

BEFORE THE STATE OF NEW YORK  
PUBLIC SERVICE COMMISSION

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CASES 26529 and 26559—Common Record  
Hearings on Health and Safety of  
765 kV Transmission Lines.

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Prepared Testimony of  
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**Q.** Would you state your name and business address?

**A.** Dr. Robert Becker, Veterans Administration Hospital, Syracuse, New York

**Q.** Would you summarize your educational and professional background?

**A.** I am a doctor of medicine, having received my MD degree from New York College of Medicine in 1948. In 1959 I became a Diploma of the American Board of Orthopaedic Surgery, having completed the necessary advanced training at Downstate Medical Center, SUNY. I have been Chief of Orthopedic Surgery at the VA Hospital, Syracuse, since 1956, and have been Professor of Orthopedic Surgery, SUNY Upstate Medical Center since 1963. I have been engaged in medical research since 1958 with particular interest in electronic biological control systems. I have published more than 70 scientific papers and given more than 75 presentations at national and international scientific meetings. In 1964 I was awarded the William S. Middleton Award of the Veterans Administration for research in biological solid state physics and biological control systems. I was presented with the Distinguished Alumnus Award from NYU College of Medicine in 1966. I became a Medical Investigator with the VA in 1972, a position enabling me to devote full time to research.

**Q.** Are you the director of a research laboratory?

**A.** Yes. I am the director of the Orthopedic-Biophysics Laboratory at the Syracuse VA Hospital-Upstate Medical Center. The staff varies between 10 and 16 people depending upon such things as the number of students on elective, the number of visiting scientists spending their sabbatical year with us, etc. The present staff includes three Ph.D. biophysicists, one Ph.D. anatomist, two M.D.'s (orthopedic surgeons) and a variety of technical personnel.

**Q.** Would you briefly described the nature of your research?

**A.** In brief, our research is aimed at elucidating the details of the control systems that living organisms utilize to direct certain basic life functions such as growth and healing, biological cycles, etc. We have determined that living organisms possess certain electric control systems characterized by the use of very small electrical currents and voltages as control signals. These are derived from certain solid state properties of cells and tissues such as semiconductivity, piezoelectricity, etc. At this time our discoveries are being used to stimulate the healing of non-united fractures and to treat certain types of infectious processes in the human by the application of small electrical currents which stimulate those which naturally occur. This work is going on at several medical centers including Syracuse. Other research groups are also using small electrical currents to relieve pain, produce surgical anesthesia or sleep and as additive treatment to acupuncture.

Because of the physical nature of the biological electronic control system, we predicted that external electromagnetic fields should produce physiological and functional changes in living organisms. We have been conducting research using a variety of such fields and a variety of experimental animals for the past 15 years. The results of these experiments have conclusively indicated that such fields do have an effect upon living organisms.

**Q.** What is the purpose of your testimony?

**A.** I will discuss the medical and biological significance of exposure to low frequency electric and magnetic fields. My testimony will encompass both the published reports and the latest results of our own research. I will testify that an electric field at 60 Hz is a biological stressor. I will discuss the question of medical ethics involved in exposing human beings to electric fields. My testimony will conclude that the transmission line should not be built as proposed.

**Q.** Would you comment on the medical significance of the reports described by Dr. Marino dealing with ELF effects?

**A.** Before answering this specifically, I would like to point out that the majority of these reports came from the refereed scientific literature. That means before they were published, they were reviewed by scientific experts in the specific area concerned; and the experimental set-up and techniques used were judged to be both appropriate and rigorous enough to have yielded valid data. Such reports cannot be lightly dismissed.

The first and most obvious conclusion to draw is that the ELF electric fields do have biological effects, some at extremely low field strengths. In general, the reports fall into two main categories, and one minor category. The first main category is growth effects. These include tumor growths, accelerated healing rates, both increased and decreased mitotic rates and abnormalities in development. There are some apparent inconsistencies in the reports; how can the same physical modality produce at one time, bone tumors, an undesirable effect, and at another time, accelerated rate of healing of bone fractures, an obviously desirable effect? The answer lies in the fact that the

biological response to such a parameter is determined much by the state of the living specimen when it is exposed. Normal unbroken bones exposed to 3 or 30 Hz fields developed tumor growth. Bones with fractures, in which a healing response of increased cellular growth has been switched on, when exposed to 65 Hz fields showed an increase over the normal rate of healing. Obviously, the two experiments involved two distinctly different biological states and there is no contradiction between the reports at the basic level. It would appear valid to postulate upon the basis of these reports that growth disturbances could result from exposure to ELF field strengths or frequencies outside of the norm. It may be wise to comment upon the fact that only one report presents the occurrence of tumors following such exposure, Why are there no confirmatory reports from other workers who similarly exposed animals? The answer lies in the nature of scientific research. The investigator operates on a limited budget and within a specific frame of reference. If he is interested in the use of such fields to obviate the osteoporosis of the bone that accompanies immobilization, you will carefully examine the bones following exposure. He will however, have neither the funds nor cooperating scientific personnel to examine all other organs and tissues of the animals for the occurrence of tumors therein. For example, in our own series of experiments described by Dr. Marino, we were fully aware of McElhaney's report and we are familiar with bone physiology, yet we structured our experiment around another thesis, that of the stressor effect, We could accomplish that with our limited funds and it would be more substantive to our overall scientific objective than would a repeat of McElhaney's experiments. While we would have liked to autopsy our experimental animals for tumor growths, we lacked both funds and personnel to do so.

The second main category of effects can be classified as functional. In this type of response, the exposure to the field produced a change in the way the organism worked. Such changes can be produced without any noticeable change in the appearance either of the total animal or of its tissues when studied under a microscope. Functional responses have included strictly behavioral effects, such as the avoidance of a field irradiated area, orientational effects within a field, and alterations in response times. Two reports dealt with alterations in the electrocardiogram and the electroencephalogram. Both the heart and brain utilize electrical energy in their operation and such interferences may be predicted. A basic aspect of function is the phenomenon of biological cycles and two extremely precise sets of experiments have indicated a sensitivity of this function to such applied fields. The medical significance of functional changes such as these have been well described in the Russian literature relating the complaints of occupationally exposed workers. These complaints all fall within the functional frame of reference and appear related to effects upon the central nervous system and the cardiovascular system. Such complaints are also concomitant with stress and indeed the stress response may be integral with other central nervous system symptoms.

The minor category includes two reports, one Russian, one American, both presenting data on the death of cells or total organisms accompanying exposure to very high strength fields. The state of knowledge in this area at present does not permit us to speculate upon the pathophysiology that might have been involved.

To sum up, from the viewpoint of possible medical significance, the literature reports represent a solid body of data indicating that living organisms are influenced by ELF fields, and that such effects are likely to occur in the areas of growth, both cellular and of the total organism, and in the function of the central nervous system and cardiovascular system. Obviously, to answer specific questions, such as the effects of various field strengths at 60 Hz upon the variable human population, will require specific laboratory experimentation. These answers are not available at this time.

**Q.** Do the results of your research on electric field exposure at 60 Hz as described by Dr. Marino indicate that the rats were subject to biological stress?

**A.** The condition of the rats at the end of 30 days exposure was consistent with chronic exposure to an environmental stressor. Chronic stress has been linked to cardiac (hypertension), renal (nephritis), gastro-intestinal (ulcers) and nervous (psychoses) diseases. There is some evidence that arthritis, particularly rheumatoid type and certain vascular diseases such as periarteritis nodosa may also be related. In addition, chronic stress results in exacerbation of any pre-existing pathological processes. There is extensive literature in this field and since there are several phases of response to stress, depending upon the length of exposure, I have limited my response to chronic stress situations.

**Q.** Would you explain the distinction between the terms “acute” and “chronic” as they are used medically?

**A.** Acute refers to a short term exposure, generally less than one day and chronic refers to long term exposure, more than one day.

**Q.** What is meant by the term “stress” or “stressor”?

**A.** A non-specific biological stressor is any environmental stimulus which causes systemic stress in an organism. Systemic stress denotes a condition in which, due to function or damage, extensive regions of the body deviate from their normal resting state.

The stress response in the organism is basically produced by alterations in the function of the pituitary and adrenal glands. Presumably the initial response is in the central nervous system—most probably the brain with information being transmitted to the pituitary gland which is directly connected to the brain.

The actual physiological changes resulting from exposure to a stressor are determined not only by the nature of the stressor itself, but also by factors within the stressed organism, such as the level of nutrition, concurrent stressful conditions, the presence of preexisting disease states, heredity and previous conditioning experiences.

The actual total stress response produced by chronic exposure to a stressor is called the General Adaptation Syndrome and is divided into three Stages. The first is called

the Alarm Reaction, in which the adrenal glands enlarge, lymph nodes and thymus gland decrease in size and gastric ulcers appear. The levels of hormones secreted by the active glands are increased. In the second stage, that of Adaptation, the hormone levels return to normal and the animal does not appear to be responding to the stress. In the final phase, that of Exhaustion, the level of the active hormones decreases below normal, and the organism is less capable of responding to the stress. Dr. Hans Selye, who first described the stress adaptation syndrome, has been able to correlate chronic stress with certain disease states including collagen diseases, periarteritis nodosa, renal arteriosclerosis, hypertension and gastric ulcers.

**Q.** It is occasionally said that stress is “good for you.” Do you agree?

**A.** If stress is “good for you,” then it is the biological response to stress that is “good for you,” since stress that does not elicit a response from the stressed organism has no effect on its own.

There are two conditions under which the stress response may be considered “good for you.” It is in fact, vital for the survival of life, having been evolved from the earliest living organisms. When an organism is stressed naturally, i.e., being pursued by a predator, the stress response enables the animal to use its body maximally to escape. The action of the muscles and nerves is enhanced and the animal becomes functionally capable of extra activity. Humans experience a similar response when subjected to bacterial infections and in this case the increase in the activity of the immune system is advantageous. Initially, the physiology associated with such acute stress was termed the “fight or flight” condition which is an apt description. Therefore, under the conditions of acute stress, the organism’s functional ability is heightened. We experience this occasionally in “being able to work best under stress.” The problem however, is two-fold. First, there are indications from Dr. Selye’s work that stresses are additive and that two stresses, neither of which would be particularly harmful, when acting in concert, will produce a pathological state. Secondly, all of the good effects of the stress response are limited to the alarm reaction phase of the stress response. If the stressful condition continues, the alterations in body chemistry and function that were advantageous in a “fight or flight” situation begin to change and ultimately, in the stage of exhaustion, the changes are reversed and the organism is less able to function in an optimal fashion.

The “stress is good for you” concept is limited to single short duration episodes of mild to moderate stress and cannot be applied to the situation of multiple stresses or long-term chronic stress.

**Q.** Could people sustain the same effects as the rats, if comparably exposed?

**A.** Yes. I know of no significant difference between rats and men in terms of their reaction to stress.

**Q.** Assuming that the electric field distribution due to the proposed transmission line is as Dr. Deno has calculated, does it present a danger, from a health viewpoint, to either

maintenance personnel or persons living near the edge of the right-of-way?

**A.** Utilizing the safety factor of 100 in connection with our research, the field strength within the proposed right-of-way and for a distance out on either side would exceed the safe level (1.5 volts/cm). Maintenance personnel would probably be exposed to levels in excess of 1.5 volts/cm for relatively short periods of time. Since our experiments involve long term (30 days) exposure, we cannot say whether or not such short exposures would produce any biological effect. By the same token, we cannot say whether or not any effects from such short time exposures (if they did occur) would be cumulative and eventually become clinically significant.

In regard to persons residing near the right-of way and within the zone of field strength of 1.5 volts/cm or higher they would run the risk of having some biological effect induced as a result of this exposure. Since the effects we noted experimentally indicated that the field acted as a stressor, I would have to assume that the effects would be harmful. Again in regard to emulative effects (dose related in this case, i.e., lower field strengths at greater distances with long term exposures) we cannot make any statements at this time.

**Q.** Would you recommend against the public periodically using the right-of-way for less than a day for such activities as farming, logging, hiking, camping, hunting, etc.?

**A.** In general, I would be opposed to the multiple use concept until the extent of the biological hazards was ascertained. In specific, it certainly seems prudent to discontinue recreational use. In the case of economic use, farming, etc. involving short term exposures, it may be possible to continue such usage provided the potential risks are made evident. In regards to the question of short term exposure to maintenance personnel, perhaps the present Russian regulations might be applied.

**Q.** Would it be unsafe to permit people to occupy residences within 329 feet of the centerline of the proposed lines if the electric field within the residences is less than 1.5 volts/cm?

**A.** We cannot answer this question at this time, not knowing the effects of chronic exposure of fields lower than we have employed in our experiments to date.

**Q.** Is it likely that different individuals will react differently to the same degree of exposure to the electric fields from these lines?

**A.** Yes.

**Q.** Would a person subject to long term exposure to electric fields from these lines be likely to discern effects from such exposure?

**A.** I believe that the weight of the evidence indicates that biological effects would occur. Such effects would be within the framework of the stress Adaptation Syndrome and may

be evidenced in a variety of fashions, from such functional changes as increased irritability and fatigue, to such actual pathological states as hypertension and stomach ulcers.

**Q.** Could a medical doctor diagnose the electric fields from 765 kV lines as the causative agent for certain stress related-illnesses?

**A.** Given the present level of knowledge and the absence of any other causative factors, I believe that such diagnosis could be made with a reasonable medical certainty.

**Q.** In your research, do you use human beings as subjects?

**A.** Yes, humans are presently used in our studies on stimulating bone growth and retarding infectious processes.

**Q.** Would you briefly describe the precautions taken when humans are involved as subjects?

**A.** In the case of human experimentation, the present regulations require that any proposed study be reviewed in detail by a committee of experts including medical and scientific personnel (it is further recommended that representatives of the clergy, psychological sciences, and laymen be included on the committee). It is the responsibility of the committee to balance risks against gains of any given experiment. In regard to risk, the nature of experimental medicine is such that the possibility that all risks may not be predicted in advance must be entertained. In regard to gain, consideration must be given to gain that may be experienced by the experimental subject (i.e., possible healing of a non-united fracture) and to general human gains in terms of the collection of knowledge that may be of value to others or to general biological understanding. After consideration of these factors, the committee must approve the proposed study. An investigator cannot proceed without such approval. It is most important to note that the key provision of present human experimentation is informed consent. If the committee approves the project, each subject must still be fully apprised of all known possible risks, the possibility of unknown risks and possible gains (if any) he or she will accrue. Only under these circumstances is human experimentation medically proper.

**Q.** Would it be considered medically unethical to apply small electric currents to humans for research purposes without securing their permission?

**A.** Yes, it would be considered unethical in my opinion.

**Q.** Would it be considered medically unethical to apply 60 Hz electric fields to humans without securing their permission?

**A.** Yes, it would be considered unethical in my opinion, if the field strengths exceeded that to which we are exposed in the normal course of everyday living (i.e., normal

household ambient levels). In that case human experimentation committee approval and informed consent would be required.

**Q.** Dr., Marino has discussed piezoelectric effects as a possible mechanism of action of 60 Hz electric fields on animals; are there any other biological mechanisms that would enable 60 Hz electric fields to have an effect on living organisms?

**A.** As I indicated previously, we have, over the past 15 years obtained evidence for the existence of electronic biological control systems based upon solid state properties of living materials. We know, for example, that injuries result in specific electrical phenomena at the site of injury and that these (very minute in amount) electrical parameters in turn cause the cells at the injured site to multiply and heal the injury. This function is controlled by an overall biological control system which is associated with, but separable from, the central nervous system. Our evidence indicates that this control system is based upon specific cells (the perineural cells) and that it transmits information by means of the actual flow of small direct electrical currents, generated by solid state properties of these cells. It may be likened to an analog computer system while the nervous system itself is similar to a digital computer. This direct current system controls growth and healing, as previously noted and in addition, we believe it may be related to the perception of pain. There is evidence that biological cycles of behavior in all organs are linked to the same cyclic pattern in the normal environmental electrical and magnetic fields. The properties of this direct current system are such that it would be influenced by such cyclic geophysical parameters and the normal biological cyclic changes in these environmental fields. It is believed that this system may provide the necessary linkage mechanism between the normal variations in these rhythms. One of the primary characteristics of the normal atmospheric electromagnetic field is its associated extra low frequency (ELF) component. These ELF fluctuations are in the region of from 1 to 20 cps with maximum power centered in the 10 cps range. It is perhaps significant that the electroencephalogram contains the same frequencies and that electroencephalograms of a wide variety of organisms are basically similar. Electromagnetic waves in this frequency range can be transmitted for great distances with little loss in strength. It has been proposed that, since all organisms arose and developed within an environment that included these electromagnetic fields and frequencies, they were a primary factor in providing the energy input for the origin of life and that the coupling between living organisms and them is a basic life function (Cole, F. and Graf, E., in *Biologic and Clinic Effects of Low-Frequency Magnetic and Electric Fields*, Charles C. Thomas, Springfield 1974). Some substantiation for this is the fact that profound disturbances in the electromagnetic field such as magnetic field reversals, occurring in the geologic past, were associated with the death of many animals and actual extinction of some species (Hays and Updyke, *Science* 158, 1001 (1967)).

If the natural electromagnetic field is directly linked to the organism via the electronic control system we have described, then changes in the natural field, including increased field strength and frequencies not normally present would result in stress in exposed organisms. Such stress responses would come about by disturbances in the normal biological cycles caused by the abnormal field exposure. Many of the scientific reports



quoted by Dr. Marino in his testimony are interpretable in this light.

Therefore exposure to electric fields differing in frequency and/or in magnitude from the normal earth's field may produce biological effects by (1) inducing small electrical fields within the tissues that could interfere with normal healing and growth processes by presenting abnormal signals to the cells (under certain circumstances such induced currents may be beneficial, i.e., in stimulating the healing of non-united fractures) and (2) by interfering with the normal biological cyclic rhythm through interaction with the electric system linking organisms to the geophysical environment. This latter effect would be evidenced as a response to stress and with prolonged exposure as the stress adaptation syndrome.

**Q.** Does your research involve magnetic fields?

**A.** Yes. I have used magnetic fields primarily as a tool system to probe the workings of the direct current control system.

**Q.** Have you published in this area?

**A.** I have reported effects of external magnetic fields upon the peripheral nerve electrical potentials (Becker, *Science*, 134, 101 (1961) and upon the electroencephalogram from the brain in animals (Becker, *Proc XI Int. Cong. Radiol.*, 1753 (1966)). In conjunction with Dr. Howard Friedman, I have investigated and reported on interactions between changes in the earth's natural magnetic field (magnetic storms) and human behavior (Becker, *Nature*, 200, 626 (1963) and Becker, *Nature*, 205, 1050 (1965)). We have also reported on the effects of low strength magnetic fields modulated at 0.1 and 0.2 on reaction times in human volunteers (Becker, *Nature*, 213, 949, (1967)). This was done to provide a base line for the experimental interest in this area that was on the increase at that time. Most recently, I have been consulted by the AEC on possible hazards associated with the ultra-high strength fields necessary for fusion reactors.

**Q.** What is the current state of research in the area of biological effects of magnetic fields?

**A.** There has been increasing interest in this area over the past 10 years. Two books have been published in the United States (Barnothy, M.F. ed., *Biological Effects of Magnetic Field*, Vol. I Plenum Press, New York 1964 and Vol. II, Plenum Press, New York 1969 and several volumes in the Soviet Union). Of particular pertinence to the present hearing are several reports of effects produced by very low strength magnetic fields (i.e., from 1 to 10 gauss). The most recent was by Dr. William Keeton (*Proc. Nat. Acad. Sci. U.S.A.* 68, 102, 1971) who was able to show that the homing pigeon utilized the earth's magnetic field for navigation with a sensitivity and precision that our best instruments cannot attain. His observations have recently been corroborated by Wolcott and Green (*Science* 184, 180, 1974) and extended to several other species of birds (Southern, W. E. *Bioscience* 22, 476, 1972 and Wiltschko, W. in *Animal Orientation and*

*Navigation*, p. 569, Government Printing Office, Washington, D.C. 1972). I believe that this is an instance of these particular animals developing the same system that is present in all animals into a specific sensing mechanism of survival value. Dr. James Hays has shown that naturally occurring reversals in the earth's magnetic fields in the geological past were accompanied by the extinction of animal species. During reversal periods, the magnetic north and south poles exchange their position. We know only that this is not associated with a drop in the field strength below half normal nor is it associated with any major increases in field strength. Since no reversals have occurred in the documented past, we cannot speculate on such factors as the appearance of specific frequencies or alterations in the earth's electrostatic field. The point is that such seemingly minor variations in the magnetic field are quite apparently events of major biological magnitude (Hays and Updyke, *Science* 158, 1001, 1967). Dr. Frank Brown, who is primarily interested in the phenomenon of biological cyclic behavior has shown that it can be influenced by applied magnetic fields as low as 1 gauss. Since the biological cycles have periodicities the same as the natural geomagnetic field cycles, the suspicion is that the biological cycles are driven by the earth's naturally fluctuating geomagnetic cycles (Brown, F. *Nature* 209, 533, 1966, *Encyclopedia Britannica* 292, 1966).

The work of Friedman and his colleagues may be relevant to Brown's observations in that he has been able to demonstrate that magnetic fields of 200 gauss strength are definite stressors for the exposed organisms (Friedman, H. and Carey, *R Physiol & Behavior* 9, 171, 1972 and *Physiol & Behavior* 4, 539, 1969). Most recently Dr. Dietrich Beischer of the Navy's Aerospace Medical Research Laboratory has shown effects upon human volunteers of exposure to very low strength (1 gauss) 45 Hz magnetic fields. The primary findings were an increase in serum triglycerides observed in two experimental runs (Beischer, D., *Navy Aerospace Med. Res. Lab. Report #1180*, 1973). The Sanguine Biological Study Committee to which these findings were reported was also advised by the responsible Navy personnel that following Dr. Beischer's report, the personnel at the Wisconsin Test Facility ( a test antenna similar to the proposed Sanguine Antenna located at the proposed Wisconsin site) were examined and all were found to have elevated serum triglycerides. The mechanism producing this effect is currently under study. The significance of the elevated triglycerides is in the fact that this material is one of the steps involved in fat metabolism and such elevations beyond the normal range are generally believed to indicate an increased risk of arteriosclerotic disease.

**Q.** Why haven't you determined safe levels for human exposure to 60 Hz magnetic fields?

**A.** We do not have sufficient funding to conduct these, or any other additional experiments on power frequency fields.

**Q.** Would you recommend construction of the 765 kV line as proposed by the applicants?

**A.** No, for the reasons that the strength of both the electric field and magnetic field produced by the line will be in the range possibly productive of biological effects. I believe that chronic exposure of humans to such fields should be viewed as human experimentation, and subjected to the rules previously mentioned, I believe that the most prudent course to follow would be to determine the complete spectrum of biological effects produced by exposure to 60 Hz fields. It should then be possible to establish firm levels of permitted exposure both to field strength and to exposure times.

**Q.** Do the conclusions you have proffered apply to transmission lines whose voltage is less than 765 kV?

**A.** Yes, proportionally so.

**Q.** Would you state for the record whether the conclusions you have reached apply equally to an underground 345 kV line, a 400 kV d-c overhead line and an underground d-c transmission line?

**A.** Our conclusions do not apply to the d-c case. In the case of the underground 345 kV line, it is my understanding that these lines may be shielded to reduce the ground level electrical and magnetic fields to the ambient level.

**Q.** Does this conclude your testimony?

**A.** Yes.