alternating electric field. Shocks of the strength that can occur there would be dangerous, even if experienced on the ground. At great heights, under working conditions that are already difficult, they are a much more serious hazard.

The shock effect of greatest concern is the simple reflex withdrawal from the offending metal object. Because of the delicate balance workers must often assume on high iron structures, and the danger of a fall that exists because of it, a sudden, unexpected move of this kind could prove fatal. Insulated gloves, such as electricians use, will protect the hands from this shock effect, but should some other part of the body that is not insulated touch the "hot" metal, the jolt could easily throw one off balance.

A static field, although not measured, certainly must exist. It may account for the raising of hair and eyebrows which was experienced, and the reported "pins-and-needles" sensation. This hypothesis, though, must be checked in the laboratory.

It is likely that there is also an enormous concentration of air ions. Each tower, acting as a huge corona point in the static field of the atmosphere, has a discharge current which is certainly more than that observed from ordinary lightning rods – 10^{-4} amperes. In addition, the very high alternating voltages appearing across the antenna insulators produce a corona discharge whose total magnitude must be large, but which we have no way of estimating. The shock sensation reported to occur most strongly on towers downwind from the radiating antenna is probably caused by the air ionization. The question of whether the air ions have any other effect cannot now be answered.

There is no evidence that the corona produced significant amounts of ozone, and the peculiar phenomenon called "rf sound" was not reported to have been perceived. This phenomenon, discovered only recently, is the perception, at microwave frequencies, of modulated electromagnetic energy as a sound. Little is known about such perception, except that it does not occur as the result of acoustic energy stimulating the ear or of tooth fillings rectifying the energy.

Whether or not VLF and LF electromagnetic radiations have subtle or long-range effects on men working in the near field is not yet known. This question is expected to be answered by a supplementary investigation.

Twelfth Annual Training Device Seminar

The Twelfth Annual Research Reserve Training Device Seminar was conducted at the Naval Training Device Center, Port Washington, N.Y., under the auspices of the Chief of Naval Research, from June 17 - 28, 1963. The general theme of the Seminar was "Recent Technological Developments and Their Application to the Training Device Program."

A message from the Chief of Naval Research was given to the Seminar by CAPT R. G. Black, USN. Political and economic aspects of the current world situation were presented by Dr. Saul K. Padover, Dean, Department of Political Science, New York School for Social Research. Military aspects of the present world situation were discussed by LT COL F. E. Tibbetts III, USA, Department of Social Sciences, U.S. Military Academy, West Point, N.Y. CDR F. H. Langdon, of the Office of Naval Research, discussed the latest developments in the Naval Reserve Program. Following these talks, emphasis was given by Training Device Center speakers on developments in anti-submarine warfare, strike and air defense, missiles, computers, and certain aspects of sea and land weapons systems.

In addition to a tour of the Training Device Center, including a demonstration of training devices, the group was given tours of the U.S. Naval Submarine School, New London, Conn., and the Brookhaven National Laboratory on Long Island. The evening preceding the New London visit, the group was also taken on a tour of Yale University, followed by dinner at the famed "Mory's."