POWERLINE ELECTROMAGNETIC FIELDS AND HUMAN HEALTH: Notes

1. INTRODUCTION

1.1. Origins

1.1. Note 1

A symposium on medical effects of electrical fields, organized by the Power and Environmental Sciences Committee of the Power Engineering Society was held at the National Science Foundation in Washington, DC on October 31, 1973. Minutes of the symposium were prepared by B.J. Ware, Secretary of the Power and Environmental Sciences Committee.

1.1. Note 2 (pp 1- 25)

In December, 1973, Dr. Becker told me about a meeting where he learned that powerline electromagnetic fields might affect human health, and he notified the New York Public Service Commission (PSC). In July, 1974 we were both asked by the staff of the PSC to testify in a PSC licensing hearing involving construction of two 765,000-volt powerlines. We both wrote reports (Becker, Marino) explaining the basis of our view that the powerline electromagnetic fields could affect human health, and the PSC sent the reports to the power companies in October, 1974.

The hearing was recessed for a year to allow the power companies to find expert witnesses. The reports of their experts were distributed in November, 1975. At the same time the PSC provided the power companies updated versions of our reports (Becker, Marino).

In 1976 I was cross-examined by the power companies for 10 days, and Dr. Becker was cross-examined for 4 days. The power companies then requested a rebuttal phase of the hearing, and their experts filed additional reports that attacked our reports. By this time Dr. Becker was disgusted with the process, and he withdrew from active participation. I, however, was afraid to withdraw because I thought it would appear that I was admitting that the power-company experts were correct, which was not the case. Consequently, in March, 1976 when they filed reports aimed at rebutting my position, I filed a report aimed at rebutting their position. I was cross-examined for 3 additional days.

After the testimony was finished, the lawyers for the power companies and for the Public Service Commission filed legal briefs in an attempt to persuade the PSC Commissioners that powerline EMFs were not a health risk. The brief of the PSC staff argued that powerline electromagnetic fields would affect human health, but I thought an even stronger position was warranted. Consequently, representing myself, I submitted a brief, and a reply brief.

A rebuttal phase for briefs was allowed and the power-company lawyers submitted rebuttal briefs. Consequently, I also submitted a rebuttal brief.

The hearing examiners wrote a Recommended Decision in March, 1978, and the Final Decision was issued by the Public Service Commission in June, 1978. That decision led to extensive litigation involving the power companies and the PSC, the upshot of which was denial of permission to build one of the powerlines, the institution of some construction rules to protect the public from exposure to electromagnetic fields from the approved powerline, and the initiation of a research program to assess more precisely whether powerline electromagnetic fields affected human health.

For a recounting of the hearing from my viewpoint see A.A. Marino and J. Ray: Electric Wilderness, San Francisco Press: San Francisco, 1986. For a description of the hearing from another viewpoint, see the Department of Energy report.

Becker testimony:

BEFORE THE STATE OF NEW YORK PUBLIC SERVICE COMMISSION

CASE 26559 - Rochester Gas & Electric Corporation and Niagara Mohawk Power Corporation: Pannell Road to Vorney and Oswego to Sterling Transmission Facilities.

Prepared Testimony of Dr. Robert O. Becker, Veterans Administration Hospital, Syracuse, New York

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 Diplomate 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 becamea 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 sabatical 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. 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 briefly describe 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. This work is going on in several medical centers, including Syracuse.

Q. Assuming that the electric field distribution due to the proposed transmission line is approximately as Dr. Marino has calculated, does it present a danger, from a health viewpoint, to either maintenance personnel, persons on the right-of-way, or persons living near the edge of the right-of-way?

A. Utilizing the concept that 1/100 of the dose shown to be not harmful may be considered safe (in this case 1.5 rms-volts/cm) the field strength within the present right-of-way and for a distance out on either side would exceed this level. Maintenance personnel would then be exposed to levels in excess of 1,5 rms-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 rms-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 cumulative 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. 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. This theory is generally accepted as a useful framework to explain some diseases and to design experiments.

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 a day.

Q. Does the proposed safety level of 1.5 rms-volts/cm mean that maintenance personnel should not service the proposed transmission line?

A. No, except for the possibility of cumulative effects.

Q. In your research, do you use animals?

A. Yes, animals are used for preliminary studies and for some studies in which large numbers of individuals are required.

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, psychcological 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 regards to gain, considerations 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 the 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 evidences 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 sane 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 changes in these environmental fields. It is believed that this system may provide the necessary linkage mechanism between the normal variations in these geophysical parameters and the normal biological cyclic rhythms. Changes beyond the normal variations in all environmental parameters (temperature, pressure and other physical variables, as well as social, psychological, etc.), if persistent for any prolonged period are stressful to living organisms. Such stress is reflected in increased production of hormones such as cortisone, in increases in blood pressure and other metabolic changes. If exposure to stressful situations is prolonged, the organism enters a physiological state characterized by Dr. Hans Selye (Stress, Acta Inc., Montreal, 1950) as the stress adaptation syndrome or the general adaptation syndrome. This is accompanied by many metabolic and functional changes which are deleterious to health. 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 heaing 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. 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 periartertis nodosa may be also 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. Could people susstain tbe same: effects as the rats, if9 comparably exposed?

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

Q. Are you familiar with the Navy research project known as Sanguine?

A. Yes.

Q. Would you please describe that project and your involvement in it, if any?

A. Project Sanguine proposes to construct a very large antenna array, buried in the ground which would produce signals perceivable by submarines around the world. The system would function with a carrier frequency of 45 or 75 hz. Because of possible environmental and health related effects, the Navy commissioned a biological study program involving about 24 different projects in many institutions. These projects included a search for the possible effects of both electrical and magnetic fields on a variety of systems including soil ecology, bird migration, embryonic development, physiological and psychological variables in man, nerve function, etc. A committee was appointed to review and evaluate the results of these experiments and I was selected to be a member thereof. The first committee meeting was held last December to evaluate the results of the first year of experimentation. The committee has been reappointed for this year and I am again a member.

Q. You have described an extensive program aimed at determining the impact of the fields associated with the Sanguine antenna. How does the strength of the Sanguine fields compare with that of the proposed 765 kV transmission line?

A. The expected Sanguine electric field directly above the antenna is 0.0007 volts/cm (Fact Sheet for the Sanguine System, FinaL Environmental Impact Statement for Research Development, Test and Eualuation, Dept. of Navy, April, 1972). The Sanguine field is therefore much smaller than that associated with the proposed transmission line.

Q. Does your research involve magnetic fields?

A. Yes. I have used magnetic fields primarily as a tool 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.16 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 hz on reaction times in human volunteers (Becker, *Nature*, 213, 949 (1967)). I was asked to review the literature on the biological effects of magnetic fields in 1963 for publication (Becker, *Med. Elect. Biol. Eng*., 1, 293 (1963). 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 (Barnathy, 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 corroaborated by Wolcott and Green (*Science* 184, 180, 1974) and extended to several other species of birds (Southern, W.E., *Bioscience* 22, 476, 1972 and Wi1tschko, 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 al1 animals into a specific sensing mechanism of survival value. Dr. James Hayes 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 th 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 Caey, R. *Physiol. & Behavior* 9, 171, 1972 and *Physiol. & Behavior* 4, 539, 1969). Most recently Dr. Dietrick 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 examimed 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 arterioscleratic disease.

Q. Are you an expert on the possibility of interference with cardiac pacemakers by emanations from the line as proposed?

22 A. No.

Q. Would you recommend construction of the 965 kV line as proposed by the applicant?

A. No, for the reasons that the strength of both the electrical 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 as to field strength and to exposure times.

Q. Do the conclusions you have proffered apply to16 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?

Yes.

<u>Moreno Report</u>:

STATE OF NEW YORK PUBLIC SERVICE COMMISSION DEPARTMENT OF PUBLIC SERVICE
EMPIRE STATE PLAZA, ALBANY 12223

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November 24, 1976

IN REPLY REFER TO Re: CASES 26529 and 26559 - Common Record
Hearings on Health and Safety of 765 kV Transmission Lines.

TO ACTIVE PARTIES:

Enclosed is the prefiled rebuttal testimony of Dr. Andrew A. Marino. Dr. Marino is being presented by the Staff as a witness in this proceeding, but his testimony does not necessarily reflect our position. His rebuttal testimony will be sworn and cross-examined at a hearing yet to be scheduled.

The references, figures and tables presented in Dr. Marino's rebuttal testimony are part of Exhibit (AAM-1), and are numbered as a continuation of those used in the prefiled direct testimony. Figure 4 is a photograph and one copy has been supplied to the representative for each active party.

Very truly yours,

ROBERT A. SIMPSON

Staff Counsel

Enclosure

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

REBUTTAL TESTIMONY OF ANDREW A. MARINO

INDEX

MARINO

Q. What is the purpose of your testimony?

A. I will rebut the applicants' position in this proceeding by showing that biological effects have been observed in organisms exposed to electric and magnetic fields such as will be produced by the 765 kV transmission lines. I will describe the inadequacy of our present information to predict specific effects in people exposed along the ROW of the proposed transmission lines. I will describe the available Soviet literature in the area of ELF field induced biological effects, and its implications for the proposed transmission lines. I will describe two possible global impacts of the radiation from the proposed transmission lines. I will recommend against construction of the transmission line as proposed. I will show that all arguments raised by the applicants to the contrary have no merit.

References, tables, and figures herein are numbered as a continuation of those used in the prefiled testimony.

ELECTRIC AND MAGNETIC FIELDS

Q. Would you describe those reports which refute applicants' position that the electric and magnetic fields of the 765 kV lines can not cause biological effects?

A. The reports that I have previously described (75) are Table 4.* The additional reports listed in Table 4 (76. 77, 78, 79, 83, 84), are described below. In a study that was originally part of the Sanguine research project, Noval and co-workers (76) at the Naval Air Development Center, Johnsville, Pennsylvania, studied the effect of ELF electric fields of 45 hertz, 0.005-1.0 volts/cm on the growth rate, and the biochemical and hormonal systems of rats. The rats were exposed continuously to the ELF electric field for one month, after which they were weighed ad sacrificed, and analyzed for levels of choline acteyltransferase (ChAc) in the brain, tryptophan pyrrolase (TrPy) in the liver, and corticosterone (cr) in the blood. In each of four experiments (which involved a total of 505 rats) it was found that the exposed rats gained weight :at a rate 20-30% slower than the controls. The growth rate depression was observed at all field strengths tested, including 0.005 volts/cm. The authors also found significantly decreased levels of ChAc, and significantly increased levels of TrPy in the exposed rats throughout the exposure range studied. Cr was found to be elevated in rats exposed at 1 volt/cm and 0.5 volts/cm, but not in rats exposed at 0.02-0.25 volts/cm.

The authors believe that the results of the TrPy and Cr measurements indicate that the rats experienced stress. They interpret the observed decrease in weight gain in the exposed rats to be a consequence of the altered levels of ChAc in the brain.

It should be noted that both our experiments (31, 32) and those of Noval's group have found the same biological effects (decreased weight gain, stress), in the same laboratory animal (25-day old male Sprague Dawley rats), employing ELF electric fields of similar frequency (45, 60 hertz) and similar orientation (vertical), using the same exposure system (acrylic cages between metal plates, with the rats electrically floating). Neither group knew of the existence of the other until each had concluded its experiments. Noval's group has, therefore, confirmed our results, and extended them down to lower field strengths.

Bassett and co-workers (77) studied the effect of ELF fields on people suffering from congenital and acquired pseudarthroses (bone non-unions). Pseudarthroses are orthopedic conditions in which bone fractures do not heal; they frequently resist surgical treatment, necessitating amputation. It was found

that the ELF fields caused bone growth, indicating a promising approach to avoid amputation in the surgically resistant non-union. The authors concluded that their report documents for the first time the therapeutic use in humans of ELF electromagnetic fields.

Patients were exposed 12-16 hours/day for 3-6 months, in a carefully monitored and supervised manner, to an ELF electromagnetic field having a rep rate of about 56 hertz. The ELF field was derived from a pulsed coil apparatus, and produced peak currents within the patient of about 10 ma/cm2, and an average current of about 1 ma/cm2.

Patients who suffered from congenital bone non-unions (all were children) had a success rate of 73%. That is, 8 of 11 patients exhibited healing bone growth. Patients who suffered from acquired bone non-unions (i.e., a bone fracture that does not heal, usually in an adult, where there is no previous indication of such a phenomenon) had a success rate of 76%. That is, 10 of 13 patients exhibited healing bone growth. Fourteen of the 24 patients had been given the standard orthopedic treatment for non-union without success prior to entering into the study, and had been scheduled for amputation. To date, the treatment received has obviated the need for amputation; long-term follow-up is, however, being carried out

Multicenter testing of the technique of ELF exposure is being organized. The authors believe that if the present success rate is confirmed, and long-term follow-up studies indicate continued functional bone union, the technique will be available for general use by orthopedists within 3-5 years. The authors also noted that the ELF exposure technique holds promise in other areas, such as relief from chronic pain, and that, therefore, extended fundamental investigations of the effects of ELF fields on other biological systems are strongly indicated.

As part of EPRI's* Research Project RP-98, the effect of acute electric field exposure on the control system governing the response to hemorrhage was studied (78). Dogs were exposed to an electric field of 150 volts/cm, 60 hertz, for 5 hours, and then were subjected to a calibrated hemorrhage over a standard period of time. The responses measured were: the ability of the adrenal gland to secrete cortisol: the mean arterial blood pressure; the pulse pressure and the heart rate. In general, these responses represent the balance between control systems functioning (i. e., decrease in caliber of blood vessels, shutting down of some vascular beds, etc., all designed to maintain blood pressure in the face of a significant loss in circulating fluid volume) and the severity of the hemorrhage. If controls work adequately and the hemorrhage is not too severe, the system can compensate well and blood pressure drops will be transient and small.

If hemorrhage is at a rate that exceeds the ability of the compensatory mechanisms to maintain pressure, or if the compensatory mechanisms are defective or not called into play because of some functional defect, then blood pressure drops will occur. The extent of the pressure drops will be directly related to either the severity of the hemorrhage or the extent of defective functions in the compensatory control mechanisms.

Under the conditions of this experiment, it was found that the responses of the adrenal gland were not affected by field exposure. The mean arterial pressure, pulse pressure, and heart rate of the experimental dogs, however, were found to be significantly different ($P < .05$) than the corresponding values of the control group. The ability of the experimental groups to put into effect the compensatory mechanisms was impaired, and they showed much greater drops in blood pressure than the control group. Since these compensatory control mechanisms are primarily neural, one must interpret this to mean that the field exposure produced disturbances in the central nervous system which in this case reflected themselves in an inability to employ effective compensatory cardiovascular mechanisms in

response to a calibrated hemorrhage. It was concluded:

> *The unexpected finding of these changes suggests strongly that dynamic effects resulting from exposure to electric fields may not be particularly subtle at all, but may be quite easy to detect. In addition to the findings with respect to magnitudes of change, the variability in the heart rates of exposed subjects was also significantly greater than that in unexposed subjects, suggesting that the observations made by Soviet workers on conscious human beings exposed to high voltage electric fields may be present in anesthetized dogs. These results are clearly preliminary but also clearly demand further exploration.*

Bawin and Adey (79) exposed tissue from brains of cats and chicks to ELF electric fields of 1-75 hertz, 0.05-1.0 volts/cm. Their aim was to determine whether the efflux of calcium (an element essential in the normal functioning of the brain) would be affected by a 20-minute exposure to such fields. It was found that ELF field exposure significantly reduced the release of calcium from brain tissue. Maximum decreases occurred at 6 hertz and 16 hertz, at electric field strengths of 0.1 volts/cm for chick and 0.56 volts/cm for cat brain tissue.

The experiment shows that very weak ELF electric fields can alter the chemical dynamics of avian and mammalian neural tissue. Furthermore, the study shows that the observed effects are non-linear; that is, doubling the causative agent (electric field strength) does not double the observed effect.

Friedman and co-workers (82) were concerned with the relationship between the natural geomagnetic environment, and human behaviour. It has long been known that the earth's magnetic field is not fixed and unvarying, but rather undergoes small changes in intensity known as magnetic disturbances. The authors found a significant relationship between human psychiatric disturbance as reflected in hospital admissions and geomagnetic field intensity (82). That is, days of peak magnetic disturbance correlated with increased admission to psychiatric hospitals. Subsequently, the authors performed laboratory experiments to test the effects of artificially produced magnetic fields on human behaviour (83). They found that ELF magnetic fields of about 3 gauss, 0.2 hertz, superimposed upon a 5 gauss static magnetic field affect human reaction time in both males and females.

Initially, 30 clinically normal male subjects were randomly placed in one of three groups of 10 subjects. One group was exposed to a 0.2 hertz magnetic field, a second group was exposed at 0.1 hertz, and the third group served as the control. The magnetic field was applied to the subject's head, and the time required for him to press a key following the appearance of a light was measured. Statistically significant differences in reaction time were seen in the group exposed at 0.2 hertz as compared to the other groups. These findings encouraged the use of a more sensitive experimental design. Twelve subjects were called back and retested according to a protocol in which they served as their own controls. Again, the results indicated that the reaction time performances of the subjects exposed to the 0.2 hertz magnetic field differed significantly from the other two conditions. The entire experiment was repeated with 30 females. Data derived from assigning the subjects randomly to the three groups often each indicated that although differences were in the expected direction, they were not statistically significant. As previously, the more sensitive design was used by calling back 12 subjects and employing a protocol in which each subject served as her own control. In this case, statistically significant results were observed. The authors concluded that ELF magnetic fields can significantly affect human reaction time performance.

In a Navy study which was part of the Sanguine. research project, Gibson and Moroney (84) studied the effect of exposure to an ELF magnetic field of 1 gauss, 45 hertz, on human cognitive and psychomotor functions. They found that after 24 hours of exposure, the two cognitive tests employed

yielded statistically significant results.

Eleven male volunteers were confined to a testing facility for seven days, during which the various tests were given. The magnetic field was turned on for a period of 24 hours during the subjects' seven-day stay in the experimental area. The subjects did not know when the magnetic field would be applied. The authors selected four sensitive tests to measure psychological functions: (1) RATER, which tested short-term memory; (2) SETA, which involved performance of a compensatory tracking task (subject required to maintain the pointer of a zero centered meter at the null position by manipulating a control device); (3) WAT, which tested the subject's ability to perform addition; (4) ROM, which measured coordination of the eyes with arm-hand manipulation (subject must manipulate blocks).

Neither the SETA nor ROM tests showed an effect due to field exposure, indicating that human psychomotor function was not affected under the conditions studied. Both the RATER and WAT tests, however, yielded statistically significant results. The WAT test showed that the experimental subjects' speed of performing addition decreased during their exposure to the ELF magnetic field. The RATER tests showed a significant increase in performance of the experimental subjects, as compared to the controls during exposure to the field. The authors concluded that the RATER and WAT tests should be employed in future studies of the effects of ELF fields on human performance.

Q. Are you aware of any other reports which refute applicants' position?

A. Yes. There are many more reports which I have read and analyzed subsequent to the prefiling of my direct testimony, which describe ELF electric and magnetic field induced biological effects (85-97). The demands of this hearing upon my time have precluded me from describing each such report in the detailed manner in which I have described previously cited reports which show ELF field induced biological effects.

Q. What do you conclude from the reports described in Table 4 of Exhibit AAM-1?

A. The electric field of the proposed transmission line will probably cause biological effects in the subjects exposed to it.

There are a very large number of scientific experiments (Table 4) which indicate that ELF electric fields cause biological effects. The experiments were performed by reputable scientists at reputable scientific institutions (see Table 4). A heavy majority of the reports were subjected to the peer review process prior to publication. In many of the remaining cases, the results of the experiment are against the interest of the U.S. Navy, for whom work was performed, thereby lending great credibility to the results reported. The electric field strength used in each cited experiment was such that it will occur somewhere on the ROW of the proposed transmission line (Table 4, column D1). If an electric field causes a certain biological effect in a laboratory, then the same electric field will cause the same biological effect on the ROW of the proposed transmission line, if the same biological system is exposed under the same circumstances. This is an obvious and direct consequence of the fact that biological systems cannot distinguish between two sources of an applied electric field, when the parameters of the field presented from each source are identical. Under these conditions, specific effects due to exposure to the fields of the proposed transmission line could be predicted. The actual biological systems that will be exposed fields of the proposed transmission line are principally people. The exposed group will consist of the old, the young, the sick, the healthy, men, women, children -- a completely uncontrolled set of exposed subjects. Since the particular biological systems that will be exposed to the fields of the proposed transmission line and the conditions of such exposure, will differ from the corresponding systems and conditions studied in the laboratory, no human agency can predict the specific biological consequences that will occur in the exposed subjects along the ROW of the

proposed transmission line. Notwithstanding our inability to predict specific effects in specific subgroups of the exposed subjects, the adumbrations of the literature are ominous and unavoidable. In each individual report described in Table 4, ELF fields interacted with and influenced the physiology or behaviour of a biological system. In no case is the mechanism of interaction understood. With respect to each individual experiment listed in Table 4, a mechanism was invoked in the laboratory which could be invoked along the ROW as a consequence of exposure to the fields of the proposed transmission line. In view of the number and diversity of the experiments listed in Table 4, and bearing in mind the relatively short exposure times that are normally employed in laboratory experimentation (Table 4, column 7), as compared to the very long-term exposure that will occur in subjects living along the ROW of the proposed transmission line, it is probable that some situations (Marino, 7200-14*) will be associated with biological effects.

Q. What do the last three columns in Table 4 indicate?

A. Column D1 indicates the distance from the proposed transmission lines at which the field strength will be comparable to that used in the particular experiment (102). Column D2 incorporates a safety factor of 100. It indicates the distance from the proposed transmission line at which the field strength will have decreased to 1/100 of the value that produced the biological effect in the laboratory. The propriety and necessity of employing a safety factor is well-recognized (Michaelson 9927-5). It is based on the unacceptability of permitting people to be involuntarily exposed to levels of a substance or agent that has been shown to produce certain kinds of effects in experimental animals, or to levels which presumably would produce such effects or related effects if tests were performed (Marino 7241-3 to 7247-13). Typical biological safety factors are: 10 for occupational exposure to microwaves; 100 for exposure to microwave leakage from ovens; 100 for food additives; and infinity for substances which cause cancer (Marino 7243-17 to 7247-5). The most appropriate safety factor for use in connection with the literature describing biological effects due to exposure to ELF fields appears to be 100 (Marino 7241-3 to 7247-l5). Column D2 has therefore, been computed on this basis. Column D3 (=2D2) gives the total width of the zone of effect (ZONE); that is, the total width of the strip of land within which the field from the proposed transmission line will exceed the safety level computed in D2.

Q. Do you recommend that the Commission employ a safety factor of 100 in evaluating permissible chronic human exposure to 60 hertz electric fields?

A. Yes. The basis for my recommendation has been discussed in detail (Marino 7241-3 to 7247-15).

Q. Do you recommend that the safety factor of 100 be applied to a specific research report listed in Table 4?

A. No. The application of the safety factor of 100 to a specific report listed in Table 4 would produce a design criterion, and I do not urge any specific design criterion (103). I believe that the particular report or group of reports in Table 4 which are chosen must reflect a view of the entire record in the hearing. In view however, of the reported effects of the 70-200 volt/cm range (Table 4), it is my judgment that the application of the safety factor of 100 to this range of experiments would be an upper limit on the available choices, notwithstanding any financially oriented considerations.

Q. Based on the safety factor of 100, and assuming the upper limit just described, what would be the width of the ROW for the proposed transmission line?

A. From Table 4, 600-900 feet.

Q. What, in your opinion, constitutes acceptable evidence concerning the biological effects of the ELF fields due to the proposed transmission line?

A. Two distinct issues arise with regard to such effects: 1) can the fields of the proposed transmission line cause biological effects, and 2) will such fields cause such effects? (Marino, 7197-14ff). There are three apparent sources of evidence to which we might turn to assess the issues.

1. Theoretical Calculations (mathematical) computations involving biological systems on the basis of which it is argued that some effect can or will or can't or must occur as a consequence of ELF field exposure). Arguments based on theoretical calculations, of necessity depend on numerous unverified and unverifiable assumptions concerning the nature of the physical system under investigation. Theoretical calculations of the possibility of ELF electric or magnetic field biological effects are properly employed to guide scientists in the choice of experiments; they are, however, not evidence because they are incapable of conveying information bearing on the likelihood of any biological effect due to ELF field exposure. Before any theoretical calculation, one knows that any given biological effect is either impossible, possible, probable, or definite. The calculation leaves the situation unchanged. This chronic infirmity of theoretical calculations is recognized in other forums. A review of the major environmental health issues raised in the United States has not revealed a single example wherein a state or federal regulatory agency or court has given decisional impact to theoretical calculations showing the absence of the possibility of a biological effect, when competent investigators have reported such effects. Theoretical calculations are therefore, not evidence on either issue discussed above.

2. Experimental reports showing no effect (ELF-Minus). ELF-minus reports have evidentiary value on the issue whether the proposed transmission line **can** cause physiological, growth, or behavioral effects in exposed subjects in only two cases: (1) wherein reports showing the existence of ELF field induced biological effects (ELF-plus) do not exist, and (2) wherein both ELF-minus and ELF-plus exist, and contradict one another. The first case clearly does not apply in the instant hearing (Table 4), and the second case has been asserted only once (Miller 6190-1 to 6191-3), and later withdrawn (Miller 6218-12 to 6220-4). In all cases other than those enumerated above, the ELF-minus reports merely establish the existence of certain conditions for which a specific effect is not observed (Marino 7201-7ff). The establishment or enlargement of this limited class does not make it more likely that the class of all conditions will be unproductive of a biological effect because the ELF-plus already exist. Thus, the ELF-minus serve no evidentiary purpose with respect to the stated issue.

The ELF-minus reports have evidentiary significance with regard to the issue whether the proposed transmission line **will** cause physiological, growth, or behavioral effects in the exposed subjects. The evidentiary weight of each report will depend on how closely it relates to the actual conditions that would prevail if the proposed transmission line were to be constructed. Thus, the ELF-minus experiments performed in connection with Project Sanguine (Sanguine ELF-minus), will clearly have evidentiary significance and some weight on the issue whether the Sanguine antenna **will** cause biological effects. The Sanguine experiments however, were performed at Sanguine field strengths, which are about one million times less intense that the field strength of the proposed transmission line. Therefore, the Sanguine, ELF-minus reports, although of evidentiary significance in this proceeding on the issue stated, can be accorded little weight.

3. Experimental reports showing an effect. The ELF-plus reports are the only proper evidence on the first issue stated above. They establish beyond reason able doubt that ELF fields **can** cause biological effects. They are obviously evidence on the issue whether the proposed transmission line **will** produce such effects in the exposed subjects, and are open to the same test for weight as described above.

Q. Is it your testimony that both the ELF-minus and ELF-plus reports have evidentiary value on the issue of whether there will be effects due to the proposed transmission line?

A. Yes. Each ELF-plus report was performed by a reputable scientist at a reputable scientific institution. Most studies were reviewed by the peers of the authors prior to publication and found scientifically acceptable. In many of the remaining instances, it may be presumed that the report was subjected to a careful examination prior to release because the conclusions reached are adverse to the interests of the Navy which sponsored the research.

Each author of an ELF-plus report reached his conclusion that ELF fields affect biological systems under the conditions studied, independently of all the other authors who reached the same general conclusion.

The reliability one may place in the ELF-plus reports as accurate descriptions of nature is no different than that associated with another comparably sized group of peer-reviewed, openly available scientific literature which has been written by competent scientists.

Each ELF-plus report involves a physical mechanism by which the applied field interacted with the biological system studied. With respect to every report, the mechanism involved which is presently unknown could operate to produce the same effect or a similar effect in subjects exposed to the proposed transmission line. One must bear in mind that the exposure of subjects under the proposed transmission line will often be chronic exposure, with the total exposure duration vastly exceeding the exposure times usually studied in the laboratory (Table 4, Column 7). Moreover, in some cases in Canada, humans are exposed to electric field levels from 735 kV lines which exceed the levels at which biological effects are known to occur. (Compare Table 4 with statements by counsel for the Power Authority at 10213-21 to 10214-5). Each ELF-plus report is some evidence that the proposed transmission line will cause biological effects. Each report makes the conclusion more likely of being true than otherwise would be the case. Individually, the reports suggest the possibility of a public health problem due to ELF field exposure. Collectively, they establish the existence of the problem -- exposure to the electric and magnetic fields of the proposed transmission line will probably cause biological effects in the exposed subjects -- and give form and shape to its dimension.

The ELF-minus experiments were performed by scientists of reputation and competence equal to that of their ELF-plus reporting colleagues. All such reports thus far cited in this proceeding can be accorded little weight with respect to the issue whether the electric and magnetic fields of the proposed transmission line **will** cause physiological, growth, or behavioral effects in exposed subjects.

Q. Why do they have reduced weight?

A. Because in each instance they were performed under conditions of exposure that are vastly different than those that will prevail under the proposed transmission line with respect to applied field strength, and duration of exposure (104).

Q. Will the probable biological effects be hazardous?

A. As I have testified previously (Marino 7199-l0ff), I cannot discuss that issue because it calls for medical MARINO expertise. Testimony on the medical significance of most of the reports cited in Table 4 was given by Robert O. Becker, M.D. (Becker 8986-20 to 8997-4). No other medical experts have testified.

It should be noted however, that even if the effects described in Table 4 could not be proved to be hazardous, they are potentially hazardous. That has always been sufficient to warrant and demand regulation in situations such as exist with regard to the proposed transmission line.

Q. Would you explain?

A. The proposed transmission line is a regulatory-public health problem with the following aspects. A private corporation (applicants) is manufacturing a product (electrical power). As a consequence of the production of its product, the corporation emits or causes to be emitted a substance or entity (electric and magnetic field) into the environment. Let us assume that the entity causes a biological effect (otherwise there would be no hazard) in some part of the general population exposed thereto. The assumed biological effect may be **any** physiological, growth, or behavioral effect. Finally, the affected part of the general population has neither given informed consent to the production of the biological effect within themselves, nor are they aware of the production of such effects.

In such a situation, there is a strong presumption that the biological effect is potentially hazardous. I have not been able to find a single instance in which a state or federal court, or administrative agency indulged in the contrary presumption. There is no precedent for an argument by the private corporation that they should not be regulated because the effect that they caused in the exposed subjects had not been proved hazardous.

Q. If the Commission concludes that certain biological effects may occur in people exposed to the fields of the proposed transmission line, should it assume that these effects are potentially hazardous?

A. Certainly. The only competent medical testimony adduced in this hearing is to that effect. Furthermore, when other forums have been confronted with similar situations, there are no instances in which the forum has presumed that the biological effect is harmless . Thirdly, it seems self-evident that the general public would expect and demand that the Commission view all such biological effects as potentially hazardous, and regulate them accordingly. Suppose for instance, that a member of the public were asked to draw up a list of the biological effects that he would permit to be induced in his body or the bodies of his children exposed to the 765 kV line. At best he would permit only those effects that were known medically to be harmless, and would prohibit all other effects on the ground that they were potentially hazardous. I believe that the Commission should do no less.

To the extent the applicants produce evidence that specific biological effects are not hazardous, then the presumption discussed above would not apply.

SYNERGISTIC EFFECTS

Q. Will people be exposed to the electric and magnetic fields of the proposed transmission line at the same time?

A. Yes. More precisely, they will be exposed to an energy flux, which is part of the energy being carried by the line. The transmission line energy is composed of an electric field and a magnetic field.

Q. What do you mean by transmission line energy?

A. The proposed transmission line will carry about 4000 megawatts of electrical power. The power will be manufactured at one location, transported, and ultimately used or consumed at the terminus of the transmission line. The 4000 megawatts will travel from the point of generation to the point of consumption, through the space surrounding the wires. The region which the transmitted power occupies extends a considerable distance outward from the transmission line. If an individual stands within this region, then a portion of the electrical power being transmitted impacts him. The amount of energy which impacts the individual depends on his size, his distance from the transmission line, and how long he stands there.

Q. Is it your testimony that the electrical power that will be transmitted by the proposed transmission line will not be confined to inside the wires, but rather will exist in the air outside the wires?

A. Yes. (105).

Q. What is the significance of the fact that when people are exposed to an energy flux from the proposed transmission line, they are exposed to simultaneous electric and magnetic fields?

A. It has been shown that ELF electric fields and ELF magnetic fields cause biological effects (Table 4). The real-life situation however, namely the simultaneous and phased application of both fields, has not been studied.

Q. Why has ELF experimentation been confined to the study of the effect produced by each field individually?

A. Experiments involving the study of the biological effects produced by the phased simultaneous application of electric and magnetic fields would be expensive to perform.

Q. Wouldn't the effect in the real-life situation be just the summation of the effects seen when each field is applied in turn?

A. One certainly could not assume that would be the case. The biological response to the simultaneous application of the fields may be equal to the summation of the effects produced by each, or may be greater than the summation of the independent effects of the two fields. The latter response is called potentiation, and represents the condition whereby one agent is made more potent in the presence of another agent. Thus, the situation which will actually occur under the proposed transmission line, namely the phased simultaneous application of the electric and magnetic fields, has not been studied experimentally. We do not know whether there will be a synergistic effect between them. Moreover we have no idea whether synergistic effects will occur between the energy flux of the proposed transmission line (i.e., the electric and magnetic field taken together) and other agents present in the environment at various locations along the ROW. Such agents may be electrical (radar, radio stations, etc.) or non-electrical in nature (air pollution, drugs, etc.).

Q. Have you performed calculations of the energy flux associated with the proposed transmission line?

A. Yes. (105). The results are given in Figure 2. As can be seen, very large energy fluxes exist for considerable distances from the transmission line. At 50 meters for instance, the ground level energy flux is 10 kilowatts/m2.

Q. Would you explain the exposure standards shown in Figure 2?

A. There are no exposure standards (in terms of energy flux) for 60 hertz in either the United States or the Soviet Union. The occupational exposure standards for microwaves in each country is 10 milliwatts/cm2 and 0.1 milliwatts/cm2, respectively.

Q. Can it presently be determined whether microwave exposure standards apply to ELF field exposure?

A. No. The United States standard is predicated on simple physiological considerations involving tissue heating (106) which do not apply in the ELF region (Marino 7190-6 to 7190-18; Carstensen 3402-16 to 3402-22). The Soviet standard on the other hand, clearly envisions non-thermal effects. We do not know if the mechanisms underlying these effects are also operable at 60 hertz.

Q. What do you conclude from your analysis of the energy flux?

A. Substantial and significant energy fluxes due to the proposed transmission line will exist within the ROW and for considerable distances beyond. The energy flux is composed of phased simultaneously present electric and magnetic fields. While experiments have shown that each field separately can cause biological effects, no experiments have been performed to test the possible synergistic effects. Thus, we have no basis for assessing whether the effects occurring under the proposed transmission line will equal or exceed the sum of the effects observed when each field is applied separately. Moreover, the possibility of synergistic interaction between exposure to the energy flux of the proposed transmission line, and other factors present in the environment, has yet to be considered.

SOVIET STUDIES

Q. Would you describe the effort within the Soviet Union with regard to the safety of high voltage transmission lines.

A. From the existence within the Soviet Union of nationwide rules governing permissible human exposure to transmission line electric fields (Marino 7209-3ff), I inferred the existence of data and information within the Soviet Union which indicates that the proposed transmission line will cause biological effects (Marino 7219-4). I was able to identify and describe two Soviet reports dealing with the effects of power frequency electric fields on humans (48,49). Subsequent to the prefiling of my direct testimony (December 1975), I have obtained additional Soviet reports and material, confirming my original conclusion (Marino 7219-4). The outline of significant Soviet-effort in the area of ELF field-induced biological effects is now evident. The applicants' position as regards to the Soviet effort is in error.

Q. Would you describe the additional material that you have obtained?

A. Filippov has described the results of physiological and medical surveys of workers exposed to power frequency electric fields and the results of experiments involving controlled exposure of workers to such fields (107).

A physiological survey of 319 workers was carried out at twenty-two high voltage substations and overhead lines of 220, 330 and 500 kV. The cardiovascular, visual and nervous systems of the workers were evaluated. The statistically analyzed data showed unfavorable changes in the central nervous and cardiovascular systems of the personnel at the 500 kV substations.

Medical surveys were carried out at sixteen 220, 330 and S00 kV substations involving a total of 286 people. Again, the survey showed that power frequency electric fields have an adverse effect on the human central nervous and cardiovascular systems.

Experiments were carried out to determine the threshold for the physiological action of the power frequency electric fields. Twenty-three men, ranging in age from 23 to 35, were exposed to electric fields while various central nervous and cardiovascular indices were measured. Filippov reported that the results showed that electric fields stronger than 50 volts/cm have an adverse effect on man.

Sazonova studied the effect of 50 hertz electric fields of 300-400 volts/cm on work capacity of rabbits (108). He first determined the amount of work that could be done by each animal if its leg muscle had been stimulated electrically. (Work defined as the lifting of a fixed weight through a fixed distance.) Subsequently, he exposed the animal to the electric field for one hour and remeasured its work capacity. The exposure-measurement procedure was repeated daily for each animal. After 18 days, ELF electric field effects were observed. Sazonova found a statistically significant decrease in work capacity in the exposed animals. He concluded that ELF electric fields of the strength studied, deleteriously

affect motor performance.

A group of Soviet investigators have described the results of clinical examinations of workers in 330 kV substations in a brief report (109). A variety of effects on blood pressure and EKG were observed. The authors asserted that their studies were sufficient to reveal the harmful effects of exposure to ELF electric fields.

An abstract of a Soviet report describes observations on nine human subjects exposed 2 meters from a 65 kV conductor for 0.5-3 hours (110). Various physiological changes were observed.

Lantsman studied the effect of exposure to an ELF magnetic field of 200 gauss, 50 hertz, on the phagocytic function of the reticulo-endothelial system (RES) of mice (111). He found that 8 hours of exposure for 4 days inhibited the ability of the RES in the liver, spleen, lungs, marrow, and lymph nodes to remove and dispose of a foreign material which had been injected into each animal.

Udintsev and Moroz exposed rats continuously to an ELF magnetic field of 200 gauss, 50 hertz (112). They found that such exposure produced a stress effect on the pituitary-adrenal system.

Exposure to the field led to a significant increase in hydroxycorticosterone (OHC) in adrenal tissue and blood plasma after one day and seven days of exposure. Statistically significant increases in free and bound levels of plasma OHC were observed after one day and seven days of exposure. The authors concluded that ELF magnetic field exposure produced a marked alteration of the secretory function of the adrenal glands.

Q. Have you found any Soviet review articles which give a broad outline of the Soviet literature in the area of ELF field-induced biological effects.

A. A review article was published in the Soviet Union in 1970 (113). In it the authors state that the modern Soviet literature contains more than 100 reports of the influence of ELF electric fields on biological systems (114).

Q. Would you list the ELF electric field effects reviewed by the Soviet authors?

A. The authors reported the following:

The existence of physiological effects due to ELF electric fields has been known since the work of Danilevskiy on frog muscle preparation in 1900 (115). ELF electric field effects observed in frog muscle are optimum at 50 hertz (116). ELF electric fields of 50 hertz, 1.2 volts/cm, can produce physiological changes in frog muscle (117). Guinea pigs were exposed to an ELF electric field of 2000 volts/cm, 50 hertz; disturbances in respiration and some lethal effects were observed (118). An increase in regeneration in hydra was seen at 50 hertz, : 200 volts/cm (119). ELF fields of 25-40 hertz, applied in pulses of 6 milliseconds, have been successfully used to treat asthma patients (120). In animal experimentation, pulsed ELF electric field therapy has been shown to affect blood pressure, respiration, and EEG (121). The results of years of use of ELF pulsed electric field therapy lead to the conclusion that it has a favorable future in physiotherapeutic practice (122). Electricians working on 220 kV transmission lines were found to exhibit a variety of slight disorders of the central nervous system (123). In tests on mice and rabbits, 50 hertz electric fields were found to cause weight loss and an increase in blood pressure (123). Persons working in strong 50 hertz electric fields experience altered pulse and blood pressure (124). An examination of 200 workers in 220, 330, and 500 kV substations found that the workers complained of fatigue, drowsiness, and headache, and that the hemoglobin content of the blood increased (125).

Q. Have you been able to obtain the original reports of the work described by the Soviet authors?

A. No. (126).

Q. Are there any review articles published in the Soviet Union subsequent to 1970?

A. I am Not aware of any.

Q . In your study of this area, what have you learned concerning the degree of communication between the American utility company engineers and their Soviet counterparts? That is, has there been much cooperation and exchange of information?

A. Communication between the two groups with regard to ELF field induced biological effects appears to be poor. The data base and the focus which each group employs is quite different. Perhaps the best example of the gap which separates the groups can be seen in the following excerpts from the correspondence between a member of the Soviet Committee for the USSR Participation in International Power Conferences, and his American counterpart, applicants' witness Barnes. On June 14, 1973, the Soviet engineer wrote (127):

> After having studied the article 'Medical follow-up study of high voltage linemen working in AC electric fields' which you kindly sent me, I can make the following comments:
>
> 1. The staff maintaining 500 and 750 kV lines in the USSR in contradiction to the staff maintaining substations of the same voltages do not complain of their health changing for the worse under the influence o□ the electric field.
>
> This can be explained by the sporadical character of jobs on the lines, while at substations men are under the influence of highly intensive fields for up to 6 or 8 hours daily and during many years.
>
> 2. The influence of external factors, such as for instance, the influence of the field, which can bring about some marked changes in the state of a man's health, including non-persistent ones which disappear after a short rest without the use of pharmacological or any other means, is considered in the USSR inadmissible.
>
> 3. The field existing at EHV substations is physically perceptible and affects the human being organism. This has been proved by long term observations made by physicians and by physiologists. The studies for determining the mechanism of this influence are being carried out.
>
> I should be very much obliged to you if you can answer the following questions:
>
> 1. Are there in the USA any standards or regulations for the admissible distances from EHV lines to settlements and individual buildings?

Barnes replied on July 12, 1973 (128):

> Our system operates in 7 of the 50 states in the USA. There are no standards or regulations in these states covering clearances to settlements or buildings other than those contained in the National Electric Safety Code (NESC).....I believe that this holds true in the remainder of the 50 states ....The NESC calls for horizontal and vertical clearances to buildings of lines in excess of 50 kV to be 10 feet plus 0.4 inch per kV in excess of 50 kV plus 0.1 foot

> for each 10 feet in excess of 150 feet. Thus a 500 kV line with 1150 foot spans would require 35 feet.... The primary consideration behind the requirement is the safety of firemen fighting building fires.

On October 3, 1973, the Soviet engineer replied (129):

> You wrote about the rated clearances to settlements and buildings from high voltage lines in view of the safety of firemen. There are such regulations in the USSR. However we are interested in the regulations covering these clearances from the point of view of the elimination of the UHV line electric field intensity upon living beings. Are there any such regulations in the USA, and if no, are they to be developed? (No answer furnished.)

American and Soviet engineers met at the CIGRE Conference in Paris in 1972. The Soviet view that power frequency electric fields cause undesirable effects in exposed workers was reported at that meeting, as were the Soviet rules governing maximum permissible exposure (50). The Soviet report caused some concern in the American power community. August 8, 1973, the Chairman of the U.S. Working Group on Energy wrote the Deputy Minister of Power and Electrification of the USSR and stated (130):

> There was at the 1972 CIGRE Conference in Paris a report by Soviet scientific workers of physical damage to persons exposed to 400-500 kV electric fields. The power industry of the US has sponsored considerable research in this field and their results are somewhat different from those of your people. Since the issue is of great importance to the power industry of both countries and the health of our power workmen, I would like to suggest that we arrange, as early as possible, for a meeting of the appropriate research people of our two countries to compare their experimental findings."

The Soviets declined to participate in the symposium which was to be held in Washington, D. C., on October 31, 1973, however.

The American and Soviet engineers did meet in Washington, in February 1975 . Again, the Soviet view on the existence of ELF electric field effects was clearly stated (47) (See Marino 7209-20 ff). In the Question and Answer session that followed the presentation, the Soviets reiterated their views under questions from the American engineers (131).

Question (American engineer):

> In the opinion of many American engineers the spark discharges are much more annoying and objectionable than steady-state induced current. Are the effects found on substation personnel in the USSR related to spark discharges or to steady-state currents induced by high electric fields?

Answer (Soviet engineer):

> Medical research on personnel, which has been conducted for the past 10 years, did not separate the effects of spark discharges from those of steady-state current. A combination of them was experienced by the personnel.
>
> Special research was done with people not subjected to spark discharges, using both artificial field and laboratory test. People were engaged in work either sitting at a table or

under physical exertion and were not told whether the field was on or off. Negative effects of the field were observed: rise in body temperature and hypertension. It was concluded that the field along w/o spark discharges can produce unpleasant effects.

Question (American engineer):

Is the medical effect of the field on people cumulative?

Answer (Soviet engineer):

If the exposure is of brief duration, the effect disappears. If the exposure is on an extended daily basis, the effects appear to be cumulative, but ill effects disappear in 1 month after removal from exposure.

In every recorded instance in which the American engineers have requested information from the Soviet engineers, they have received it (47, 50, 110, 131). On the other hand, there is no recorded instance in which a request has been made to the proper Soviet authority requesting copies of **all** reports in the Soviet literature dealing with ELF field effects.

On the basis of all the information which I have obtained, including that furnished to the Staff in the applicants' responses to our Interrogatories, it is not possible to avoid the impression that the difference in perspective and approach indicated by the excerpted correspondence is characteristic of the relationship of the American and Soviet power engineers.

Q. What is the Soviet view with regard to the biological effects of the magnetic field associated with transmission lines.

A. Detrimental effects appear in the 2-3 gauss range, and, therefore, only occupationally exposed individuals need be concerned (47).

Q. Would you list the rules and standards that prevail in the Soviet Union with regard to maximum permissible electric fields and widths of ROWs that you know of based on the data and information available to you?

A. Permissible values of the electric field intensity at ground level vary from 10 kV/m to 20 kV/m, depending on the location. 750 kV power lines must not be closer than 300-500 meters from the future borders of population sites, 100 meters from inhabited dwellings, and 40-60 meters from old and new non-inhabitable dwellings (47). For 750 kV lines, farm personnel receive special instructions, and the reasons for the restrictions imposed on them are explained. The zone with electric fields higher than 2 kV/m is clearly defined by signs. Farm personnel must utilize metallic shields over the seat of farm vehicles with rubber tires. No recreational activity is allowed in the zone where the electric field exceeds 2 kV/m (20 volts/cm) (131).

Q. What conclusions do you reach concerning your analysis of the Soviet reports and information?

A. There are rules within the Soviet Union governing the maximum permissible occupational exposure to high-voltage transmission line electric fields (46). Similar standards are being developed for agriculture workers and for the general population (47). Previously, I inferred from the existence of the rules, the existence of a data base within the Soviet Union concerning the subject of the biological effects due to ELF electric field exposure (Marino 7208-13 to 7219-8). I was able to identify only two Soviet studies (48, 49), and for a variety of reasons I reached no conclusion directly thereon (Marino

7208-13 to 7219-8). Subsequently, I have obtained four reports (108, 109, 111, 112), one abstract of a report (110), and two summary articles (107, 113); the first summary article described and identified by bibliographic citation a total often reports. Thus 18 additional reports have been identified, 14 of them by complete citation, all concerned with the effects of ELF electric fields on biological systems. In 1970, the Soviet literature contained more than 100 such reports (113), and work in the area has increased substantially since then (47). Because of the poor quality of the translations that are generally available and because of the very small percentage of the Soviet literature on the subject that is available to me, and because of the possible differences which may exist between American and Soviet scientists in terms of methods and procedure, I remain unable to reach any conclusion concerning the likelihood of biological effects from the electric field of the proposed transmission line directly from an analysis of the Soviet literature. Nevertheless, one cannot gainsay the existence of the Soviet rules, the Soviet standards, and the Soviet plans for additional rules. Taken together, they indicate the existence of a data base within the Soviet Union showing that the proposed transmission line will probably cause biological effects.

The applicants have not made any serious attempt to uncover the Soviet data base dealing with the biological effects from ELF fields.

1.1. Note 2

Dr. Becker's theories emphasized the importance of biolectricity in understanding medicine and biology. Any success that he might enjoy would necessarily come at the expense of the paradigm of solution biochemistry, which was the dominant biological viewpoint at the time he began his work. Biochemists were therefore prone to attack Dr. Becker at scientific meetings, and he worked out strategies for dealing with them which he passed on to me. For example, at a meeting Dr. Becker described some research involving application of weak electrical currents to tissue and the resulting cellular changes that he concluded were caused by the current. When he finished his presentation Dr. Becker was asked about the composition of the metal wire that was used to make physical contact with the tissue, and he replied that he used silver. At that point the questioner began a critical tirade in which he claimed that there were numerous reasons to indicate that silver was the absolute worst choice, and that all the observations made by Dr. Becker were artifacts that were caused by biochemical reactions of silver ions that dissolved from the wire, and had nothing to do with the exceedingly weak current that was being passed through the tissue using the silver wire. The questioner took almost 5 minutes to make his case that Dr. Becker's observations were spurious, after which a hush fell over the auditorium as Dr. Becker stood up to reply. "What metal should I have used", he asked. "Platinum, because platinum does not dissolve when placed in contact with tissue" was the reply. "Well," said Dr. Becker, "I repeated the experiments using platinum and the results were exactly the same.

1.1. Note 3

We reported that powerline EMFs affected the growth rate of mice (see A.A. Marino, R.O. Becker and B. Ullrich: “The effect of continuous exposure to low frequency electric fields on three generations of mice: a pilot study,” *Experientia* 32: 565, 1976; also A.A. Marino, M. Reichmanis, R.O. Becker, B. Ullrich and J.M. Cullen: “Power frequency electric field induces biological changes in successive generations of mice,” *Experientia* 36: 309-311, 1980). Investigators at Battelle Pacific Northwest Laboratories received a contract to perform similar studies (see Phillips, R.D., Anderson, L.B. and Kaune, W.T.: “Biological Effects of High-strength Electric Fields on Small Laboratory Animals,” DOE/TIC-10084, Richland, WA: Pacific Northwest Laboratories, 1979).

1.1. note 4

We reported that powerline electric fields retarded fracture healing (see A.A. Marino, J.M. Cullen, M. Reichmanis and R.O. Becker: “Fracture healing in rats exposed to extremely low frequency electric fields,” *Clin. Orthop*. 145:239-244, 1979; see also A.A. Marino and R.O. Becker.: “Biological effects of extremely low frequency electric and magnetic fields: A review,” *Physiol. Chem. Phys*. 9:131-147, 19). Again, investigators at Battelle received a contract to perform similar studies (see B.J. McClanahan and R.D. Phillips: “The influence of electric field exposure on bone growth and fracture repair in rats,” *Bioelectromagnetics* 411-19, 1993

1.2. Personal Crisis

1.2. note 1

In the 1960s, Dr. Becker worked with Howard Friedman, a psychologist, in an experiment involving the effects of low-frequency magnetic fields on histopathological changes in the central nervous system in rabbits. Following relatively brief exposures, Friedman had observed unusual abnormalities in brain tissue that appeared to be due to the magnetic field. But Friedman also observed the abnormal changes in the brains of the control rabbits, suggesting that the magnetic field was not the causative factor. As I heard the story, Dr. Becker asked Friedman whether the abnormal changes were seen with the same frequency in the exposed and control groups. Upon checking the slides, Friedman concluded that the changes occurred more often in the exposed group. Dr. Becker knew that laboratory rabbits were commonly infected with a virus that, although present, normally did not cause pathological changes. When the rabbit was subjected to stress, however, the ability of the animal's immune system to hold the virus in check was weakened, resulting in the loss of control in some animals, and the consequent increased frequency of pathophysiological changes. This, Becker speculated, was what happened when the rabbits were exposed to the magnetic field, implying that the field was a stressor.

The mechanism of stressors was first proposed by Hans Selye, who described the role of corticoids as the classic biochemical mediator of the body's response to any nonspecific stimulus. Friedman tested Dr. Becker's hypothesis about the role of EMFs in causing stress by determining whether animals exposed to magnetic fields exhibited higher corticoid levels. He found higher levels of corticoids in animals that were exposed to magnetic fields, suggesting that Dr. Becker's theory was correct (see H. Friedman and R.J. Carey: Biomagnetic stressor effects in primates, *Physiol. Behav*. 9:171-173, 1972).

1.2. note 2

R.O. Becker: The bioelectric field pattern in the salamander and its simulation by an electronic analog, *IRE Trans. Med. Electronics* ME-7:202-208, 1960.

The electrical response of human skeletal muscle to passive stretch, *J. Bone Joint Surg.* 42A:1091-1103, 1960.

R.O. Becker: The bioelectric factors in amphibian limb regeneration, *J. Bone Joint Surg.* 43A:643-656, 1961.

R.O. Becker: Search for evidence of axial current flow in peripheral nerves of salamander, *Science* 134:101-102, 1961.

C.A.L. Bassett and R.O. Becker: Generation of electrical potentials by bone in response to mechanical stress, *Science* 137:1063-1064, 1962.

R.O. Becker, C.H. Bockman and W. Slaughter: The longitudinal direct current gradients of spinal

nerves, *Nature* 196:675-676, 1962.

H. Friedman, R.O. Becker and C.H. Bockman: Direct current potentials in hypoanalgesia, *Arch. Gen. Psych*. 7:193-197, 1962.

R.O. Becker: Electron paramagnetic resonance in non-irradiated bone, *Nature* 199:1304-1305, 1963.

H. Friedman, R.O. Becker and C.H. Bockman: Geomagnetic parameters and psychiatric hospital admissions, *Nature* 200:626-628, 1963.

C.A.L. Bassett, R.J. Pawluk and R.O. Becker: Effects of electric current on bone in vivo, *Nature* 204:652-654, 1964.

R.O. Becker and F.M. Brown: Photoelectric effects in human bone, *Nature* 206:1325, 1965.

H. Friedman, R.O. Becker and C.H. Bockman: Psychiatric ward behavior and geophysical parameters, *Nature* 205:1050-1055, 1965.

1.3. Sorting Things Out

1.3. note 1

At the time our laboratory at the Veterans Administration Hospital in Syracuse, New York was closed I was a full-time federal employee, GS-14, which paid quite well. Because I had long since passed my federal probationary period for employment, I had a guaranteed salary, but not a guaranteed job. With the laboratory gone, there was simply no need for a GS-14 research biophysicist at the Hospital. According to the Personnel Department, there were only two other jobs for which I was qualified - janitor and hospital director.

1.3. note 2

A fiduciary is someone who acts on some else's behalf. Power companies are fiduciaries for residents along their rights-of-way because they act on behalf of these residents to protect them from disease caused by powerline EMFs that spread off the right-of-way onto the adjacent property. Consider this analysis on fiduciary responsibility by Justice Cardozzo in a legal proceedings in New York involving the sale of a building.

A broker was hired to sell the building. Through a dummy corporation, the broker himself made an offer of $80,000 and the client accepted. When the corporation resold the property a few weeks later for $87,500, the client suspected hanky-panky and sued. First, Cardozzo pointed to the obvious conflict-of-interest: a broker's duty is to get the highest price, but a buyer's goal is the opposite. The broker claimed that he revealed enough information when he told his client that the corporation was also a client. Not good enough, said Cardozzo, and he laid down the rule regarding disclosure that applies to anyone who owed divided fealty. "If dual interests are to be served, the disclosure to be effective must lay bare the truth, without ambiguity or reservation, in all its stark significance".

1.3. note 3

In December, 1973, Dr. Becker told me about some **classified information** suggesting that powerline electromagnetic fields might affect human health, and he notified the New York Public Service Commission (PSC). In July, 1974 we were both asked by the staff of the PSC to testify in a PSC licensing hearing involving construction of two 765,000-volt powerlines. We both wrote reports (Becker, Marino) explaining the basis of our view that the powerline electromagnetic fields could affect human health, and the PSC sent the reports to the power companies in October, 1974.

The hearing was recessed for a year to allow the power companies to find expert witnesses. The reports of their experts were distributed in November, 1975. At the same time the PSC provided the power companies updated versions of our reports (Becker, Marino).

In 1976 I was cross-examined by the power companies for 10 days, and Dr. Becker was cross-examined for 4 days. The power companies then requested a rebuttal phase of the hearing, and their experts filed additional reports that attacked our reports. By this time Dr. Becker was disgusted with the process, and he withdrew from active participation. I, however, was afraid to withdraw because I thought it would appear that I was admitting that the power-company experts were correct, which was not the case. Consequently, in March, 1976 when they filed reports aimed at rebutting my position, **I filed a report** aimed at rebutting their position. I was cross-examined for 3 additional days.

After the testimony was finished, the lawyers for the power companies and for the Public Service Commission filed legal briefs in an attempt to persuade the PSC Commissioners that powerline EMFs were not a health risk. The **brief of the PSC staff** argued that powerline electromagnetic fields would affect human health, but I thought an even stronger position was warranted. Consequently, representing myself, I submitted a **legal brief**.

A rebuttal phase for briefs was allowed and the power-company lawyers submitted rebuttal briefs. Consequently, I also submitted **rebuttal briefs**.

The hearing examiners wrote a **Recommended Decision** in March, 1978, and the **Final Decision** was issued by the Public Service Commission in June, 1978. That decision led to extensive litigation involving the power companies and the PSC, the upshot of which was denial of permission to build one of the powerlines, the institution of some construction rules to protect the public from exposure to electromagnetic fields from the approved powerline, and the initiation of a research program to assess more precisely whether powerline electromagnetic fields affected human health.

For a recounting of the hearing from my viewpoint see A.A. Marino and J. Ray: Electric Wilderness, San Francisco Press: San Francisco, 1986. For a description of the hearing from another viewpoint, see the Department of Energy report.

1.3. note 4

Watson rose to prominence in the EMF area while working for the Crowell and Moring law firm. He subsequently formed his own law firm, Watson and Ritter. Since the 1970s, which is when I first met him, he has played Inspector Javert to my Jean Valjean in numerous settings, both here and abroad. He is one of the finest lawyers I ever met. He is indefatigably tenacious and consummately professional - he could represent me any time, if I could afford him.

It is difficult to overestimate Watson's importance in the area of EMFs, and the significance of the information that he possesses. At the present stage of legal evolution, most of Watson's activities are probably shielded by attorney-client privilege. If this privilege were overcome, however, either by a judicial limitation on its scope in a particular case, or if one of the exceptions could be proved (for example, that the privilege was invoked for the purpose of concealing fraud) then, I think the information that could be obtained from Watson's file cabinets would shock the American public.

1.4. Changed Purpose

1.4. note 1

If electromagnetic fields affected living systems, there had to be a point in time where the electromagnetic field was converted into the language of biology. When we hear something, for example, the sound does not travel from the ear to the brain. Rather, the sound impinges on specialized cells in the ear and the presence of the acoustic energy causes movement of particular cell processes that result in the opening of ion channels in the cell's membrane that, in turn, alter the membrane potential of the cell, resulting in movement of an electrical signal along a nerve to the brain resulting in the subjective sensation of sound. This pattern is common to the way the body detects each factor in the environment - the body transduces the environmental factor into its own language, and initiates an appropriate response. It must, I thought, also be the case for electromagnetic fields.

1.4. note 2

Which disease? That depends, I think, not only on which component of the immune system was affected by the EMF, but also on other factors present in the subject's environment. Different subjects are exposed to different factors and have different genetic predispositions and should therefore exhibit different diseases or different forms of the same disease. I began my study of the effects of powerline EMFs on the immune system in 1995, and it was the most fantastically successful study in my career.

1.4. note 3

By the 1980s, I had been cross-examined under oath by power company lawyers, including Watson, for many hundreds of hours. Sometimes I was paid. Sometimes I was not paid. But the gist of my testimony was always the same: powerline EMFs can affect human health. Always the power companies took the opposite position. Clearly one of us was wrong. I didn't want the wrong party to be me, and for a while I think I lost sight of the idea that the goal was to define and then find the truth, not simply to sustain my theories. If powerline EMFs are health risks, then an army of Watsons can do no more than delay the inevitable recognition of that fact. Alternatively, if they are not a health risk, then opposing scientists who held that view was equally foolish.

1.5. Congressional Interest

1.5. note 1

To a physicist, it is an incorporeal entity, pure energy, whose physical existence is required by the set of four linear differential equations that explain electricity. It's not possible to have electricity without having fields. On the other hand, it's a lot simpler and easier for the layman to think about electricity as something flowing through wires, cellular telephones, microwave ovens, high-voltage powerlines, or batteries, without resorting to the notion of an EMF.

An intrepid layman who did inquire into the nature of EMFs would have to try to assimilate the fact that there was not one field, but rather two fields - electric and magnetic. Further, sometimes these fields propagated through space with the speed of light, whereas at other times they simply stayed near the hardware that gave rise to them, as in the case of powerline EMFs. Sometimes the two fields could be separated from one another, but in other situations it was essentially impossible to do so.

The notion an EMF is Kafkaesque. It's easy to be afraid of something you understand poorly, but it's hard to be afraid of something you never heard of, and in the 1970s I think the American public had no

meaningful understanding of the reality of electromagnetic fields. That situation changed dramatically during the next 2 decades.

1.5. note 2

Evidence of Congressional suspicion of industry research can be seen in the language contained in the Congressional record, and in an interview given by Congressman Brown, the chief House sponsor of the legislation that eventually led to the NIEHS EMF program

1.5. note 3 (pp. 28-30)

The hearings and the witnesses who participated were: "Electric Powerlines: Health and Public Policy Implications," hearings before the Subcommittee on General Oversight and Investigations, House Interior and Insular Affairs Committee, March 8, 1990. Witnesses:

Allen, Diane, Reporter, WCAU-TV, Philadelphia, PA;

Boeggeman, Charles J., Electric Engineer, Philadelphia Electric Co.;

Carpenter, David O. (Dr.), Dean, University of Albany School of Public Health, representing New York State Powerlines Project;

Cunningham, James M., Senior Vice President, New York Power Authority; also representing Large Public Power Council;

Deason, Jonathan F., Director, Office of Environmental Affairs, Department of Interior;

De Vito, Frank D., Township Committeeman, Middletown, NJ;

Dodge, Christopher H., Specialist in Life Science, Science Policy Research Division, CRS;

Guimond, Richard J., Director, Office of Radiation Programs, EPA;

Larsen, Karen, Senior Analyst, Energy and Materials Program, OTA;

Lee, Jack M., Jr., Environmental Health Specialist, Bonneville Power Administration;

Morgan, M. Granger, Head, Engineering and Public Policy Department, Carnegie Mellon University;

Pallone, Frank, Jr., Rep., D-NJ;

Sagan, Leonard A. (Dr.), Program Manager, EMF Health Studies Program, Electric Power Research Institute;

San Martin, Robert L., Deputy Assistant Secretary, Renewable Energy, DOE;

Siberski, Regina R., Chairperson, Environmental Committee on Radiation, Newton Square, PA.

"Federal Research on Electromagnetic Radiation," hearings before the Subcommittee on Natural Resources, Agriculture Research, and Environment, House Science, Space, and Technology Committee, July 25, 1990. Witnesses:

Adey, W. Ross (Dr.), Associate Chief of Staff, R&D, Pettis Memorial VA Medical Center, Loma Linda, CA;

Cunningham, James M., Senior Vice President, New York Power Authority; also representing Large Public Power Council;

Farland, William H., Director, Office of Health and Environmental Assessment, EPA;

Griesemer, Richard A., Director, Division of Toxicology Research and Testing, NIEHS;

McGraw, David C., Manager, Corporate Environmental Health and Safety, Apple Computer;

Nagel, David C., Vice President, Advanced Technology Group, Apple Computer;

Pallone, Frank, Jr., Rep., D-NJ;

Procaccini, Daniel A., representing Rhode Islanders for Safe Power Association.

Sagan, Leonard A. (Dr.), Program Manager, EMF Studies, Environmental Division, Electric Power Research Institute;

San Martin, Robert L., Deputy Assistant Secretary, Utilities Technology, Office of Conservation and Renewable Energies, DOE;

Sussman, Stanley S., Project Manager, Radiation Studies Program, Environmental Division, EPRI;

Zweiacker, Paul. L., Manager, Environmental Planning, Texas Utilities, representing Edison Electric Institute.

"National Electromagnetic Fields Research and Public Information Dissemination Act," hearings before the Subcommittee on Environment, House Science, Space, and Technology Committee, March 10, 1992. Witnesses:

Anderson, Girard F., President, Tampa Electric Co., representing Edison Electric Institute;

Bergland, Robert, Executive Vice President, National Rural Electric Cooperative Association;

Coughlin, John T., Commissioner, Wisconsin Public Service Commission, representing National Electromagnetic Fields Research Program;

Cunningham, James M., Senior Vice President, New York Power Authority, also representing Large Public Power Council and Empire State Electric Energy Research Corp.;

Davis, J. Michael, Assistant Secretary, Conservation and Renewable Energy, DOE;

Dushaw, James L., Director, Safety and Health Department, International Brotherhood of Electrical Workers;

Florig, H. Keith, Fellow, Center for Risk Management, Resources for the Future;

Haughie, Glenn E. (Dr.)., Corporate Director of Health, International Business Machines Corp, representing VDT Health Research Foundation,

McCarthy, Charles B., Jr., Senior Vice President, Employee, Technology, and Management Services, Southern California Edison Co.;

Morgan, M. Granger, Head, Department of Engineering and Public Policy, Carnegie Mellon University;

Peterson, Ronald C., Nonionizing Radiation Protection Manager, AT&T Bell Laboratories, representing Electromagnetic Energy Policy Alliance;

Richardson, Alan H., Assistant Executive Director, American Public Power Association;

Sussman, Stanley S., Program Manager, Environment Division, Electric Power Research Institute;

Ziemer, Paul L., Assistant Secretary, Environment, Safety, and Health, DOE.

1.5. note 4

Normally when scientific data is used rationally in decisions that affect society, it is done in the context of specific rules and procedures. For example, the law requires the Commissioner of the Food and Drug Administration to determine that a drug is efficacious before it can be sold, and a formal procedure exists whereby a proponent of a drug can determine, in advance, what exactly needs to be done in order to demonstrate that drug is efficacious. The rules constrain the judgment of the decision-makers at FDA and, in particular, they specify what kind of evidence indicates that a drug is, in fact, efficacious.

Federal law regarding the use of pesticides provides another example. The law requires that pesticides be safe and non-injurious to the general population, and the factual determination whether a given pesticide meets the legal requirements is made pursuant to a set of rules and a procedure that are known, in advance, to all participants in the application process.

The Director of the NIEHS, in contrast, was effectively hamstrung because the law required him to determine whether powerline EMFs affect human health, but it provided no methodology or standards by which the Director could make such a judgment. The question simply cannot be answered on the basis of laboratory and epidemiological data and biophysical analysis alone, and these were the only resources potentially available to the Director. These issues are discussed below in detail.

1.6. Why Continue?

1.6. note 1

These rules presently do not exist, and that is why the Director's report to Congress will be unreliable and contentious. The Director lacks the authority to create the rules required to adequately address the issue posed by the law. Only Congress has that authority.

1.7. Tom Watson and the Rules of the Contest

1.8. Ultimate Goals

2. TWO SCIENCES.

2.1. Introduction

2.1. note 1

Cross-examination testimony of Herman Schwan In the Matter of the Application of the Rochester Gas and Electric Corporation and Niagara Mohawk Power Corporation to the State of New York Public Service Commission for a Certificate of Environmental Compatibility and Public Need - Pannell-Road/Sterling-Volney 765 kV Line and South-Oswego/Sterling 115 kV Line (PSC Cases 26559) and the Application of the Power Authority of the State of New York to the State of New York Public Service Commission for a Certificate of Environmental Compatibility and Public Need - Massena-Moses 230 kV Line, Massena-Marcy 765 kV Line and Massena-Quebec 765 kV Line (PSC Case 26529).

2.1. note 2

See for example E.L. Carstensen and E.L Sevier: Biological Effects of Transmission Line Fields, New York, 1987; K. Foster: Weak magnetic fields: cancer connection?, In: *Phantom Risk*, K. Foster, D. Bernstein & P. Huber, Eds., MIT Press, 1993; W.R. Bennett: Cancer and powerlines, *Phys. Today* 47:23-29, 1994; T.S. Tenforde and W.T. Kaune: Interaction of extremely low frequency electric and magnetic fields with humans, *Health Phys.* 53:585-606, 1987; R.K. Adair: Constraints on biological efects of weak extremely-low-frequency electromagnetic fields, *Phys. Rev*. A43:1039-1048, 1991.

Schwan's conclusion seems broadly acceptable to professional physicists. For example, in 1995, the Board of Councillors of the American Physical Society voted 35:1 to issue a press release saying that powerline EMFs do not affect human health. Not all physicists agree with Schwan's calculations and assumptions. There have been many attempts to explicate EMF-induced bioeffects on the basis of different assumptions. See for example A.R. Liboff: Cyclotron resonance in membrane transport, In: *Interactions Between Electromagnetic Fields and Cells*, A. Chiabrera, C. Nicolini and H.P. Schwan, Eds., Plenum, New York, pp. 281-2956, 1985; F.S. Barnes: Extremely low frequently and very low frequency electric fields: Electrification, frequency sensitivity, noise, and related phenomena, In: *CRC Handbook of Biological Effects of Electromagnetic Fields*, C. Polk & E. Postow, Eds., CRC Press, Boca Raton, FL, 1986, pp.122-138; V.V. Lednev: Possible mechanism for influence of weak magnetic fields on biological systems, *Bioelectromagnetics* 12:71-75, 1991; W. Grundler, F. Kaiser, F. Keilmann and J. Walleczek: Mechanism of electromagnetic interaction with cellular systems, *Naturwissenschaften* 79:551-559, 1992; J.P. Blanchard and C.F. Blackman: Clarification and amplification of an ion paramagnetic resonance model for magnetic field interactions with biological systems, Bioelectromagnetics 15:217-238, 1994; J.C. Weaver and R.D. Astumian: Issues related to causality of bioelectromagnetic effects, In: *Electromagnetic Fields: Biological Interactions and Mechanisms*, M. Blank, Ed. American Chemical Society, Washington, DC, 1995, pp. 79-96.

2.2. Scientific Methods

2.2. note 1

See, for example: J. Bogen and J. Woodward: Saving the phenomena, *Phil. Rev*. 97:303-352, 1988; R. Boyd, P. Gasper and J.D. Trout (eds.): *The Philosophy of Science*, Cambridge MA: MIT Press, 1991; N. Cartwright: *How the Laws of Physics Lie*, New York: Oxford University Press, 1983; S. Culp: objectivity in experimental inquiry: Breaking data-technique circles, *Philosphy of Science* 62:438-458, 1995; L. Fleck: *Genesis and Development of the Scientific Fact*, Chicago: University of Chicago Press, 1979; C.G. Hempel: *Philosophy of Natural Science*, Englewood Cliffs, NJ: Prentis-Hall, 1966; T.S. Kuhn: *The Structure of Scientific Revolutions*, 2ndEd., Chicago: University of Chicago Press, 1962; and C.S. Peirce: Collected Papers of Charles Sanders Peirce, Harvard University Press, 1958.

2.2. note 2

To the philosopher, this procedure has no justification whatsoever because representative sampling is not how truth is pursued in philosophy. To the scientist, however, representative sampling is the only justified procedure for choosing individual objects for use as the basis of generalization, and is therefore usually the only acceptable basis for ascertaining truth.

2.2. note 3

What has been summarized and characterized is scientific reasoning deemed by the editors of *Science* to be worthy of publication in *Science*. I chose *Science* as the source of material for analysis of the character of modern scientific reasoning because I thought most readers would agree that the work published there is of the highest scientific quality. A drawback of this choice is that there are valid forms of scientific reasoning not normally represented in *Science* because of the policy of its editors. Consequently the analysis presented here is incomplete, even though it is sufficient for my purpose which is to demonstrate the existence of two main fundamentally different reasoning processes. For example, epidemiological papers are rarely published in *Science*. Epidemiological reasoning does not readily fit into either of the two kinds of scientific reasoning discussed in this section.

As a second example, consider the work of Mendel. He grew pea plants, counted the numbers of cross-breeds that had certain specific characteristics in each generation, and generalized the results to reach his laws. This form of scientific reasoning does not normally appear in *Science* because it is neither deductive nor hypothesis-driven. The point is that there are valid forms of scientific reasoning **in addition to** the forms of scientific reasoning that appear in the pages of *Science*.

2.2. note 4

Table 1

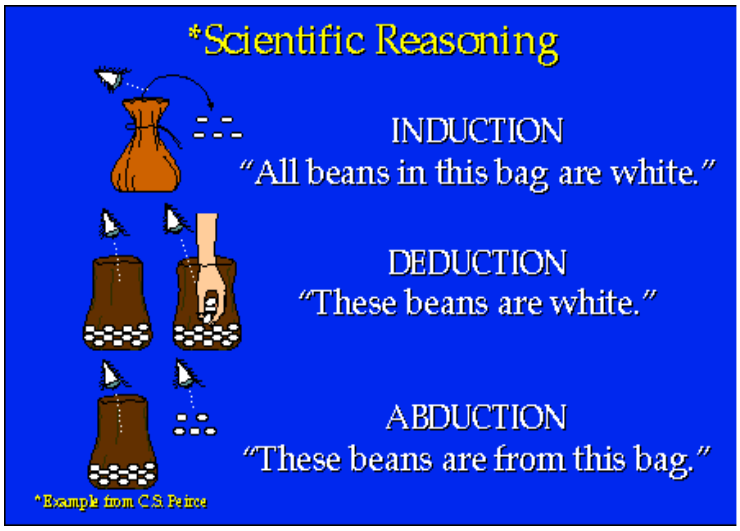
REPORT NO.	MODEL	COVERING LAW	PHENOMENON EXPLAINED
1	1600 atoms 128 polymer chains	Physical theory	Energy dissipation
2	55-256 atoms	Physical theory	Structure and stability of liquids
6	Phosphorus coupling with C, O_2, and Fe	Heuristic rate equations	Stabilization of atmospheric oxygen during the phanerozoic
7	Any non-specific immune process	Heuristic rate equations	Clearance of HIV from the blood
9	Structure of selected proteases; CES	Heuristic parsimony algorithm	Serine protease diversity
REPORT NO.	MODEL	CAUSE	EFFECT
		Increased CDK	Decreased cyclin-E/CDK2

		inhibitors decreased phosphorylation of Thr_{160}	activity
11	A31.C1 cells	Osteopontin	Activation of CD44 receptor
12	10 human subjects	Vigilance	Increased brain blood flow
	CES	Cu^{2+} chelation	Altered cell growth
14	CES	High density lipoprotein	Activation of SR-B1 receptor
15	CES	Products of ALG-2, ALG-3	Apoptosis
16	5 barn owls	Ligation of NMDA receptor	Auditory learning

TABLE 1. The two kinds of scientific reasoning employed in *Science* Issue 5248 were explanations based on the application of a covering law (Reports 1, 2, 6, 7, 9), and proof of cause-effect relationships (Reports 8, 11-16). Because Report No. 9 contained both kinds of reasoning, its classification in this Table is arbitrary. Note that, whether or not consciously, the editor of *Science* grouped the Reports on the basis of the kind of reasoning employed, as evidenced by their order of appearance in the Journal (Report No.). CES, cell expression system. Reports No. 3-5 and 10 involved invention or discovery, but did not utilize formal reasoning processes. They were therefore not considered further. The lines in the last column provide a brief summary of the individual reports. The reports are numbered in the order of their appearance in the Journal.

2.3. Scientific Reasoning

2.3.note 1



Slide 17:

This slide illustrates the 3 types of scientific reasoning (employing an example first used by C.S. Peirce). Physics is a mature science in the sense that the inductive stage is essentially complete. With a few exceptions that are not important here, physicists can explain virtually all physical phenomena on the basis of one or more of 4 forces. Physicists, therefore, employ these forces (along with auxiliary hypotheses) to provide deductive explanations of particular phenomena. However, as the reports in the issue of Science amply demonstrate, biologists almost never reason in that fashion. Instead, they proceed by first demonstrating a cause-and-effect relationship, and then making an abductive argument (clearly recognized by the use of "suggests" or related euphemis

2.3. note 2

An important question exists regarding exactly what should be expected to be replicated in order that the results of the original study might be considered to be verified. Some argue that the original data should be replicated, the relative density of splodges on a gel, for example. It could also be argued, however, that it is the phenomenon itself, not the data, that need be replicated for verification purposes. This issue will be discussed in detail in the section dealing with trade-association science.

2.3. note 3

Table 2

... indicate **...**
... may have been instrumental **...**
... not unreasonable **...**
... results in **...**
... may be one of the mechanisms **...**

... consistent with **...**
... provide direct evidence for **...**
... is the most likely **...**
... is involved in **...**
... raised the possibility **...**
... believed that **...**
... may underlie **...**
... provide insight into **...**
... support a determining role **...**
... orchestrated **...**
... does not readily account for **...**
... showed **...**
... confirmed the role of **...**

TABLE 2. Euphemisms for *suggests* used in Science, Issue 5248.

2.4. Thought-Styles

2.4. note 1

Here, and throughout this report, I use the terms functionally to indicate the kind of reasoning employed, rather than to indicate the subject area of the Ph.D. of a particular expert, or his job title, unless the context specifically indicates otherwise.

3. PHYSICS AND POWERLINE EMF HEALTH HAZARDS.

3.1. Schwan and the Linear Model

3.1. note 1

See H.P. Schwan: Nonionizing radiation hazards, *J. Franklin Inst*. 296:485-497, 1973; H.P. Schwan: Biological Hazards from Exposure to ELF Electrical Fields and Potentials, *Navy Weapons Laboratory Technical Report* TR2713, 1972; H.P. Schwan: Direct testimony, and cross-examination testimony In the Matter of the Application of the Rochester Gas and Electric Corporation and Niagara Mohawk Power Corporation to the State of New York Public Service Commission for a Certificate of Environmental Compatibility and Public Need - Pannell-Road/Sterling-Volney 765 kV Line and South-Oswego/Sterling 115 kV Line (PSC Cases 26559) and the Application of the Power Authority of the State of New York to the State of New York Public Service Commission for a Certificate of Environmental Compatibility and Public Need - Massena-Moses 230 kV Line, Massena-Marcy 765 kV Line and Massena-Quebec 765 kV Line (PSC Case 26529).

3.1. note 2

See for example E.L. Carstensen and E.L Sevier: Biological Effects of Transmission Line Fields, New York, 1987; K. Foster: Weak magnetic fields: cancer connection?, In: *Phantom Risk*, K. Foster, D. Bernstein & P. Huber, Eds., MIT Press, 1993; W.R. Bennett: Cancer and powerlines, *Phys. Today* 47:23-29, 1994; T.S. Tenforde and W.T. Kaune: Interaction of extremely low frequency electric and magnetic fields with humans, *Health Phys.* 53:585-606, 1987; R.K. Adair: Constraints on biological

efects of weak extremely-low-frequency electromagnetic fields, *Phys. Rev.* A43:1039-1048, 1991

3.1. note 3

Technically, this is not accurate. But it is a fair encapsulation of Schwan's overall position. Not even Herman Schwan had the chutzpah to explicitly maintain that he knew that it was impossible that there could exist a physical process that he didn't know anything about. That's why the statement is technically incorrect. But, after conceding this limitation on his knowledge, Schwan's writings are pregnant with the notion that the reader should ignore this consideration and reach the conclusion that EMF bioeffects are impossible because they are impossible as a consequence of the two processes he recognized. Thus, when confronted with effects that didn't fit within the purview of his two processes, he simply denied the data. Why? Because he knew the data could not come about as a result of the two processes that he accepted.

3.1. note 4

Schwan said "the principal support for the postulation of subtle effects is derived from studies which are either incomplete and/or of poor scientific quality. There is no evidence from established biophysical principles suggesting that subtle effects may be caused by or are due to electromagnetic fields or what biological mechanisms might be expected to cause such effects. The studies claiming to have demonstrated subtle effects are further characterized by a lack of proven cause-and-effect relationships and inconsistent experimental results. Additionally assuming that such subtle effects may exist and nothing the extreme difficulty with which they are 'demonstrated', tehre is no basis to substantiate the ocnclusion that any such effects are harmful." Schwan also said: "A good part of the support for the postulation of subtle effects is derived from studies which are either incomplete and/or of poor scientific quality. There is no evidence from established biophysical principles suggesting that subtle effects may be caused by or are due to electromagnetic fields or what biological mechanisms might be expected to cause such effects. Most of the studies claiming to have demonstrated subtle and dangerous effects are further characterized by a lack of proven cause-and-effect relationships and inconsistent experimental results."

For discussion of Schwan's comments about specific investigators and his views regarding the relative worth of studies that do or do not find EMF bioeffects, see Andrew Marino and Joel Ray: The Electric Wilderness, San Francisco Press, San Francisco, CA, 1986, pp. 41-48.

3.1. note 5

See for example A.R. Liboff: Cyclotron resonance in membrane transport, In: *Interactions Between Electromagnetic Fields and Cells*, A. Chiabrera, C. Nicolini and H.P. Schwan, Eds., Plenum, New York, pp. 281-2956, 1985; F.S. Barnes: Extremely low frequently and very low frequency electric fields: Electrification, frequency sensitivity, noise, and related phenomena, In: *CRC Handbook of Biological Effects of Electromagnetic Fields*, C. Polk & E. Postow, Eds., CRC Press, Boca Raton, FL, 1986, pp.122-138; V.V. Lednev: Possible mechanism for influence of weak magnetic fields on biological systems, *Bioelectromagnetics* 12:71-75, 1991; W. Grundler, F. Kaiser, F. Keilmann and J. Walleczek: Mechanism of electromagnetic interaction with cellular systems, *Naturwissenschaften* 79:551-559, 1992; J.P. Blanchard and C.F. Blackman: Clarification and amplification of an ion paramagnetic resonance model for magnetic field interactions with biological systems, Bioelectromagnetics 15:217-238, 1994; J.C. Weaver and R.D. Astumian: Issues related to causality of bioelectromagnetic effects, In: *Electromagnetic Fields: Biological Interactions and Mechanisms*, M. Blank, Ed. American Chemical Society, Washington, DC, 1995, pp. 79-96.

3.2. Nonlinear Interaction Models

3.2. note 1

Figure 1

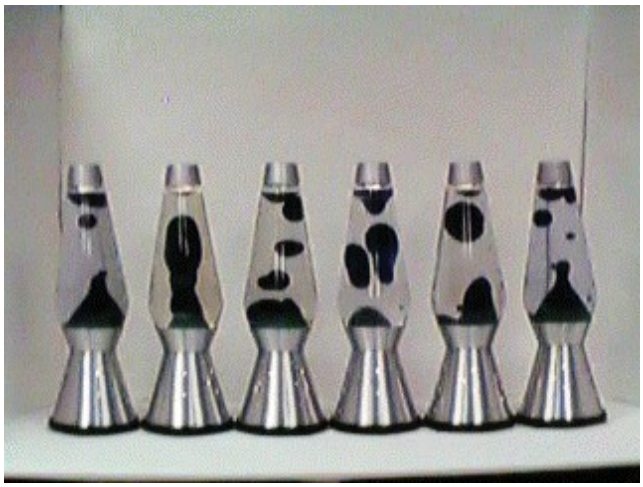


Figure 1: Variability exhibited by identical lava lamps. The lamps were all the same model and were operated under identical conditions insofar as that was possible. Nevertheless, a consistent pattern of lava flow in the different lamps never occurred despite many attempts to produce it. It can be concluded, therefore, that small differences in conditions between the lamps (too small to discern) were capable of dramatically affecting the future behavior of the lamps.

3.2. note 2

How small a difference in initial conditions might be capable of causing an effect? Consider the Lorenz system, a set of nonlinear equations that govern the behavior of weather in the atmosphere. Initial conditions that must be specified in this model include the temperature, humidity, and pressure. Any particular set of initial conditions corresponds to a predicted pattern of change. Differences in initial conditions lead to unpredictability (deterministic chaos) even though the behavior is completely determined. To understand how chaos can result, suppose a description of the weather at a certain time is used, and the subsequent change in relative humidity is calculated. If the calculation is repeated exactly except for a change in the initial temperature of 0.000001?C, after a short time the system evolves along a totally different path (Figure 2).

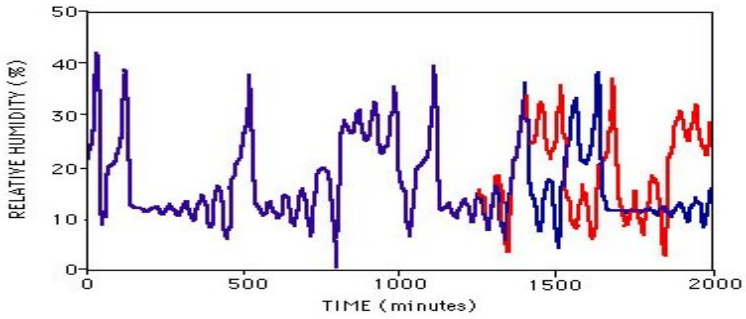


Figure 2: Unpredictability in a deterministic model of the weather. The blue line depicts the relative humidity predicted by the nonlinear model for a given set of conditions. The red line shows the humidity under exactly the same conditions except that the initial temperature was increased by 0.000001?C. The change had no effect on the prediction for about 1300 minutes. Thereafter, the two cases differed markedly, showing that the system could respond to and modify its behavior as a result of changes that would be entirely insignificant under the assumption of a linear model

3.3. Physics and Complexity

3.3. note 1

The edifice of modern physics is a great intellectual achievement of mankind. Based on the work of many scientists, from Bacon and Newton to Einstein and Feynman. It consists of a relatively small number of laws that appear to govern everything that occurs. What this means is that almost no one expects that observations will be made that are inconsistent with these basic laws. That does not mean, however, that the laws can predict everything. Actually, the basic laws predict nothing. It is always the case that they are useful only in conjunction with auxiliary hypotheses and models tailored to make the resulting combination of laws and hypotheses adequate and pertinent to particular observations.

In most cases in the physical world and a few cases in the biological world, the auxiliary hypothesis of linearity is sufficient. In a few cases in the physical world and almost all cases in the biological world the auxiliary hypothesis of nonlinearity is required. In few cases in the physical world and no cases in the biological world, the precise structure of the nonlinear model has been identified.

3.4. Theoretical Limit of the Physics Thought-Style

3.4. note 1

For example, consider a claim by a plaintiff that his chronic myelogenous leukemia was caused by EMFs from a high-voltage powerline on his property. Even if the interaction model were known whereby exposure to powerline EMFs led to CML, it would still not be possible to conclude deductively that the plaintiff's exposure to powerline EMFs caused his cancer because other factors besides powerline EMFs can cause cancer. Only if an expert were permitted to go beyond the deductive reasoning style of physics and reason abductively, could the question be resolved on the basis of evidence and observations (as opposed to a general decisional rule that said, for example, the plaintiff cannot win because an answer from within the physics thought-style is not possible).

3.5. Conclusion

4. BIOLOGY AND POWERLINE EMF HEALTH HAZARDS.

4.1. Introduction

4.2. The Biological Evidence

4.2. note 1

Some have urged that the EMF bioeffects studies on animals cannot properly serve as a basis for

evaluating human health hazards. I think this argument should be rejected entirely. The predicate for the expenditure of a large amount of public funds for EMF bioeffects research has precisely been that the model cellular and animal systems proposed by the investigators for study were biologically relevant and appropriate to support inferences involving consequences for exposed human subjects. Now that the data has been obtained, it simply cannot credibly be maintained that the mode of reasoning in which results from cells and animals are imputed to human subjects is intrinsically faulty.

4.2. note 2 (pp. 38-40)

For citations to the lamb and other melatonin studies, and for many examples of the negative/positive weighing argument, see Clinical and *In Vivo* Laboratory Findings, NIEHS, April 6, 1998, pp. 136-156. For an editorial comment regarding the negative/positive argument see Negative Studies and Common Sense

NEGATIVE STUDIES AND COMMON SENSE

Journal of Bioelectricity, v. 8(1), v-vii (1989)

EDITORIAL

During a recent trial in Florida, Phillip Cole, Chairman of the Department of Epidemiology, University of Alabama, testified regarding health risks due to chronic exposure to powerline electromagnetic fields. There are 19 studies, he said, that reported associations between disease and a surrogate for exposure, but there are 11 studies that did not report such an association. Cole doubted the validity of the positive studies because there were 80 many negative studies. Furthermore, the positive studies were "implausible" because he knew of no reason that electromagnetic fields should cause physiological changes. Consequently, Cole opined, children exposed to powerline fields would not experience increased risk of disease.

Cole's approach dovetails nicely with the position of the national power industry. If negative studies do indeed balance out positive studies, then a convenient trap door exists to escape liability and responsibility for the disease-promoting aspects of their activities. This is one plan: Award a contract to a research-for-hire laboratory or a university professor willing to play ball, and specifically define the desired research. For example, provide that only very old rats shall be studied, thereby minimizing the possibility that specific neuroendocrine variables will exhibit a sustained response to an impressed field. Or, require that the experiment be performed in animal cages 40% smaller than normal. Since both the exposed and control animals will be significantly stressed by confinement, the possibility of observing a stressor response caused by the field will be minimized. Another strategy involves the method of data analysis: Suppose the sponsor requires that the dependent variable exhibit a dose-effect relationship with field intensity as a condition precedent to the acceptance of the occurrence of a field-induced effect. If the dependent parameter is altered (compared to the control) at all field intensities studied, but does not exhibit a linear relationship with intensity, it can be concluded that no effect was observed. Entering into a contract with an inept scientist is another method for bringing about negative studies. Ignorance then becomes a virtue for the sponsor because there is only a minimal possibility that useful information will be obtained. If anyone doubts that this overall strategy actually exists, let him explain the plethora of industry-bankrolled negative studies.

Every worthwhile scientific study is performed to test a hypothesis: The experimental hypothesis relates to the meat-and- potatoes of the study, but it is the statistical hypothesis that is formally tested. This statistical (null) hypothesis asserts that the mean values of the dependent variable in the

experimental and control groups are identical. When this occurs, we conclude that the null hypothesis has not been disproved, and thus that the experiment produced no evidence to indicate that the independent variable affected the dependent variable. This is essentially what is meant by a negative study, and it has been elevated by Cole and his colleagues who speak for the industry to the level of an affirmative finding. But a negative study suggests only that, under the precise conditions and limitations of the experiment, the dependent and independent variables were probably not related. Such a study, however, is utterly silent regarding the relationship of the variables under conditions not studied. As Edwin Carstensen (certainly no friend of those who believe powerlines create health risks) observed during his testimony in New York in 1976, "a negative study may simply mean that the investigator looked for the wrong thing in the wrong place at the wrong time". There is only one small window of relevance for negative studies: If two studies performed under identical conditions reach opposite results, then the true behavior of nature under those conditions is uncertain. But replications are rare; none of the 11 negative studies employed by Cole to undercut the 19 positive studies, for example, could honestly be said to be a replication of a positive study. All 30 studies were different. With this narrow exception, it is clear that negative studies have no probative value - - they do not make any material fact more likely than not of being true. They are simple monuments to failure (whether intentional or otherwise), and do not merit consideration as affirmative data. Texas and Louisiana contain many holes in the ground that yielded no oil. Cole's logic leads to the conclusion that there is no oil, but common sense says that there is no oil in the dry hole-40 feet away, it may be (and frequently is) a different story.

Cole has concluded that there is no truth, and he employs the art of persuasion for the ends he chooses. The good news is that neither the chicanery of a sponsor who seeks to clutter the literature with negative reports, nor the incompetence or avarice of the scientist who cooperates with this effort can actually corrode the structure of science. The careful student of bioelectricity quickly learns to separate poison-pill experiments and sophistry from facts and rational analysis, and to determine which individuals and groups are truly interested in building bioelectricity into a useful and important science, and which are interested in burying the subject under a mountain of innuendo, doubt, and disdain. The bad news is that judges and other generalist laymen, unfamiliar with the concept of the null hypothesis, may be susceptible to the Siren call of the negative study.

Andrew A. Marino

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4.2. note 4

When we hear something, for example, the sound does not travel from the ear to the brain. Rather, the sound impinges on specialized cells in the ear and the presence of the acoustic energy causes movement of particular cell processes that result in the opening of ion channels in the cell's membrane that in turn alter the membrane potential of the cell, resulting in movement of an electrical signal along a nerve to the brain and the subjective sensation of sound. The acoustic energy that impacted cells in the ear did not travel to the brain, it was the subsequently induced electrical signal that propagated. This pattern is common to the way the body reacts to every environmental stimulus - the body changes

the environmental factor into a biological signal that, in turn, leads to some kind of a biological response. The stimulus causes detection, and detection causes the response. Consequently, there can be no response in the absence of detection. The process whereby detection results in a biological signal is typically called *transduction*.

4.3. Possible Bases of Apparent Inconsistency

4.3. note 1

Further, the inference that the study was positive could be rationalized using an appropriate statistical test in conjunction with Hypothesis No. 7 even when **neither** the average alone nor the variance alone were individually sufficient for that purpose. For a discussion of an appropriate statistical test and its rejection regions, see the L test. [see http://www.ortho.lsuhsc.edu/Faculty/Marino/Stat.html

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4.4. Powerline EMFs and Growth Rate

4.4. note 1

A.A. Marino, R.O. Becker & B. Ullrich. The effect of continuous exposure to low frequency electric fields on three generations of mice: a pilot study. *Experientia* 32: 565, 1976; A.A. Marino, M. Reichmanis, R.O. Becker, B. Ullrich & J.M. Cullen. Power frequency electric field induces biological changes in successive generations of mice. *Experientia* 36: 309-311, 1980.

4.4. note 2

TABLE 1. Influence of 60-Hz vertical electric field, 100 kV/m, on development and variance in development in mice. The average value ? SD (in grams) are listed at the indicated number of days after birth. Values of mean weight and standard deviation that differed significantly from the corresponding controls are indicated by an asterisk. N is given in parentheses. See R.D. Phillips, L.B. Anderson and W.T. Kaune: Biological Effects of High-Strength Electric Fields on Small Laboratory Animals, Richland, WA, Pacific Northwest Laboratories. DOE/TIC-10084, Contract E4-76-C-06-1830, 1979. The statistical tests for the mean and variance (here and in Table 2) were the t test and the F test, respectively. These tests were performed by me.

		Day 1	Day 14	Day 28	Day 35	Day 70
		(28)	(28)	(27)	(27)	(26)

		Day 1	Day 14	Day 28	Day 35	Day 70
		(28)	(28)	(27)	(23)	(27)

		Day 1	Day 14	Day 28	Day 35	Day 70
		(30)	(30)	(29)	(29)	(28)

*P < 0.05

4.4. note 3

TABLE 2. Influence of 60-Hz vertical electric field, 100 kV/m, on development and variance in development in mice. The average value ? SD (in grams) are listed at the indicated number of days after birth. Values of mean weight and SD that differed significantly from the corresponding controls are indicated by an asterisk. N is given in parentheses. See R.D. Phillips, L.B. Anderson and W.T. Kaune: Biological Effects of High-Strength Electric Fields on Small Laboratory Animals, Richland, WA, Pacific Northwest Laboratories. DOE/TIC-10084, Contract E4-76-C-06-1830, 1979.

		Day 1	Day 14	Day 28	Day 35	Day 70
		(27)	(27)	(25)	(25)	(24)

		Day 1	Day	Day 28	Day 35	Day 70

				14			
			(30)	(19)	(29)	(29)	(28)

			Day 1	Day 14	Day 28	Day 35	Day 70
			(34)	(34)	(34)	(34)	(34)

*P < 0.05

4.4. note 4

Had it been the case that he interpreted his experiments to show that they were consistent with my experiments, then I think both our careers would have evolved in a substantially different fashion. But that is not what he did. By adding the results of two statistically positive experiments under the aegis of the linear model he could conclude that, overall, his study was negative. The general industry spin was that his experiments refuted my experiments. But, insofar as I am aware, that was never his personal position. I think he personally believed that powerline EMFs caused effects, and that he was truly concerned about the potential health consequences. In a meeting at which Phillips and I were part of a four-man panel, we were asked whether we would live beside a high-voltage powerline, Phillips said that he would not do so.

> The problem with Phillips, I think, is that it never occurred to him that viewing the world exclusively through the lens of the linear model was an error. He was heavily involved in the politics and business of science, and was strongly influenced in EMF matters by William Kaune, an engineer (for whom a consideration of a nonlinear model was hopelessly out of the question). Phillips was simply not in a position to be receptive to a new idea

4.5. Beyond Linear

4.5. note 1

TABLE 3. EMF effects on variance in body weight of mammals. The studies that used low-frequency fields and presented sufficient data to permit analysis are included. The means ? SD are listed; the number of animals is given in parentheses. M, male; F, female. In most of the studies, the average value of the body weight was **chosen** as the basis of comparison. but this need not have been the case because there is no logical or biological requirement that the **average** weight of the exposed animals should be altered as a consequence of powerline EMF exposure as a condition for accepting the conclusion that powerline EMFs were detected by the animal. The **variance** is also an appropriate statistic for assessing whether powerline EMFs were detected by the body, and it is logically as probative of the occurrence of detection as is the average. The statistical tests for the means were t-tests, which were performed by the investigators. The tests for variance (F tests) were performed by me. The F value and the corresponding probability are listed in the last two columns. The rejection

region for F is P < 0.025, which corresponds to a probability of type-1 error of P < 0.05.

REF NO.	SPECIES	EMF	EXPOSURE DURATION		SEX	BODY WEIGHT (gms)			F	P
				Exp. No.		Control		EMF		
1	Pigs	30 kV/m 60 Hz	Conception - birth	1	M	536 ? 74.2 (28)		553 ? 157.5 (56)	b4.50	<0.001
					F	510 ? 91.7 (29)		518 ? 135.0 (56)	b2.16	0.015
				2	M	576 ? 129.2 (29)		532 ? 109.3 (71)	b1.40	0.130
					F	573 ? 123.8 (29)		a488 ? 118.0 (71)	b1.10	0.36
2	Monkeys	2 gauss 20 V/m 72-80 Hz	1 year		M	2290 ? 510 (14)		a3060 ? 470 (14)	1.18	0.39
					F	1290 ? 700 (16)		1260 ? 920 (16)	1.73	0.15
3	Rats	150 kV/m 60 Hz	Conception - 21 days		M	47 ? 6.7 (56)		45 ? 13.7 (58)	b4.18	<0.001
					F	43 ? 8.2 (56)		44 ? 12.9 (58)	b2.47	<0.001

4	Rats	80 kV/m 60 Hz	Conception - weaning	1	M	66.5 ? 31.1 (123)		65.6 ? 35.4 (148)	1.29	0.070
					F	60.8 ? 29.4 (119)		59.4 ? 25.8 (126)	1.30	0.075
				2	M	45.1 ? 27.9 (268)		42.9 ? 40.0 (220)	2.06	<0.001
					F	42.7 ? 20.6 (295)		42.7 ? 31.2 (270)	2.29	<0.001
				3	M	41.7 ? 16.4 (188)		41.9 ? 29.6 (199)	3.25	<0.001
					F	38.9 ? 15.7 (204)		41.3 ? 28.8 (208)	3.36	<0.001
5	Rats	3. kV/m 4. 45 Hz	36 days		M	414 ? 17 (47)		a362 ? 9 (47)	3.57	<0.001
6, 7	Rats	2. kV/m 3. 45 Hz	28 days	1	M	398.5 ? 30.1 (16)		395.9 ? 40.6 (16)	1.82	0.13
				2	M	349.1 ? 29.3 (16)		358.1 ? 25.5	1.32	0.30

				3	M	398.6 ? 34.2 (16)		388.3 ? 21.3 (16)	2.58	0.038

a P < 0.05, compared with control mean

b Contains round-off error due to uncertainty in sample size

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4.5. note 2

Mice in three generations were exposed to powerline EMFs to assess the effect on body weight (1). The F-test was used to compare variances in the exposed and sham-exposed animals. A total of 12 F-tests were performed, corresponding to 2 fields x 3 generations x 2 sexes. The test statistic was that F=s12/s22, where s12 was the largest sample variance in each comparison. The two-tailed rejection region of the F distribution for a single comparison was F > F0.025, which corresponds to a probability for a type-1 error of 0.05. The family-wise error rate was controlled by using the Bonferonni procedure to adjust the comparison-wise error to be 0.05/12=0.0042, which corresponded to a rejection region of F > F0.002. After controlling for the family-wise error in this manner, the occurrence of one or more significant tests with F > F0.002 would have been sufficient justification to accept the hypothesis that the field exposure affected variance. Two such cases were observed. It could be concluded, therefore, that EMF exposure affected variance.

(1) A.A. Marino. Different outcomes in biological experiments involving weak EMFs: Is chaos a

possible explanation? *Am. J. Physiol.* 268 Regulatory Integrative Comp. Physiol. 37: R1013-R1018, 1995.

4.5. note 3

It is possible to view an inconsistent change in body weight in causal terms by reference to a nonlinear model, just as it is possible to view a consistent change in body weight in causal terms by reference to a linear model. How? Let Wi be the weight of the ith animal, and assume that it is absolutely determined by the instantaneous value of the variables xj, j=1, 2, J. Some xj are exogenous, such as temperature, and some are endogenous, such as the level of enzyme X; the xj depend on time and on each other. The ith and kth animals are selected because they are identical with respect to all internal and external factors that affect body weight; the kth animal is exposed to an EMF for time T while the ith animal is maintained in a field-free but otherwise identical region. If EMF exposure caused an increase in enzyme X which, in turn, caused an increase in body weight, we could validly identify the EMF as the cause of the increase in body weight. But the ultimate effect on body weight due to the change in enzyme X induced by the EMF will also depend on the particular combination of values of the j-1 variables other than enzyme X. An identical effect on enzyme X might occur in each of a group of reasonably homogeneous animals exposed to the EMF, but an identical effect on body weight will not necessarily occur because, in general, the animals will differ from one another with regard to the instantaneous value of each non-X variable. Thus, the EMF may increase or decrease body weight, or cause no change at all; such changes may sum to zero in a particular group of animals, but each change biases toward an effect on sample variance. In this manner, by allowing that an animal response is determined by both its outer environment (which can be controlled by the investigator), and its internal environment (which is not well controlled), EMF causality can be reconciled with apparent inconsistency.

4.6. The Nonlinear Model and Consistency of EMF Bioeffects

4.6. note 1

TABLE 4. Proportions of normal living embryos (means ? SE). Approximately 100 embryos in the MEF and in the control group were studied at each laboratory. On the basis of ANOVA, there was a significant difference between the EMF and control groups, F(1,54)=12.09, P=0.001. See Berman, E., Chacon, L., House, D., Koch, B.A., Koch, W.E., Leal, J., Løvtrup, S., Mantiply, E., Martin, A.H., Martucci, G.I., M ild, K.H., Monahan, J.C., Sandström, M., Shamsaifar, K., Tell, R., Trillo, M.A., Ubeda, A. and Wagner, P.: Development of chicken embryos in a pulsed magnetic field, Bioelectromagnetics 11:169-187, 1990.

Principal Investigator	Location	Sham-Exposed	Exposed
A.C. Martin	London, Ontario, Canada	0.936?0.024	0.794?0.024
K.H. Mild	Umeå, Sweden	0.916?0.026	0.874?0.026
J.C. Monahan	Rockville, MD, USA	0.903?0.030	0.778?0.030
J. Leal	Madrid, Spain	0.829?0.041	0.796?0.057

W.E. Koch	Chapel Hill, NC, USA	0.784?0.027	0.785?0.035
G.I. Martucci	Las Vegas, NV, USA	0.730?0.050	0.699?0.044

4.6. note 2

Their results appeared in two publications, and their interpretations were publicized in a third report. See Saffer, J.D. and Thurston, S.J.: Cancer risk and electromagnetic fields, Nature 375:22, 1995; Saffer, J.D. and Thurston, S.J.: Short exposures to 60-Hz magnetic fields do not alter MYC expression or NHL60 or Daudi cells, Radiat. Res. 144:18-25, 1995; Taubes, G.: Another blow weakens the Emf-cancer link, Science 269:1816-1817, 1995.

Saffer and Thurston strongly claimed that EMF exposure produced no effects on transcription, but that was not true because their data showed that variance was affected significantly by the EMFs. $F = 4.95$, $P < 0.05$. For further details see A.A. Marino: Comments on "Short exposures to 60 Hz magnetic fields do not alter MYC expression in HL60 or Daudi cells, Radiat. Res. 145:513-515, 1996.

4.6. note 3

TABLE 5. Mean and standard deviation of percentage Ca2+ released from chick brain tissue slices. See Albert, E.N., Slaby, F., Roche, J. and Loftus, J.: Effect of amplitude-modulated 147 MHz radiofrequency radiation on calcium ion efflux from avian brain tissue, *Radiat. Res.* 109:19-27, 1987. The authors concluded that the EMF had no effect, but this was not true as assessed on the basis of the L test ($L = 28.371$, $P < 0.0005$). The overall effect was due almost equally to an effect of the EMF on variance ($L = 14.314$) and the mean ($L = 14.057$).

Experiment Number	Percentage Ca2+ Released From Tissue Slices In Test Chamber	Percentage Ca2+ Released From Tissue Slices In Control Chamber
1	24.8 ? 3.1	23.0 ? 3.0
2	15.4 ? 2.5	17.4 ? 4.7
3	34.6 ? 2.1	32.2 ? 4.9
4	45.6 ? 3.8	40.1 ? 0.7
5	38.3 ? 5.2	40.7 ? 8.7
6	26.4 ? 3.3	28.3 ? 4.8
7	24.1 ? 2.9	27.5 ? 2.1

P < 0.0005, L test

Studies that reported a positive effect of EMFs on Ca++ include:

Bawin, S.M. and Adey, W.R.: Sensitivity of calcium binding in cerebral tissue to weak environmental electric fields oscillating at low frequency, *Proc. Natl. Acad. Sci*. USA 73:1999-2003, 1976;

Bawin, S.M., Adey, W.R. and Sabbot, I.M.: Ionic factors in release of 45Ca++ from chick cerebral tissue by electromagnetic fields, *Proc. Natl Acad. Sci.* USA 75:6314-6318, 1978;

Blackman, D.F., Elder, J.A., Weil, C.M., Benane, S.G., Eichinger, D.C. and House, D.E.: Induction of calcium ion efflux from brian tissue by radio-frequency radiation: Effects of modulation frequency and field strength, *Radio Sci.* 14(6S):93-98, 1979;

Adey, W.R.: Frequency and power windowing in tissue interactions with weak electromagnetic fields, *Proc. IEEE* 68:119-125, 1980;

Blackman, C.F., Benane, S.H., Elder, J.A., House, D.E., Lampe, J.A. and Faulk, J.M.: Induction of calcium ion efflux from brain tissue by radiofrequency radiation: Effect of sample number and modulation frequency on the power-density window, *Bioelectromagnetics* 1:35-43, 1980;

Blackman, C.F., Benane, S.G., Joines, W.T., Hollis, M.A. and House, D.E.: Calcium ion efflux from brain tissue: Power density versus internal field intensity dependencies at 50 MHz RF radiation, *Bioelectromagnetics* 1:277-283, 1980.

4.6. note 4

TABLE 6. Effect of EMF on human reaction time performance. See Podd, J.V., Whittington, C.J., Barnes, G.R.G., Page, W.H. and Rapley, B.I.: Do ELF magnetic fields affect human reaction time?, *Bioelectromagnetics* 16:317-323, 1995.

	ALL BLOCKS		
	MEAN?SD	F	P
No Field	220.7?13.6	3.2453	0.0316
0.1 Hz	224.3?24.5		
0.1 Hz	224.3?24.5	2.0056	0.1319
0.2 Hz	218.0?17.3		

No Field	220.7?13.6	1.6181	0.2187
0.2 Hz	218.0?17.3		

	BLOCK 1			BLOCK 2			BLOCK 3		
	MEAN?SD	F	P	MEAN?SD	F	P	MEAN?SD	F	P
No Field	219.0?13.4	3.9109	0.0164	220.6?13.9	2.5963	0.0660	225.3?15.3	2.0116	0.1309
0.1 Hz	225.5?26.5			221.3?22.3			223.2?21.7		
0.1 Hz	225.5?26.5	1.4642	0.2688	221.3?22.3	1.6238	0.2170	223.2?21.7	2.8297	0.0493
0.2 Hz	219.9?21.9			217.9?17.5			216.3?12.9		
No Field	219.0?13.4	2.6710	0.0590	220.6?13.9	1.5851	0.2286	225.3?15.3	0.7109	0.7095
0.2 Hz	219.9?21.9			217.9?17.5			216.3?12.9		

	BLOCK 4			BLOCK 5		
	MEAN?SD	F	P	MEAN?SD	F	P
No Field	218.4?12.9	5.2296	0.0054	220.4?13.8	2.6113	0.0632
0.1 Hz	226.4?29.5			225.2?22.3		

0.1 Hz	226.4?29.5	3.4423	0.0258	225.2?22.3	1.5013	0.2557
0.2 Hz	214.7?15.9			221.0?18.2		
No Field	218.4?12.9	1.5192	0.2497	220.4?13.8	1.7393	0.1863
0.2 Hz	214.7?15.9			221.0?18.2		

SHAM-EXPOSURE COMPARISONS			
	MEAN?SD	F	P
Block 1	219.0?13.4	1.0760	0.4527
Block 2	220.6?13.9		
Block 2	220.6?13.9	1.2116	0.3779
Block 3	225.3?15.3		
Block 3	225.3?15.3	0.7109	0.7095
Block 4	218.4?12.9		
Block 4	218.4?12.9	1.1444	0.4135
Block 5	220.4?13.8		

The data was collected in blocks of 30 trials each. When the data was combined, the result was that the 0.1 Hz condition differed from the control, a result that was generally consistent with the result found by Friedman and Becker (see Friedman, H., Becker, R.O. and Bachman, C.H.: Effect of magnetic fields on reaction time performance, Nature 213:949-956, 1967). When the data was analyzed block by block, the implication was the same; of 15 comparisons, 5 were significant at a 5% level, and 7 were significant at a 10% level.

As a positive control I compared the results between different blocks in the no-field condition. No

differences would be expected, and none were found.

4.6. note 5

TABLE 7. Effect of EMFs on operant behavior of rats. See Stern, S., Laties, V.G., Nguyen, Q.A. and Cox, C.: Exposure to combined static and 60-Hz magnetic fields: Failure to replicate a reported behavioral effect, *Bioelectromagnetics* 17:279-292, 1996.

	EXPERIMENT 1								
Behavioral Measure	Condition 1 (0.26 G DC; 0.5 G, 60 Hz)			Condition 2 (0.27 G DC; 0.5 G, 60 Hz)			Condition 3 (0.27 G DC; 0.7 G, 60 Hz)		
DRL (resp/s)	MEAN?SD	F	P	MEAN?SD	F	P	MEAN?SD	F	P
Control	0.066?0.003	1.8595	0.2755	0.065?0.002	16.000	0.0100	0.064?0.003	20.2500	0.0064
EMF	0.066?0.002								
FR (resp/s)									
Control	1.420?0.026	1.0937	0.4665	1.442?0.089	2.2033	0.2315	1.224?0.065	0.8977	0.5404
EMF	1.481?0.027			1.310?0.133			1.265?0.061		
DRL (pellet/min)									
Control	1.045?0.114	110.1537	0.0002	1.102?0.061	2.2950	0.2204	1.202?1.202	1.0324	0.4880
EMF	1.011?0.011			1.107?0.040			1.183?1.183		
	EXPERIMENT 2								

Behavioral Measure	Condition 1 (0.26 G DC; 0.5 G, 60 Hz)			Condition 3 (0.26 G DC; 0.88 G, 60 Hz)		
DRL (resp/s)	MEAN?SD	F	P	MEAN?SD	F	P
Control	0.066?0.0013	1.1736	0.4191	0.061?0.0044	1.7778	0.2509
EMF	0.065?0.0012			0.060?0.0033		
FR (resp/s)						
Control	1.844?0.0212	1.9975	0.1908	1.793?0.0437	6.7662	0.0174
EMF	1.874?0.0150			1.823?0.0168		
DRL (pellet/min)						
Control	1.257?0.0657	15.2937	0.0009	1.374?0.0607	2.5484	0.1399
EMF	1.224?0.0168			1.308?0.0969		

	EXPERIMENT 2		
Behavioral Measure	Condition 2 (0.27 G DC; 0.72 G, 60 Hz)		
DRL (resp/s)	MEAN?SD	F	P
Tuesday	0.071?0.0028	1.2258	0.4055
Friday	0.058?0.0031		

Friday	0.058?0.0031	7.6961	0.0127
Control	0.068?0.0086		
Tuesday	0.071?0.0028	9.4337	0.0076
Control	0.068?0.0086		

	EXPERIMENT 2		
Behavioral Measure	Condition 2 (0.27 G DC; 0.72 G, 60 Hz)		
FR (resp/s)	MEAN?SD	F	P
Tuesday	1.936?0.0030	952.7511	0.0000
Friday	1.923?0.0926		
Friday	1.923?0.0926	7.1785	0.0151
Control	1.812?0.2481		
Tuesday	1.936?0.0030	6839.2900	0.0000
Control	1.812?0.2481		

	EXPERIMENT 2		
Behavioral Measure	Condition 2 (0.27 G DC; 0.72 G, 60 Hz)		
DRL (pellet/min)	MEAN?SD	F	P
Tuesday	1.223?0.0336	11.9189	0.0041

Friday	1.374?0.1160		
Friday	1.374?0.1160	22.6015	0.0007
Control	1.311?0.0244		
Tuesday	1.223?0.0336	1.8963	0.2279
Control	1.311?0.0244		

A reasonable interpretation of the large number of statistically significant comparisons is that they indicate transduction of the EMF resulting in changes in operant behavior. The study was therefore consistent with the earlier study that it was intended to replicate, as determined on the basis of the F test. See Thomas, J.R., Schrot, J. and Liboff, A.R.: Low-intensity magnetic fields alter operant behavior in rats, Bioelectromagnetics 7:349-357, 1986.

4.7. Reproducibility of Nonlinear Phenomena

4.8. Biological Generalizations Generally

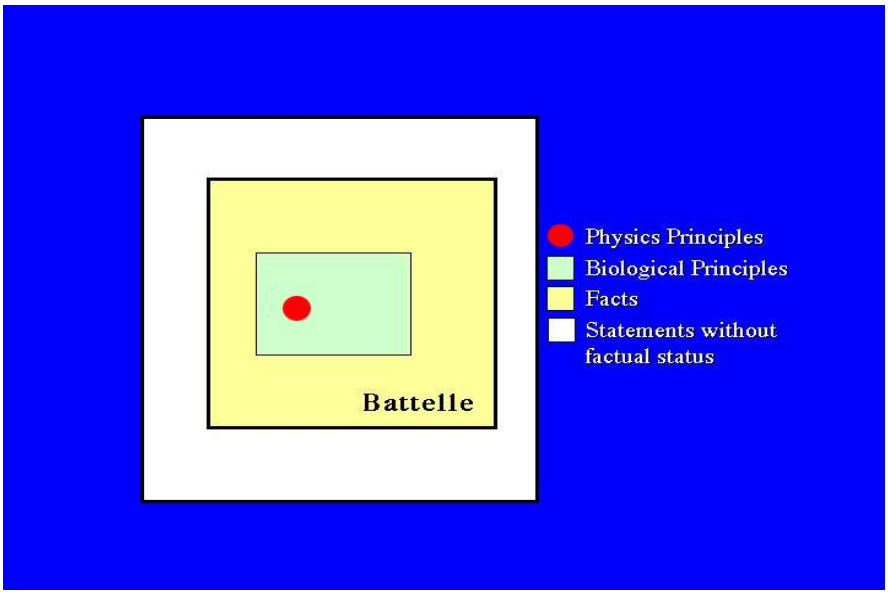
4.8. note 1

The fact that subjective considerations can influence what is accepted as a scientific fact can occur in any area of science, but the point being made here is that it is an important characteristic of biological reasoning, not a minor aspect or an aberration. It **is** what biologists do. Subjectivity is less significant in physics. Disagreements among physicists regarding explanations or behavior of physical systems are rare. Their occurrence, consequently, attracts attention as, for example, the dispute among physicists regarding whether nuclear reactions occurred in a particular apparatus resulting in the production of power via cold fusion. Otherwise, what could be called disputes among physicists are prosaic (the 5th decimal point in the melting point of lead, or the 8th decimal point in the universal gravitational constant) or obscure (the strangeness and color of a yet undiscovered quark).

4.9. The Generalization About Whether Powerline EMFs Affect Human Health

4.9. note 1

Figure 1



4.9. note 2

TABLE 8. The investigators and their designated area of expertise (designated by NIEHS) are:

Larry Anderson, Ph.D., Staff Scientist - Group Manager, Battelle Pacific Northwest National Laboratories (*in vivo* cancer studies);

Gregory Blumenthal, Ph.D., Research Fellow, NIEHS Laboratory of Computational Biology and Risk Analysis (*in vivo* noncancer studies: neuroendocrine);

Joseph Bowman, Ph.D., National Institute of Occupational Safety and Health (epidemiologic studies on occupational exposure);

Elisabeth Cardis, Ph.D., International Agency for Research on Cancer (epidemiologic residential adult studies);

Charles Graham, Ph.D., Senior Advisor for Life Sciences, Midwest Research Institute (clinical human laboratory studies);

Richard Luben, Ph.D., University of California at Riverside (*in vitro* studies, excluding differentiation);

Kenneth McLeod, Ph.D., Associate Professor, SUNY at Stony Brook, Musculo-Skeletal Research Lab (*in vitro* studies: cell differentiation);

Mat-Olof Mattsson, Ph.D., Associate Professor, Dept. of Cellular and Developmental Biology, Umea University, Sweden (molecular biology studies);

James Morris, Ph.D., Staff Scientist, Battelle Pacific Northwest National Laboratories (*in vivo* noncancer studies: immunotoxicity, hematology, reproduction and development);

Charles Polk, Ph.D., Professor Emeritus, Dept. of Electrical and Computer Engineering, University of Rhode Island (theoretical mechanistic studies);

Walter Rogers, Ph.D., Associate Professor of Environmental Science, University of Texas School of Public Health (*in vivo* noncancer studies: neurobiologoy and neurobehavior);

Claire Sherman, Ph.D., Radiation Effects Research Foundation (epidemiologic residential childhood studies);

Michael Yost, Ph.D., University of Washington (exposure characterization studies).

4.9. note 3

Figure 2

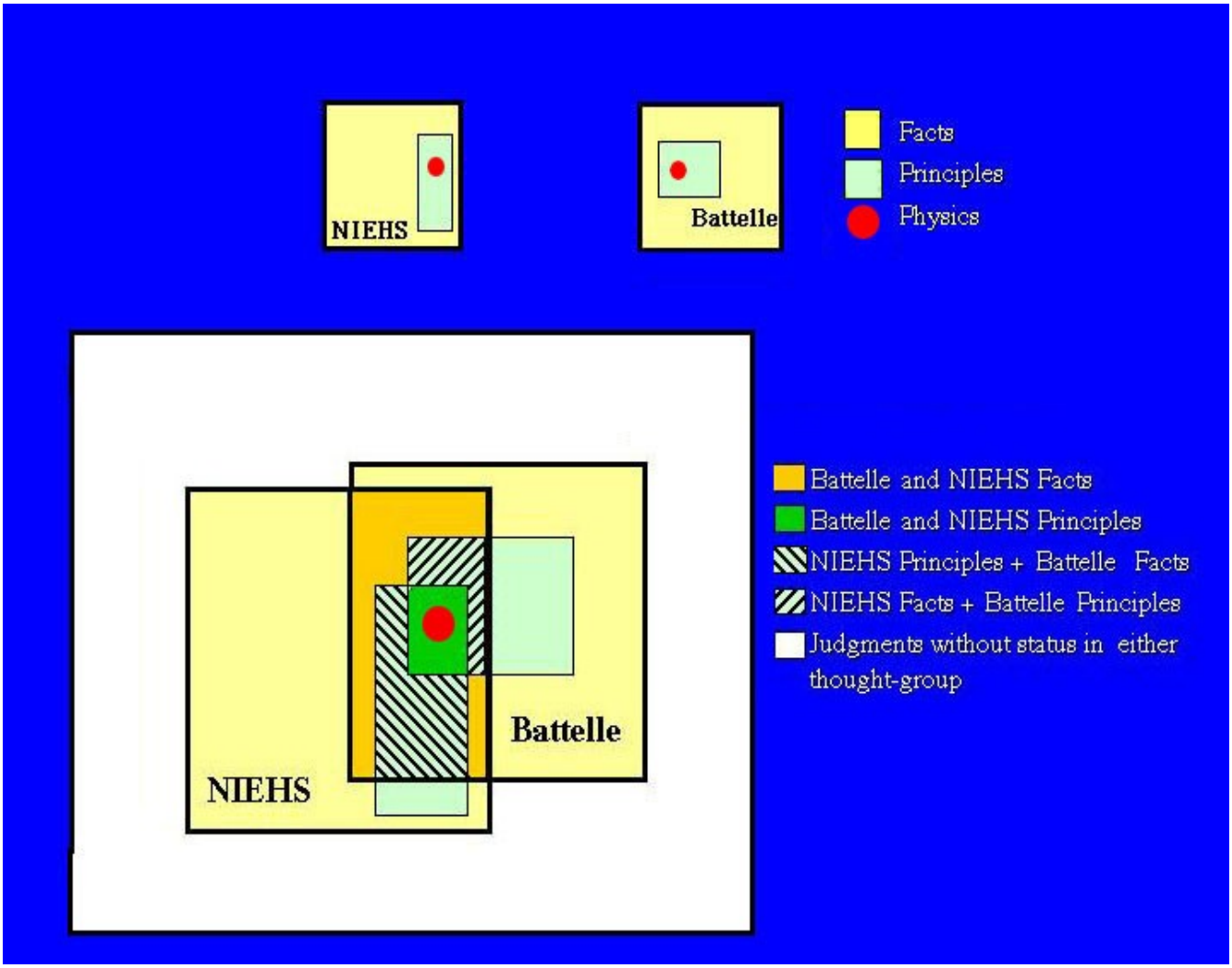


FIGURE 2. The status of scientific knowledge with respect to the Battelle and NIEHS thought-groups. The two groups of investigators differ regarding the principles in which they believe. Consequently, they differ in their respective interpretations of particular experiments, resulting in some disagreements regarding what is or is not a scientific fact.

4.9. note 4

TABLE 9. Scientists who testified under oath regarding their opinion whether powerline EMFs affect human health. The group that represented the Landowners answered the question affirmatively. The group sponsored by Watson on behalf of the power company answered in the negative.

LANDOWNER GROUP	WATSON GROUP
Dr. Harris Busch, Baylor College	Dr. Stuart Aaronson, National

of Medicine, Houston, Texas	Cancer Institute, Bethesda, Maryland
Dr. Andrew Marino, LSU Medical Center, Shreveport, Louisiana	Dr. Richard Bockman, Memorial Sloan-Kettering Cancer Center, New York, New York
Dr. Jerry Phillips, Cancer Therapy and Research Center, San Antonio, Texas	Dr. Roswell Boutwell, University of Wisconsin, Madison, Wisconsin
Dr. Lennart Tomenius, Stockholm, Sweden	Dr. Edmund Egan II, University of Buffalo, Buffalo, New York
	Dr. Lucius Sinks, National Cancer Institute, Bethesda, Maryland
	Dr. Herbert Terrace, Columbia University, New York, New York
	Dr. Margaret Tucker, National Cancer Institute, Bethesda, Maryland
	Dr. Kan Zaner, Harvard Medical School, Cambridge, Massachusetts

4.9. note 5 (pp. 60-73)

Summary Statement from Diagnostic Radiology and Nuclear Medicine Study Section, June, 1979.

SUMMARY STATEMENT

(Privileged Communication)

Application Number:

Dual Review:

Review Group: DIAGNOSTIC RADIOLOGY & NUCLEAR MED. S.S.

Meeting Date: JUNE 1979

Organization: S U N Y AT ALBANY

City, State: ALBANY, N.Y. Requested Start Date: 02/01/80

Project Title: BIOLOGICAL EFFECTS OF LOW-FREQUENCY FIELDS

PROJECT YEAR	DIRECT COSTS REQUESTED	DIRECT COSTS RECOMMENDED	PREVIOUSLY RECOMMENDED	GRANT PERIOD
04	48,626	41,951		
05	50,060	43,724		
06	52,553	45,476		

RESUME: This proposal is to study the health effects of 60 Hz electric and magnetic fields. It proposes to expose three generations of mice to fields of 5 volts/meter, with each generation of mice to fields of 5 volts/meter, with each generation maintained for two years to ascertain long term effects of radiation. Fibular fracture repair will be studied in rats exposed to 10 V/cm fields and 0.1-1.0 gauss fields. It is also proposed to study blood chemistry changes, especially blood steroids, in rabbits and motor activity in mice. The multigenerative mouse studies and fracture repair study are deemed worthy of support. Blood chemistry changes have been studied at Battelle with no significant results, and no rationale is offered for the study of gross motor activity changes at low intensity fields.

DESCRIPTION: The proposal is to continue the investigation of the biological effects of low frequency electric fields (ELF) and magnetic fields. In the first two years, this team has developed appropriate cages and exposure apparatus. They report that at 35 volts/cm, 60 Hz, three generations of mice exhibited altered body weight and increased mortality. At 50 volts/cm experimentally induced fractures healed more slowly than controls. They were unable to find any differences in hematologic or blood chemistry parameters between control rats and rats exposed for 15-30 days to 50 volts/cm. In future work three generations of mice are to be exposed for at least two years to 5 volts/cm fields to determine effects on growth and mortality. Previously developed methodology will be used for study of fibular fracture healing during application of magnetic fields of 0.1-1.0 gauss to rats. This species will also be used to determine synergistic effects of simultaneously applied electric and magnetic fields. Somewhat higher fields of 50 volts/cm are to be used for short term studies of activity or motor performance in mice and changes of blood chemistry in rabbits. Experimental Animals: mice, rats, rabbits.

CRITIQUE: This proposal offers reasonably simple assessments of field interactions, long term in mice, shorter term in rats and rabbits. These simple assessments, if confirmed, would indicate much wider intervention of these fields in biological systems than has been supposed. The major strength of this continuation proposal is the detailed delineation of the observed altered body weights and increased mortality of mice exposed to ELF fields. While there is a real need for chronic, long-term exposure studies of the nature proposed here, there is an equal need for such studies to be placed in a theoretical context so specific hypotheses can be tested. This proposal, with its many different aspects, growth, life span, bone healing, blood chemistry, and gross activity measurements presents not one argument for doing the study nor any hypothesis to be tested. The work to better define the mortality and growth changes seems to be worthy of further support. This portion of the proposal is presented as though the use of multigenerations of mice were important to the observation that mortality and growth alter upon exposure to the ELF fields. This implies a genetic, a maternal-offspring, interaction or a congenital influence. While it is important to understand the thresholds at which these effects occur, once it is confirmed that they do occur, then questions about mechanisms are of equal importance and should be investigated. Regarding the methods of expressing growth curves, usually one uses one of the "constant risk" parodigms giving a curve of the form W0=K1eK2t-K3(t-tR) allowing comparisons of K1 (birth or starting weight), K2 and K3 for several experimental points per animal rather than the 2 time measurements chosen. The fracture healing technique is well founded and gives valuable information. If bone healing occurs as described by Bassett, the exposure parameters of this proposal do not even approximate the parameters Bassett reports as effective. If there is inhibition, as reported in this application, then it is mandatory to confirm the parameters and to investigate the biophysical and biochemical changes responsible for the inhibition. The analysis of circulatory steroids has already been performed at Battelle-Northwest together with catecholamine analysis and the hemoglobin analyses. The Battelle results did not support the authors findings of slight hematopoietic suppression.

In the light of their own negative results with rats as well as those of Dr. Steve Cleary with rabbits, there is serious question as to the utility of these studies. No justification or rationale is given for the motor activity studies of mice.

2/79 RADIATION STUDY SECTION (Ad Hoc)	
REBA, Richard C., M.D., Chairperson *Prof. Of Radiology (Nuclear Medicine)* *George Washington University Hospital* *Washington, D.C. 20037*	*LELE, Padmakar P., M.D.* *Professor of Experimental Medicine* *Department of Mechanical Engineering* *Massachusetts Institute of Technology* *Cambridge, Massachusetts 02139*
BAILY, Norman A., Ph.D. *Professor of Radiology* *University of California, San Diego* *La Jolla, California 92093*	*LODWICK, Gwilym S., M.D.* *Research Professor of Radiology* *University of Missouri* *Columbia, Missouri 65201*
BIRNHOLZ, Jason C., M.D. *Asst. Prof. of Radiology (Harvard)* *Peter Bent Brigham Hospital* *Boston, Massachusetts 02115*	*LOKEN, Merle, M.D.* *Prof. & Director of Nuclear Medicine* *University of Minnesota Hospital* *Minneapolis, Minnesota 55414*
CORRY, Peter, Ph.D. *Assoc. Prof. Of Biophysics* *University of Texas Cancer Center* *Houston, Texas 77030*	*LORDS, James L., Ph.D.* *Professor of Biology* *University of Utah* *Salt Lake City, Utah 84112*
DUNN, Floyd, Ph.D. *Prof. Of Biophysics & Elect. Eng.* *Bioacoustics Research Laboratory* *University of Illinois* *Urbana, Illinois 61801*	*POPP, Richard L., M.D.* *Assoc. Prof. Of Medicine (Cardiology)* *Stanford Medical Center* *Stanford, California 94305*
FISCHER, Harry W., M.D. *Professor & Chairman of Radiology* *University of Rochester* *Rochester, New York 14642*	*SIKOV, Melvin R., Ph.D.* *Research Associate, Biology Department* *Battelle-Pacific Northwest Laboratories* *Richland, Washington, 99352*
FREIMANIS, Atis K. M.D. *Professor & Chairman of Radiology* *The Ohio State University* *Columbus, Ohio 43210*	*SPENCER, Richard P., M.D., Ph.D.* *Prof. & Chrmn. Of Nuclear Medicine* *University of Connecticut*

	Health Center *Farmington, Connecticut 06032*
JOYNER, Claude R., M.D. *Clinical Professor of Medicine* *Allegheny General Hospital* *Pittsburgh, Pennsylvania 15212*	*TER-POGOSSIAN, Micel M., Ph.D.* *Professor of Radiation Physics* *Washington University School of Medicine* *St. Louis, Missouri 63110*
KRICHEFF, Irvin I., M.D. *Professor of Radiology* *New York University* *New York, New York 10016*	*THURSTONE, Frederick L., Ph.D.* *Professor of Biomedical Engineering* *Duke University* *Durham, North Carolina 27706*
KUNDEL, Harold L., M.D. *Professor of Radiology* *Temple University School of Medicine* *Philadelphia, Pennsylvania 19140*	

2. Summary Statement from Diagnostic Radiology Study Section, June, 1982.

SUMMARY STATEMENT

(Privileged Communication)

Application Number:

Dual Review:

Review Group: DIAGNOSTIC RADIOLOGY STUDY SECTION

Meeting Date: JUNE 1982

Organization: LOUISIANA STATE UNIV MED CTR

City, State: SHREVEPORT, LA Requested Start Date: 12/01/82

Project Title: EFFECTS OF 60-HERTZ FIELDS ON SUCCESSIVE GENERATIONS

PROJECT YEAR	DIRECT COSTS REQUESTED	DIRECT COSTS RECOMMENDED	PREVIOUSLY RECOMMENDED	GRANT PERIOD
01	53,098	53,098		
02	43,776	43,776		
03	44,398	44,398		

RESUME: This is a proposal to investigate the growth, development, serum corticoid and

histopathology of three generations of mice exposed to low level 60 Hz magnetic fields of 1 gauss or less and simultaneous electric fields. The results may be useful in assessing biological effects of power fields in the environment. The approaches are relatively straightforward. However, there are a number of methodological questions and uncertainties about the exposure system and the animal protocols, as well as a lack of convincing preliminary data.

DESCRIPTION: The primary purpose of this proposal is to study the effects of electromagnetic fields of 60 Hz frequency on successive generations of mice. The stated significance of these studies lies in the potential hazards of exposure to electric and magnetic fields associated with everyday household electric power, based on reports in the literature of adverse effects on health and the autonomic nervous system and increased mitotic indices in mice in the Soviet Union. Specifically, the investigators propose raising three generations of mice in a 1 gauss magnetic field and comparing the mortality rate, growth rate, serum corticoid level, food and water consumption, and tissue morphology to those parameters in sham exposed groups. Should any positive effects be observed they will repeat the experiments at lower magnetic field levels, 0.4 and 0.1 gauss, until the threshold for the effects is found. Subsequent to completion of the experiments with magnetic fields the investigators plan a series of experiments utilizing simultaneous electric fields at 0.5 kV/m to test for synergistic effects.

The study will involve four sequential activities: analytic design of magnetic-field coils, fabrication of exposure and control units and coils, testing of magnetic field coils, and animal exposure and data collection. The magnetic field will be generated by a pair of 12-inch wide, 400-500 turn coils made from 34-gauge wire. The coils will be mounted on wooden exposure units, which have also incorporated in them aluminum plates to produce vertically polarized electric fields. An identical unit will serve as a control. Ambient temperature and environmental conditions will be measured to insure that no differences exist between the two units. The exposures are to be carried out in specially built racks that are constructed entirely of plastic and glass in order to minimize artifacts that could be induced by the conventional metal mouse-housing racks. Each exposure unit will support 18 cages, each will initially contain two female and one male CUB/ICR mice. However, only one female will be allowed to deliver. The pups will be weighed one day after birth and thereafter at three-day intervals until they are 100 days of age. The mice will be weaned at 21 days of age. Their average food and water consumption from day 21-100 will be measured to help interpret any observed effects on growth. At 100 days of age, 50 m ice randomly selected from the first generation in each group will be mated to produce the second generation. Ten animals of each sex in both the control and exposed groups will be killed for serum corticoid determinations and gross histological evaluation. The remaining animals will be used in a joint study with Dr. Hans-Arne Hannson of Sweden to ascertain any histopathological changes in the brain. The same procedure will be followed for the second and third generations to characterize birth weight, sex ratio, mortality, growth rate, food and water consumption, corticoid level, and histology including the brain in order to determine any hereditary effects. Animals: mice.

CRITIQUE: The proposed studies are feasible and this kind of information should probably be obtained, although the reports from the Soviet Union are often discounted by U.S. scientists on the basis of poor experimental design. The experiments proposed here are straightforward. The procedures are time-consuming but relatively uncomplicated.

This proposal lacks relevant preliminary data although some experiments are mentioned, nor does it include any design principle or specification for the magnetic field coils. The configuration of the cages with respect to the field coils was not mentioned. The design objective of a ?20% magnetic field uniformity within the animal living space is well below state-of-the-art capabilities. Further, using a pair of coils 12 inches on each side they would likely encounter difficulty in attempting to irradiate

uniformly 18 cages sufficient in size to house six mice each. A number of other problems also were noted. For example, no plan was offered to avoid sibling matings; in fact, the methodology of random selection for mating suggests a strong possibility of sibling matings in each generation. Also, it was not explicitly stated whether or not the mice would be exposed during pregnancy. It is stated that analytical studies of magnetic coil design will be conducted by Dr. Hart of the University of the South, Sewanee, Tennessee, and that histopathological examination of the mouse brain will be performed by Dr. Hansson, University of Goteborg, Sweden. However, neither of them has formally committed himself in writing to these tasks, which is considered essential. There is also doubt that any such data obtained in mice could be meaningfully extrapolated to man due to the very large difference in body weight, life span, and gestational and developmental periods between mouse and man.

The investigators claim that in a preliminary experiment with mice they observed effects (unspecified) on body weight and mortality. Yet even casual observation of the North American population, which probably has the highest electromagnetic exposure in the world, indicates that low-frequency EM radiation-induced weight loss does not appear to induce any significant weight loss problem.

DIAGNOSTIC RADIATION STUDY SECTION
June 21-23, 1982
ROSTER

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3. Summary Statement from Radiation Study Section, June, 1998.

SUMMARY STATEMENT

(Privileged Communication)

Review Group: RADIATION STUDY SECTION

Meeting Dates: IRG: JUNE 1998

LSU MEDICAL CENTER SCHOOL OF MED
DEPT OF ORTHOPAEDIC SURGERY
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Project Title: EFFECT OF 60-HZ MAGNETIC FIELDS ON LYMPHOID PHENOTYPE

PROJECT YEAR	DIRECT COSTS REQUESTED
04	151,443
05	150,747
06	155,389
07	160,217
08	163,738
TOTAL	781,534

CRITIQUE 1:

SIGNIFICANCE: One possible scenario by which environmental electromagnetic fields might play a role in the development of a variety of diseases, including cancer, is that EMF exposure might interfere with immune surveillance by inhibiting the activity, differentiation, and/or function of lymphocytes or other cells in the immune system. This project was funded as an initial investigation to determine if specific measurements of immune cell function could support this hypothesis. The current investigation proposes to build upon the findings obtained in the first three years of funding.

APPROACH: This competitive renewal cites six published papers, with one in press and one submitted. The primary data on which the renewal application is based are presented in the application itself. Mice were exposed to EMF at 1000 and 5000 mG for periods of time up to 175 days. Data from male mice only are presented in this application; the data from female mice will not be available until September of 1998. There is no clear pattern of response to EMF in any of the measurements presented. Comparisons between sham and exposed animals show experimental/control ratios close to 1.0 in all cases, with the average change being +/- 10% - 20% or so, with standard deviations ranging from 1-20% in general. The applicant attempts to make a case that statistically, the fact that not every sham/control pair of groups had an experimental/control ratio of precisely 1.0, and that the variances were not consistent, means that there was some response to EMF, even though he cannot concisely describe the nature of the response that occurred. He even develops a new statistical test, which can apparently demonstrate that some of the responses are non-random although the classical T-test or other commonly used tests would not be able to confirm this non-randomness. The novel position is

proposed that it is not the direction of the change that matters in these experiments, but that any deviation from the experimental/control ratio of 1.0 represents a response top EMF, even though the pattern or physiological significance of the response may not be apparent to either the reviewer or the experimenter. This argument impresses study section as sophistry. A far more sober scientific judgment would be that the data show overwhelmingly that even at very high exposures for long periods, there is no consistent or convincing change in the immune function of the exposed animals relative to the sham exposed ones. The applicant proposes essentially to repeat the same set of experiments with somewhat more sophisticated techniques however, there is no specifically testable hypothesis as to the mechanism (or even the direction) of the putative response, no testable experimental predictions (other than the obvious certainty that not every experiment will have an experimental/control ratio of 1.0000), and no coherent explanation of how the results might ultimately help to explain any human disease process. The insistence by the applicant that these data show a pattern of change rather than of non-response is troubling. Although "Occam's razor" may not always be the best approach to data interpretation, in this case it seems clear that the one simplest theory that best explains all the data is that no response has occurred.

INNOVATION: The applicant has developed a new statistical test that purports to show significance in data where the mean deviation is small, the variance is large, and the direction of the change is random. However, this does not appear to help in providing clues to mechanisms or biological significance.

OVERALL EVALUATION: This competing application is based on data obtained in the first three years of funding which are not convincing to study section of any consistent or physiologically significant immune response to EMF. No hypotheses are proposed which plausibly justify further investigation. The refusal of the applicant to recognize that the data are negative makes it very difficult for study section to take seriously any likelihood of future progress in this line of investigation.

CRITIQUE 2:

SIGNIFICANCE: This proposal is designed to examine the effects of MF exposure on a large variety of parameters of immune function. The stated hypothesis is that exposure to environmental EMF can predispose towards disease by causing immunopathological changes via neuroendocrine-mediated mechanisms. The proposal as designed will examine a small component of this hypothesis and thus will have only a minor impact on the field. Additionally, the preliminary data do not adequately support the hypothesis so that confidence in the success of the project is minimal. Finally, the work to be done is broad in scope, and it is not clear from the proposed experiments precisely how the anticipated results will impact the stated hypothesis. While the possible impact of EMF exposure on health issues is important, this proposal as written and designed is not likely to significantly impact that question.

APPROACH: This competitive renewal as designed will address many of the aims in the original application made 3.5 years ago. While there have been several publications related to MF from this group, few if any of them related to this proposal; therefore, it is difficult to assess progress on this application. Much of the preliminary data relate to the establishment of the exposure system and to theoretical expectations from experiments. The data that did relate to the aims of the proposal are shown in Figures 6-10 and Table 1. These data are stated to demonstrate an effect of MEF exposure on various parameters of immune function, but it is not clear how much variation is due to age, circadian rhythm, steroid levels, stress, etc. variations among individual mice and all of these are reported in the literature to affect immune parameters. The differences observed are noted to be statistically significant, but the differences between exposed and controls are so marginal that other factors cannot be ruled out as playing a role. For example, in Table 1 in which IgG1 and IgM serum concentrations are presented (Ig isotypes that are "particularly affected by EMF exposure"), the results are not

consistent with EMF exposed animals showing higher levels in some experiments but not in others for both isotypes. There is no evidence in the proposal or in the previous work from this group that factors known to influence immune parameters (such as those described above) will be appropriately controlled in this study. Because the work as proposed here is to be done in whole animals, these sources of variation may confound the results and lead to inappropriate conclusions regarding the effects of EMF exposure on immune parameters. The preliminary data do not support the hypotheses of the proposal, and there is concern that these investigators may not be able to appropriately interpret the results of their own experiments. The proposal is generally unfocused, examining the effects of EMF on a large number of different immune response parameters. The proposal would have been strengthened by a focus on a few immune parameters showing differences between EMF exposed and controls and studies of mechanisms related to the response. As it is, this proposal is merely a broad study of the effecdt of EMF exposure on every immune parameter that may be related to health issues-NK cells, T-cells, immunoglobulin levels, steroid levels, etc. One would have expected that the initial funding period would have provided some focus for the future work of the grant. It is also not clear why the particular parameters to be studied have been included here since they did not appear to be related to each other-the relationship of NK cells, corticosteroid levels, circulating serum Ig levels, T-cell surface marker expression, and T-cell cytotoxicity in the context of this proposal is not apparent from the proposal itself.

INNOVATION: The experimental design and assays to be conducted are straightforward and standard. These do not reflect any innovation in approach and are not likely to contribute conceptually new designs to the literature. The hypothesis around which these experiments are defined is also not unique in the literature. The breadth of the hypothesis and experimental scope establish that the experiments as defined are not likely to contribute important new data to the field. Rather, it is likely that these results will establish some marginally significant effects which may result from animal variation but will be attributed to EMF exposure and thus confuse the field of study even further.

OVERALL EVALUATION: This is a competitive renewal application that is broad in scope and is not likely to contribute innovative or important information to the literature. The experiments as designed are not focused on a single theme, and the relationship among the various aims is not clearly stated. In addition, past progress on this application has been limited and thus there are concerns about the future direction of the work.

CRITIQUE 3:

There are three problems with this research application:

Lack of PUBLICATIONS. Any grant will require a start-up period, but the publications listed in the application cannot fairly be ascribed to this grant.

PAPERS: Of the listed 8 papers, none can are within the scope of the specific aims of the original research proposal. Moreover, the first four papers listed (appearing in journals in 1995 and 1996) could not have plausibly been reporting results on research which got underway in November 1995. Amazingly, co-investigators Drs. Wolcott and Chervenak, who appear as co-investigators both on the original and renewal application, appear as co-authors in NONE of the 8 papers listed.

ABSTRACTS: Of the listed 8 abstracts, only two appear to deal with the subject matter of the original research proposal. Co-investigators Drs. Wolcott and Chervenak, who also appear as co-investigators on the renewal application, appear as co-authors in only TWO of the 8 abstracts listed, and never as first authors.

Lack of progress regarding development of NEW HYPOTHESES:

Even with overall negative results, the investigators could have come up with some better ideas than EMF-immune interactions are more complex than previously supposed. The question here is whether the investigative team should be given additional funds in order to make sense of apparently inconsistent data by torturing them to fit a hypothesized nonlinear model. If they did not observe a dose-response, this should be handwriting on the wall that some new ideas are needed.

The rationale, biological meaning of, and usefulness of the cornerstone data analysis method, the non-linear model, is never made clear.

One has difficult understanding the logic of the non-linear approach. That is, the investigators state that in nonlinear modeling, a response may seem erratic, and nevertheless be completely deterministic (p.22). However, it is never made clear how the responses reported are ascertained to be deterministic rather than random. The investigators go even further and assert that the pattern of inconsistency observed in the studies by other laboratories of the immune system might be integrated under a non-linear model where an infinitesimally small input can produce dynamic changes (p. 23). This type of reasoning seems to lead to the conclusion that anything is possible, which lacks any helpful content. It's the very nature of homeostasis that stabilizes the function of organ systems against the perturbations of small changes. Why would this biologically robust principle be overturned when considering the action of EMF on the immune system?

The investigators postulate that the immune system is very complex and may be responding to several hidden variables in addition to the EMF exposure. However, they fail to explore the potential complexity of the EMF exposure metric itself. Why are the frequencies, amplitudes, vector directions, combinations with the earths field, the polarization state, duration of exposures, etc., that characterize their EMF relevant to the immune system?

This reviewer found the data presented in Figures 6, 7, and 8 impossible to interpret in a meaningful way. There are many examples, where, in comparison to control values, the ratio, M=1.0,and the error bar extends far beyond the M=1.0 level, yet the mean (M) is designated as being statistically different from 1.0 (i.e., a difference between control and exposed). In fact, the investigators acknowledge that the L test produces statistically significant differences where none is apparent in the data. Yet the biological relevance of such a finding is never made clear. How can the hypothesis of a complex pattern of changes ever be disproved? Did the investigators check what pattern of changes results from sham-sham exposures?

The exposure system appears to be well designed and well characterized in terms of stray fields, the geomagnetic field, and the applied magnetic field exposure. However, the system does not appear to use double-would coils that would allow active-sham exposures with applied current being identical between field-on and field-off conditions. Such active sham coils are a necessary component of a good double-blind protocol. Even though it is stated that data were analyzed in a blinded fashion, this is not the same as having the experimental procedures blinded as to active or sham exposures.

The proposed experiments appear to be more of the same e.g., changes in lymphoid phenotype a seemingly scattershot collection of imprecise and uncritical questions. The analysis of changes and effects in the context of a post-hoc, non-specific, non-linear model seems to be terribly unfocused. The lack of well formulated hypotheses diminishes enthusiasm for the proposed work.

Radiation Study Section
Oncological Sciences Initial Review Group

CENTER FOR SCIENTIFIC REVIEW
RAD
June 15, 1998 June 17, 1998

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4.10. Rendering Unto Caesar

4.10 note 1

Each of us in our daily lives makes myriad decisions on the basis of incomplete and less-than-conclusive evidence. The legislators, executives, and judges whose decisions shape our society do the same. It would be amazing, I think, if most people expected that the evidence regarding powerline EMFs and human health should be conclusive or near conclusive, while accepting evidence that is far less than conclusive in decision-making generally, as well as in decision-making that specifically utilizes scientific data.

As examples, evaluation of the efficacy of drugs and medical devices, the safety of drinking water, the utility of mammographic screening, the risk from pesticides, the side-effects of drugs, the link between cigarettes and cancer, and the role of cholesterol in heart disease are typically based on 95% studies and an evaluation of the significance of the studies according to a standard that is far less than conclusive. There is no rational reason to treat a putative link between EMFs and health effects differently from the other cases where decisions are made in the public interest using scientific data. Whatever the rules are for using scientific data to make judgments that affect society generally, I think it should be the case that there is only one set of rules, and not different rules when different issues arise or where different parties are interested in the outcome.

4.11. The Proper Choice

4.11. note 1

Occurrence of **detection** of EMF by biological systems is **necessary** to support a conclusion that powerline EMFs affect human health. If it is not also sufficient, what else is needed? There are three possibilities: (1) additional scientific evidence; (2) standardized rules for evaluating the evidence in

relationship to the conclusion; (3) consideration of the economic, political, and sociological circumstances within which human subjects are presently exposed to powerline EMFs. I think it is incumbent upon those who deny the sufficiency of detection to come forward with a prescription or analysis regarding what **ought** to be required in addition to the present evidence so as to provide sufficiency. If additional scientific evidence is needed, what sort of evidence? How is the evidence to be evaluated? With what degree of certainty: should decisions be made by scientists and simply adopted or ratified by Congress or the courts?

4.11. note 2

The prohibition is against **involuntary** human experimentation, not against human experimentation in general. If it were the case, for example, that the pertinent research funded by the Electric Power Research Institute were honestly done and openly disclosed, then the members of the public who chose to do so could assess their risks and make whatever decision regarding exposure seemed best. On the other hand, exposure is effectively involuntary when it comes about as a result of fraud or deceit regarding the possible adverse consequences, which I think is now the case. It is not the EMF exposure that should be prohibited, but rather its involuntariness.

5. EPIDEMIOLOGY AND POWERLINE EMF HEALTH HAZARDS.

5.1. Introduction

5.1. note 1

The first evidence that I can recall that prompted Dr. Becker to suspect that powerline EMFs could affect human health was the information that he received at a blue-ribbon committee meeting in December, 1973 in Washington, DC. Prior to that time I do not think he realized the potential problem, nor the relationship of the research then being performed in our laboratory to that problem. Dr. Becker reasoned that if environmental EMFs were a health risk, then there ought to be evidence of such an impact among the general population. He therefore conducted an epidemiological study aimed at directly assessing this question. See R.O. Becker: Microwave radiation, New York State J. Med. 77:2172, 1977. Dr. Becker's report was the first to link environmental EMFs with cancer. Some months earlier, Milton Zaret published a report in the same journal that linked occupational exposure to EMFs and cancer. See M. Zaret, Potential hazards of Hertzian radiation and tumors, New York State J. Med. 77:146, 1977.

The process whereby scientific reasoning regarding potential health risks begins with animal studies and then seeks confirmation in epidemiologic studies simply seemed natural to Dr. Becker. But as the EMF dispute grew, the relative importance of epidemiological and laboratory data itself became a contentious issue. Some epidemiologists argued that EMFs don't affect human health because the epidemiological studies were equivocal or otherwise not reliable. The gist of their argument seemed to be that highly reliable epidemiological studies were **possible**, and were **needed** to sustain a conclusion that powerline EMFs affect human health.

5.2. Clinical Study Standards: Randomization

5.2. note 1

Typically, in EMF epidemiological studies, no direct information was provided indicating that the two study groups were not comparable. It is simply expected that this will be the case, because the groups

were not chosen using randomization. Occasionally, however, investigators collected information that explicitly showed the non-comparability of the groups. For example, in a study involving powerline EMFs and acute non-lymphocytic leukemia, the EMF and control groups differed with regard to the percentage of smokers, non-whites, and poor people. See R.K. Severson, R.G. Stevens, W.T. Kaune, D.B. Thomas, L. Heuser, S. Davis and L.E. Server: *Am. J. Epidemiol*. 128: 10, 1988. In a study of the link between powerline EMFs and acute lymphoblastic leukemia in children, a difference in economic status was reported. See M. Linet, E. Hotch, R.A. Kleinerman, L.L. Robison, W.T. Kaune, D.R. Friedman, R.K. Severson, C.M. Haines, C.T. Hartsock, S. Niwa, S. Wacholder and R.E. Tarone: Residential exposure to magnetic fields and acute lymphoblastic leukemia in children, *N. Eng. J. Med*. 337:1, 1997.

How can the absence of randomization perhaps explain finding an association? David Savitz, an epidemiologist at the University of North Carolina, reported in 1988 that exposure to powerline EMFs was associated with an increased risk of leukemia and brain cancer in children. The controls in that study were identified at random, based on telephone numbers. Charles Poole, a statistician at Boston University, theorized that the control group was defective because poor people were unlikely to have telephones. When Poole parsed Savitz's data, Poole found associations indicating that his theory might be valid. If so, this would suggest that something other than EMFs might have resulted in the observed increase in risk for cancer. See D. Taubes: Epidemiology faces its limits, *Science* 269:164-169, 1995.

5.2. note 2

Many things can affect human judgment, including emotion and bias. For example, Marcia Angell, editor of the New England Journal of Medicine, has an opinion about the magnitude of a potential public-health risk that must be shown before she will accept a report of the work for publication in her journal. "As a general rule of thumb", says Angell of the New England Journal, "we are looking for a relative risk of 3 or more (before accepting a paper for publication), particularly if it is biologically implausible or if it's a brand-new finding." See D. Taubes: Epidemiology faces its limits, *Science* 269:164-169, 1995. Angell is an outspoken critic of suggestions that man-made or environmental factors cause disease. For example, she appeared on talk shows and strongly opposed suggestions that ruptured breast implants cause disease. In spite her general view that risks greater than 3 are needed for publication, she published an article involving powerline EMFs where the risks found were less than 3. See M. Linet, E. Hotch, R.A. Kleinerman, L.L. Robison, W.T. Kaune, D.R. Friedman, R.K. Severson, C.M. Haines, C.T. Hartsock, S. Niwa, S. Wacholder and R.E. Tarone: Residential exposure to magnetic fields and acute lymphoblastic leukemia in children, *N. Eng. J. Med.* 337:1-7, 1997. One possible explanation for why Angell disregarded her general rule and published the study is that Linet and her colleagues adopted an interpretation of the data that was consistent with Angell's general philosophy (Linet and her colleagues concluded that their evidence provided "little evidence" that would suggest that powerline EMFs affect human health). This explanation is supported by the fact that another editor of the New England Journal editorialized emotionally in support of a definitive interpretation of the Linet study showing that powerlines are safe ("it is sad that several hundreds of millions of dollars have gone into studies that never had much promise of finding a way to prevent the tragedy of cancer in children." See E.W. Campion: Powerlines, cancer, and fear, *N. Eng. J. Med*. 337:44-46, 1997).

5.3. Other Clinical Study Standards

5.4. EMF Epidemiological Studies

5.5. Absence of Hypotheses in EMF Epidemiological Studies

5.5. note 1

With the exception of occupational exposure, no other surrogate for deciding who was or was not exposed to EMFs has been discovered. The codes first appeared in N. Wertheimer and E. Leeper: Am. J. Epidemiol. 109:273, 1979. The validity of the individual WL codes was never established, but when grouped (end pole + OLCC = Control; OHCC + VHCC = EMF) they were shown to code for EMF exposure in all 4 studies in which the issue was considered.

			EMF RESIDENCES	CONTROL RESIDENCES
1	Denver, CO	Median	1.6 (N=190)	0.5 (N=227)
2	Denver, CO	Mean	1.3 (N=100)	0.6 (N=334)
		Median	1.0 (N=100)	0.4 (N=334)
3	Seattle, WA	Mean	1.4 (N=13)	0.5 (N=26)
4	Los Angeles, CA	Mean	0.9 (N=326)	0.6 (N=345)
		Median	0.8 (N=326)	0.5 (N=345)

1. N. Wertheimer and E. Leeper: Int. J. Epidemiol. 11:345, 1982.
2. D.A. Savitz, H. Wachtel, F.A. Barnes, E.H. John, J.G. Tvdik: Am. J. Epidemiol. 128:21, 1988.
3. W.T. Kaune, R.G. Stevens, N.J. Kallahan, R.K. Severson and D.B. Thomas: Bioelectromagnetics 8:315, 1987.
4. S.J. London, D.C. Thomas, J.D. Bowman, E. Sobel, T.C. Cheng and J.N. Peters: Am. J. Epidemiol. 134:923,

5.5. note 2

Next study: N. Wertheimer and E. Leeper: Int. J. Epidemiol. 11;345, 1982.

Subsequent study: R.K. Severson, R.G. Stevens, W.T. Kaune, D.B. Thomas, L. Heuser, S. Davis and L.E. Sever: Am. J. Epidemiol. 128:10, 1988.

Rhode Island study: J.T. Fulton, S. Cobb, L. Prevle, L. Leone and E. Forman: Am. J. Epidemiol. 111:292, 1980.

Los Angeles Study: S.J. London, et al.: Am. J. Epidemiol. 134:923, 1991.

Stockholm, Sweden: L. Tomenius: Bioelectromagnetics 7:191, 1986.

Series of studies:

1. J.H. Youngson, A.D. Clayden, A. Myers and R.A. Cartwright: Br. J. Cancer 63:977, 1991.

2. M.P. Coleman, C.M. Bell, H.L. Taylor, M. Primic-Zakelj: Br. J. Cancer 60:793, 1989.

3. S. Bastuji-Garin, S. Richardson, R. Zittoun: Eur. J. Cancer 26:1119, 1990.

4. N. Pearce, J. Reif, J. Fraser: Int. J. Epidemiol. 18:55, 1989.

5. M.E. McDowall: Lancet i:246, 1983.

6. D. Loomis: Br. J. Indust. Med. 47:633, 1990.

7. R.S. Lin, P.C. Dischinger, J. Conde, K.P. Farrell: J. Occup. Med. 26:413, 1985.

8. M.A. Spears, J.G. Dobbins, V.S. Miller: Am. J. Ind. Med. 13:629, 1988.

Another English study: M.P. Coleman, C.M. Bell, H.L. Taylor, M. Primic-Zakelj: Br. J. Cancer 60:793, 1989.

5.6. Misclassification

5.7. Epidemiological Criteria for Causal Association

5.8. Koch and Hill

5.8. note 1

One need only consider the pig-headed refusal of R.A. Fisher to recognize the link between cigarette smoking and lung cancer to see that even a brilliant person can adopt subjective criteria for recognizing cause-effect relationships that result in the exclusion of recognition of such a relationship even when the epidemiological data is as strong as it gets. Considering the Fisher example, it is easy to see how some could adopt criteria of causality that effectively excluded cause-effect relationships in EMF epidemiology. See P.D. Stolley: When genius errs: R.A. Fisher and the lung cancer controversy, Am. J. Epidemiol. 133:416-425, 1991

5.9. Conclusion

5.9. note 1

The focus here is on cause-effect relationships in the context of EMF epidemiological studies. The issue, however, is only a part of the larger issue facing epidemiologists, namely how should epidemiological studies be designed and conducted?

Greenland, S.: Invited commentary on "Causes", *Am. J. Epidemiol*. 141:89, 1995.

Rothman, K.J.: Causes, *Am. J. Epidemiol*. 104:587-592, 1976.

MacMahon, B. and Pugh, T.F.: “Causes and entities of disease.” In: Clark, D.W. and MacMahon, B., Eds. *Preventive Medicine*. Boston, MA: Little, Brown, and Company, 1967, pp. 11-18.

Lewis, D.: “Causation,” *J. Philos*. 70:556-567, 1973.

Miettinen, O.S.: “Causal and preventive interdependence: Elementary principles,” *Scand. J. Work Environ. Health* 8:159-168, 1982.

Robins, J.M. and Greenland, S.: “The noidentifiability of direct and indirect effects in epidemiologic studies,” *Epidemiology* 3:143-155, 1992.

Koopman, J.S.: “Interaction between discrete causes,” *Am. J. Epidemiol*. 113:716-724, 1981.

Winkelstein, W. Jr.: “Invited commentary on 'Judgment and causal inference: Criteria in epidemiologic studies',” *Am. J. Epidemiol*. 141:699-700, 1995.

Susser, M.: “Judgment and causal inference: Criteria in epidemiologic studies,” *Am. J. Epidemio*l. 105:1-15, 1977.

Susser, M.: “Judgment and causal inference: Criteria in epidemiologic studies.” In: Greenland, S., Ed. *Evolution of Epidemiologic Ideas*. Chestnut Hill, MA: Epidmeiology Resources, Inc., 1987, pp. 68-83.

Susser, M.: *Causal thinking in the health sciences*. New York: Oxford University Press, 1973.

Yerushalmy, J. and Palmer, C.E.: “On the methdology of investigations of etiologic factors in chronic disease,” *J. Chronic Dis.* 10:27-40, 1959.

5.9. note 2

One need only consider the pig-headed refusal of R.A. Fisher to recognize the link between cigarette smoking and lung cancer to see that even a brilliant person can adopt subjective criteria for recognizing cause-effect relationships that result in the exclusion of recognition of such a relationship even when the epidemiological data is as strong as it gets. Considering the Fisher example, it is easy to see how some could adopt criteria of causality that effectively excluded cause-effect relationships in EMF epidemiology. See P.D. Stolley: When genius errs: R.A. Fisher and the lung cancer controversy, *Am. J. Epidemiol*. 133:416-425, 1991

5.9. note 3

Peter Hamill, one of the authors of the 1964 Surgeon General's report, said this regarding the epidemiologic criteria: "The most important point is that we propounded and articulated these criteria de novo during the progress of our deliberations. At the time, we did not consider them hewn in stone or intended for all time and all occasions, but as a formal description of how we drew our most important epidemiologic conclusions from the totality of tobacco-related materials extant."

Hill made no secret of where he got the causal criteria. "In fact, Hill's 1965 paper contained only one reference regarding causal criteria, namely the report of the advisory committee." See P. Hamill: Invited commentary: Response to Science article, "Epidemiology faces its limits", *Am. J. Epidemiol*. 146:527, 1997.

5.9. note 4

Not only EMF epidemiological studies are controversial for lack of standards. See the review of 56 areas with contradictory epidemiological data where the authors concluded "We suggest that much of the disagreement may occur because a set of rigorous scientific principles has not yet been accepted to guide the design or interpretation of case-control research." (L.C. Mayes, R.I. Horwitz and A.R. Feinstein: “A collection of 56 topics with contradictory results in case-control research,” *Int. J. Epidemiol*. 17:680-685, 1988.)

6. BLUE-RIBBON COMMITTEES AND POWERLINE EMF HEALTH HAZARDS.

6.1. EMF Blue-Ribbon Committees

6.1. note 1

The committee members were: Dr. William T. Ham, Jr., Chairman, Department of Biophysics, Virginia Commonwealth University, Richmond, VA (Chairman); Dr. Robert O. Becker, Department of Surgery, Veterans Administration Hospital, Syracuse, NY; Dr. Mark De Santis, Department of Anatomy, Georgetown University Medical & Dental Schools, Washington, DC; Dr. Don R. Justesen, Director, Neuropsychology Research Laboratory, Veterans Administration Hospital, Kansas City, MO; Dr. Guenther Stotzky, Biology Department, New York University, New York, NY; Dr. Karl D. Straub, Veterans Administration Hospital, Little Rock, AR; Dr. Charles Walcott, Department, State University of New York (SUNY), Stony Brook, NY.

The final report of the 1973 Navy committee was: Proceedings of the Ad Hoc Committee for the Review of Biomedical and Ecological Effects of ELF Radiation, Bureau of Medicine and Surgery, Department of the Navy, December 6-7, 1973.

6.1. note 2

The committee members were: J. Woodland Hastings, The Biological Laboratories, Harvard University, Cambridge, MA (Chairman); W. Ross Adey, Department of Anatomy, School of Medicine, Univeristy of California, Los Angeles; Vincent G. Dethier, Department of Zoology, University of Massachusetts, Amherst; Thomas S. Ely, Health, Safety, and Human Factors Laboratory, Eastman Kodak Company, Rochester, NY; Wilford R. Gardner, Department of Soil Science, University of Wisconsin, Madison; Leon Gordis, Department of Epidemiology, Johns Hopkins School of Hygiene and Public Health, Baltimore, MD; Elizabeth F. Loftus, Department of Psychology, University of Washington, Seattle; sol M. Michaelson, Department of Radiation Biology and Biophysics, School of Medicine and Dentistry, The University of Rochester, Rochester, NY; Morton W. Miller, Department of Radiation Biology and Biophysics, School of Medicine and Dentistry, The University of Rochester, Rochester, NY; Donald W. Novotny, Department of Electrical and Computer Engineering, University of Wisconsin, Madison; William G. Reeder, Department of Zoology, University of Wisconsin, Madison; William J. Schull, Center for Demographic and Population Genetics, Graduate School of Biomedical Sciences, University of Texas, Houston; Herman P. Schwan, Department of Bioengineering, University of Pennsylvania, Philadelphia; Harold B. Tukey, Jr., Department of Floriculture and Ornamental Horticulture, Cornell University, Ithaca, NY; George M. Wilkening, Environmental Health and Safety Department, Bell Laboratories, Murray Hill, NJ; Tai T. Wu, Gordon McKay Laboratory of Applied Science, Harvard University, Cambridge, MA.

The final report of the 1976 NAS committee was: Biological Effects of Electric and Magnetic Fields Associated with Proposed Project Seafarer, Report of the Committee on Biosphere Effects of Extremely-Low-Frequency Radiation, Division of Medical Sciences, Assembly of Life Sciences, National Research Council, National Academy of Sciences, Washington, DC, 1977.

The National Academy of Sciences has some of the most prestigious scientists in the United States as members. Election to the NAS is considered very prestigious, yet such an honor is essentially ceremonial because NAS itself has few important functions. The National Research Council (NRC) is the operating arm of the NAS, and actually carries out its scientific and political functions. The NAS president is the head of the NRC. It is the NRC, with its large staff and facilities, which is the

significant source of the president's clout. When NAS gives a scientific opinion about this or that, the job has actually been carried out by the NRC, or more precisely by a committee appointed by the NRC president. Members of such ad hoc committees need not be, and usually are not members of the NAS. The theory is that the best people are supposed to be chosen for the particular task, regardless of whether they happen to be NAS members.

6.1. note 3

The committee members were: H.B. Graves, Departments of Biology & Poultry Science, The Pennsylvania State University, University Park, PA (Chairman); Larry E. Anderson, Bioelectromagnetic Section, Battelle Northwest, Richland, WA; Neil Chernoff, Developmental Biology Division, Health Effects Research Laboratory, Environmental Protection Agency, Research Triangle Park, NC; W.T. Kaune, Biology Department, Battelle Northwest Richland, WA; Robert Lindberg, Laboratory of Biomedical & Environmental Sciences, University of California-Los Angeles, Los Angeles, CA; David Savitz, Department of Preventive Medicine & Biometrics, University of Colorado School of Medicine, Denver, CO; Asher Sheppard, J.L. Pettis Veterans Administration Hospital, Loma Linda, CA; Ralph Smialowicz, Developmental Biology Division, Health Effects Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, NC; Mays Swicord, Electromagnetic Radiation Branch, Division of Life Sciences, Food and Drug Administration, Rockville, MD; Thomas S. Tenforde, Biology & Medicine Division, Lawrence Berkeley Laboratory, Berkeley, CA.

The final report of the 1984 AIBS committee was: Biological and Human Health Effects of Extremely Low Frequency Electromagnetic Fields: Post-1977 Literature Review, Report of the Committee on Biological and human Health Effects of Extremely Low Frequency Electromagnetic Fields, American Institute of Biological Sciences, Arlington, VA, March, 1985.

6.1. note 4

The committee members were: Dr. M. Repacholi, Royal Adelaide Hospital, Adelaide, South Australia (Chairman); Dr. A. Sheppard, J.L. Pettis Memorial Hospital, Loma Linda, CA (Rapporteur); Dr. J. Bonnell, Central Electricity Generating Board, London, England; Dr. B. Bosnjakovic, Ministry of Housing, Physical Planning, and Environment, Rijswijk, The Netherlands; Dr. J. Cabanes, Medical Committee, Electricité de France Gaz de France, Paris, France; Dr. M. Grandolfo, Laboratoary of Radiation, Institute of Public Health, Rome, Italy; Dr. B. Knave, Research Department, National Board of Occupational Safety and Health, Solna, Sweden; Dr. J. Kupfer, Occupational Hygiene Standardization, Central Institute of Occupational Medicine, Berlin, German Democratic Republic (Vice-Chairman); Dr. R. Phillips, Biology Department, Pacific Northwest Laboratory, Richland, WA; Dr. A. Portela, Institute of Biophysical Research, National Council of Scientific and Technical Research (CONICET), Buenos Aires, Argentina.

The final report of the 1984 WHO committee was: Environmental Health Criteria 35: Extremely Low Frequency (ELF) Fields, World Health Organization, Geneva, 1984

6.1. note 5

The press release was approved by 97% of the members of the Council of the American Physical Society that were present and voting. The members of the Council were: C. Kumar N. Patel, University of California, Los Angeles, CA (President); Robert Schrieffer, Florida State University, National High Magnetic Field Lab, Tallahassee, FL; D. Allan Bromley, Write Nuclear Structure Laboratory, Yale University, New Haven, CT; Burton Richter, Linear Accelerator Center, Stanford University, Stanford,

CA; Judy R. Franz, American Physical Society, College Park, MD; Harry Lustig, American Physical Society, College Park, MD; Benjamin Baderson, Department of Physics, New York Univeristy, New York, NY; James S. Langer, Institute for Theoretical Physics, University of California, Santa Barbara, CA; David Bodansky, Department of Physics, University of Washington, Seattle, WA; CONDENSED MATTER PHYSICS: Allen M. Goldman, Department of Physics, University of Minnesota, Minneapolis, MN; Shirley Jackson, Department of Physics, Rutgers University, Piscataway, NJ; Lu J. Sham, Institute of Pure & Applied Physical Science, University of California, San Diego, CA; Joe Thompson, Los Alamos National Laboratory, Los Alamos, NM; CHEMICAL PHYSICS: R. Stephen Berry, Department of Chemistry, University of Chicago, Chicago, IL; FLUID DYNAMICS: Guenter Ahlers, Department of Physics, University of California, Santa Barbara, CA; HIGH POLYMER: Andrew J. Lovinger, AT&T Bell Laboratories, Murray Hill, NJ; MATERIALS PHYSICS: Bill R. Appleton, Oak Ridge National Laboratory, Oak Ridge, TN; NUCLEAR PHYSICS: Steven E. Koonin, California Institute of Technology, Pasadena, CA; Peter Paul, Department of Physics, SUNY, Stony Brook, NY; PHYSICS OF BEAMS: Andrew Sessler, Lawrence Berkeley Laboratory, Berkeley, CA; PARTICLES & FIELDS: Henry J. Frisch, University of Chicago, Chicago, IL; Anne Kernan, Department of Physics, University of California, Riverside, CA; PLASMA PHYSICS: Roy Gould, Caltech, Pasadena, CA; PHYSICS & SOCIETY: Barbara Lefi, Physics Today, Santa Barbara, CA; Albert Wattenberg, Department of Physics, University of Illinois, Urbana, IL; Ernest M. Henley, Department of Physics, University of Washington, Seattle, WA; EDUCATION: James J. Wynne, IBM, T.J. Watson Research Center, Yorktown Hts., NY; GENERAL COUNCILLORS: Kevin Aylesworth, Cambridge, MA; Arthur Bienenstock, Stanford Synchrotron Radiation Lab, Stanford, CA; Virginia R. Brown, Lawrence Livermore National Laboratory, Livermore, CA; Jolie A. cizewski, Department of Physics & Astronomy, Rutgers University, Piscataway, NJ; Jennifer Cohen, Shippensburg, PA; Charles B. Duke, Xerox Webster Research Center, Webster, NY; Elsa Garmine, Center for Laser Studies, University of Southern California, Los Angeles, CA; Jerry P. Gollub, Department of Physics, Haverford College, Haverford, PA; Larua H. Greene, Loomis Laboratory, University of Illinois, Urbana, IL; William Happer, Physics Department, Princeton University, Princeton, NJ; Wick C. Haxton, Department of Physics, University of Washington, Seattle, WA; Anthony M. Johnson, Department of Physics, NJ Institute of Technology, Newark, NJ; Miles Klein, Loomis Laboratory, University of Illinois, Urbana, IL; Zachary Levine, Gaithersburg, MD; Barbara A. Wilson, Jet Propulsion Laboratory, Pasadena, CA; ATOMIC, MOLECULAR & OPTICAL PHYSICS: Joseph L. Dehmer, Argonne National Laboratory, Argonne, IL; Gordon Dunn, University of Colorado, Boulder, CO; ASTROPHYSICS: Frank C. Jones, Lab for High Energy Astrophysics, NASA Goddard Space Flight Center, Greenbelt, MD; BIOLOGICAL PHYSICS: Watt W. Webb, School of Applied & Engineering Physics, Cornell University, Ithaca, NY.

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Statement by the Council of the American Physical Society

April 1995

POWER LINE FIELDS AND PUBLIC HEALTH

Physicists are frequently asked to comment on the potential dangers of cancer from electromagnetic fields that emanate from common power lines and electrical appliances. While recognizing that the connection between power line fields and cancer is an area of continuing study by research workers in many disciplines in the United States and abroad, we believe that it is possible to make several observations based on the scientific evidence at this time. We also believe that, in the interest of making the best use of the finite resources available for environmental research and mitigation, it is important for professional organizations to comment on this issue.

The scientific literature and the reports of reviews by other panels show no consistent, significant link between cancer and power line fields. This literature includes epidemiological studies, research on biological systems, and analyses of theoretical interaction mechanisms. No plausible biophysical mechanisms for the systematic initiation or promotion of cancer by these power line fields have been identified. Furthermore, the preponderance of the epidemiological and biophysical/biological research findings have failed to substantiate those studies which have reported specific adverse health effects from exposure to such fields. While it is impossible to prove that no deleterious health effects occur from exposure to any environmental factor, it is necessary to demonstrate a consistent, significant, and causal relationship before one can conclude that such effects do occur. From this standpoint, the conjectures relating cancer to power line fields have not been scientifically substantiated.

These unsubstantiated claims, however, have generated fears of power lines in some communities, leading to expensive mitigation efforts, and, in some case, to lengthy and divisive court proceedings. The costs of mitigation and litigation relating to the power line-cancer connection have risen into the billions of dollars and threaten to go much higher. The diversion of these resources to eliminate a threat which has no persuasive scientific basis is disturbing to us. More serious environmental problems are neglected for lack of funding and public attention, and the burden of cost placed on the American public is incommensurate with the risk, if any.

SERVICE TO SCIENCE AND HUMANITY since 1899. The American Physical Society is a non-profit scientific and educational organization devoted to the advancement and diffusion of the knowledge of physics. It is the principal membership organization of physicists in the United States, with over 43,000 members in Academia, industry and government.

6.1. note 6

The friends of the court were: Robert K. Adair, Professor of Physics, Yale University; Nicolaas Bloembergen, Nobel laureate in Physics, Professor Emeritus of Physics, Harvard University; David Bodansky, Professor Emeritus of Physics, University of Washington; Allan Cormack, Nobel laureate, Professor emeritus, Tufts University; Walter Gilbert, Nobel laureate (Chemistry), Professor of Biology, Harvard University; Sheldon Lee Glashow, Nobel laureate, Professor of Physics, Harvard University; David Hafemeister, Professor of Physics, California Polytechnic State University; James H. Merritt, Colonel, United States Army; John E. Moulder, Professor of Radiation Oncology, Medical College of Wisconsin; Robert L. Park, Professor of Physics, University of Maryland; Robert V. Pound, Professor of Physics (emeritus), Harvard University; Glenn T. Seaborg, Nobel laureate, Professor Emeritus of Chemistry, University of California, Rosalyin Yalow, Nobel laureate, Professor-at-Large, Mount Sinai School of Medicine; Richard Wilson, Professor of Physics, Harvard University.

The friends-of-the-court were organized by Richard Wilson. Their impact on the judges in the case is hard to discern. San Diego Gas & Electric issued a press release that described the opinion of the physicists, and particularly the role of the Nobel laureates.

6.1. note 7

The committee members were: Charles F. Stevens, Howard Hughes Medical Institute, Salk Institute, La Jolla, CA (Chair); David A. Savitz, Department of Epidemiology, University of North Carolina, Chapel Hill, NC; Larry E. Anderson, Pacific Northwest National Laboratory, Richland, WA; Daniel A. Driscoll, Department of Public Service, State of New York, Albany, NY; Fred H. Gage, Laboratory of Genetics, Salk Institute, San Diego, CA; Richard L. Garwin, IBM Research Division, T.J. Watson Research Division, Yorktown Heights, NY; Lynn W. Jelinski, Center for Advanced Technology-Biotechnology, Cornell University, Ithaca, NY; Bruce J. Kelman, Golder Associates, Inc., Redmond, WA; Richard A. Luben, Division of Biomedical Sciences, University of California, Riverside, CA; Russel J. Reiter, Department of Cellular and Structural Biology, University of Texas Health Sciences Center, San Antonio, TX; Paul Slovic, Decision Research, Eugene, OR; Jan A. Stolwijk, Department of Epidemiology and Public Health, Yale University School of Medicine, New Haven, CT; Maria A. Stuchly, Department of Electrical and Computer Engineering, University of Victoria, B.C., Canada; Daniel Wartenberg, UMDNJ-Robert Wood Johnson, Medical School, Piscataway, NJ; John S. Waugh, Department of Chemistry, Massachusetts Institute of Technology, Cambridge, MA; Jerry R. Williams, The Johns Hopkins Oncology Center, Baltimore, MD.

The final report of the 1997 NAS committee was: Possible Health Effects of Exposure to Residential Electric and Magnetic Fields, National Academy Press, Washington, DC, 1997

6.1. note 8

The members of the final 1998 NIEHS Working Group were: L.E. Anderson, Research Scientist, Battelle, Pacific Northwest, Richland, WA; J.D. Bowman, Research Industrial Hygienist, National Institute for Occupation Safety and Health, Taft Laboratories, Cincinnati, OH; A.L. Brown, Emeritus Dean and Professor, University of Wisconsin at Madison, Department of Pathology and Laboratory Medicine, Madison, WI; E. Cardis, Chief, Unit of Radiation and Cancer, International Agency for Research on Cancer, Lyon, France; F.M. Dietrich, Principal Engineer, Electric Research and Management, Pittsburgh, PA; M.L. Dubocovich, Professor, Northwestern University Medical School, Department of Molecular Pharmacology and Biological Chemistry, Chicago, IL; J.S. Felton, Division Leader, Molecular and Structural Biology Division, University of California, Biology and Biotechnology Research Program, Lawrence Livermore National Laboratory, Livermore, CA; M. Feychting, Epidemiologist, Institute of Environmental Medicine, Karolinska Institute, Division of Epidemiology, Stockholm, Sweden; P.C. Gailey, Director, Electric and Magnetic Fields Bioeffects Research Program, Oak Ridge National Laboratory, Energy Division, Oak Ridge, TN; M.A. Gallo, Director and Professor, NIEHS Center of Excellence, UMDNJ-Robert Wood Johnson Medical School, Department of Environmental and Community Medicine, Piscataway, NJ (Chair); C. Graham, Senior Advisor for Life Sciences, Midwest Research Institute, Department of Life Sciences, Kansas City, MOI; G.J. Harry, Neurotoxicology Group Leader, National Institute of Environmental Health Services, Laboratory of Toxicology, Research Triangle Park, NC; L.I. Kheifets, Senior Scientist, EPRI, Los Altos Hills, CA; R.A. Luben, Associate Dean for Research, University of California at Riverside, Department of Biomedical Sciences, Riverside, CA; M.-O. Mattsson, Associate Professor, Umeä University, Department of Cellular and Developmental Biology, Umeä, Sweden; K.J. McLeod, Associate Professor, State University of New York at Stony Brook, Department of Orthopaedics, Stony Brook, NY; S.C. Miller, Director, Signal Transduction Program, SRI International, Pharmaceutical Discovery Division, Menlo Park, CA; M. Misakian, Physicist, National Institute of Standards and Technology, Gaithersburg, MD; C. Polk, Professor Emeritus, University of Rhode Island, Department of Electrical and Computer Engineering, Kingston, RI; C.J. Portier, Chief, Laboratory of

Computational Biology and Risk Analysis and Coordinator, EMF Hazard Evaluation, national Institute of Environmental Health Sciences, Research Triangle Park, NC; W.R. Rogers, Associate Professor of Environmental Sciences, University of Texas School of Public Health, Department of Family Practice, San Antonio, TX; A. Sastre, Principal Scientist, Midwest Research Institute, Health Assessment and Research Center, Kansas City, MO; C.D. Sherman, Assistant Professor, San Francisco State University, Department of Mathematics, San Francisco, CA; L.E. Slesin, Editor, Microwave News, New York, NY; R.G. Stevens, Staff Scientist, Battelle, Pacific Northwest National Laboratory, Department of Molecular Biosciences, Richland, WA; L. Tomatis, Scientific Director, Istituto Per L'Infanzia, Trieste, Italy; D. Wartenberg, Associate Professor, EOHSI UMDNJ-Robert Wood Johnson Medical School, Department of Environmental and Community Medicine, J.R. Williams, Professor of Oncology, Johns Hopkins University, Department of Radiation Oncology, Baltimore, MD; H. Yamasaki, Chief, Unit of Multistage Carcinogenesis, International Agency for Research on Cancer, Lyon, France; M.G. Yost, Associate Professor, University of Washington, Department of Environmental Health, Seattle, WA; P.L. Zweiacker, Environmental Permitting Manager, Texas Utilities Services, Dallas, TX.

The report of the Working Group was: Assessment of Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields, Christopher J. Portier and Mary S. Wolfe, Eds., National Institute of Environmental Health Sciences, Research Triangle Park, NC, 1998.

6.2. The Appointment Process

6.3. Qualifications

6.4. The Politics of Appointment to EMF Blue-Ribbon Committees: A Case Study

6.4. note 1

Morton Miller, a botanist said "it is my considered professional opinion that the current state of the art with respect to the potential of adverse biological effects from the electric and magnetic field associated with the proposed transmission line is adequate to ensure the public that there will be no unreasonable risks to health or safety or harm to the environment as a result of electric and magnetic fields resulting from the operation of these lines."

Solomon Michaelson, a veterinarian, said "there is no demonstrable biological effect which may be hazardous to health or safety or to the general biological environment as a result of the presence of the proposed line's electric and magnetic fields."

Herman Schwan said "it is my firm conclusion that exposure to the proposed line's electric and magnetic fields will not be harmful or unsafe."

I asked the NRC staff how they determined that their experts were unbiased and qualified, but they told me that the NRC never released any information except for final reports. Thus, how they evaluated the potential problem of bias and how they ascertained expertise was to be their secret. At that point I learned, for the first time, that the NRC is not covered by the Freedom-of-Information laws, even though NAS is a corporation chartered by Congress.

The NRC consistently refused to provide information to anyone regarding the activities of the EMF

committee, for example, during his testimony in the New York hearing on behalf of the power companies, Morton Miller said that he had been given "three feet" of scientific material by the NAS in connection with his role on the committee. Alfred Kahn, chairman of the Public Service Commission, wrote to Handler requesting the material. But the NRC told Kahn that they would not provide the material. Dr. Becker thought that Handler's decision was contemptuous. He told the Sanguine Committee in a letter that it was completely inappropriate for the NRC to refuse scientific information to government officials who needed it to make good decisions in the public interest

6.4. note 2 (pp. 85-87)

TO: The National Research Council: Samuel Abramson, Staff Officer, Committee to Assess the Biological and Ecological Impact of Project Seafarer: J. W. Hastings, Chairman.

FROM: Andrew A. Marino, Ph.D., and Robert O. Becker, M.D., Veterans Administration Hospital, and Upstate Medical Center, Syracuse, New York.

We hereby submit the following information and comments, for the record, in lieu of a personal appearance before the Committee to Assess the Biological and Ecological Impact of Project Seafarer (committee). We regret that the procedures adopted by the committee, and our lack of personal resources, do not permit an appearance or a more detailed presentation.

COMPOSITION OF THE COMMITTEE

The committee is composed of approximately 16 members, 13 have no connection with Sanguine/Seafarer (S/S) in particular, or with the field of extremely low frequency (ELF) biological effects in general. The remaining 3 members, Dr. Morton Miller, Dr. Herman Schwan and Dr. Sol Michaelson, have worked or written in the ELF area, and Miller and Schwan have performed S/S research for the Navy.

Miller, Schwan and Michaelson have submitted testimony to the New York State Public Service Commission in connection with high voltage transmission lines. The transmission lines have a frequency and magnetic field comparable to the proposed S/S system, and an electric field that is roughly ten million times stronger than the proposed S/S system.

Miller has stated:

"..it is my considered professional opinion that the current state of the art with respect to the potential of adverse biological effects from the electric and magnetic fields associated with the proposed transmission lines is adequate to insure the public that there will be no unreasonable risks to health or safety or harm to the environment as a result of electric and magnetic fields resulting from the operation of these lines." (1, at pg. 23).

Most of the experimental research conducted by individuals in the academic community for S/S has demonstrated a biological effect associated with the S/S fields (2). Miller is an exception. By letter dated March 9, 1976, directed to the chairman of the committee, we urged that Dr. Eugene Goodman and/or Dr. William Southern, who belong to the larger group of investigators described above, be appointed to the committee for balance. We regret that our recommendation was not favorably considered.

Schwan has stated:

"It is my firm conclusion that exposure to the proposed lines' electric and magnetic fields will not be harmful or unsafe." (3, at pg. 9).

Harking back to Theopharastus, Gilbert, Galvani and Maxwell, among others, Schwan argues on theoretical grounds that ELF electric fields can not affect biological systems (3, 4, 5). One can not imagine an individual with scientific views more closely associated with this conclusion. His presence on the committee is inconsistent with the notion of a fair inquiry.

Michaelson has stated:

"There is no demonstrable biological effect which may be hazardous to health or safety or to the general biological environment as a result of the presence of the proposed lines' electric and magnetic fields." (6, at pg. 29).

Michaelson is an expert in the field of thermal effects of microwaves. He has spoken strongly against the possibility of non-thermal biological effects at low frequencies, or in fact at any frequency.

All three individuals have therefore stated publicly that the ELF fields associated with transmission lines will not cause harmful biological effects. Bearing in mind that the transmission line electric field is roughly ten million times stronger than the S/S electric field, it is inconceivable that the three named individuals will find that the S/S is an environmental hazard, regardless of the evidence adduced.

Thus the committee is composed of 13 individuals unfamiliar with the ELF area, and three who are conversant therewith. The latter three have repeatedly and strongly stated publicly their position in favor of one side of the issue that is being considered by the committee. We respectfully urge that the composition of the committee is inimical to the pursuit of truth.

ROLE OF THE COMMITTEE

We have been unable to determine whether the committee is designed to be primarily adjudicative or investigative. It appears that the committee can not merely judge the evidence presented to it, since the only detailed, indepth presentation, encompassing all aspects of the S/S system, that it is likely to obtain will be from the proponents of the system. We conclude therefore that if the process is genuine, the committee is investigatory. We are deeply troubled however, by the apparent dearth of staff, money and time necessary to conduct an investigation.

NAVY IN-HOUSE RESEARCH

We wish to call the attention of the committee to the research performed at the Naval Air Development Center, Johnsville, Pa., from 1970 to 1974. This work is briefly described in Bioeffects Project Resume MR041.08.010100, June, 1973, Office of Telecommunications Policy, Executive Office of the President. The observations made in the course of these investigations do not appear to be consistent with the Navy's present position regarding S/S. We have been unable to obtain any data from the Navy regarding the Johnsville Project, other than that it existed.

With the exception of the Johnsville Project, the only in-house Navy research project which has shown a biological effect due to ELF fields is, to our knowledge, that of Beischer (7). Reviewing Beischer's work, and data from the S/S Wisconsin Test Facility, an Ad Hoc Committee assembled by the Navy in 1973 recommended (8):

"Priority 1-Urgent and Absolutely Necessary. The reports of elevated serum triglycerides in humans exposed to experimental ELF magnetic fields for short periods of time as well as in individuals working at or near the Sanguine Wisconsin Test Facility cause this area to have the highest priority for scarce research resources. Most emphasis should be placed on controlled laboratory studies. Detailed animal experiments on triglyceride levels should be undertaken simultaneously with a continuation of the human experimentation."

No further human experimentation has been conducted, nor has the absence thereof been explained or justified by the Navy.

We believe that both the secrecy surrounding the Johnsville Project, and the failure to follow up Beischer's work, reflect adversely upon the Navy's position in relation to S/S, and that both areas should be studied by the committee.

SANGUINE / SEAFARER

We have sent to the chairman of the committee, under separate cover, copies of testimony submitted to the New York State Public Service Commission in connection with transmission line electric and magnetic fields (9, 10). Based on our study of the literature contained therein, which includes but is not limited to work sponsored by the Navy, we believe that the S/S electric and magnetic fields may cause biological and ecological effects, and that a great deal more research is needed. The net result of the Navy S/S research program has been to make the possibility of ELF field biological and ecological effects more credible than would have been the case in the absence of the program. It therefore seems impossible to us to sustain the view that the research done to date is adequate to support a decision in favor of building S/S. We recognize also that the environmental and health hazard posed by S/S may be outweighed by considerations of national defense or other factors not in the scientific domain.

Respectfully submitted,

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4. Biological Hazards from Exposure to ELF Electric Fields and Potentials, Herman Schwan, NWL Technical Report TR-2713, March, 1972.

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7. D. Beischer, J. Grissett and R. Mitchell, Exposure of Man to Magnetic Fields Alternating at Extremely Low Frequency, Naval Aerospace Research Laboratory, NAMRL-1180, AD770140, July, 1973.

8. Proceedings of the Ad Hoc Committee for the Review of Biomedical and Ecological Effects of ELF Radiation, Bureau of Medicine and Surgery, Department of the Navy, Washington, D.C., December, 1973.

9. Andrew A. Marino, Testimony Before the State of New York Public Service Commission in Cases 26529 and 26559.

10. Robert O. Becker, Testimony Before the State of New York Public Service Commission in Cases 26529 and 26559.

6.4. note 3

NATIONAL ACADEMY OF SCIENCES

OFFICE OF THE PRESIDENT
2101 CONSTITUTION AVENUE
WASHINGTON, D. C. 20418

January 22, 1980

Mr. Caril Tucker
Editor
Saturday Review
1290 Avenue of the Americas
New York, New York 10019

Dear Mr. Tucker:

As you are by now quite aware, the article "The Invisible Threat: The Stifled Story of Electric Waves" (SR, 9/15/79) has dismayed the scientists most familiar with the issues. Having read the article with extreme care and having reviewed the criticisms offered by several of the scientists mentioned in the article, I can only share that dismay. The article is replete with distortions, inaccuracies, and misrepresentations that are difficult to regard as other than willful and venal. It is insulting to several distinguished scientists and to the National Academy of Sciences.

We do, of course, have alternative means available to deal with the article, most especially its slanderous description of Professor Hastings. As you may know, this institution has in the past successfully sought legal redress when one of our committees was slandered in the public prints and we would not hesitate to so commit our resources again, should that be necessary. However, in the hope of being more positive and of extracting something of value from this episode, we have prepared the enclosed article for publication in the Saturday Review. It has several purposes: to rectify in part the grievous injustice done to this institution and to several reputable scientists; to outline the actual scientific knowledge relevant to the issue treated in the article; and to inform SR readers who have been misled by Ms. Schiefelbein's article as to how the episode occurred.

I request that you give the enclosed manuscript your prompt attention, and that publication of the article be scheduled expeditiously.

Sincerely yours,

Philip Handler
President

Enclosure

6.4. note 4 (pp 88-94)

January 21, 1980

SCIENTIFIC EVIDENCE AND PUBLIC DECISION MAKING

By Philip Handler, Alvin G. Lazen, and Normal Metzger

The authors are all associated with the National Research Council of the National Academy of Sciences. Philip Handler is Chairman of the Council and President of the Academy; Alvin G. Lazen is

Associate Executive Director of the Assembly of Life Sciences; and Normal Metzger is Senior Editor in the Office of Information.

A continuing stream of diverse new technologies, introduced for private profit or public benefit, characterizes our civilization. Stimulated by a growing list of unfortunate experiences, increasing attention is now being given to possible dysbenefits of these technologies, such as social disturbance or hazard to the public health. In consequence, risk assessment has become a major enterprise. Establishment of the nature and magnitude of the risk, if any, associated with a given technology is a valid scientific question. The acceptability of such risk, however, is a political question. The role of the scientist is to inform; decision is the responsibility of the polity, albeit frequently made by those to whom the polity has temporarily delegated that responsibility on its behalf.

The public is informed that automobile seat belts do save lives but each of us decides whether we wish to use them; less than 20 percent do. Evidence describing the linkages of cigarette smoking to lung cancer and cardiovascular disease is offered to the citizenry, which then decides, individually, whether or not to smoke. Those instances in which the public purpose can only be served by government action, e.g., licensing of nuclear power plants, approval of food additive or - the examplars in this article - construction of high voltage transmission lines or of antennae that emit extremely low frequency radiation, again entail a two-stage process, viz., scientific appraisal followed by political decision. While the formal separation of scientific information from public judgment is a truism, the two are not always easily distinguishable, they do not always operate independently of each other and their intertwining may have messy consequences in the making of public decisions. The unwary can be trapped and unprincipled advocates rewarded when the rules of either arena are not understood or their operation is inadvertently or deliberately distorted. The problem may be particularly serious when relevant, conflicting evidence derives not from the mainstream of scientific understanding but from a relatively little explored fringe and is offered by partisan scientists in the employ of an entity that benefits from the technology in question or by scientist-advocates already committed to the view that the technology is, in some way, dangerous or undesirable. It is then that the intricate structure and built-in safeguards of the scientific enterprise become particularly important.

The elements of that structure consist of journals, each with its squadron of references, of informal networks by which scientists relentlessly critique each other, of peer review systems by which applications for research grants are appraised, of deliberately harsh competitions within academic departments by which a select few are given tenure and others left to find work elsewhere. This is a rather brutal but unparalleled system for rewarding excellence and culling out that which is shoddy, a system for defeating Gresham's Law as it might otherwise operate in the matter of scientific excellence. It is a tough arena in which to work. Critics are ready to spring on the slightest mistake; daring hypotheses are met with skepticism and bitterly fought. The older establishment is ever the target of brash graduate students and assistant professors. A unique feature of this system is the National Research Council, the working arm of the National Academy of Sciences. Having no interest but the ultimate public interest, it operates as objectively and impartially as possible. The Council is a unique system for definition of the scientific questions relevant to a given problem, the appointment of a committee of the most knowledgeable and competent scientists with assurance of representation of all legitimate points of view and interests, and for the rigorous, impartial, critical review of that committee's report before its release.

The system of science works; but the nonscientist unfamiliar with the rules of the system can misread it, can mistake honest scientific contention for persecution, can interpret angry attacks on controversial assertions as a cover up, can imagine the emergence of "mainstream" views as the telltale of a cabal. As

an example, let us consider in some detail the possible biological effects of certain forms of electromagnetic radiation, a matter concerning which controversy has arisen in connection with the acceptability of high-voltage lines for transmission of electricity and with the proposed construction of an antenna which would enable communication with deep-running submarines (Project Seafarer) [See box for brief explanation concerning electromagnetic radiation.]. This was the subject of a recent Saturday Review article entitled "The Invisible Threat: The Stifled Story of Electric Waves," written by SR reporter Susan Schiefelbein (SR: 9/15/79]. That article, largely premised on the writer's selection of what scientific evidence is believable and what is not, is powerfully illustrative of the mischief that can be engendered by a misunderstanding that can be engendered by a misunderstanding of the workings and rules of the scientific enterprise. The article attacks the integrity of a number of individual scientists and of a committee of the National Academy of Sciences. It calls into question the probity of the Academy itself and the validity of the very methods of science. Nevertheless, here we will specifically address the central issue, one that supersedes the problem of prejudiced reporting: the assaying of scientific information in a public arena.

The issue can be stated simply enough: does extremely low-frequency (ELF) electromagnetic radiation such as that associated with high-voltage lines and the Project Seafarer antenna cause biological effects; if so, are such effects harmful in any way?

Obtaining a reliable, definitive answer to that question turns out to be rather difficult. Our environment is suffused by electric and magnetic fields of many origins: the natural stationary and undulating electric and magnetic fields of the planet; local fields from electric wiring, appliances, electric machinery, and transmission lines. Such fields surround all flowing electric currents. To appreciate their magnitude, the natural electric field of the earth, which averages 130 volts per meter, is about the same as that about 12 inches from an electric broiler; the natural magnetic field of the Earth is about 0.5 Gauss, is may be about 5 Gauss in close proximity to an electric can opener, an electric razor, or hair dryer, and much higher under an electric blanket.

Several thousand miles of existing high voltage transmission lines now operate at 765 kilovolts (kV), and carry enough energy to supply the requirements of both Boston and Baltimore. The maximum associated electric field directly under a 765 kV power line is approximately 10,000 volts per meter; the maximum magnetic field is approximately 0.5 Gauss. Both fall sharply with distance from the source. At the edges of a 250 foot right of way, the fields are about 2500 volts/meter and 0.15 Gauss; at 500 feet they are less than the natural levels, 100 volts per meter and 0.01 Gauss. Most houses and other buildings are shielded from the electric field by conductors in their walls and roofs.

In any case, fields do surround transmission lines, people are exposed to them; and they do penetrate through biological tissue. What are the consequences of such exposures? We can readily provide some gross answers. An electric field is created within a person standing under an electrical transmission line but, in general, for reasons having to do with the conductivity of electricity in living tissue as compared with that of air, such an internal electric field, on the average, is thousands or more times smaller than the external field in the air. In considering whether even such an attenuated field is a hazard, we move into difficult and perhaps insufficient experimental science and into controversy.

While there are plentiful data, much of them are contradictory, and some simply experimentally valid. That may seem remarkable, given both the ubiquity of electromagnetic radiation and a long history of curiosity concerning any possible biological effects. Accordingly, let us note some of the contradictory results and then examine several experiments that have been claimed to indicate adverse biological effects but which have not survived appraisal of the validity of their results by the normal procedures of science, yet which, nevertheless, have been awarded credence in the public arena.

Efforts to search for biological effects of ELF have been persistent, catholic, and imaginative. The examination has included searches for possible effects of electric and magnetic fields on the growth and development of plants and animals, for changes in physiological or molecular aspects of cellular metabolism, for genetic and chromosomal changes, for any effects on the behavior of animals or people, in particular on the health of utility linemen working on live 765 kV and 345 kV transmission lines.

The general conclusion extractable from the sum of these efforts is that **if a hazard does exist it has not been demonstrated**. In the absence of any such proof and in the absence of any theory that predicts such effects, we are left with the unprovable negative: that there does not exist any danger from extremely low frequency radiation at the level at which people are customarily exposed. And we are left also with a burden to improve the experimental methods necessary to this field, and appraise further those small effects that have been seen to ascertain whether they signal real hazards.

Many results have been inconsistent, with superficially similar experiments seemingly finding opposite results. For example, one report claimed a significantly increased human reaction time upon exposure to electrical fields of 3 Hz (Hz=Hertz=cycles per second) as compared to exposure to 10Hz, whereas another report claimed that there was an increased reaction time at 12Hz as compared to 2Hz.

Two studies assessed the effect of 60Hz fields on the growth rate of chickens; one found no effect and the second a decreased growth rate. Such inconsistencies have been obtained repeatedly in the history of science, particularly when, as in this case, the effects sought are small and particularly when they depend on the subjective judgment of the investigator or subject, e.g., estimation of the time of initiation of "fatigue" after exposure to a given field. They can be dealt with by the classical procedures of science; their evaluation is not facilitated by *ad hominem* attacks.

Aside from inconsistencies, there are flaws in some experiments, incomplete information in others, and a drawing of conclusions not supported by what has purportedly been measured. To illustrate, Soviet investigators have reported a number of complaints - listlessness, excitability, headache, drowsiness, and fatigue attributable to exposure to high intensity electric fields. However, a nine-year study of linemen working on energized high-voltage transmission lines, conducted by scientists at Johns Hopkins University, found no physical, mental, or emotional effects attributable to exposure to high electric fields. Similarly, a study in France of people working and living in proximity to transmission lines found no increase either in the frequency of visits to physicians or use of medications. Studies in Canada, Germany, Sweden, and Japan have failed to show significant effects on electrical workers from the electrical and magnetic fields in which they intimately work.

What is one to do under these conditions?: The wary layman should certainly recognize that conclusions from the seemingly positive experiments are tentative at best and perhaps invalid; scientists would attempt to appraise each of the experiments. They would note, for example, that the Russians found similar results in different working environments and then ask whether these variances were properly controlled for, indeed whether there were commonalities other than electric fields that might have been responsible for the reported effects, and how the effects were measured and evaluated. Scientists are made mistrustful by the fact that the array and number of illnesses of Russian workers exposed to high intensity electromagnetic fields were not compared by the same investigators with those of workers not so exposed. Finally, scientists in the United States are now attempting to repeat some of the Russian experiments.

Similar puzzles crop up in experiments with rats and mice. One experiment, for example, reports no effects on either the growth or development of mice exposed for over 10 months to 60 Hz fields of 160

kV/m. In contrast to this benign result is one report that asserts statistically significant decreased water consumption, food intake, and weight gain as well as increased adrenal and pituitary weights and decreased blood steroid levels in rats exposed to a 60Hz 15kV/m field for about a month. This dramatic report is a centerpiece of the *Saturday Review* article; hence, we shall return to its appraisal below.

A number of experiments have looked for changes in the chemical composition of the blood, principally the concentrations of serum triglycerides (fat), prompted by the posited relation of blood triglyceride levels to various types of heart disease. Human volunteers confined to a small room and exposed to unusually high intensity electromagnetic fields did, one experimenter reported, show higher triglyceride levels than did controls. But, again, one is left on slippery ground for public decision, for another experiment in which humans were exposed, again day and night, to similar electric and magnetic fields found no differences between control and experimental subjects. In a related series of experiments conducted on personnel involved in the Navy's Project Sanguine/Seafarer facility at Clam Lake, Wisconsin, supposedly elevated serum triglyceride levels were found both in these personnel and in matched controls living in Illinois. What is one to make of that, other than methodological inadequacy or operation of chance in these several studies?

One could continue in this fashion, but the leitmotif remains the same: a preponderance of the data showing no effects and some data purporting to indicate small effects of uncertain relation to the public health, all without a guiding theoretical background.

Oddly, the *Saturday Review* article even derides attempts to understand at a fundamental level the effects of electric and magnetic fields. After indicating that "using a metal ball as a model of the human body, together with his own assumptions of how much heat the body can throw off by means of perspiration and other biological processes, [Dr. Herman] Schwan figured that a person can safely handle an exposure of 10 milliwatts of microwaves per square centimeter of body surface.", the author opines that "metal balls and calculations cannot determine what is or is not a dangerous assault on internal organs "

What chutzpah! After passing many errors for many matters, we cannot quite ignore such errors as: stating that Dr. Schwan's funding is largely from the Department of Defense when the bulk thereof derives from the National Institutes of Health; indicating that his research is in "electromagnetics" when it is in biophysics and biology; stating that Dr. Schwan used "metal balls" when he employed spheres of tissue to approximate exposures to electric fields; failing to note that the work referred to, done over a period of thirty years, has been rigorously reviewed and reaffirmed in the scientific literature; and failing to note that Dr. Schwan, a member of the National Academy of Sciences, is perhaps the leading authority in the United States, if not the world, on the interactions of electromagnetic fields with living tissue.

More important than these indefensible errors is the fact that after exhibiting her failure to understand science, the author naively derides the use of one of science's most helpful tools - the use of simple models of complex structures. Models are intrinsic to the scientific method and vital guides to the design of experiments. Hydraulic pressure models, for example, have been applied to studies of blood circulation, with consequent gains in the treatment of circulatory disease; other model systems, including computer models, have aided in the design and syntheses of drugs now used to treat various human ills. The examples are legion. Dr. Schwan's use of models to study the effects of electromagnetic radiation on living tissue was in the classical tradition of science: to study the possible effects of a possibly toxic agent at lower and simpler levels of biological organization as a prelude to organ and whole animal studies.

Let us return to the experiments referred to earlier, those of Andrew Marino of the Veterans Administration Medical Center at Syracuse and his colleagues, who assert that there are quite clear effects which are, in fact, the pillar for the *Saturday Review* article. The point is not simply to indict that article, but rather to illuminate the consequence when selected experimental results are taken as facts - in this case, by a journalist - deliberately in disregard of the fact that they have been rejected as valueless by the rules by which science guards against shoddy work.

To recapitulate, Dr. Marino published papers claiming that fairly low intensity electric fields cause "stress" in experimental animals, the consequences including stunted growth, food avoidance, and changes in physiological state. To quote from the Saturday Review article: "In one study, rats exposed to an ELF field failed to gain weight normally. In another, three successive generations of mice exposed to ELF fields were stunted. Marino concluded that the animals were exhibiting the classic signs of stress." A photograph used in the *Saturday Review* article to illustrate these effects shows a test mouse about one third the size of a control mouse.

These results seem provocative. Are they believable? If, indeed, they occurred, were the experimental arrangements such as to preclude other causes of the reported effects? A prime role of committees of the National Research Council is to appraise the scientific validity of experimental results relating to the topic at hand; only scientifically valid, meaningful findings should reasonably figure in public decision making. Upon request from the Defense Department, the National Research Council appointed a committee to investigate the possible biological or other effects related to the construction by the Navy of a very large grid antenna to communicate with deep-running submarines, Project Seafarer. Appointment of the committee is the sole responsibility of the President of the National Academy of Sciences.

The Committee's reviewers found that the cages used to house the experimental animals could have transmitted small electric shocks each time the rats ate or drank. Was it then these shocks or the fields that led to poor feeding by some rats? Did Marino consider such shocks in his conclusions? One doesn't know, but it seems likely that to be "buzzed" when one eats is not to eat well. A reviewer whose professional career has been devoted to the study of stress pointed out that stress can be validly ascertained only by comparisons under precisely controlled conditions. That was patently not the situation in the Marino experiments; thus, the animals that were exposed to ELF were housed three to a cage, while the control animals were each alone in a smaller cage; vibration isolation pads were added to the experimental cages but not to the control cages.

Line concerns beset interpretation of the alleged results of these experiments. The data were themselves paradoxical: Marino reported **reduced** levels of corticosteroid hormones whereas classic stress research shows that stress **raises** such levels. Independent analysis of Marino's own data shows that there was **no statistically significant difference in the weight of the treated versus the untreated rats**! And that picture of the woefully stunted mouse? Perhaps the growth of some mice was indeed stunted, but it must have been a very small fraction of the total. And the experimental procedures used do not unequivocally tell us why; they most surely do not provide scientifically acceptable evidence that extremely low frequency radiation causes such effects.

Yet on this trivial, dubious ground, the article in the *Saturday Review* built a case for a conspiracy in which are united the National Academy of Sciences and its National Research Council, the federal government, the legal system, and for that matter any scientist who dares to disagree with Marino's claims. QED!

These are not trivial matters. Both the print- and the electronic-news media have utilized the thin tissue

of fancied biological effects of ELF to inflame the imagination of the public. At stake are future options for the siting of major electrical power plants and a means for communicating with deeply submerged submarines, obviating the need for a telltale surface antenna. It boggles the mind that some of the news media have been willing to treat such matters with mischievous irresponsibility.

A final matter. Once one chooses, by ignorance or venality, to accept and use only those findings and observations that might buttress a particular point of view, one is forced in time to paranoia so that the fairness and honesty of others is treated as mere cavilling. One shameful example. The *Saturday Review* article libeled the chairman of the National Research Council's Committee on Project Seafarer, Professor J. Woodland Hastings, Chairman of the Biology Department at Harvard University, stating explicitly that he "publicly lied", yet failed to indicate the nature of the lie or the identity of the public in question.

Upon direct inquiry to the author, we were informed that she, personally, was the "public" in question. The "lie" consisted of Dr. Hastings' statement to her, in 1979, that Dr. Marino and a VA colleague, Dr. Robert Becker, had conducted no research in this field that contributed significantly to current understanding whereas she had in her possession a letter from Hastings to Becker and Marino that indicated that Hastings knew otherwise. That letter, dated three years earlier, was a canvassing letter, written early in the course of the committee study, in which Hastings as committee chairman states that **he had been informed** that Marino and Becker had conducted investigations relevant to the effect of ELF, and, **if that was true**, requested that they more fully inform the committee of their work so that the committee could give it due consideration in the course of its deliberations. (Marino and Becker never responded nor did they accept the committee's invitation to attend a committee meeting and present their experiments and findings in person.) By the time of Ms. Schiefelbein's conversation with Dr. Hastings, the committee had long since reported their dismissal of the Marino-Becker findings as essentially without scientific value - as Hastings told her. There was indeed lying reported in the pages of SR - but it was not done by Dr. Hastings.

We end with two quotations. One, taken from the National Research Council report on Project Seafarer, neatly reveals the committee's frustrations with the need to form judgments on sometimes flimsy data: "The Committee has examined a number of cases in which a claimed effect of an ELF field was very likely an effect of something else in the experiment and cases in which no effect was found, but the design of the experiment was such that probably none could have been found even if it did exist . The Committee has not enlarged on these inadequacies on an experiment-by-experiment basis, because, in the absence of an effect (whether real or artifactual), an appraisal of the possible impact of experimental shortcomings becomes an exercise in prophecy, rather than analysis." The *Saturday Review* article contains one statement that we embrace entirely: "The controversy is a complex and many-facted one; it is not well-served by simplified conspiracy theories and personal vendettas." Would that the author thereof had taken her own lesson to heart.

6.4. note 5 (pp. 94-103)

I wrote the Editor of Saturday Review urging that he publish the article. I included a detailed response to Handler's charges.

February 5, 1980

Carll Tucker

Editor

The Saturday Review

1290 Avenue of the Americas

New York, New York 10019

Dear Mr. Tucker:

I realize that many factors must necessarily affect your decision regarding Dr. Handler's proposed article. The very fact that he would react as he has done brings into sharp focus the basic problem reported in Susan's article. When a dispute develops concerning scientific matters which strongly affect the national interest and welfare, who should decide and how? I could well understand a decision that such a debate was not appropriate for Saturday Review; but, on the other hand, Dr. Handler has never done anything like this before, and publication of his article, together with a suitable rebuttal, would, I think, be highly readable and distinctly in the public interest. I hope you find it possible to publish his article, together with perhaps two replies - one from Susan and one from me, since we're both attacked at roughly equal efforts. If you feel that this would not be worthwhile, I'd be very grateful if you let me know so that I could pursue this idea of an open exchange with other publishers who might feel it would be appropriate for their readers.

Sincerely,

Andrew A. Marino, Ph.D.

Research Biophysicist

Detailed response:

COMMENT		REPLY
"Our environment is suffused by electric and magnetic fields of many origins and much higher than an electric blanket."		The present electromagnetic environment contains some components arising from galactic sources and from the earth's own geomagnetism. But the overwhelmingly dominant portion is man-made. At virtually every frequency, the intensity due to man-made sources is from thousands to billions of times greater than a natural background - the background which has prevailed throughout evolutionary history. The natural electric and magnetic fields of the earth are direct-current fields. The man-made fields are **alternating current** fields. To compare the magnitude of AC and DC fields is simply to compare apples and oranges; such comparisons are almost never made by workers in the field of biological effects of electricity.
"The maximum associated electric fields directly under a 765 kV power line is approximately 10,000 V/m; the maximum magnetic field is approximately 0.5 gauss. Both fall off sharply from the source At 500 feet they are less than the natural levels, 100 V/m and 0.1 gauss."		The statement is false. The fields of transmission lines do not reach "natural" levels for distances on the order of 5000 feet on either side of the centerline. Even at that distance, the fields due to the transmission lines exceed the naturally present field at that frequency.
"Most houses and other buildings are shielded from the electric field		There is no scientific study which demonstrates this, and, therefore, the contention cannot be accepted. Furthermore, it

by conductors in their walls and roofs."	seems clear on general principles the **magnetic field** would be completely unaffected by walls and roofs. Finally, either the fields create a health risk or don't create a health risk; if they don't create a health risk, then whether or not they are shielded is immaterial.
"In any case, fields is thousands or more times smaller than the external field in air."	There is no proof that the fields which penetrate human beings are only 'thousands or more times smaller' than the applied fields. And, therefore, the statement cannot be regarded as truth or fact. **Some scientists** using vastly oversimplified models of human beings - models in which they are envisioned as metal balls - have **calculated** that the internal fields are everywhere very small ( ). But there is ample evidence to indicate that mathematical calculations involving simple models such as spheres, ellipsoids, or solid rectangles, can result in asserted internal values which vary over millions of percent, depending on the **initial assumptions** one cares to make ( ). Thus, it is true that (1) there is no evidence to support the claim, and (2) the claim itself is based on arbitrary calculations which have no greater claim to correctness than other calculations which can establish internal values that are different by more than 100 million percent.
"In considering insufficient experimental science and controversy."	It is well to remember that whether the evidence is "insufficient" depends not only on the evidence per se, but also on the individual making the judgment. If Dr. Schwan, for example, or some other utility industry consultant says the evidence is "insufficient", that's one thing. But it's quite another for a person without an economic interest to make such a judgment. For another example, Dr. Handler has appointed Dr. Schwan to an NAS committee charged with evaluating wehther evidence in this area indicates whether there exists a health risk - that is, is sufficient or insufficient. If Dr. Schwan turns out to be biased, what does that say for Dr. Handler's judgment? Suppose Dr. Handler appoints three men to a committee and they all turn out to be biased; this, I submit, can have an important impact on Dr. Handler's view of the scientific evidence - its sufficiency or insufficiency with regard to health risks - when Dr. Handler himself decides to give scientific opinions.
"While there are plentiful data, much of them are contradictory and some simply experimentally invalid."	If Dr. Handler has personal knowledge of invalid scientific results that are currently held out in the general scientific literature to be valid, it is his moral obligation to disclose that fact; certainly none of the examples he cites below fall into this class. It must be asked why Dr. Handler has waited until now to disclose his knowledge that certain results in the scientific literature are invalid. I have diligently searched the literature in this field since 1974; my library is considerable, and yet does not reveal **even one instance** in which reputable scientists have published contradictory "results." I find it difficult to believe that Dr. Handler - whose interest in this field is very recent - could

	have discovered "contradictory" results which all other workers in the field have missed.
"Efforts to search for biological effects and 345 kV transmission lines."	ELF investigators have been hampered by the fact that the only two sources of research funds in the United States - the electric utility companies and the Department of Defense - have the strongest possible interest in denying all effects and hence all risks. That there have been some studies is a tribute to the tenacity and perseverance of a small group - perhaps several hundred investigators at most - who have labored under very different conditions. Even so, they have found and reported in the open scientific literature ELF effects on plants and animals, and have found changes in the physiological and cellular metabolism, and genetic and chromosomal patterns of many species including human beings.
"The general conclusion extractable from the sum of these efforts is that if a hazard does exist, it has not been demonstrated."	The statement is certainly untrue. In my view, the potential hazards for human beings is demonstrated when it is shown that scientists can find biological changes in test animals when those animals are forced to live in an electrical environment similar to that in which people live. There are more than eighty scientific reports in the open peer-reviewed scientific literature in which investigators simulated the electric environments of either high-voltage transmission lines or the Sanguine antenna and found biological changes in the exposed organisms - those organisms ranged from amoebae to man ( ). The first question to be determined is whether the scientific literature is creditable. In this connection it must be noted that the literature has met the same tests which have applied to scientific literature in every other field; how could a reasonable person reject all of it and yet maintain that the scientific literature in general is reliable? The only individuals who have attacked the competency and credibility of all of these ELF investigators is a small group of individuals who are consultants for electric utility companies, and, Philips Handler, who chose this small group as an "unbiased" and "expert" group to evaluate the Navy's Sanguine program and to advise him on the health risks of high-voltage transmission lines. In my judgment, it is a potential risk to health for individuals to be chronically exposed to **the same** environment shown to be productive of biological effects in laboratory studies - it's as simple as that. Reasonable men may differ in the degree of risk and, in a proper case, on the ratio of this risk to the costs involved in ameliorating it. But the time should be passed when an investigator is branded as incompetent merely because his published work violates a Procrustean bed of another party.
"Many results have been inconsistent, with superficially similar experiments seemingly	Dr. Herbert Koenig is professor of electrophysics at Technical University in Munich, Germany. He has a long and distinguished career in the study of ELF bioeffects. Among his publications is

finding opposite results. For example, one report claimed a significantly increased human reaction time upon exposure to electrical fields of 3 hertz as compared to 10 hertz, whereas another report claimed that there was an increased reaction time at 12 hertz as compared to 2 hertz."		one in which he describes his observation of decreased human performance at 3 hertz as compared to the field-free situation, and increased performance at 10-25 hertz when compared to the field-free situation ( ). Dr. James R. Hamer worked in the Space Biology Laboratory of the Brain Research Institute at the University of California. Dr. Hamer performed studies using two discrete frequencies within the 2-12 hertz range and found a decreased performance at the higher frequency as compared to the lower frequency ( ). Both scientists reported their results in the open peer-reviewed literature - the studies were both found to meet the tests for competency and quality which are applied to the scientific literature in general. There is simply **nothing** contradictory about these results. It is difficult to imagine why Dr. Handler **thinks** these results are contradictory. Even if they **were** contradictory, that would mean that one scientist was correct and one incorrect; but this would **still mean** that there was such a thing as an ELF bioeffect and hence for people to be inadvertently exposed to the fields constituted a potential risk. So that unless Dr. Handler is prepared to assert that **both scientists are wrong** - that is, they fooled themselves into thinking that they had an effect, and succeeded in fooling the peer-review and editors in the journals in which they published their results - then it follows that Handler's statement has no merit.
"Two studies assess the effect of 60-hertz fields on the growth rate of chickens; one found no effects and the second found a decreased growth rate. Such inconsistencies "		There have been many studies of the effects of electric fields on the growth rate of chickens. Some - for example, those performed under a contract to the Electric Power Research Institute at Penn State University - have been kept secret, and others have been reported in the literature ( ). In general, the results show that fields **can affect** the growth rate of chickens - but not every experiment demonstrates this effect. Whether or not an effect is seen depends on the length of time the field is applied, and the **intensity** of the field. Surely, Dr. Handler will agree it is silly to compare experiments done at widely different intensity levels and for widely different durations of exposure - yet that is what he has done.
"Their evaluation is not facilitated by ad hominum attacks."		That is a laudable sentiment which I heartily endorse. But it should be pointed out that the only scientists who have engaged in ad hominum attacks are Dr. Handler himself, and those who he appointed to the Sanguine Review Committee. For example, the Chairman chosen by Dr. Hastings has called me a "quack".
"Aside from inconsistencies, there are flaws in some experiments, incomplete information in others, and a drawing of conclusions not supported by what has reportedly been measured."		Such broad-scale attacks on an entire group of scientists is unworthy of the chairman of the National Academy of Sciences. Let him come forth and stipulate the inferior studies, or let him be silent.

"To illustrate, Soviet and magnetic fields in which they intimately work."	The nine-year study conducted by scientists at Johns Hopkins University found reduced sperm counts in some workers. This has led to a number of other studies of exposed workers and the great majority have found biological effects associated with the exposure conditions. Dr. Handler has simply misread the literature. Studies in Canada and Germany and Sweden have all shown significant effects of high-voltage transmission line-type fields - it is difficult to believe that Dr. Handler could have so misread the literature. The Soviet studies were much more thorough and involved many more subjects than the Johns Hopkins study and the Soviets found many biological effects associated with exposure to transmission-line fields. In response, the Soviet government has recognized diseases associated with field exposure as occupationally related, and they have instituted work rules governing the amount of exposure, and have embarked on a large research program to devise such rules for the public at large. The Soviets have evolved a large regulatory apparatus to govern the exposure of human beings to transmission-line-type fields. Pursuant to information exchanges between the U.S. and the USSR, NIOSH has been given copies of the latest Soviet research in this area, the great majority of it demonstrating marked effects of transmission-line fields on animals and people. With all this, Dr. Handler's reading of the literature seems particularly jaundiced.
"Similar puzzle crop we shall return to its appraisal below."	There is nothing in Dr. Handler's history which suggests that he has ever used such an argument previously. That is, nothing in which he tries to draw a contrast or parallel between two **widely different experiments** and imply that they are contradictory or that there is a "puzzle" about them. Nature is what it shows; if two different and competently done experiments are performed, then their results are what we use to determine theory. The procedure does not work the other way around - we do not say 'We expect such and such' and reject all results which do not conform. So, the only issue is whether the experiment is competently done, not whether, in Dr. Handler's mind, the results comport with an entirely different experiment - that is not the criteria of scientific validity.
"Human volunteers confined to a small room and experimental subjects."	The experiment was performed by Dr. Dietrich Beischer in 1973 at a time when he was Director of the Naval Aerospace Medical Research Facility in Pensacola, Florida. As part of the Sanguine research projectd, Dr. Beischer exposed human volunteers to an ELF magnetic field and found that after 24 hours, their serum triglyceride levels were affected. The results were at marked variance with the policy of the Navy, which was to build Sanguine. In consequence, it was necessary for the competency of the study - Dr. Beischer at that time was perhaps the most prestigious investigator in biomagnetics in the world - to be

		attacked and destroyed. To his shame, Dr. Handler has participated in this shoddy episode. Dr. Handler appointed Dr. Michaelson to the Sanguine review committee; Dr. Michaelson reviewed Dr. Beischer's experimental procedures and concluded that the experiment was sloppily done, incompetently run, and completely worthless - Dr. Michaelson did not mention that at the time of the Beischer experiment, he had been a scientific advisor to Dr. Beischer. We can only speculate about Dr. Handler's motivation in cooperating with the vicious attack on Dr. Beischer, but it is clear that the attack has no merit, that the study was competently done, and showed a biological effect, and, therefore, that the comments made by Dr. Handler here are without merit.
"In a related series of experiments conducted on personnel involved in the Navy's living in Illinois."		Studies done at Clam Lake also found elevated serum triglycerides in workers exposed there. These studies in fact led to the studies by Beischer in the laboratory. Soon after the physician in charge of the Clam Lake facility reported the elevated serum triglyceride levels, he went on "extended sea duty" and a second physician who repeated the measurements found no effects. The circumstances here do not suggest credibility on the part of the Navy. Certainly, it seems difficult to understand how someone as prestigious as the President of the National Academy of Sciences could have been fooled by these developments.
"One could continue a theoretical background."		There is **no data** showing "no effects." There is only some data in which investigators have failed to find any biological effects under certain circumstances. Such failures can have no public health significance in the face of the vast amount of literature in which effects have been found ( ).
"Oddly, what chutzpah!"		If it's shaped like a ball, and has the electrical **properties of metal**, then, to me, it's a metal ball! It is precisely this - metal balls - which Professor Schwan has used to calculate what he says are safe values for ELF fields. **That's chutzpah**.
"Dr. Schwan's funding is largely derived National Institute of Health."		Dr. Schwan has been supported by the Department of Defense almost from the day he entered the United States (January 17, 1949, as part of the Navy's project Paperclip). The record clearly shows that for almost two decades, he has enjoyed almost continuous DoD support - perhaps more than any single investigator in history.
"Dr. Schwan, a member of the National Academy of Sciences, is perhaps the leading authority in the United States, if not the world, on the interactions of electromagnetic fields with living tissue."		I hope that's not true!
"Let us return which science		My work has been rejected by Drs. Michaelson, Schwan, and

guards against shoddy work."	Miller and by Dr. Handler, but I understand their motivation and readily concede that they have a right to attack anyone they please. It is another matter, however, to try to make it appear that a full committee, the National Research Council, the National Academy of Sciences, organized science, and perhaps others, have unanimously joined in roundly condemning my work. That seems to be the thrust of Dr. Handler's argument and fair-minded people must reject it.
"Dr. Marino published papers on experimental animals."	Our initial studies were published in 1976 ( ). Subsequently, further work by us and others has strengthened this conclusion. It is not established beyond reasonable doubt that low-intensity electric fields can cause biological stress.
"A prime role of committees of the National Research Council National Academy of Sciences."	Dr. Handler was approached by officials of the Navy and asked to empanel a group to evaluate the health risks of Project Sanguine. The Navy had empaneled its own group in 1973 and when the results of the committee evaluation proved displeasing to the Navy, they were quietly shelved. When the results were released to the public by Sen. Nelson of Wisconsin, the Navy approached Handler in early 1976 with a proposal for a second Sanguine review committee.
"Appointment of the committee is the sole responsibility of the President."	That, of course, is Phillip Handler. Dr. Handler appointed Dr. Michaelson, Dr. Schwan, Dr. Miller to the committee; he did this despite the public positions by each of these men that ELF fields, approximately one million times stronger than those of Sanguine, were harmless ( ). It was thus inconceivable that any of them would jeopardize their lucrative financial arrangements with the electric utilities by concluding that ELF fields one million times weaker than those of high-voltage transmission lines were possibly harmful - not to mention the problem of perjury that was thereby presented. A fourth individual Dr. Handler chose for the panel was Dr. Adey; he's an established ELF investigator well-known for his position that public discussion of potential side-effects must not take place until more knowledge is gained, or else the public may be unduly alarmed. Beyond these four, Dr. Handler chose eleven individuals who have virtually no training or experience or background in the field of ELF bioeffects. Dr. Handler did this in derogation of the rules governing the choice of NAS committees which state that they are to be composed of experts in the field. The choice of the utility witnesses and of a group of scientists unfamiliar with the field to me indicates a desire that the committee reach a specific conclusion - Phillip Handler clearly rigged the Sanguine committee. Having done that, it is not surprising Drs. Miller, Michaelson, and Schwan reached the conclusion that my work lacked merit and further, it is not surprising that Dr. Handler now agrees with them.
"The committee reviewers found	It is difficult to believe that the President of the National

that the cage used to house the experimental animals could have transmitted small electrical shocks each time the rats ate or drank."	Academy of Sciences would argue in this manner. Of course it "could" happen; and I discussed the possibility in the original article. I gave there the scientific reasons why it was most likely that the results were due to ELF fields and not some supervening cause.
"Was it the shocks or the fields that led to poor feeding by some rats?"	This question was first posed by Dr. Morton Miller during his tenure as an expert for the Rochester Gas & Electric Company. With the help of RG&E engineers, Dr. Miller built a duplicate of my apparatus, using detailed plans and schematics which I furnished him. Dr. Miller took color movies of rats exposed to ELF fields in his mock-up of my apparatus. Dr. Miller found that there were no shocks; these films are available from RG&E, and from the New York Public Service Commission.
"A reviewer whose professional career control cages."	In the very first experiments we performed, we did not standardize the number of animals per cage in the experimental and control group. When we first began to observe ELF effects, however, we did. Only the very first studies we performed were done in the absence of such standardization. Later experiments confirmed the earlier experiments, thereby showing that the variation in number was not a significant determiner of the final result. Even if it were, and one ignored the initial study that did not control for cage number, and considered only subsequent studies wherein it was done, **then**, the evidence still clearly shows an ELF field effect. It was never true that vibration pads were used for the experimental cages but not the control cages; Dr. Handler's badly mistaken. Dr. Handler chooses to ignore many studies done simultaneously with and subsequent to the ones to which he refers which **corroborate** and **verify** the results which I've reported.
"Like concerns beset such levels."	We indeed found reduced serum corticosterone levels under the conditions of exposure which we employed. Again, the only proper question is whether we performed the experiment properly, not whether the results are "classic".
"Independent analysis rats!"	We furnished all of the raw data for all of our experiments to the Rochester Gas & Electric Corporation because they said it would be useful to them in understanding our work. These engineers and their consultants then "analyzed" the data we had given them and, not surprisingly, came to the conclusion that the data were worthless and showed no effects at all. But fair-minded will not agree that this was an "independent analysis", and the record shows that the utility company merely rearranged the data in an arbitrary fashion to obtain the results it wanted. Dr. Handler appoints approximately 200 committees to advise government per year; he is a member of each of the committees, and has ultimate authority over the final report and its time of release. I can only wonder if, in other important matters affecting the

		public health and welfare, Dr. Handler has exercised similarly poor judgment with regard to the scientific literature which he reviews.
"Perhaps the growth of some mice was indeed stunted, but it must have been a very small fraction of the total."		On the contrary, the stunted mice shown were quite typical of those in the second generation. Dr. Handler would have realized this had he consulted our article in which all relevant details are given ( ).
"And the experimental procedures used do not unequivocally tell us why;"		Experimental procedures almost never do. There is no condition that an investigator know **why** a result which he observes does in fact occur.
"They most surely do not provide scientifically acceptable evidence that extremely low-frequency radiation causes such effects."		The staff of the Public Service Commission of New York, the staff of the Energy Development Commission in New York, the full Commission in California, and the staff of the Department of Environmental Conservation in New York all disagree ( ). Each has specifically found that our mice study was done properly, and could deservedly be the basis of a regulatory approach to high-voltage transmission lines. We shall shortly publish an experiment in which these results have been confirmed and extended ( ).
"A conspiracy in which are united the National Academy of Sciences, the National Research Council, the Federal government, the legal system, and for that matter any scientist who dares to disagree with Marino's claims. Q.E.D.!"		Awww, c'mon, Phil! The dispute is solely with Drs. Miller, Michaelson, Schwan, and Handler.

6.5. Rules and Procedures of EMF Blue-Ribbon Committees: A Case Study

6.5. note 1 (pp. 103- 121

COMMENT ON
"STRATEGY FOR EVALUATING DATA RELATED TO THE HEALTH EFFECTS OF ELECTRIC AND MAGNETIC FIELDS"

INTRODUCTION

This comment is in reply to a request from Christopher J. Portier, Ph.D., Chief, Laboratory of Computational Biology and Risk Assessment and Chair, Risk Assessment Research Committee, NIEHS, dated October 8, 1996. The subject of the comment is the proposed strategy for evaluating the health risks of powerline electromagnetic fields described in the letter, and in a document obtained from the NIEHS web site (1). It is concluded here that the proposed strategy is seriously flawed and should be disregarded, and a new strategy is proposed.

THE NIEHS PROPOSAL

Scientific meetings and other activities have been proposed by the NIEHS to address the question of whether electromagnetic fields (EMFs) produced by powerlines pose a risk to human health, and if so, to determine the significance of the risk and to develop mitigation technologies. The process will begin with three sequential multi-day symposia to treat non-overlapping subject matter in which experts would discuss relevant information within a particular procedural framework, and attempt to reach a consensus regarding the health risks due to exposure to power-frequency electromagnetic fields. The participants in the first symposium will determine whether theoretical and in vitro research findings support a causal linkage between EMFs and health effects. Participants in Symposium II will address the same question after considering the epidemiological results. The question will be considered for a third time by the participants in Symposium III, who will be charged with reviewing in vivo experimental and clinical laboratory findings.

Participation in the review and evaluation process will be by invitation from NIEHS. Each symposium will be chaired by a facilitator, and a record of the proceedings will be maintained by a rapporteur. The cost of participation in the symposium will be borne by the invitee, except in special cases.

The work of the rapporteurs will be submitted to a Working Group consisting, in part, of Principal Authors, who will produce a preliminary decision based on the proceedings from the symposia and

other relevant information. Thereafter, the Working Group will produce a more definitive written decision for submission to the NIEHS Director. The Director will consider the decision and other relevant information, and prepare a report to Congress regarding the potential for human health effects from exposure to powerline EMFs. The overall proposal is summarized below. [not available]

EVALUATION OF NIEHS PROPOSAL

For the reasons discussed below, the proposed strategy for ascertaining the health risks of powerline EMFs is fatally defective. The Proposal should therefore be withdrawn, and a new proposal that remedies the present defects should be circulated.

Resort to Blue-Ribbon Committees is an Historical Error

Essentially all previous attempts to resolve the issue of health risks due to powerline EMFs have included appointment of a blue-ribbon committee charged to form a consensus regarding the risks. Committees assembled by the National Research Council of the National Academy of Sciences, the World Health Organization, the American Institute for Biological Studies, The American National Standards Institute, and many state agencies have each reached a consensus tending to exonerate electromagnetic fields, but their efforts lacked credibility and were largely ignored. Thus, the blue-ribbon committees have failed to resolve the issue. The need for the NIEHS to undertake the present activity is good evidence of the fact that the previous efforts failed.

The blue-ribbon committees failed principally because the results of their efforts were predictable once the members of the committees were identified. It was possible to predict the nature of the reasoning that would be followed, and the conclusion that would be reached, independently of the existing evidence. Thus, those who chose the committee members also chose the result that the committee would reach.

There is no reason to expect that the blue-ribbon panel proposed by the NIEHS will succeed because previous committees chosen in the manner outlined in the Proposal have failed. That flawed format should not, therefore, be implemented again.

Seeking Consensus Among Scientists is an Unreasonable Strategy for Finding the Truth Regarding EMF Health Risks

Investigators concerned with the health effects of EMFs come from all areas of scientific endeavor, display all levels of competence, and all degrees of interest and focus on the study of EMFs within their particular scientific specialty. Their value systems vary widely, as do their opinions regarding the manner and conditions under which the results of scientific studies ought to be used and applied in society at large. They also exhibit personalities that range from the meek to the aggressive. The conclusions of a blue-ribbon committee chosen non-randomly from the ranks of this group, therefore, would consist of an admixture of the science, values, philosophy, and personality traits of the committee members, and would not be representative of the objective state of the science. Additionally, essentially every EMF investigator who, credibly, could be asked to participate in the symposia or the Working Group is already explicitly or implicitly identified with particular views regarding the main issues. It will not be possible to prevent the symposia from being dominated by individuals having strong views, and it is those views rather than the reasons underlying them that will be reported.

Seeking consensus among non-EMF investigators would be even more futile because, in addition to the enumerated problems, there would exist the further difficulty that the non-EMF scientists would be

ignorant of the large body of experimental data that exists regarding EMF-induced bioeffects, and it would be a hopeless task to expect such an individual to master that information within the time frame of a symposium (2).

A non-EMF biological scientist is likely to have only a rudimentary understanding of electromagnetic fields because they are not encountered in the classical biological education in the United States. With regard to the biologists on the faculty of my Institution, for example (which I think is representative of other faculties), Ohm's law is the limit of their working knowledge. It simply makes no sense to ask such individuals to make global judgments regarding EMF studies by biologists who have learned about electromagnetic fields and then proceeded to employ them in scientific studies that were ultimately published in peer-reviewed publications. A non-EMF physical scientist is also incompetent to make global judgments regarding health risks because such matters are as far from the area of expertise of the classically trained physicist as are electromagnetic fields from the expertise of the biologist.

These considerations indicate that a strategy for replying to Congress that was based on seeking consensus among EMF experts, non-EMF experts, or a combination of such experts would have a scant possibility of ascertaining the truth regarding EMF health risks.

A Tri-Partate Adjudicatory Process is Logically Defective

The question posed by Congress to the NIEHS Director can be answered only by individuals who have considered all the pertinent evidence. But the Proposal arbitrarily divides the scientific data, and forces participants in individual symposia to reach judgments regarding the ultimate issue based on only part of the evidence. It is not logical to pose the basic question to the participants in the individual symposia because whatever shortcomings might exist in the data within the jurisdiction of one symposium might be cured by the data within the jurisdiction of another symposium. Only if the evidence is considered altogether is it reasonable to make a final decision regarding the ultimate issue.

Symposium 1 is Unnecessary

The nature of EMF biological transduction mechanisms are of fundamental scientific importance, and great scientific accolades will be received by the individual who provides an explanation for the process. It is well to remember, however, that the question posed to NIEHS by Congress did not involve that issue, but rather the issue of whether present patterns of exposure to powerline EMFs create a health risk. The latter can be answered without answering the former, and it is my view that such was Congress' intent. On the other hand, linkage of the two issues has the effect of delaying indefinitely a substantive reply to Congress' question because, despite some promising leads, we are far from meeting the heavy burden imposed on anyone who proposes a deductive explanation of EMF bioeffects from physical theories. The first symposium, therefore, will create heat but no light because the only relevant question that could be posed to a physicist regarding the main issue is whether the laws of physics predict or preclude EMF transduction. Since the answer obviously is No, the symposium can serve no useful purpose (3).

The Proposal's Verbal Ambiguities Preclude Its Implementation

The Proposal speaks of "causal linkage", but nowhere are these and other fundamental and dispositive terms actually defined. A cause to a physical scientist is a force, like gravity, that constitutes a necessary and sufficient factor to bring about a result. In contrast, the biologist normally uses the term

to indicate a factor that is sufficient in the circumstances. The issue of whose cause is to be employed is outcome determinative. EMFs may be a cause of physical changes, but can never be a cause of disease under the physicist's definition of the word.

Similarly, health risk to a physicist implies concepts such as dose-effect, linearity of response, robustness, rigorous reproducibility, and near certainty. Others, particularly biologists, disagree regarding the degree of the applicability of these criteria in making judgments regarding what constitutes scientific knowledge regarding the question of health risks due to EMFs. Again, the choice is outcome determinative.

The Proposal also contains implicit ambiguities, the most important of which involves the extent of the burden of proof in making a judgment concerning health risks. In most physical measurements, accuracy and precision are usually matters of choice because they are under the control of the investigator. In biological studies, however, chance and uncontrolled factors are always present, and protection at the 5% level against a type-1 error is generally considered sufficient to warrant an assertion of a cause-and-effect relationship in a particular study. Generalization of results of biological studies never occurs with such a high degree of confidence, and when scientific data is taken over into the public domain the law imposes a preponderance-of-the-evidence burden (4). In physics, in contrast, a measurement to within 5% is generally considered to be only a first approximation, and the generalization of the results of such measurements (the electrical resistance of copper, as opposed to the results of a particular measurement, for example) is expected to be better than the results of individual experiments. The choice as to which rule to follow, again, is outcome determinative.

The Proposal Inextricably Commingles Science and Values

Over the past 30 years, I have attended numerous scientific meetings and spoken with many EMF scientists. I have encountered two extreme positions regarding the issue of health risks posed by environmental electromagnetic fields. Some scientists are strongly impressed by the critical role of electricity in modern civilization, and adversely disposed to any steps that might restrict its use except where warranted by clear, obvious, and certain scientific data. At the other pole are those who see EMFs as a principal factor in human disease, to be guarded against by government mandate, irrespective of the cost. Not surprisingly, individuals in the respective camps give different answers to the question posed by Congress while professing to reason from the same data base. The point is that for these scientists, and those with in-between views, personal values influence the answers that would be given to the question of EMF-induced health risks. Although this is a normal human reaction, it would be improper for the NIEHS to employ a strategy that encouraged commingling of scientific judgment and personal values because they are entirely separate factors, within the adjudicatory domain of entirely different groups. Scientists should judge the science, but society's representatives should judge the judgment of the scientists and utilize the values of society to determine the appropriate response to any risk posed by EMFs.

In the United States, decisions affecting the public that involve scientific issues must be made on the basis of "scientific knowledge" (5). In the Daubert case (5), the Supreme Court specifically rejected consensus and general acceptance as a basis for public policy decisions involving science. None of the parties or interveners in the case had the temerity to argue to the Court that such decisions ought to be made on the basis of the value system of particular scientists. Despite this, the Proposal envisions an adjudication process that will essentially guarantee a pivotal role for the personal values and beliefs of the symposia participants.

Extrinsic Validity of the Data is Not Assured

The source of funding of a scientific experiment is not a factor in the peer review of a manuscript because the review process is limited to scientific considerations. But suppose that an employee of a power company published a study that concluded that living near powerlines does not result in increased risk for disease. Even though the employee-employer relationship does not affect the peer evaluation, ordinary human experience suggests that such studies might be biased in some manner. The relationship could, therefore, properly serve as a basis to give less weight to the results of the study. Thus, depending on how a study was funded, a question concerning its extrinsic validity may arise. Similar concerns are also engendered when a study is funded via contract.

A contract is a method of funding research to provide knowledge that is desired by the funding party. Both the Electric Power Research Institute (EPRI) and individual electric utility companies have routinely employed the contract mechanism for funding research. Data obtained pursuant to these contracts is owned by EPRI or the individual utility company, and it is the industry itself that has the right in the first instance to determine disposition of the data and the extent of access that will be permitted. Investigators working under a contract may be permitted to submit some of their work for peer review, depending on the needs and desires of the sponsor. But the sponsor may have various concerns, including potential civil liability, that could encourage secrecy regarding some or all of the study results. The lack of academic freedom to publish whatever data one chooses is a well-understood aspect of contract research. In agreeing to perform contract research, an investigator acknowledges that the primary goal is the satisfaction of the contract, not contribution to the corpus of public knowledge in science.

In the case of EPRI, restricted access to scientific information is the rule from the beginning to the end of the contract process. The experimental design is not disclosed in advance, mid-stream changes in experimental strategies can be implemented with no need to rationalize the changes, only selected portions of the results need be disclosed, and when final reports are prepared they normally cannot be obtained by non-members of EPRI unless the requesting scientist is willing to pay $200 for a copy of the final report. There is no national registry of EMF research performed by the power industry; it is not possible, therefore, to establish what research is occurring or has occurred.

The nature of the privity between the author of a scientific study and the electric utility industry in whose favor the results are advanced can affect the weight accorded the study because directed research such as that performed by an employee or contractor of a party may be partisan in the sense that non-scientific considerations may affect what is done, what is released, and how it is interpreted (6).

In contrast, research funded by grants from the National Institutes of Health is performed pursuant to a specific plan, and the plan itself, as well as all data reported to the granting agency, is available under the federal Freedom-of-Information statute. Moreover, NIH has promulgated policies directing that the raw data obtained during the conduct of the research, as well as associated materials, should be made available to all interested parties.

Although the idea of dishonesty in science, in any form and to any degree is repugnant, various species of dishonesty do occur. The steps envisioned in the Proposal for assuring the reliability of data are inadequate because NIEHS cannot guarantee that the data volunteered by the industry is valid.

Work Product of Previous Blue-Ribbon Committees Not Excluded

Several factors indicate that the work product of the previous EMF blue-ribbon committees is not

reliable. First, the primary goal of all the past committees was to arrive at a consensus, whereas the primary goal of the strategy implemented by NIEHS is to convey truthful and accurate knowledge to the Congress. Since there is no necessary connection between the consensus reached by any past EMF blue-ribbon committee and the accuracy of its work, there is no justification for allowing symposia participants to utilize the results of previous blue-ribbon committees.

Second, no consensus has any practical value unless it is formed by a representative group of individuals, because only in that case would it be reasonable to regard the committee's opinion as an accurate characterization of the state of the EMF science. If the committee members were chosen because of their opinions, as has frequently been the case, there would not be a basis for according the committee's opinion more weight than that due the members as individuals.

Third, blue-ribbon committees often have obvious conflict-of-interest problems that it would be excessively naive to ignore. It is not realistic to expect that employees of companies deriving profit from the manufacture or use of devices that emit electromagnetic fields will adequately represent the interests of those who are exposed to the emissions of these devices. Conflicts-of-interest occur even when a committee is appointed by a federal (7) or state (8) agency. Governmental involvement in committee selection therefore confers no advantage in this regard. Conflicts-of-interest should be suspected whenever the results of a blue-ribbon committee are colorably dispositive of an EMF bioeffects dispute because the disputes are incapable of resolution on a purely scientific basis (9).

Fourth, the credibility of the EMF bioeffects blue-ribbon committees has been seriously damaged by the manner in which the committees were chosen and tasked, and by the circumstances that characterized their activities. For example:

1. The persons responsible for selection of committee members and the mechanism by which they chose the members were usually not disclosed.

2. The committees frequently contained many, sometimes even a majority, of scientists having no previous professional experience with studies involving the biological effects of electromagnetic fields.

3. EMF biological scientists appointed to the committees generally identified with their own research as robust and well-established, and the results of other EMF investigators as problematical.

4. EMF biophysical scientists appointed to the committees were usually strident polemicists who derided the possibility of EMF-related health effects on the basis of their understanding of physical theory.

5. The final judgments of EMF blue-ribbon committees have nearly always supported the agency or industry whose EMF-emitting hardware gave rise to the concern that led to the formation of the committee, particularly in those cases where the agency or industry funded the committee (10).

6. The final reports of EMF blue-ribbon committees usually deprecated the EMF studies that were not performed by members of that committee, but accepted or even lauded the work of committee members (11).

Despite the shortcomings of previous EMF blue-ribbon committees, the Proposal fails to preclude or account for these problems, thereby guaranteeing that they will play a prominent part in the proposed symposia.

Failure to Consider Industry Arguments

The question posed by Congress to NIEHS has a long history in administrative and judicial forums in

the United States, beginning with the Public Service Commission of New York, in 1974. A discernible pattern of industry arguments has evolved, and those arguments can be anticipated to also arise during the NIEHS review of the EMF bioeffects issue. Under the Proposal, these arguments will proceed in the absence of guidelines for assessing their relevance and materiality, and for determining the role that they will play in the process. Typical examples of industry arguments are as follows.

Role of Frequency. The issue posed by Congress involves the health and safety of electromagnetic fields from the electric power system, which operates at 60 Hz. Consequently, all theoretical and experimental data dealing with other frequencies is irrelevant and should not be considered.

Specificity of Response. In order for electromagnetic fields to be considered a health risk, they must cause specific human illness. For example, they must be capable of causing non-Hodgkin's lymphoma, or chronic lymphocytic leukemia, or other specific histological subtype of cancer. Studies linking electromagnetic fields to cancer in general or to other disease processes are therefore irrelevant.

In Vitro Studies. All in vitro studies are irrelevant because one cannot infer the likelihood of disease and the occurrence of any particular effect in an isolated cell. At best, in vitro studies are useful for understanding mechanisms, but it is universally conceded that mechanisms are not identified or even reasonably suspected.

These, and other similar arguments (12), have been well crafted by industry attorneys during the past 20 years. The industry has assembled a well-oiled machine consisting of an extensive database, private consulting companies, a seasoned group of expert witnesses and attorneys specializing in the defense of EMF claims, and a battle-tested sequence of arguments and positions that can be condensed or expanded and changed in complexity or detail to meet the constraints of any forum. The industry arguments can be mastered quickly by any reasonably competent scientist who chooses to do so. Does NIEHS intend to allow these arguments to be made during the course of its review of the evidence? If so, whom does NIEHS expect will argue the contrary position? If no one does, as will likely be the case for the reasons discussed above and in the next section of this comment, would it be fair to say that both sides of the issues were considered?

Financial and Personal Risks Not Adequately Considered

In 1975, Robert O. Becker, M.D., was the first investigator in the United States to seriously warn of health risks from powerlines. At that time he was an established investigator with an international reputation. He had received the highest award offered by the Veterans Administration (VA) for scientific research, was a fully funded medical investigator within the VA, and had several NIH grants. When he opined publicly (in a proper forum, at the request of the officers of that forum, and without remuneration) that powerline electromagnetic fields were health risks, the bottom simply dropped out of his scientific career. During the next 5 years Dr. Becker lost all his grants, and was forced into retirement at the age of 56. Dr. Becker's fate is well known within the EMF community, and stands as a strong deterrent to those who would speak publicly on the wrong side of the powerline EMF issue.

Powerful organizations including EPRI, the law firms of Crowel & Moring and Watson & Ritter, the American Physical Society, the Department of Energy, and Florida Power & Light Company steadfastly maintain that powerline electromagnetic fields are not health risks. Why would anyone choose to oppose that view publicly, despite the evidence? How would that investigator be protected from reprisals?

Furthermore, participation in the symposia is largely self-funded. This will present no problem for the industry groups, which possess abundant resources, but it will largely preclude scientists with opposing

views from participating for lack of funds because these scientists have no sponsor. What resources would be made available to someone who agrees to oppose the industry groups?

No procedure evolved by NIEHS can succeed unless it is appropriately funded and the participants are protected from reprisals. These considerations, however, are ignored in the Proposal.

ALTERNATIVE PROPOSAL

The United States is at an historically significant point in the development of the relationship between science and society, and the NIEHS has an opportunity to chart the course of this development. Congress has vested considerable responsibility in the NIEHS regarding resolution of the EMF health-risk issue. This action was, in my view, an indication of the confidence and respect that those on all sides of the dispute have in the independence and impartiality of the NIEHS, and the resources and competence that it can muster.

Brief reflection will establish that, as a society, we are quickly running out of possible mechanisms for dealing in a fair and expedient manner with the EMF issue. State and federal blue-ribbon committees have failed because they lacked the mechanisms needed for elaboration of decisions in the public interest. State and federal regulatory agencies have failed because political considerations and the concerns of special interests have dominated the processes. The courts have failed because the extraordinary costs of civil litigation cannot normally be borne by ordinary citizens. Only the National Institutes of Health has the requisite technical expertise, credibility, resources, freedom from political pressure, and respect for dealing fairly with complex issues.

The fundamental problem with the Proposal as a putative strategy for responding to Congress' charge is that the Proposal fails to recognize the extent to which the blue-ribbon committee approach is a rotted structural mechanism that is incapable of serving the public interest regarding EMFs. Beneath the patching, paint, and polish, the NIEHS has proposed the same rotted structure.

If the NIEHS found it desirable to seize the present opportunity, it could design and implement an entirely new process for decision-making in the public interest regarding the EMF issue. If successful, that process could serve as the model for decision-making in future similar debates.

Evolution of the needed decisional mechanism should begin with a recognition that the blue-ribbon-committee process has failed, but that this failure can serve as the point of departure for the creation of a new system of scientific decision-making in the public interest. This can be accomplished by analyzing the factors that led to the failure, and creating a new system that avoids them. Such a plan is no guarantee of success, but it is sufficient to avoid the guarantee of failure.

Prior to any symposia or meetings dealing with the substantive issues, the NIEHS should formulate a comprehensive plan regarding how it will discharge its responsibilities under the Energy Policy Act of 1992, and submit that plan for (New Proposal) comments. Following whatever modifications may be appropriate, a direct inquiry into the substantive issues could proceed. Some of the important issues that ought to be considered in the New Proposal are discussed below.

Important Unresolved Issues

The intent of the NIEHS is to "... address the question of whether the EMFs produced by the generation, transmission, and use of electric energy pose a risk to human health, and if so, to determine the significance of the risk and develop mitigation technologies." Each of these goals, however, is far too vague. What does it mean, for example, to identify a factor as "a risk to human health?" How would

an objective investigator determine whether a particular agent is or is not a risk? What kinds of reasoning would or would not be acceptable? Some argue, for example, that if powerline electromagnetic fields were shown to affect the growth rate, brain electrical activity, or neuroendocrine system of animals, then it would follow that it would be reasonable to assume that similar effects could occur in similarly exposed human subjects, and that such a situation would reasonably indicate a risk to human health. Others argue that the human body could handle such changes and perturbations, and that evidence of risk to human health must be based on a showing that exposed animals developed diseases.

Are the results of in vitro studies capable of providing evidence regarding risks to human health? If so, how? If not, should they be excluded from consideration?

Some argue that the physical process by which EMFs are transduced by the body must be established as a condition precedent to accepting any EMF-induced biological effect as real. Those opposed to this view argue that the transduction mechanism is irrelevant to a consideration of the existence or non-existence of a human health risk. Should this question be decided by scientists at a symposium, or is it more properly a decision reserved to a more disinterested group, or a group with public-policy responsibility?

Some argue that the question of risk cannot be considered in isolation, and must be considered in relation to other factors such as cost of potential mitigation strategies. In this view, the methodology usually followed in relating scientific knowledge to society at large in non-EMF areas is not applicable to the powerline issue (4). In other words, the process ordinarily used to decide whether a particular drug is effective for treating disease, or whether the drug has side effects of a particular kind, or for deciding whether a particular pesticide residue will be a risk to human health, should not be followed in determining whether EMFs are health risks because economic dislocation could result. Economic consequences should be accepted by society, in this view, only if the quantum of the risk to human health is sufficiently great. Is this an acceptable argument? Is it an argument that ought to be permitted to be considered or decided by scientists? If so, should scientists making the argument be required to document these economic considerations?

The point of these and many other comparable examples is that one cannot pose a question regarding whether "risk" to human health exists unless one first indicates the type of evidence and reasoning by which an affirmative or negative answer to the question will be judged.

Similar comments can be made regarding the vagueness of the goal of determining the "... significance of the risk." "Significance" is a relative concept and therefore requires a frame of reference for rational discussion. It seems obvious that the risk posed by EMFs will be insignificant compared with some risks and significant when compared with others.

Other questions arise. For example: Is the question of "significance" related in any way to the involuntary aspect of present-day patterns of powerline EMF exposure? That is, would the significance of a risk properly be considered to differ in the case where a power company builds a powerline beside an already existing home, compared with the situation in which the home is purchased after construction of the line, with the new owner fully aware of the controversy and willing to accept whatever risks might exist?

Imprecise use of language and the implicit incorporation of inapplicable standards is pervasive in the EMF bioeffects literature, particularly in the literature that colorably exonerates electromagnetic fields as a health risk. For example, a recent press release from the National Research Council EMF Committee asserted that "no clear, convincing evidence exists to show that residential exposure to electric and magnetic fields (EMFs) are a threat to human health ...". The press release also says that

"research has not shown in any convincing way that electromagnetic fields common in homes can cause health problems...". But what is "clear and convincing evidence" in the context of the EMF health issue? What agent or factor has been identified in the environment with respect to which, in the opinion of the Committee, there is clear and convincing evidence that the agent poses a risk to health? If none are identified, then perhaps it is the case that no amount of evidence could meet the "clear and convincing" standard. Statements that evidence was not "convincing" should therefore be accompanied by a definition or suitable examples of the kind of evidence that would be convincing. Only then can the judgment be adequately evaluated, and determined to have been made in accordance with the applicable evidentiary burden.

Where did the Committee get the idea that "clear and convincing" was the applicable standard? That is simply not the rule in the United States, yet it was apparently the rule imposed by the Committee.

In summary, the goals of the fact-finding effort must be precisely characterized so that the evidence obtained is relevant, and reasonable rules and procedures must be formulated in advance of the fact-finding phase. Otherwise, the resulting vacuum will be filled by the individual participants according to their own ideas.

Stipulated Questions

The answers to the ultimate questions to be addressed in the fact-finding effort should be decided by a proper group of judges, applying a defined procedure to the scientific facts as determined by the scientists. This is so because questions affecting the general public must be decided by disinterested representatives of the public, not by participants in the dispute, according to a pre-established set of rules. It is the NIEHS' responsibility, not that of the scientists, to create an appropriate procedure to implement the scientific fact-finding.

The most desirable strategy would consist of propounding stipulated questions to the scientists in the context of a reasonable procedure, and asking the judges to resolve the ultimate issue, depending on the answers to the stipulated questions. Thus, the scientists would determine the facts, and the judges would assess whether the opinions of the scientists were adequately based on scientific knowledge and were formed according to the proper rules and guidelines, and the judges would then determine what (and to what extent) values would be incorporated in addressing the question posed by Congress.

The stipulated questions could, for example, include the following:

1. Do the animal studies show that powerline electromagnetic fields can cause biological effects in similarly exposed human subjects?

2. Are the animal studies showing putative cause-and-effect relationships between electromagnetic fields and biological effects different in quantity or quality from similar types of studies that involve agents other than electromagnetic fields?

3. In considering the laboratory studies purporting to show a relationship between electromagnetic fields and biological effects, what frequencies, waveforms, and field strengths should be considered in answering the question?

4. Was scientific information from research projects performed under contract to the Electric Power Research Institute or individual power companies withheld?

5. Do the epidemiological studies purporting to show an association between EMF exposure and human disease, particularly cancer, differ in quantity or quality compared with epidemiological reports purporting to link other factors with human disease?

A record pertinent to the charge from Congress will be created only if questions are posed that are reasonably related to that charge. Otherwise, the symposia participants will simply formulate questions that they consider important.

The Science Court

The mechanism of the blue-ribbon committee is quite useless for resolving the EMF powerline dispute. The only reasonable alternative proposed thus far is the science court (13). The time has come to implement this concept.

How might a science court work? After the issues to be decided are identified and framed, case managers for each side could readily be chosen. Each side would then present the evidence in favor of its view, and have the opportunity to directly test the evidence presented by the opposing side. The great strength of the science court approach, is the ability it allows to force each side to directly confront the affirmative evidence advanced by the other side (14).

The judges would then decide which side presented the more persuasive case based on the scientific evidence, and they would determine whether one side carried its burden by a preponderance of the evidence. The judges would then formulate a final decision of the science phase of the inquiry which would be considered by the NIEHS Director, together with other relevant information, in making his report to Congress. The proposed procedure is illustrated below. [not available]

The Judges Should Be Laymen

The choice of judges is a pivotal question. There are several reasons why the judges should be laymen, not scientists. First, each EMF investigator can reasonably be expected to have a predisposition toward one side or the other in the dispute. This is an appropriate and desirable state of affairs with regard to intra-science considerations because the goal of scientific expertise involves ascertaining the superior data within one's specialty. On the other hand, such individuals, almost by definition, lack judicial temperament. Ideally, a judge should be a knowledgeable person with a scholarly intellect, no preconceived attitudes toward the issue in question, and the determination to make a decision based on the entirity of the evidence presented under the rules.

Scientists who possess EMF bioeffects knowledge are particularly valuable as participants in the science court, where the strength of the data and the power of their reasoning can be displayed. It is at this level of the process that all first-rank EMF investigators should be employed because they are uniquely qualified to relate and discuss the available evidence.

Second, non-EMF scientists should not function as judges because the advantages that would be conferred by having judges who were familiar, generally, with the methodology of science would be outweighed by the disadvantage of the effect of the respective scientific traditions of the judges in the decisional process. For example, obviously, judges selected from the Board of Councillors of the American Physical Society would be more likely to acquit EMFs than would be more biologically-oriented judges. The reason is that the scientific tradition of the physical scientist differs fundamentally from that of a biological scientist, and all evidence presented in a science court would be seen through the prism of the judges' prior conditioning (15). The same comment generally applies to any group of non-EMF scientists who might be chosen: In each case, even given objective procedural guidelines and procedures, the tendency will be to see the evidence in terms of the scientific traditions of the respective fields of the judges (16).

Third, the questions posed by Congress are not scientific questions, but rather are non-scientific questions the resolution of which requires evaluation of scientific data. Congress did not call on the

NIEHS to evaluate the scientific sufficiency of the ion paramagnetic resonance model, the role of melatonin or ornithine decarboxylase, the utility of the use of wire codes as a surrogate for exposure to magnetic fields, or the role of the neuroendocrine system. These are scientific questions that must be answered by scientists. On the contrary, Congress asked whether exposure to electromagnetic fields from powerlines pose a significant risk to human health. The question cannot be answered purely within the scientific domain because it incorporates values and concepts that are themselves defined and given meaning only in the context of society at large, the larger community of which science is only a part. It is desirable that the particular step in the adjudicatory process at which the transition from science to society occurs should be precisely identifiable, and should be taken only by those competent to do so.

The Lay Judges Should be Judges

Judges are routinely charged with the responsibility for deciding issues based in the relatively narrow world of science, but having an impact in the more general world of society. They are therefore uniquely qualified to make judgements in the general public interest. There can be no serious question regarding the integrity and independence of judges, generally, and their freedom from undue influence. Thus, professional, competent scientists would judge the science, and professional, competent judges would judge the scientists, exactly as occurs in every other area in the United States in which scientific knowledge has a role or an impact (4).

To minimize possible conflicts and insure that only the best persons would be involved, it would be desirable to choose the judges from among senior federal judges who have a documented history of scholarship in matters involving science and science policy.

Procedures in the Science Court

The procedures to be followed in the science court must be specified by NIEHS, but they could include the following.

(1) The adversary proceeding will consist of affirmative cases put forth by case managers on each side of the debate, followed by a thorough cross-examination of the positions taken by representatives of the other side. This is the key aspect of the science court, and it is of profound importance in ascertaining the public interest. Events of the past 25 years have amply demonstrated that any view regarding EMF bioeffects, regardless of how extreme it may be, can be made to appear plausible if the proponent of that view is not required to directly confront the opposing evidence and arguments.

(2) The rules of evidence will be the scientific rules, not the legal rules of evidence. Consequently, personal attacks on the participants will not be allowed, and the expertise of participants will not be challengable. At the outset, the managers of the issue in the science court will agree upon a formulation of the rules ofscientific evidence which, after any appropriate modification will be approved by the NIEHS and will then govern the proceedings.

(3) The affirmative case for each side will be written and pre-filed, prior to oral proceedings conducted in an open fashion.

(4) At the open proceedings, each scientist who has agreed to participate will briefly summarize the position he has taken, after which that position will be challenged by scientists on the opposite side. It will be the responsibility of the case managers on either side to present an orderly and

logical succession of scientists capable of explaining and defending the overall position advocated by each side. The record created, on which the decision will be made, will thus consist of the pre-filed direct positions of the scientists advocating each side of the issue, and the verbatim transcript of the cross-examination.

(5) The entire proceeding will be open to the public, but the deliberations of the judges will be in private.

(6) If participants rely on the results of contract research, the NIEHS should make an effort to convince the sponsoring company to make all the data gathered pursuant to that research available to the science court.

(7) The decision of the judges will consist of an enumeration of the specific findings made by the judges, and the relationship of those findings to the answers given to the stipulated questions. The judges will then make an overall decision indicating which side, if any, has carried its burden by a preponderance of the evidence. If the judges conclude that the evidence is in equipoise, they shall so state. This decision should serve as the answer to Congress regarding the question posed, and should not be substantially modified by the NIEHS Director.

(8) No appeals will be permitted in any judicial or administrative forum.

The NIEHS should invite top scientists on both sides of the dispute. If, however, the NIEHS is unable to secure the cooperation of a sufficient number of qualified scientists on one or the other side of the dispute, the judges and the NIEHS Director will be entitled to appropriate presumptions regarding the main issue. When an attempt was made almost 20 years ago to implement a science court procedure regarding the issue of health risks from powerline electromagnetic fields (17), scientists who spoke on behalf of the industry refused to take part because they felt that the science court would simply provide publicity for those on the other side of the dispute. If the same result were to occur today, then it may be reasonable to draw some obvious presumptions from the failure of individuals who might strongly oppose the notion that the EMFs were health risks when testifying, for example, in various court proceedings, but who then refused to take part in an NIEHS proceedings. On the other hand, if the NIEHS secured complete cooperation from the industry side, but none whatever from the opposite side, it would similarly be possible to draw reasonable presumptions and incorporate them into a decision or recommendation to Congress (18).

Bioethical Considerations

The question of exposure to powerline EMFs has serious bioethical implications that should be considered concomitantly with the question of health risks. Some would argue that the scientific evidence indicating that EMFs are a health risk is strong and becoming progressively stronger, and that the quantum and quality of the scientific knowledge tending to establish the existence of the risk exceed those for any other environmental factor. In this view, if the results of the NIEHS effort failed to establish the existence of the risk, it would follow that the process simply did not provide adequate resources, opportunity, an appropriate procedure, and a fair forum for an adjudication of the issue. Others would entirely disagree with the opinion. The point is that there exists a bona fide dispute among competent scientists regarding the health-risk issue. That being the case, is it ethically permissible for any result of the adjudication process to be presented to the Congress and the people in terms of a black-or-white answer?

In distinction to smoking which is a voluntary act, exposure to the electromagnetic fields of powerlines and other electrical appliances is usually involuntary. The bioethical ramifications of this distinction

have been ignored by the EMF blue-ribbon committee, but they should be addressed by the NIEHS. Added urgency is provided by the asymmetry that presently exists between the parties that gain the benefit of public exposure to powerline EMFs and those who bear the risk of the exposure. If the power industry is correct in its assertion that environmental power-frequency EMFs do not constitute a health risk, the proper response would be to take no steps that would limit or interfere with the delivery of electric power because such steps would amount to an unjustified economic burden on the industry. On the other hand, if the industry is wrong, then disease rates among the exposed subjects would be increased. Thus, the benefit flows to the industry stockholders whereas the risks accrue to the exposed members of the public. Again, no such fundamental dichotomy exists with regard to smoking because the individual who enjoys the benefits and pleasures of smoking also runs any risks associated with smoking. Further, smokers are generally aware of the controversy regarding smoking's link to disease. However, most people are unaware of the existence of electromagnetic fields, and of the controversy surrounding exposure to fields.

When these various facets are considered, the situation seems reasonably akin to an experiment - collecting data with the intention of assessing whether the facts support a favored hypothesis. Indeed, if bioethicists and other similar experts determine that the situation does not amount to involuntary human experimentation, it would be important to delineate the aspects of the present exposure patterns that warrant the distinction. Identification of these distinctions and their acceptance by Congress might forestall development of future controversies. Failure to evaluate the bioethical dimensions of the question posed by Congress would be a serious error.

FOOTNOTES AND REFERENCES

(1) The request for comments was received October 24, with a deadline for reply of November 10, 1996. The short time period provided for comments did not permit a full discussion of some of the points raised, nor time to sufficiently document all sources and references cited in the comments.

(2) It would obviously be reasonable to pose specific questions to non-EMF experts as an aid in evaluating particular EMF reports. For example: Were molecular biological studies performed by Goodman and her colleagues, or Saffer and Thurston carried out at a level of competence typically exhibited by scientists working in the area of molecular biology? If not, what procedures or strategies constituted the sub-par performance? Since peer-review is no guarantee that the published work is valid, it might be entirely reasonable to consider such specific questions, and to seek the services of a non-EMF expert in doing so. For example, if Dr. Stuart Aaronson, National Cancer Institute, were asked to review published EMF studies involving molecular virology, his comments would deserve considerable weight because of his standing in that scientific discipline. On the other hand, Dr. Aaronson's opinion concerning the global issue whether powerlines constitute a health risk (they do not, according to his testimony in Zappavigna v. New York) would be exactly the role that a non-EMF expert should not be afforded in evaluating the health risks of powerline EMFs.

(3) The role of the physicist in the EMF bioeffects debate has been consistently dogmatic and focused on irrelevant issues.

Following World War II, questions arose concerning the safety of military personnel exposed to the EMFs from the newly-invented radar systems. Herman Schwan was brought to the United States, where he joined the engineering faculty at the University of Pennsylvania and secured support for research regarding EMFs. In the early 1950s Dr. Schwan presented calculations

showing, he argued, that electromagnetic fields were safe. Those calculations were implemented by the military and federal agencies as if they had the force of law (which they did not).

In 1975, Dr. Schwan extended his calculations to high-voltage owerlines, and concluded that they also were safe. All subsequent physicists who have opined publicly regarding health risks of EMFs have simply repeated Dr. Schwan's reasoning. The assertions became increasingly shrill, culminating in a recent manifesto in which the Board of Councillors of the American Physical Society expressed belief and doctrine, but provided no reasoning based on scientific knowledge.

Congress wants the NIEHS to answer the question: Does exposure to powerline EMFs constitute a health risk? The physicist, in contrast, wants to answer the question: What is the transduction mechanism for biological detection of EMFs? It is clear that these questions are different. It is also clear that the absence of knowledge regarding mechanisms (almost universally conceded) is irrelevant and immaterial. It is irrelevant because the absence of knowledge regarding a mechanism does not make the biological evidence more or less credible. We do not understand the mechanisms that underlie gravity, love, pain, fracture healing, the loss of anchorage independence by neoplastic cells grown in culture, clearance of human immunodeficiency virus from the bloodstream, or the mechanisms underlying a plethora of other observable processes. In no case, however, is it rationally argued that the absence of mechanistic knowledge is relevant to the issue whether the phenomena exist.

The argument is immaterial because, even if true, it has no consequences with regard to the issue of whether EMFs are a health risk to human beings. It might be material to a question involving mitigation strategies because mechanistic knowledge would permit the industry to devise remedies that would minimize its costs. The question of mitigation strategies, however, is far from the main thrust of the Congress's interest, and that question is not ripe for consideration unless the main question posed by Congress is first addressed.

In any sensible inquiry into the health risks of EMFs, the issue of mechanisms would not enter at the fact-finding stage because no true issue of fact is presented - no credible scientist maintains that he knows or understands the mechanism. Injection of the issue of mechanism merely serves to consume the resources of the tribunal.

(4) Many federal laws (and accompanying regulations) require the use of animal studies to assess human health risks, and none contain provisions that would vary the normal evidentiary burden associated with civil litigation. Clean Air Act, codified at 42 U.S.C. §7401 et seq. (1983 & Supp. 1995); Consumer Product Safety Act, codified at 15 U.S.C. §2051 et seq. (1982 & Supp. 1995); Federal Food, Drug, & Cosmetic Act, codified at 21 U.S.C. §301 et seq. (1972 & Supp. 1995); Federal Hazardous Substances Act, codified at 15 U.S.C. §1261 et seq. (1982 & Supp. 1995); Federal Insecticide, Fungicide, & Rodenticide Act, codified at 7 U.S.C. §136 et seq. (1980 & Supp. 1995); Federal Water Pollution Control Act, codified at 33 U.S.C. §1251 et seq. (1986 & Supp. 1995); Occupational Safety and Health Act, codified at 29 U.S.C. §651 et seq. (1985); Resource Conservation and Recovery Act, codified at 42 U.S.C. §6901 et seq. (1983 & Supp. 1995); Safe Drinking Water Act, codified at 42 U.S.C. §300 et seq. (1991); Toxic Substance Control Act, codified at 15 U.S.C. §2601 et seq. (1982 & Supp. 1995).

Federal public health authorities invariably consider both animal and epidemiological studies. U.S. Environmental Protection Agency, Final Guidelines for Developmental Toxicity Risk Assessment, 56 Fed. Reg. 63798, 63799 (1991) ("hazard identification/dose-response evaluation involves examining all available experimental animal and human data"); U.S.Environmental

Protection Agency, Proposed Guidelines for Assessing Female Reproductive Risk, 53 Fed. Reg. 24834, 24836 (1988) (EPA consistently relies on "evaluation of toxicological data from humans and experimental animals" in assessing reproductive and developmental risks); U.S. Occupational Safety and Health Administration, Final Standard for Occupational Exposure to Ethylene Oxide, 49 Fed. Reg. 25734, 25743 (1984) (OSHA ruling rested on a "comprehensive review of the scientific evidence ... based on information from many investigations in several species of experimental animals ... as well as positive results from several human studies"); U.S. Occupational Safety and Health Administration, Final Rule for the Identification, Classification, and Regulation of Potential Occupational Carcinogens, 45 Fed. Reg. 5002, 5040-59 (1980) (requiring data from other human studies or from experimental studies in test animals).

(5) Historically, the courts in the United States did not ask a scientist "how do you know?". Rather, the courts assumed that science was objective, dispassionate, and without the bias that is sometimes seen in other areas of human endeavor. The error resulting from this unrealistic view of scientists was rectified in Daubert v. Merrell Dow Pharms., Inc., 113 S.Ct. 2786, 61 U.S.L.W. 4805 (1993). In that case, the question presented to the Supreme Court was whether "general acceptance" was the standard for admitting scientific testimony. The Supreme Court rejected the "general acceptance" standard and held that the reliability of scientific opinion must be determined from a consideration of how the scientist arrived at his opinion. The testimony would be acceptable only if it was based on "scientific ... knowledge."

Every scientific dispute, the dispute in the Daubert case and the dispute regarding the bioeffects of powerline EMFs are only two examples, involves two schools of thought regarding the scientific evidence, one of which is generally favorable toward each side. Science on the opposing side of the dispute is called "junk science" to distinguish it from the "good science" advanced by the other side; "good science" is my science, and "junk science" is the other guy's science. The Supreme Court said, in effect, that all such disputes must be decided in an open adversarial process based on scientific knowledge. For further discussion see The Scientific Basis of Causality in Toxic Tort Cases. A.A. Marino and L.E. Marino. Dayton Law Review, vol. 21, pp.1-62, 1995.

(6) The following is an example of how the manner of disclosure of a study can affect its interpretation. Since the mid-1970s, investigators at Battelle Pacific Northwest Laboratories have performed contract research, partly funded by EPRI and DoE, to show the safety of high-voltage powerlines. One study involved the effects of long-term exposure to electromagnetic fields on the growth rate of mice. One group of animals was exposed to the field, and the other served as the comparison group to permit assessment of the effects of the field. The result was that the mice in the exposed group were smaller, on average, compared with the controls, and the difference could not be attributed to chance (less than a 5% possibility). The result was unexpected, and the experiment was repeated; this time, however, the exposed mice were found to be larger than their corresponding controls. Again, the results could not be attributed to chance. If the data from each study was evaluated separately, which was the initial plan, it would be concluded that exposure to electromagnetic fields can decrease or increase growth in mice, depending upon the presence or absence of other, unascertained factors. What the investigators did, however, was average the results of the two studies and conclude that electromagnetic fields had no effect on growth in mice and, consequently, that the studies did not suggest a likelihood of harm to similarly exposed human subjects. R.D. Phillips et al., U.S. Dept. Energy, Biological Effects of High Strength Electric Fields on Small Laboratory Animals, DOE/TIC-10084 (1979). Discussed in R.O. Becker & A.A. Marino, Electromagnetism & Life

150 (1982); A.A. Marino & J. Ray, Electric Wilderness 98 (1986).

(7) The National Academy of Sciences (NAS), in cooperation with the U.S. Navy, appointed a blue-ribbon committee to evaluate the safety of a large Navy antenna that would emit electromagnetic fields similar in some respects to those emitted by powerlines, except that the fields from the antenna would be 100,000 times weaker. Three experts who previously testified that powerline electromagnetic fields create no health risk were appointed to the NAS committee. Not surprisingly, the NAS committee found that the proposed antenna would be safe. National Academy of Sciences, Committee on Biospheric Effects of Extremely-Low-Frequency Radiation, Biologic Effects of Electric and Magnetic Fields Associated with Proposed Project Seafarer: Report of the Committee on Biospheric Effects of Extremely-Low-Frequency Radiation (1977). P.N. Boffey, Project Seafarer: Critics Attack National Academys Review Group, 192 Science 1213 (June 18, 1976); Discussed in A.A. Marino & J. Ray, Electric Wilderness 98 (1986).

(8) H.B. Graves, who previously performed contract research for EPRI, was appointed by a state agency in Florida to chair a blue-ribbon committee regarding powerline safety. The committee generally exonerated state regulatory practices (which did not require any special efforts to lessen exposure to electromagnetic fields or to apprise the public of the nature or extent of the exposure). Shortly thereafter, Dr. Graves became the chief of staff for Crowel & Moring, which represents power companies in legal actions involving the issue of health risks due to electromagnetic fields from powerlines. See Florida Electric and Magnetic Fields Science Advisory Commission (H.B. Graves, Chairman), Biological Effects of 60-Hz Power Transmission Lines, Florida Electric and Magnetic Fields Science Advisory Commission Report (Mar. 1985); 8 Microwave News 3 (Mar./Apr. 1988).

(9) Industry employees, consultants, and contractors have routinely served on EMF blue-ribbon committees. Indeed, almost all EMF investigators who have served on the committees fall into one or more of the categories.

The most sensitive conflict-of-interest issue is raised when prominent and well-respected scientists accept industry contracts, and then agree to serve on EMF blue-ribbon committees that lack mechanisms capable of forcing them to explain and defend their views. Perhaps the two most prominent examples are Drs. Ross Adey, Veterans Administration Hospital, Loma Linda, California, and Dr. David Savitz, University of North Carolina, Chapel Hill, North Carolina.

It is not wise to make public policy on the basis of judgments formed in part by scientists in the position of evaluating the potential liability and responsibility of parties that control their research funding.

(10) Perhaps the only exception was an EMF blue-ribbon committee impaneled by the Navy (Proceedings of the Ad Hoc Committee for the Review of Biomedical and Ecological Effects of ELF Radiation, Bureau of Medicine and Surgery, Department of the Navy, Washington, DC, December 6-7, 1973).

(11) For example, the 1977 National Research Council report (Biological Effects of Electric and Magnetic Fields Associated with Proposed Project Seafarer, Report of the Committee on Biosphere Effects of Extremely-Low-Frequency Radiation, National Academy of Sciences, Washington, DC, 1977) lauded only the calcium efflux studies. Similarly, the 1996 NRC report seemed to afford the existing science little respect, except for the studies dealing with melatonin and the epidemiological studies involving wire codes and childhood leukemia. In each case, the

studies were performed by committee members.

(12) Zappavigna v. New York, Claim No. 74085 (testimony of Richard Bockman, Oct. 11, 1988); only animal studies need be considered. Zappavigna v. New York (testimony of Margaret Tucker, Oct. 13, 1988); only epidemiological studies need be considered. Rausch v. School Board of Palm Beach County, Civ. No. CL 8810772 AD (D. Fla. 1989) (testimony of Phillip Cole); powerlines are safe because the number of negative studies is greater than the number of positive studies. For further details see A.A. Marino, Negative Studies and Common Sense, 8 J. Bioelectricity v (1989). Alabama Power Co. v. Western Pocahontas Props., No. CU88-676 (Cir. Ct. Ala. Apr. 17 1992) (testimony of Mary Ellen OConnor); knowledge of underlying mechanisms is required to show a causal relation between electromagnetic fields and health risks.

(13) The Science Court Experiment: An Interim Report, 193 Science 653-56 (1976).

(14) In a blue-ribbon committee approach, even if it were the case that both sides of the dispute were represented by virtue of their choice of the committee members, it would still be difficult to constrain the two sides to address the same issues. Each side would likely focus on its own evidence, and ignore the evidence championed by the other side.

(15) The lack of reticence on the part of individuals and groups that ought to know better to make judgments that are beyond their competence is a hallmark of the EMF bioeffects dispute. The best known, recent example was the manifesto of the Board of Councillors of the American Physical Society which exonerated EMFs as a health risk. That action was supported by 35 (of 36) Councillors, even though none has a history of competence in the subject, as indicated by the lack of publications listed in Index Medicus. An even more striking example was that of 6 physicists and a chemist, all Nobel Prize winners, who sought legal counsel and then filed a voluntary friend-of-the-court brief with the California State Supreme Court in which they forcefully argued against the idea that powerline EMFs were a health risk. These cases illustrate both the depth of the feeling regarding the EMF issue, and the tendency for even first-rank scientists to opine in areas well beyond their competency.

(16) A major problem with the Proposal of the NIEHS is the implicit assumption that there is only one form of scientific reasoning, and that consequently the main issue involves the sufficiency of the data. This is not the case. See: The EMF bioeffects debate results from a paradigmatic shift. A.A. Marino, Abstracts from the 18th Annual Meeting of the Bioelectromagnetics Society, Victoria, B.C., Canada, 1996. Briefly, the physical scientist follows a hypothetico-deductive form of reasoning, and explains observations as deductive consequences from particular mathematical equations. The biological scientist follows an abductive form of reasoning and suggests general principles that may govern biological activity.

(17) A. Mazur, A.A. Marino, & R.O. Becker, Separating Factual Disputes from Value Disputes in Controversies over Technology, 1 Technology in Society 229-37 (1979).

(18) There is obviously no serious danger that the industry position regarding the health effects of EMFs will be undersupported, assuming that the proponents of that view agree to participate. On the other hand, as discussed, there is a serious question regarding the available resources and possible risks that would be faced by those who would argue against the industry position. If NIEHS does not adequately redress the imbalance, it would not be reasonable to conclude that the anti-industry view has no merit based on the refusal of scientists to participate in advancing those arguments, given the personal expenses and jeopardy that would accrue to them.

6.5. note 2 (pp. 122-127)

NIEHS' purpose is "(1) To review the overall quality of research findings relating to the interaction of electric and magnetic fields (EMF) with biological endpoints focusing on biophysical observations and experimental findings and (2) to evaluate if the biological effect is reproducible and if there is sufficient evidence to support a causal linkage between EMF and the effect. The focus of this symposium will be on the use of experimental systems below the level of the whole animal (e.g., in vitro cell culture assays)." But as described previously, the plan is flawed.

Summary of Flaws in Purpose #1. [see below]

Summary of Flaws in Purpose #2. [see below]

One consequence of the flaws is that the results of the Symposium are predictable.

MONDAY, MARCH 24, 1997 **BIOPHYSICAL MECHANISMS**	**PREDICTED RESULT OF THE SESSION**
8:00 AM - 12:30 PM Plenary Session	
Epidemiological studies on EMF	None (no known biophysical mechanisms pertinent to the epidemiological studies)
Nongenotoxic mechanisms of carcinogenesis	None known (pertinent to EMF)
EMF dosimetry - internal fields resultingfrom environmental exposures	Meaningless mathematical formulas
Implications of biophysical mechanisms on the detection of effects from weak fields	Speculation
Theory versus experimentation: how great isthe burden of proof?	Extreme idiosyncratic opinions
2-5:30 PM Breakout Groups	
Magnetochemistry and magnetite	Speculation
Magnetochemistry and magnetite	Speculation
Internal fields produced by EMF, dosimetry,and endogenous fields	Meaningless mathematical formulas
Physical theory and human health risks	No risks predicted
TUESDAY, MARCH 25, 1997 **CELLULAR REPLICATION, DIFFERENTIATION, AND CONTROL OF**	

GENE EXPRESSION	
8:00 AM - 12:30 PM Plenary Session	
EMF effects on cellular replication	None conclusively established
EMF effects on cellular differentiation	None conclusively established
EMF effects on the molecular biology of the cell	None conclusively established
2-5:30 PM Breakout Groups	
EMF effects on cellular replication	None conclusively established
EMF effects on cellular differentiation	None conclusively established
EMF effects on the molecular biology of the cell	None conclusively established
The role of *in vitro* assays in clarifying and quantifying human health risks	Practically none
WEDNESDAY, MARCH 26, 1997 **ENZYMES, INTRACELLULAR PATHWAYS, AND SIGNAL TRANSDUCTION**	
8:00 AM - 12:30 PM Plenary Session	
EMF effects on calcium	None conclusively established
EMF effects on enzymes and polyamines	None conclusively established
EMF effects on signal transduction	None conclusively established
2-5:30 PM Breakout Groups	
EMF effects on calcium	None conclusively established
EMF effects on enzymes and polyamines	None conclusively established
EMF effects on signal transduction	None conclusively established
THURSDAY, MARCH 27, 1997 **IMPLICATIONS OF THEORETICAL MECHANISMS AND IN VITRO RESEARCH FINDINGS FOR HUMAN**	Practically none

HEALTH RISK	

ANALYSIS

It seems to me that the NIEHS is walking directly into an ambush cleverly arranged by Thomas Watson, an attorney who has represented the electric power industry on numerous occasions during the past 15 years. Watson, formerly of Crowel & Moring, and presently a partner in Watson & Renner, has assembled an enormous documentary archive of scientific reports, testimony, and other pertinent documents dealing with the biological effects of electromagnetic fields. He has assimilated and understood the evidence far better than one might expect could be done by a layman, and has confected and manipulated the evidence into a powerful series of sophist arguments that can be delivered in court by scientists previously identified by Watson and his former chief of staff, H.B. Graves, in an unprecedented and systematic search of American scientists to find friendly witnesses.

Watson's arguments can be used in high-frequency cases or low-frequency cases, depending on the interests of his clients. Watson's stunning successes during the past 15 years are a tribute to both his own lawyerly abilities, and the enormous financial and logistic resources that he can bring to bear in each case. His successes, however, are generally inconsistent with basic notions of scientific truth or societal justice, both of which fare poorly when Watson has an opportunity to implement his strategy.

The key elements in Watson's strategy that threaten to flatten the NIEHS effort to find the truth regarding the health risks of EMFs involve Watson's specific aims of (1) divide-and-conquer, (2) creation of a fictional facade to suggest that scientists involved in the EMF dispute, including those whom he has hired directly, are dispassionate investigators, rather than partisan advocates, and (3) fostering confusion.

Divide-and-Conquer

Watson has encouraged and exploited the natural antagonism between physicists and biologists regarding the biological effects of electromagnetic fields. The press release of the American Physical Society illustrates the growing sense of irrelevance felt in the physics community regarding what is somehow felt to be a stimulus that should be within the jurisdiction of physicists. The fact that NIEHS is holding the present symposium is mute testimony to Watson's success in exploiting the anger of physicists. NIEHS has, apparently, bought into the notion that physicists can say something relevant to the charge that NIEHS received from Congress, even though I can find no evidence supporting that view. It is understandable, perhaps, that Watson can exploit the situation in a courtroom setting because of his vast knowledge of the mechanics and details of the EMF dispute, and the relative unfamiliarity with the area on the part of his opposing counsel. This explanation, however, cannot excuse the NIEHS, which was specifically consulted by Congress because of its expertise.

Partisan Scientists

Watson has cleverly encouraged the perception that scientists are objective, unbiased, and free of the passions and prejudices manifested by other human beings. For this reason, a scientist can be both an advocate, as well as a judge of the position that he advocates.

This fundamental miscalculation regarding human nature has been accepted by NIEHS, as best I can

tell, because it appears that the offices of advocate and judge are to be combined in the procedure planned by NIEHS.

It is excessively naive to ignore the influence that money exerts in the judgment of individuals and in the positions that they champion. It seems reasonable to expect that any fair adjudicatory procedure intended to serve the public interest will not ignore the influence of money, but will take it into consideration in designing the truth-seeking procedure to be followed.

The NIEHS need look no farther than the National Cancer Institute (NCI) to appreciate what effect Watson's large bankroll can produce. Watson was able to hire Stuart Aaronson, a senior investigator at the National Cancer Institute and one of the country's foremost molecular virologists and elicit from him, in open court, testimony [see insert below] to the effect that EMFs from high-voltage powerlines were not a health risk. For a few hours' testimony in court, Aaronson earned an amount roughly equal to his annual salary from the NCI.

Testimony: In the 1980s, Watson identified a group of investigators who agreed to testify as experts on his behalf in cases involving health risks due to electromagnetic fields. He concentrated on individuals affiliated with prestigious institutions, and his biggest success was his recruitment of Stuart Aaronson, one of the most cited investigators in the United States in the area of molecular virology.

Aaronson became an expert in the EMF area in contemplation of specific litigation in New York, a condemnation case involving the construction of a high-voltage powerline. The legal procedure in the case involved the filing of a written report, followed by testimony in open court. In his report (Molecular and Cellular Biological Effects of Power Frequency Electric and/or Magnetic Fields), Aaronson gave his reasons for concluding "there is no scientific basis for concluding that power-frequency electric and magnetic fields induce any consistent effects on cell growth properties in culture or in vivo that are associated with the acquisition of malignant properties." Subsequently, on October 12, 1988, Aaronson gave oral testimony.

A perusal of the direct examination of Aaronson, conducted by Watson, will reveal how Watson uses his experts to support his client's position. Note that Watson's opposing counsel was vastly overmatched, and consequently did not conduct a meaningful cross-examination of Aaronson.

Fostering Confusion

An important lesson that can be learned from the EMF controversy during the past 15 years - a lesson well understood by Watson - is that confusion and uncertainty always work to the benefit of his clients because judges and juries are unlikely to change the status quo in the face of apparent confusion. It is hard to imagine a more confused procedural design than that presently being followed by NIEHS. It is unclear exactly who will procedurally bring together the facts in evidence on each side of the issue, exactly who will testify or opine regarding the substance of that evidence, exactly who will be able to challenge the opinions proffered by individual scientists, and exactly who will actually decide the issue and draft the report sent to the Director of the NIEHS.

SUMMARY

Watson, his employers, and other proponents of EMF-emitting devices have effectively co-opted the mechanism of the blue-ribbon committee, thereby obviating the possibility that such a mechanism will function strictly in the public interest. If only one point-of-view is represented on the EMF blue-ribbon committee, as has usually been the case, then history shows that it will be to the industry point-of-view. This is what I expect will occur at the first NIEHS meeting. The symposium will not yield any affirmative evidence favoring the industry position, but rather will result in negative arguments, condescension, invocation of irrelevant criteria, speculation, and a falsely-created sense of an absence

of appropriate scientific facts.

Despite this anticipated scenario, the symposium will not necessarily have a serious impact on the ability of the NIEHS to fulfill its responsibility under the law to advise Congress about the health risks of powerlines because there never was any serious possibility that the results of the symposium could produce information that was probative with respect to the EMF health-risk issue. What physicists have to say is simply not relevant.

The looming danger is that the reputation of the NIEHS may be adversely impacted if NIEHS does not modify its present plan for determining what is or is not a scientific fact in preparation for the second and third symposia. I think that Watson and his employers do not share the perspective of most independent American scientists that the integrity and independence of the NIH must be preserved at all costs, even at the cost of decisions that might adversely affect Watson's clients. He is a lawyer whose job is to represent the power industry, not to promote the interests of the NIH, the public, or unbiased science.

As the NIEHS contemplates its second and third symposia, it seems to me to be important that the fact-finding procedure be designed to blunt Watson's pervasive influence. I think that a science court, as described in my previous Comment, where the presiding officers would be senior federal judges, is one possible mechanism. There may be other possibilities, but the point is that it is impossible to reach decisions in the public interest unless the historical impact of Watson's strategies are recognized, and a mechanism for resolving the question posed by Congress is developed that effectively thwarts those strategies.

Summary of Flaws in Purpose #1.

The only relevant and meaningful question that can be posed to a physicist is: do laws of physics predict or preclude EMF transduction? The present (and undisputed) answer is no. Therefore, the Symposium can serve no useful purpose because the physicists who appear at the Symposium can only state the obvious.

"Overall quality of research findings" is a relative concept, not an absolute concept. NIEHS' failure to specify a frame of reference for evaluating quality will encourage idiosyncratic notions of quality, leading inexorably to the conclusion that all present EMF studies suffer in comparison.

The most fundamental principle involved in the fact-finding is that all the relevant evidence ought to be considered - a good answer cannot emerge from considering only part of the evidence. Even if biophysical evidence were relevant to whether environmental EMFs are a health risk, the planned attempt to evaluate the question on the basis of biophysical evidence is intrinsically flawed because it explicitly ignores pertinent evidence - the results of animal and human studies.

Summary of Flaws in Purpose #2.

It is not possible to evaluate evidence to determine whether a causal linkage exists between two factors until one first defines the state of the evidence that will be viewed as manifesting such a linkage. Because "causal linkage" has not been defined, each scientist-advocate who opines regarding this point will do so with reference to his own notion of the meaning of that phrase. Some investigators [see below] require that evidence be conclusive before a causal linkage can be established. In my view, much evidence indicates that the appropriate standard is less than conclusive. Regardless of which view is correct, however, the decision regarding which burden is appropriate belongs to society, not to individual scientists.

1. *Altoonian v. Atlantic City Electric Co.*, Testimony of P. Baumgarten, E. Gelmann, D. Golan, and D. LaBarthe, Superior Court, New Jersey, No. L-1342-91, 1995.

2. *Zappavigna v. Power Authority of the State of New York*, Testimony of R.K. Boutwell, R.S. Bockman, S.A. Aaronson, M.A. Tucker, L.F. Sinks, E.A. Egan II, and K.S. Zaner. Court of Claims, Claim #74085, 1988.

3. *Rausch v. The School Board of Palm Beach County*, Testimony of P. Cole, Circuit Court, Florida, Case No. CL-88-10772-AD, 1989.

4. *Oberon Powerline Investigation Committee v. The Electricity Commission of New South Wales*, Testimony of K.S. Zaner, Y. Stolwijk, R.S. Bockman, E.P. Gelmann, and M. Repacholi, Land & Environment Court of New South Wales, Australia, #40308, 1989

5. *Bendure v. Kustom Signals, Inc.*, Testimony of W. Guy, L. Erdreich, and R.K. Boutwell, Civil #C911173SAW, United States District Court, Northern District of California, 1992.

6.6. Conclusion

7. POWER-INDUSTRY SCIENCE AND POWERLINE EMF HEALTH HAZARDS.

7.1. Introduction

7.1. note 1

In December, 1973, Dr. Becker told me about a meeting where he learned that powerline electromagnetic fields might affect human health, and he notified the New York Public Service Commission (PSC). In July, 1974 we were both asked by the staff of the PSC to testify in a PSC licensing hearing involving construction of two 765,000-volt powerlines. We both wrote reports (Becker, Marino) explaining the basis of our view that the powerline electromagnetic fields could affect human health, and the PSC sent the reports to the power companies in October, 1974.

The hearing was recessed for a year to allow the power companies to find expert witnesses. The reports of their experts were distributed in November, 1975. At the same time the PSC provided the power companies updated versions of our reports (Becker, Marino).

In 1976 I was cross-examined by the power companies for 10 days, and Dr. Becker was cross-examined for 4 days. The power companies then requested a rebuttal phase of the hearing, and their experts filed additional reports that attacked our reports. By this time Dr. Becker was disgusted with the process, and he withdrew from active participation. I, however, was afraid to withdraw because I thought it would appear that I was admitting that the power-company experts were correct, which was not the case. Consequently, in March, 1976 when they filed reports aimed at rebutting my position, I filed a report aimed at rebutting their position. I was cross-examined for 3 additional days.

After the testimony was finished, the lawyers for the power companies and for the Public Service Commission filed legal briefs in an attempt to persuade the PSC Commissioners that powerline EMFs were not a health risk. The brief of the PSC staff argued that powerline electromagnetic fields would affect human health, but I thought an even stronger position was warranted. Consequently, representing myself, I submitted a brief, and a reply brief.

A rebuttal phase for briefs was allowed and the power-company lawyers submitted rebuttal briefs. Consequently, I also submitted a rebuttal brief.

The hearing examiners wrote a Recommended Decision in March, 1978, and the Final Decision was issued by the Public Service Commission in June, 1978. That decision led to extensive litigation involving the power companies and the PSC, the upshot of which was denial of permission to build one of the powerlines, the institution of some construction rules to protect the public from exposure to

electromagnetic fields from the approved powerline, and the initiation of a research program to assess more precisely whether powerline electromagnetic fields affected human health.

For a recounting of the hearing from my viewpoint see A.A. Marino and J. Ray: Electric Wilderness, San Francisco Press: San Francisco, 1986. For a description of the hearing from another viewpoint, see the Department of Energy report.

7.1. note 2 (pp 128-134)

RESEARCH PROJECTS IN BIOLOGICAL EFFECTS OF ELECTRIC AND MAGNETIC FIELDS CONTROLLED BY THE POWER INDUSTRY AND THE DEPARTMENT OF ENERGY

PROJECT AND CONTRACTOR	FUNDING AND DURATION	OBJECTIVE
RP1644-1 "Epidemiological Study of Utility Employees Exposed to High Voltage Electric Fields" Tabershaw Occupational Medicine Association.	$139,871 4/80-6/81	Provide information on health effects of individuals regularly or frequently exposed to high level electric fields. Provide a population base for updating morbidity information on these individuals. Provide dosimetry experience and estimates of exposure for various utility tasks.
RP1641-1 "CNS* and Endocrine Studies of Power Electric Field Effects" Tulane University.*(Central Nervous System)	$260,653 4/79-4/81	Determine if high intensity 60Hz fields affect endocrine and/or CNS function in rats. If effects are observed, the mechanisms will be sought and relative degree of adversity will be established.
RP1640-1 "Evaluation of Biological Effects of DC Fields Air Ions" University of California-Berkeley.	$251,375 5/79-4/81	Investigate the effects of air ions produced by high voltage DC fields on the biologic properties of mice. Effort is to be focused on growth, biochemistry, hematology, resistance to infection, tumor growth and tumorogenesis.
RP1064 "Effects of Electric Fields on Plants and Developing Embryos" Westinghouse Electric Corporation.	$796,617 6/77-7/81	Coordinate with other EPRI projects. Extends upon RP129. Determine the environmental consequences of EHV and UHV transmission lines.
RP0799-1 "Electric Field Effects on Large Animals" Battelle Pacific Northwest Laboratories	$2,740,775 3/76-5/80	Design, fabricate, and test a 60Hz exposure facility for Hanford Miniature Swine (HMS) having no corona discharge, mini-shock, or hair stimulation. Study the effects of HV fields over long periods on HMS.

RP0679-6 "Evaluation of Electric Fields on Implanted Cardiac Pacemakers in Humans" University of Rochester.	$55,728 9/79-9/81	Evaluate the effect of varying intensities of electric fields from EHV transmission lines on implanted unipolar and bipolar pacemakers in patients. For comparison, evaluate the effects of household sources of electromagnetic energy such as microwave ovens.
RP0857 "Biological Effects of Electric Fields General Support Study" ITT Research Institute.	$153,272 8/76-9/79	Collect and review the literature that has become available since mid 1974. Prior to this date, literature was reviewed under RP381.
RP0799-4 "Probe for Measuring Internal Voltages and Engineering Support: Effects of Electric Fields on Bees" ITT Research Institute.	$26,611 7/78-3/79	Develop Instrumentation
RP-TPS76-639 "Epidemiology of Lineman and Switchyard Workers" Equitable Environmental Health, Inc.	$24,175 3/76-7/78	Develop Instrumentation
RP0679-1 "The Effect of 60Hz Electric and Magnetic Fields on Patients with Implanted Cardiac Pacemakers" ITT Research Institute.	$142,467	Study the effect of EHV fields on cardiac pacemakers.
RP-TPS76-630 "Possible Effects of High Voltage Electric Fields on Honeybees: Feasibility Study" Bioconcern, Inc.	$42,500 2/76-8/76	Determine effects of high voltage powerlines on colony population, honey stores, bee generated noise, hive temperature, queen cell production, swarm tendency.
RP0581-1 "Effects of Electric Fields on Large Animals A Feasibility Study" Battelle Pacific Northwest Laboratories.	$74,900 8/75-2/76	Define conditions for experimental exposure of large animals to high intensity electric fields.
RP-381-1 "Biological Effects of High Voltage Electric Fields" ITT Research Institute.	$82,300 12/74-4/76	Develop a plan describing research necessary to determine if there are biological effects from EHV transmission lines.
RP129 "Ecological Influences of Electric Fields" Westinghouse Electric Corporation.	$521,374 5/74-5/77	Determine effects of high intensity electric fields on plants, animals and soils.

RP0098-1,2 "Biological Effects of Exposure to High Intensity Electrical Fields" Johns Hopkins University, School of Medicine.	1970-1976 $450,439 (included $5,000 support from TVA)	Determine if there are any biological effects to humans from exposure to high voltage fields.
RP0098-3 Johns Hopkins University	$98,000 7/75-2/76	Use anesthetized dogs and telemetered baboons for determining physiological effects of electric fields.
EA-77-A-01-6010/A017 "Psycho-Acoustic Response to Line Noise" National Bureau of Standards.	$891,000 1/76-9/80	Investigate the psycho-acoustic responses of humans to audible noise associated with high voltage transmission lines.
ET-78-C-01-5059 "HVDC Data Base to ?1500kV" General Electric Company.	$1,469,754 5/77-10/79	Develop a sufficient data base on the effects and characteristics of electric fields and air ion concentrations from DC transmission lines. Evaluate DC transmission as an alternative or complement to AC transmission.
FG 01-78ET10157 "Design, Construct and Test DC Bioeffects Enclosure for Small Animals" Illinois Institute of Technology Research Institute.	$570,000 24 months	Design, fabricate and test a prototype enclosure to subject small laboratory animals to a simulation of the electrical environment under HVDC lines.
AC02-80RA-5053 "New Conductor Systems" Charles T. Main.	$423,000 9/80-9/81	Develop promising concepts for new AC transmission conductors and prepare a test program. Develop techniques top quantify and characterize audible noise from corona.
ALO 0789/RPIS 2636 "The Effects of Low Frequency Electromagnetic Fields on Biological Systems" Sandia Laboratories.	$490,000 7/77-9/80	Using 3-300 MV/m and 5-500 A/m2 fields, develop an exposure system to produce electric fields within a cell culture medium and grow mammalian cells within that system; determine if the cell system is perturbed by electric fields, and if so, investigate the basic mechanisms for these changes.
EA-77-A-01-6010/A018 "Electric and Magnetic Field Measurements" National Bureau of Standards.	$742,000 3/75-9/80	Establish requirements for traceabilikty, performance criteria. Evaluate available instrumentation for measurements of AC and DC fields, calibration criteria, field use procedures.

AC02-80RA-50293 "Neutral, Cardiac, and Behavioral Effects of 60hz Fields" Randomline, Inc.	$190,000 9/80-9/8224 months	Investigate, using a battery of central nervous system tests in rats, effects from electric fields and to determine the mechanisms by which the effects may have developed. Determine threshold field strengths for effects found under previous DOE contracts.
A C01-80RA-50219 "Effects of Electric Fields on Non-Human Primates" Southwest Research Institute.	$4,000,000 38 months	Long-term study of the biological effects of 60Hz electric fields on non-human primates in both individual and group cultures. Data will be related to humans.
ET 78-C-01-2875 "Preliminary Study of the Behavioral and Biological Effects of High Intensity 60Hz Electric Fields" Southwest Research Institute.	$800K/Year 4/78-8/80	Study effects of 60Hz electric fields on non-human primates. Verify experimental protocols for the effects of high-intensity electric fields on biological parameters and behavior. The feasibility of predictive modeling of baboon and man for computer solutions will be addressed.
DE-W-3109-ENG-0038 "Biomedical Effects Associated with Energy Transmission Systems" = Argonne National Laboratory.	$1,132,000 10/77-10/80	Design and construct facilities for exposing small laboratory mammals to ELF (10-60Hz) electric fields. Study effects on circadian rhythm regulation viz physiological and behavioral patterns in mammals. Results of the study will assist in establishing allowable 60Hz field strengths for humane exposed to high transmission systems.
ET-76-C-06-1830 "Biological Effects of High Strength Electric Fields on Small Animals" Battelle Pacific Northwest Laboratory	$2,879,449 2/76-9/80	Establish a system for exposing small laboratory animals to 60Hz electrical fields. Study animal responses to these fields. Determine if there are any adverse biological effects. Field strengths up to 130kV/m.
AI01-79ET2-9078 "Tissue Interaction with Non-Ionizing Electromagnetic Fields" Jerry L. Pettis Memorial Veterans Hospital.	$536,324 4/79-4/81	Study effect of 60Hz electromagnetic fields on the central nervous system to achieve an understanding of mechanisms associated with fields and living tissues.
ET-79-C-06-1830 "Genetic Effects of Electrical Fields"- Battelle Pacific Northwestern Laboratory. (jointly funded by DOE and EPA)	$335,000 1/79-1/81	Determine whether DC and 60Hz electric fields can influence mutation rate in well characterized genetic systems (fruit fly) and if so, to establish a relationship between field

		strength and mutagenic potential and the mechanisms involved.
AC02-80RA-50153 "Electric Field and Ion Effects of HVDC Lines: ?60 to ?1500kV" General Electric Company.	$1,329,695 1/80-12/83	Investigate and quantify the effects of fields and ions which are observed near HVDC lines up to ?1500kV. Complete data base. (PHASE 2 of ET-78-C-01-5059).
AC01-79ET2-9016 "Analysis of Electromagnetic Fields and Noise Measurements on TVA 500kV Transmission Lines" Tennessee Valley Authority	$100K/Year 4/79-4/81	Measure and assess electromagnetic fields and audible noise along TVA's 500kV lines. Assess the effects on growth and development of selected plants.
CH03490-RPIS 3456 "Tibia Growth and Metabolism in ELF Fields" University of Rochester.	$127,000 7/79-9/82	Investigate the metabolic effects of electrical stimuli. Determine the mechanisms of stimuli.
CH03490/RPIS 2907 "Mechanisms of Neuroendocrine and Neurochemical Responses to Electromagnetic Radiant Energy" University of Rochester.	$744,000 10/77-9/82	Assess the stability of physiological regulation in rats exposed to 60Hz electric fields. Relate changes to behavioral studies.
CH03490/RPIS 2858 "Detection of 60Hz Electric Fields" University of Rochester.	$555,000 10/77-9/82	Investigate the threshold and mechanisms by which rats perceive the presence of 60Hz electric fields. Determine rat's preference, aversion or indifference to various field strengths.
CH03490/RPIS 2908 "Physical and Environmental Radiation Cytology" University of Rochester.	$305,000 10/77-9/82	Investigate the effects of high amplitude electric fields on selected cell systems. Develop dose/response data. Investigate mechanisms of interaction.
RL 01830/RPIS 2747 "Magnetic Field Dosimeter Development" Battelle Pacific Northwest Laboratory	$197,000 10/77-9/80	Develop working model of a magnetic field dosimeter to monitor exposure of individuals.
SF ENG48/RPIS 3097 "Magnetic Field Dosimetry" University of California, Lawrence Berkeley Laboratory.	$295,000 10/78-9/81	See above.

RL0183/RPIS 2720 "Biomagnetic Effects" Battelle Pacific Northwest Laboratory.	$1,190,000 10/76-9/82	Study short-term and long-term effects of strong DC magnetic (1 Tesla) fields in small mammals and other systems. Define possible functional, pathologic or mutagenic responses to these fields. Primary concern is human exposure in connection with magnetic fusion reactors, magnetohydrodynamics systems. Intrauterine exposure of mice.
SF ENG48/RPIS 2189 "Bioeffects of Magnetic Fields" Univeristy of California, Lawrence Berkeley Laboratory.	$1,435,000	Investigate physiologic functions in small animals under DC magnetic field exposure. Determine mechanisms of biologic interaction if any.
EY-76-C-03-0115/RPIS 800189 "Environmental Control Technology Requirements for Future AC Overhead Transmission Facilities" SRI International.	$110,000 6/78-9/79	Assess environmental control requirements identified as part of the concluded New York State Public Service Commission hearings on applications for approval of two 765kV transmission lines.
BPA 846-902 "BPA 1200kV Prototype Biological Study" Battelle Pacific Northwest Laboratory	$535,000 3/76-9/81	Determine possible effects of a prototype 1200kV line on natural vegetation, crops, wildlife, cattle and honeybees. (Joint BPA-DOE funding)
TVA942-15-531.08 "Effects of High Intensity Electric Fields" Tennessee Valley Authority.	$71,400 6/76-9/79	Review ongoing research conducted nationally. Investigate specific problems and solutions related to the TVA power system.
LPL91252 - "Study of Subtle Effects Induced by High Intensity 60Hz Electric Fields" (Louisiana Power and Light) Tulane University.	$46,122 9/77-8/78	Investigate the actual cause of subtle effects of high intensity electric fields.
SCE052.010 "Transmission/ Substation Electromagnetic Field Effects" (Southern California Edison Co.) Loma Linda University; Manpower Inc.; Washington State University.	$1,105,000 2/78-12/83	Assess and minimize physical and biological effects of existing and future transmission systems. Identify areas of concern. Monitor and assess projects in this area being conducted by DOE, EPRI, EEI, EPA and other utilities. Construct a data base on physical effects such as TVI, RFI, AN. Identify areas of concern and formulate detailed study plans to reduce the effects.

"Assessment of UHV Transmission Impact" (Niagara Mohawk Power Corporation) Westinghouse Electric Corporation	$65,000 1974-1976	Review and assess environmental impact of UHV transmission lines.
BPA840-611 "HVDC Transmission Line Biological Study" Western Interstate Commission.	Funding not available 6/76-7/77	Determine if ?400kV transmission lines produce biological effects on crops, natural vegetation, and wildlife along the Celilo-Sylmar intertie.
BPA846-623 "Environmental Effects of Electric Fields and Ion Currents from DC Transmission Lines" Bonneville Power Administration.	Funding not available 7/76-12/79	Develop analytical computational methods to predict fields, ion densities and current distributions, under idealized conditions in the proximity of DC transmission lines. Compare with data obtained under BPA840-611.
Lawrence Berkeley Laboratory	$670,000 into 1980	Identify and characterize biological effects from magnetic fields particularly generic. Study cellular systems and tissues.
Lawrence Berkeley Laboratory	$120,000 into 1980	Epidemiological study of 2000 scientists and technicians who have been exposed to over 4000 "Gauss Days" per year for 5 years.
BPA 840-706 "Effect of Transmission Lines on Raptors" Bonneville Power Administration.	$30,000 9/77-9/79	Assess status of raptor (hawks, eagles, osprey) nesting on BPA transmission structures. Determine effects of electric fields. (Joint BPA-DOE funding)
BPA 846-704 "Lyons 1200kV Test Line: Field Strength Study" Bonneville Power Administration.	$440,000 12/76-9/83	Measure or evaluate E and H fields, audible corona noise, RI and TVI.
Battelle Pacific Northwest	$605,000 into 1980	Study of the response in animal and cellular systems from magnetic fields; effects on growth development, behavior; other responses in mice and trout. Investigate possible mutagenic effects, chromosome pattern alteration, nerve function and altered cell growth in simpler systems.
Brookhaven National Laboratories	$605,000 into 1980	Genetic effects of static magnetic fields in drosophila and tradascautia (flowering plant).

7.2. Powerline EMF research at Battlelle

7.2.1 Introduction

7.2.2. Negative Results by Design

7.2.2 note 1 (pp 135-138)

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7.2.3. Negative Results by Analysis

7.2.3. note 1

Comments of the Battelle investigators concerning the study, made in their monthly reports, were:

November 7, 1977: "To date, we have found only two potentially adverse effects of over 380 parameters we have examined. The prostatitis we observed in our first series of experiments has been replicated. A third replicate of this experiment is in progress."

January 30,1978: " there are no statistically significant differences between groups."

"These recent findings by the Task Leaker are sufficiently important to justify updating and revising Chapter VII (Pathology, pp. 81-88) of our semi-annual report. This chapter, as now written, shows the results of incompleted experiments and leaves the prostatitis question open. The data could be misconstrued by certain parties to support their claims that electric fields produce adverse biological effects. Revision of the chapter with our recent results will minimize the risk of abuse by others."

7.2.4. Negative Results by Omitting Positive Results

7.2.4. note 1 (pp. 139-146)

***IN VIVO* BIOELECTROCHEMICAL CHANGES ASSOCIATED WITH EXPOSURE TO EXTREMELY LOW FREQUENCY ELECTRIC FIELDS**

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One hundred seventy-four 21- to 24day-old Sprague-Dawley rats were continuously exposed to a 60 Hz electric field of 150 V/cm for one month in ten separate experiments. Biological effects observed included depressed body weights, serum corticoids, and water consumption. The findings are tentatively interpreted as indicating that a power frequency electric field is a biological stressor. The observed efects cannot be a consequence of Joule heating and therefore indicate that electric fields can influence biological systems either at the systemic level, or at the cellular level via electrochemical alteration of the microenvironment.

INTRODUCTION

While there have been many reports of biological effects resulting from exposure of organisms to

electromagnetic (EM) fields,[1-4] no generally accepted coupling mechanism between organism and field has yet been elucidated. During the past decade, two new biological concepts were proposed that bear upon the problem. The first was the concept, drawing partially upon experimental results and partially upon theoretical considerations, of an analog type data transmission and control system antedating the central nervous system proper.[5,6] Evidence has been presented for this system being based upon semiconduction or other solid state physical processes.[7,8] Information is carried as small currents and voltages that produce changes in the local electrical environment of the cells. The second concept is that of electrochemical information transfer associated with the mechanisms involved in the local cellular responses to such alterations in the local electrical environmental. Both concepts imply that exposure to EM fields should have generalized biological effects; in the first case by perturbation of an operating system and, in the second, by direct cellular effects.

In view of the widespread alteration in the electrical environment produced by electrical power transmission systems, a study of the generalized effect of exposure to 60 Hz electrical fields was undertaken. This paper reports the results of that study.

METHODS

Male Sprague-Dawley rats, 21-24 days old, were continuously exposed to a 60 Hz electric field for approximately one month. The nominal electric field, computed from the plate separation and the applied voltage, was 150 rms-V/cm. It was applied across plastic cages (Fig. 1) with a variety of grounded metal tops (as shown in Fig. 2).

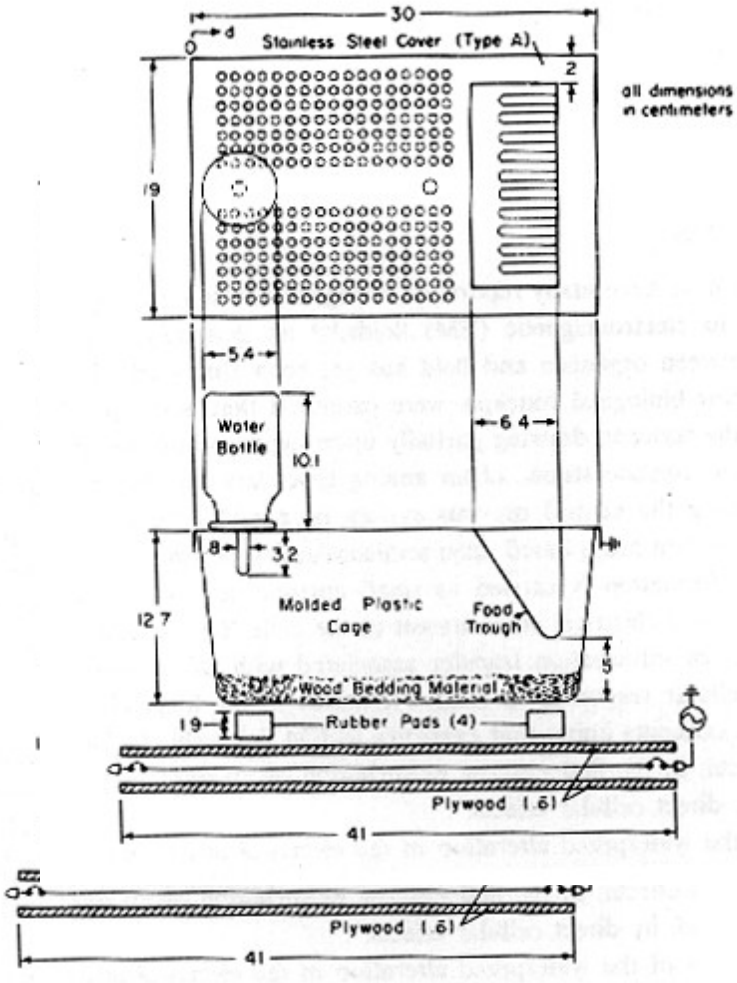

FIGURE 1. Apparatus employed to generate the power frequency electric field. A metal plate was permanently mounted between two sheets of plywood with provisions for applying and measuring the working voltage. Vibration isolation pads that supported the cage were glued to the upper wood surface.

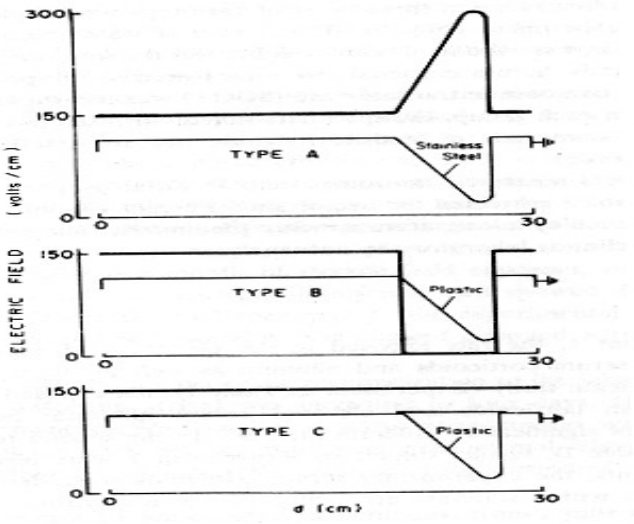

FIGURE 2. Three different designs for the grounded cage top. (I) An all stainless steel top- Type A. (2) A modification of Type A in which the metal feed trough was replaced with one of plastic-Type B. (3) A modification of Type B in which a stainless steel lid covering the plastic feed trough was added- Type C. Calculated electric field profiles corresponding to each type of cage top are shown. Perturbing effects due to the presence of the various dielectric materials and the water bottle were neglected.

All rats were purchased from commercial breeders. Except where noted, they were 1-2 days in transit and were held 1-2 days after arrival prior to initiation of field exposure. All rats placed on study were free of any recognizable diseases or defects. Occasionally, respiratory infections occurred during exposure; in such cases the animal was destroyed. All rats were maintained in a single room of a government accredited, standard (i.e., not pathogen free) animal care facility and were fed and watered *ad libitum*. Environmental conditions were 23?C, 50% relative humidity, and light/dark cycle of 12:12.

Following exposure, the rats were weighed then sacrificed by decapitation. The serum was recovered and frozen until analyzed. In the first four experiments the experimental rats were housed in individual cages, similar to that shown in Fig. 1, with Type A cage tops (Fig. 2). Control rats were housed three per cage in larger cages with metal tops. In addition to final body weight, we measured serum hydroxycorticosterone (corticoids) and serum proteins in the pooled sera of all rats within each of the experimental and control groups. In the remaining experiments every rat was caged individually, and vibration isolation pads were added. The -pads reduced the electric field induced vibration in the vicinity of the cages from 2.5 X 1O-3 cm/sec to 1.0 X 1O-3 cm/sec. (Normal background vibration was 2.8 X 1O-3 cm/sec.) One of three types of cage tops was employed, depending on the particular experiment (Fig. 2). The food and water consumed by every rat were measured as were the final body weights and the final weights of the pituitary and adrenal glands. Serum corticoids were measured in sub-pools of 2-3 rats, and serum glutamic oxaloacetic transaminase (SGOT) was measured in the pooled sera of all rats within each group. Except where noted, all listed tolerances are standard deviations. All statements of statistical significance are based on the t-test (two- tail) with $p < 0.05$.

Corticoids were measured fluorometrically.[11] Total proteins were measured by the Biuret method[12] corrected for hemolysis.[13] Percent albumin was determined by electrophoresis on cellulose acetate, with planimetric integration.[14] SGOT was measured in a clinical laboratory by autoanalyzer.

RESULTS

In Experiment 1, the rats exposed to the electric field exhibited altered concentrations of serum;corticoids and albumin as well as depressed body weights. In the first replicate stldy (Experiment 2, Table I), the exposed rats again showed depressed serum corticoids and elevated serum albumin; however, the body weights were not significantly different (at 5o). In the second replicate study (Experiment 3, Table I), results simi]ar to Experiment 2 were observed. In the first three experiments, the experimental serum corticoids were depressed by a grand mean of 31.7% with a standard error of 2.4%. The corresponding values for the increase in albumin were 28.2% and 9.1%. The data also suggested that the average body weight was lower in the experimental groups (by a grand mean of 6.6% with a standard error of 4.3%), but a 5% level of confidence within each experiment was achieved only in Experiment 1.

TABLE 1. Effects of Continuous Exposure to Power Frequency Electric Fields on Some Biological Parameters of Rats. Serum corticoids and albumin were measured employing the pooled sera of all rats within each group. Italic numbers in first column indicate age in days at initiation and termination of exposure.

				Total	Albumin
	19 control	273.1 ? 16.7	22.0	7.1	3.8
	22 control	290.8 ? 27.9	18.0	6.6	3.2
	18 control	277.8 ? 15.8	14.5	7.1	3.5
	11 control	251.0 ? 11.3	53.4	--	--
*$p < 0.05$					

Experiment 4 was performed to determine whether the observed disturbances in the adrenal-pituitary system would prevent the exposed rats from responding to a known stress. As previously, the rats were exposed for one month and weighed. A lower average weight in the exposed group ($p < 0.05$) was observed. Immediately after weighing, the rats were subjected to a cold stress (-13?C for 1 h) and sacrificed. The serum corticoids in both groups rose markedly (Table I), indicating that the exposed rats remained capable of responding to a cold stress in the predictable fashion.

In Experiment 5, after one month of electric field exposure, the experimental rats consumed less water,

had enlarged pituitaries, and showed depressed levels of serum corticoids (Table II). In Experiment 6, the experimental rats drank less water, exhibited depressed body weights, and showed enlarged adrenals and pituitaries.

In Experiment 7, the allotted period of acclimatization to the laboratory environmental conditions following arrival was increased to four days, after which time exposure was commenced. We found that water consumption was depressed as previously, but that the body and organ weights were normal. Similar results were observed in Experiment 8, wherein an acclimatization period of three days was provided.

In Experiments 9 and 10, we exposed rats obtained from a different source. The animals were purchased locally (shipment time 2 h), and acclimatized for three days prior to exposure. In Experiment 9 we found the water consumed, pituitary weights, and serum corticoids were significantly different in the exposed rats. In Experiment 10 food consumption was the only parameter significantly affected.

Values of SGOT are shown in Table II. The concentration in the experimental sera was marginally higher in some cases (Experiments 5, 7, 9), and substantially higher in others (Experiments 6, 8, 10).

The observed pattern of water consumption was consistent from experiment to experiment, thus deserving some comment. In all experiments in which it was measured, the cumulative water consumer by the experimental and control groups, when compared statistically after 1, 3, 7, and 14 days of exposure, showed no significant differences. In all cases (except Experiment 10) the comparison of water consumed during the last half of the exposure period showed significant differences, with the experimental group exhibiting depressed consumption. The differences remained significant (at 5%) even when the comparisons were extended to include the entire exposure period (Table II). These data are considered particularly important in that they indicate that microcurrents produced in the rats during the act of drinking were not significant determinants of the experimental results. If either perceptible or subliminal microcurrents were significant factors, alterations in the drinking patterns of the experimental rats would have been apparent from the start of the experiment.

No specific effects were detected in the entire series of experiments that could be ascribed to the different types of field configuration produced by the three types of grounded cage tops. Questions concerning the relative effects of uniform vs. non-uniform fields require further experimentation.

During these studies, which involved a total of 154 experimental rats and 179 control rats, an additional 11 experimental and 5 control rats died during the exposure period.

TABLE II. Eiurther Effects of Continuous Exposure to Power Frequency Electric Fields on Some Biological Parameters of Rats. Serum corticoids were measured employing sub-pools of 2-3 rats within each group, Italic numbers in first column indica.e age in days at initiation and termination of exposure.

Experiment	Number of rats	Cage top type	Water consumed (ml/rat)	Food consumed (grams/rat)
	18 control		940 ? 142	603 ? 40
	20 control		891 ? 93	--

	21 control		890 ? 104	588 ? 42
	14 control		1,054 ? 84	545 ? 36
	20 control		1,099 ? 117	618 ? 43
	16 control		1,202 ? 107	664 ? 17
*p < 0.05				

TABLE II, *continued*

Experiment	Final body weight (g)	Final adrenal weight (g/g)	Final pituitary weight (?g/g)	Serum corticoids weight (?g/100ml)	SGOT (I.U.)
	286.7 ? 22.1	181.8 ? 16.0	35.2 ? 3.8	8.7 ? 1.2	194
	281.0 ? 12.5	158.9 ? 18.3	40.6 ? 3.1	7.6 ? 2.1	157
	287.8 ? 18.4	168.8 ? 20.3	35.2 ? 2.6	--	157
	283.0 ? 12.7	155.8 ? 30.6	39.0 ? 2.6	6.4 ? 0.6	134
	290.2 ? 13.2	125.7 ? 14.3	29.4 ? 2.9	16.3 ? 3.8	185
	300.4 ? 12.0	179.3 ? 15.8	30.6 ? 1.8	9.7 ? 4.0	133
*p < 0.05					

DISCUSSION

In each of the 10 experiments, one or more measured parameters were significantly different in the experimcntal animals as compared to the control animals. In general, these results indicate that exposure to a 150 V/cm 60 Hz electric field is productive of a physiological stress response.[15] The physiological response has been shown to be not attributable to such secondary effects as the field induced mechanical vibration or the occurrance of microcurrents produced by drinking, and we

conclude that the field itself is the responsible agent.

While there are apparent inconsistencies in the data, to the extent that the same measured parameters are not always statistically significant from one experiment to the next, none of those inconsistencies would mitigate against the general conclusion reached.

It is generally agreed that stressors are additive when assayed by the physiological response.[15] This phenomenon has been manifested as the accentuation of a pre-existing, sub-clinical pathological condition by exposure to low frequency magnetic fields.[16] In the present series of experiments, as in all animal experimentation other than that involving totally germ-free animals in a rigidly controlled environment, the multitude of factors productive of minor stress responses are impossible to completely control. This is evidenced by the disparate results obtained in Experiments 9 and 10. In both experiments we attempted to mitigate the stressful effect of shipment from a distant supplier to the laboratory. The animals were purchased locally so that prolonged transit time was avoided and a period of several days acclimatization was afforded prior to the initiation of exposure. Despite these precautions, Experiment 9 demonstrated measurable differences between experimental and control animals in three parameters, while in Experiment 10 only one parameter was so influenced. We attribute this disparity to other stress-producing factors, such as disturbances in the biological rhythms and the presence of zoonoses, over which we had no control in such acute experiments.

In addition to the microcurrents described above which occurred only during eating and drinking, the exposed rats continuously experienced induced currents because of the presence of the electnc field. To establish the non-thermal nature of the effects described here, we measured the induced current in the rats and found that 0.68 ?a was induced at 150 V/cm, with a corresponding current density of about 11.1 m?a/cm^2. If we assume the rat to be a uniform mass with a resistivity of 100ohm-cm, then the total power dissipated is about 2.3 X $1O^{-12}$ watts, obviously too low to produce heating.

In conclusion, one month's exposure to power frequency electric fields produced quantifiable biological changes in rats. The changes produced in at least some experiments were depressed water consumption, depressed body weight, increased adrenal and pituitary weights, and altered serum concentrations of albumin, hydroxycorticosterone, and SGOT. The observed changes are consistant with, but do not categorically establish, the hypothesis that a power frequency electric field is a biological stressor. To assess the potential hazards of such exposure, further work wherein larger groups of animals might be studied at different exposure times and at different field strengths appears desirable. Additionally, the data do not permit a choice between the two postulated coupling mechanisms with respect to the observed responses. The data do establish however, that there must exist some mechanism other than Joule heating by which electric fields can alter biological function.

Vibration measurements were performed by Dr. Daniel A. Driscoll, New York State Department of Environmental Conservation.

This work was supported by Veterans Administration Research Service, Project No. 0865-01.

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(*Received May 23, 1977*)

7.2.3. note 2

Table 1. Mean heart rate (□ S.E.) of female Sprague Dawley rats (N = 10/group) after ~632 hours exposure to a 100 kV/m electric field. All animals were measured within 1 hour post exposure. Heart rate values were measured over a 1 hour period (5 minute sampling intervals).

Elapsed Time in Acclimation Holder (min)	Exposed	Sham Exposed
5	430 □ 8	422 □ 8

10	426 □ 9	411 □ 10
15	412 □ 11	403 □ 7
20	425 □ 12	409 □ 9
25	425 □ 13	405 □ 11
30	432 □ 8	421 □ 9
35	434 □ 11	416 □ 10
40	419 □ 8	405 □ 12
45	427 □ 8	427 □ 13
50	419 □ 13	427 □ 11
55	436 □ 10	431 □ 15
60	427 □ 11	427 □ 12
Overall mean for 1 hour	*426 □ 2	417 □ 3
		P < 0.05, paired t test

7.2.3. note 3

Table I. Mean heart rate (+ S.E.) of rats after 4 months exposure to a 100 Kv/m electric field.

Elapsed time in Acclimation Holder (min)	Exposed	Sham Exposed
5	468 □ 13	475 □ 14
10	429 □ 13	457 □ 13
20	420 □ 9	429 □ 11
30	420 □ 12	421 □ 9
40	430 □ 13	429 □ 9
50	415 □ 14	414 □ 8
60	412 □ 13	409 □ 10
Overall Mean 1 Hr.	430 □ 10	434 □ 7

7.2.3. note 4

Comments of the Battelle investigators concerning the study made in their monthly reports were:

December 19, 1977: "We plan to start the Marino 3-generation mouse study in January. It will take 9 months to complete."

April 5, 1978: "The first generation (F1) of the mice in the three-generation study were born in early March. Breeding for the second experiment will begin in early May, when the F1 reach 60 days of age."

May 10, 1978: "The three-generation mouse experiment is being conducted with two replicate experiments which are staggered in their timing by three weeks. The first generation of the first replicate is now 60 days old and is being bred this week to provide the second generation. Animals not used for breeding in the first and second generations will be used for evaluation of hematology and serum chemistry by Harvey Regan. Thus we will be extracting a maximal amount of information from these animals. In the first replicate, one group of the first generation had a lower body weight than the others. Since this experiment, like the others, has a double-blind design, the exposure history of these groups will not be available until completion of the experiment in December, i.e. the smaller group could be exposed or sham-exposed. We do not know whether the differences are statistically significant at this time."

June 19, 1978: "The three-generation mouse study is progressing smoothly and the second generation mice are now two weeks old. The code (exposed and unexposed) will not be broken on this study until all three generations have been achieved, scheduled for December of this year."

November 22, 1978: "The system for exposing mice will be used continuously until the middle of March when the fourth generation of exposed mice will be 6 weeks old."

March 14, 1979: "The three-generation mouse experiment has been completed and the data are partially evaluated. There were no significant differences in size or mortality between exposed and sham-exposed animals."

May 25, 1979: "The data on growth and development of the fourth generation of mice raised in the field have been tabulated and is now being analyzed."

7.2.3. note 5

The Battelle investigator who actually conducted the study was not supposed to know whether or not the EMF was causing an effect. Battelle commonly employed this strategy because it permitted them to claim, in the presentations, that the data was evaluated without subjective bias.

7.2.6. Negative Results by Argument

7.2.7. Negative Significance of Concededly Positive Results

7.2.7. note 1

How did Battelle know that the strong EMFs that they used caused the hairs on the animals to vibrate? They took high-speed motion pictures and documented the hair vibration. What was the mechanism responsible for the hair vibration? It had something to do with molecules in the air as well as with the EMF. When the Battelle investigators placed a jar over a pig's ear and applied a strong EMF, the hairs on the ear vibrated. When they evacuated the jar so that no air was in contact with the hairs, and then applied the EMF, the hairs did not vibrate.

How did the Battelle investigators know that the animals did not like having their hairs in a continuous state of oscillation? The Battelle investigators did many experiments in which an animal was given a choice regarding which side of the cage it preferred, one of which contained the EMF, and one of which did not. Not surprisingly, the animals preferred not to be in the EMF.

7.2.8. Unreliability of Contract Research

In preparation for our talks, Phillips sent me a complete set of the Battelle published articles (which I already had), and I sent him a letter that detailed the points that I would make during my presentation.

7.2.8.note 1 (pp. 149-169)

By 1984, I had concluded that, from a scientific perspective, the Battelle powerline EMF studies were unreliable, and I was ready to explain why I thought this was the case. With the assistance of Don Justesen, who was then the president of the Bioelectromagnetics Society, arrangements were made for me and Richard Phillips, Battelle's Task Leader for EMF research, to go head-to-head at the 1984 annual meeting in Atlanta, Georgia. Justesen was a good friend of Phillips, and I think his cooperation was prompted by his expectation that I would make a fool of myself at the meeting.

On the day of our talks the room was packed. I went first, and I made all my intended points in a series of slides, and I concluded that the Battelle EMF research program had failed. At the exact moment I

finished my presentation there was a tremendous clap of thunder and the meeting room went completely dark. When the lights came back on I was back in my seat and Phillips was at the podium swinging his head from left to right trying to figure out what happened. He did a reasonable job trying to defend Battelle's EMF research, but the facts were against him. He focused his presentation on isolated positive aspects of Battelle's work, rather than on dealing with my charge that, in sum, the Battelle effort failed. Nevertheless, Phillips' effort was warmly received, because they were his people in the room, and the Battelle juggernaut continued during the next 15 years. Their level of funding increased, and Battelle investigators were appointed to every major powerline EMF blue-ribbon committee.

Letter of July 9, 1984

Richard D. Phillips, Ph.D.
Bioelectromagnetics Group
Biology & Chemistry Department
Battelle
Pacific Northwest Laboratories
P.O. Box 999
Richland, WA 99352

Dear Dick:

Thank you for sending the additional report regarding dosimetry.

I am enclosing a list of the points that I plan to raise in Atlanta. I may not raise them all because of our time constraints, but I will not comment on aspects of your work that are not on the attached list.
you to reciprocate. I am disturbed by a tendency that I see in your publications to take cheap shots at me, and I sincerely hope you have the desire and ability to call a halt to this practice.

I look forward to our exchange.

I don't plan any surprises or cheap shots, and, obviously, I expect
Sincerely,
Andrew A. Marino, Ph.D.
Assistant Professor

AAM:aw

Enclosure

- The Battelle rodent studies wee conducted using housing modules that had ceiling heights which violated Federal guidelines. This resulted in chronic stressful crowding of the animals.
- A decrease in adrenal and pituitary gland weights in 120-day caged animals was reported. This suggests that the method of caging was highly stressful.
- The rodents were electrically grounded throughout the exposure period. This technique has no discernible relationship to typical human exposures near power lines.

- The method of caging resulted in the existence of testicular grounding microcurrents. I estimate them to be 2-3microamperes/cm2 at 100 kV/meter. The existence of these currents is inconsistent with the claim that an artifact-free animal model has been developed.
- Grounding microcurrents through the rat testes may have been responsible for the observed field-induced changes in serum testosterone. The method of caging is not suitable for perinatal experiments because it does not provide for the nest-building instinct at birth without introducing artifacts.
- Battelle publications regarding dosimetry are repetitive, arbitrary, and self-serving. The claimed enhancement factors result from an arbitrary choice of mathematical modeling and measuring techniques, and are not truly representative of the actual case.
- All of the published claims by Battelle that positive effects have been observed are unreliable because of the concomitant existence of the artifact of hair oscillation.
- The claim that cardiovascular function was not altered by electric field exposure is not credible because of the likely randomizing effect of the constraint used following field exposure to perform the reported measurements.
- The claim that elements of the endocrine system are altered following field exposure is not credible because an inhalation anesthetic was used to sacrifice the animals.
- The claim that evoked potentials were not altered following field exposure is not credible because a needlessly invasive technique of measurement was employed thereby obscuring any effects that may have existed in the dependent parameter (which itself was needlessly complex).
- The claim that fracture healing was delayed by electric field exposure is not credible because mechanical testing and not histological observation was used.
- The Battelle studies frequently resort to subject of data analysis. The two examples that will be presented are: (1) the three generation mouse study; (2) elevation of the Negative Result to a level actually suggestive that it has meaning. One of the major reasons for the failure of the Battelle studies is that its investigators are not answerable from conception of a study to its publication.

- Considering all sources, during the past eight years the Battelle investigators have spent approximately as much money as has been expended in the Tri-Service, Pandora, Sanguine, New York, and NIH programs put together. Despite this, they have failed to achieve their stated goals.

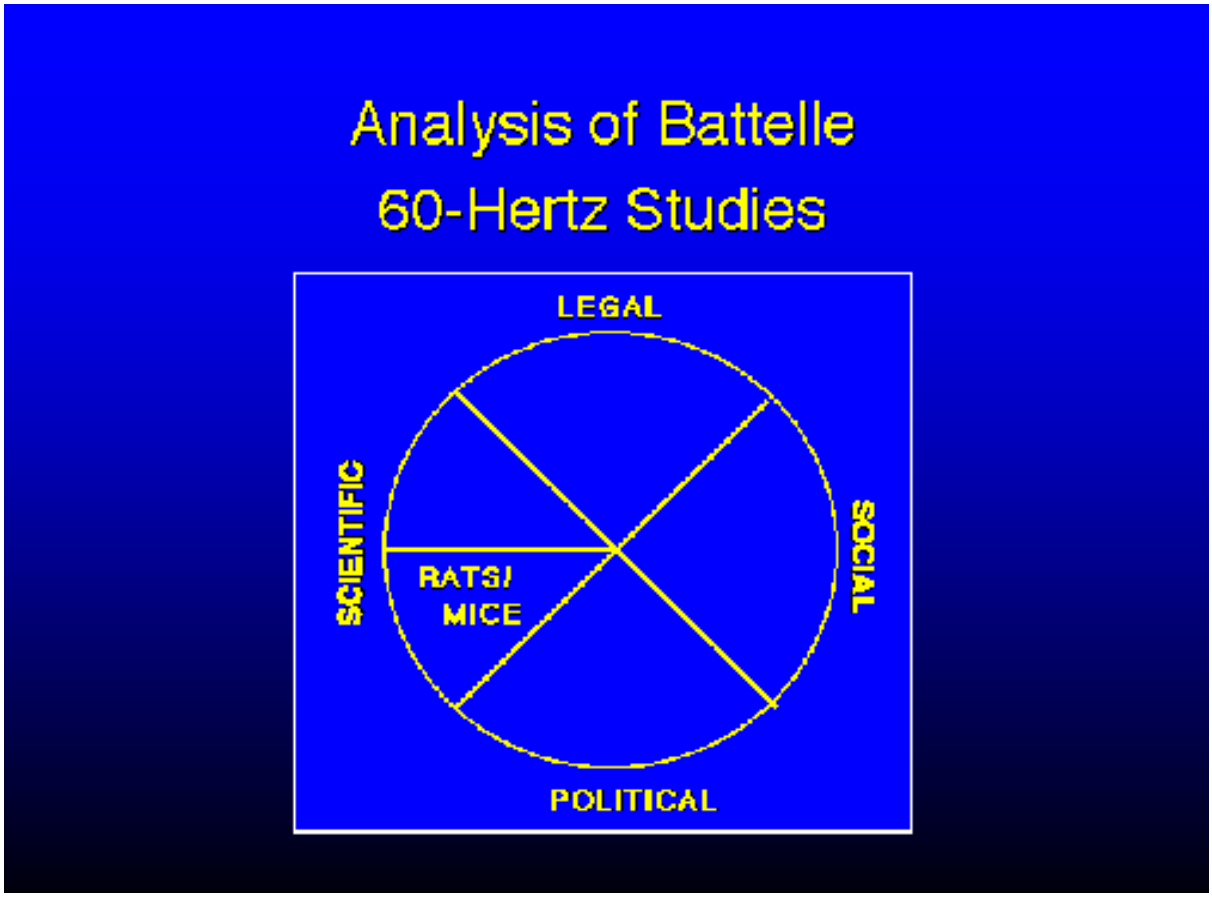
Slides:

"Analysis of Battelle 60-Hertz Studies."

Presented at the 6th Annual Meeting of the Bioelectromagnetics Society, Atlanta, GA, 1984.

lBEMS 1984 PRESENTATION

Slide 1:

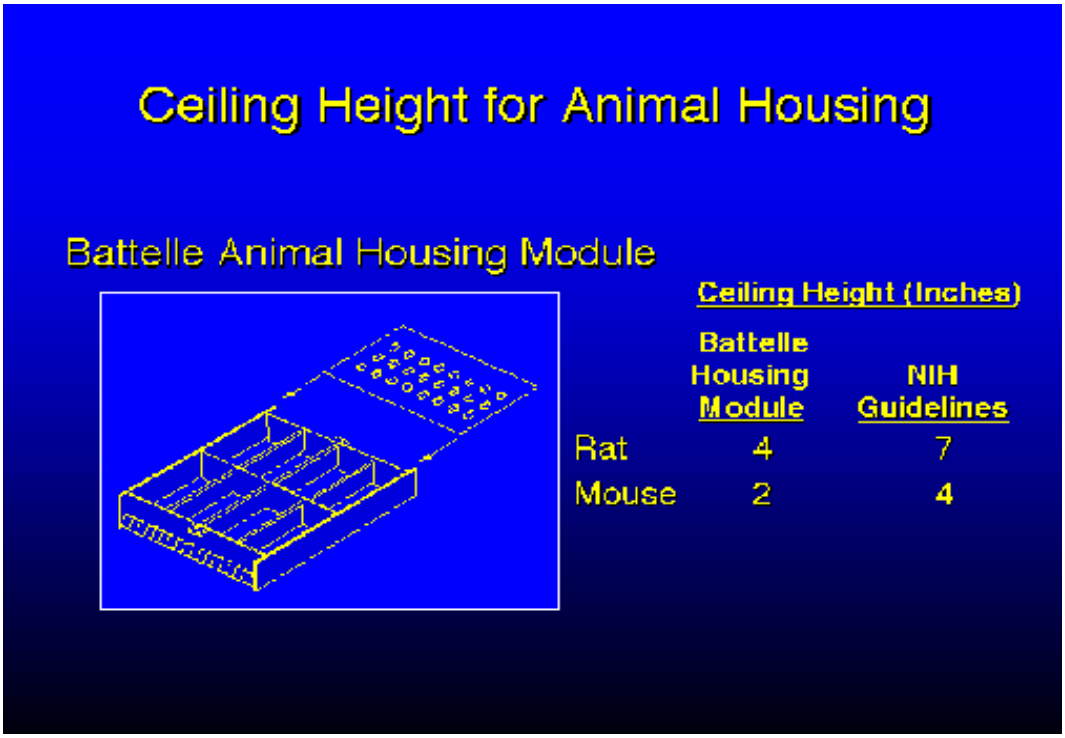


For more than 8 years, investigators at Battelle have been intimately involved in a complex process of assessing the potential health hazards of high-voltage powerlines. During this time, many experiments were conducted at Battelle involving rats, mice, and pigs. In my talk today, I will concentrate on the experiments involving rats and mice.

Slide 2:

My conclusion today will be that, measured against the aims stated by the Battelle investigators, their experiments have failed.

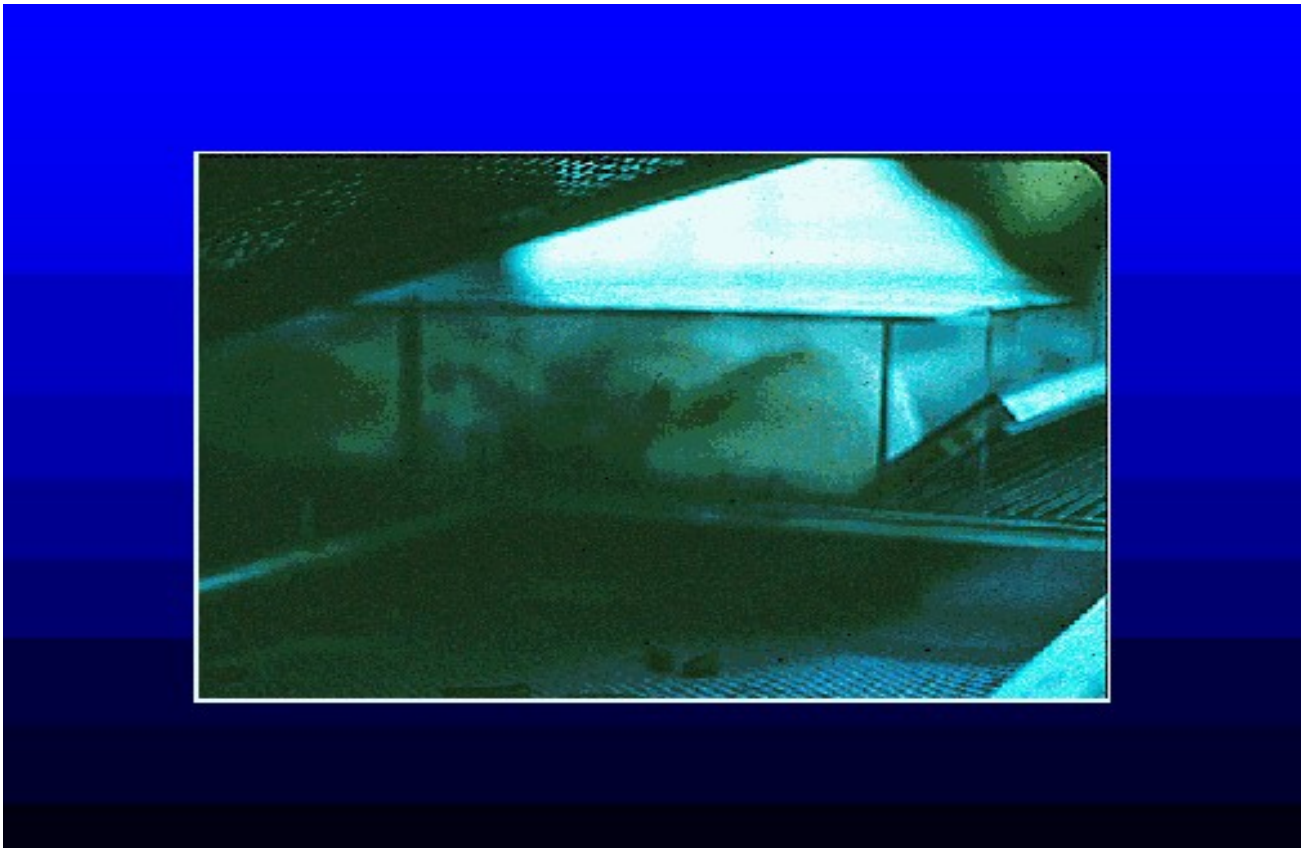
Slide 3:



To perform their rodent experiments, Battelle investigators designed and built modules for housing

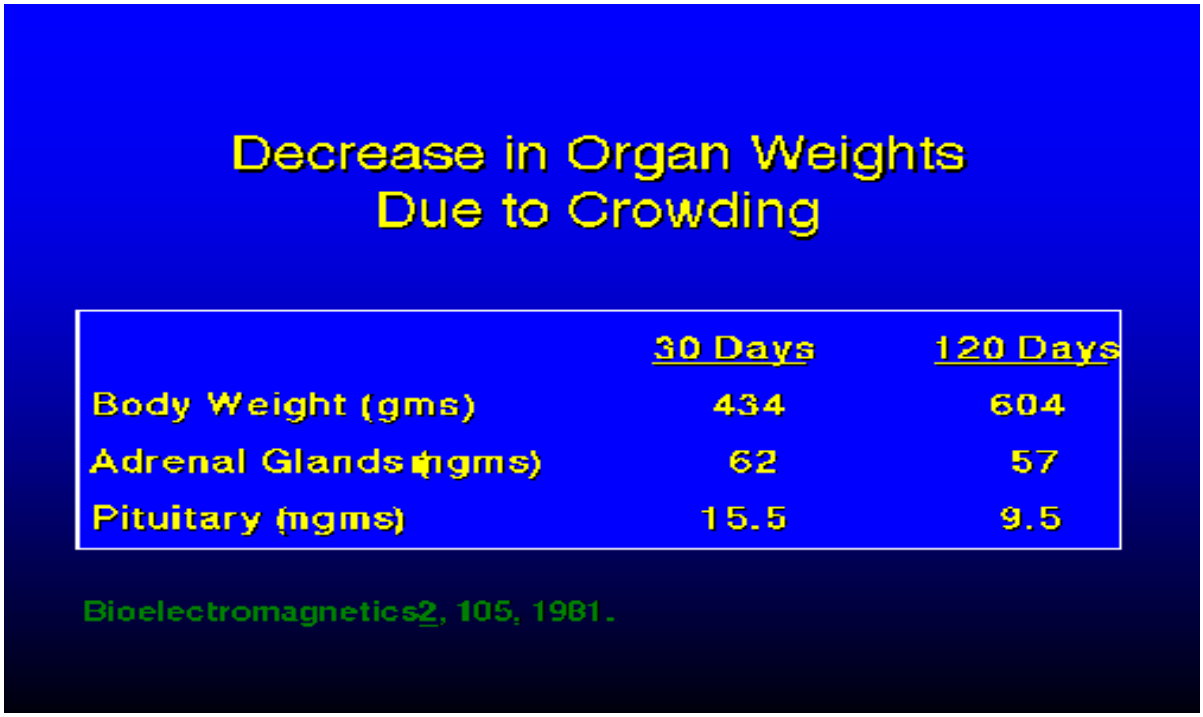
their animals. Each unit housed 8 animals, and the ceiling height was chosen to prevent them from standing erect. But these ceiling heights violated NIH Guidelines for laboratory animals, which called for a minimum of 7 inches for the ceiling height of rat cages, and a minimum of 5 inches for the ceiling height of mouse cages. The NIH guidelines were intended to provide a comfortable environment for the animals, free of any chronic stress that could lessen or even destroy their value as experimental subjects.

Slide 4:



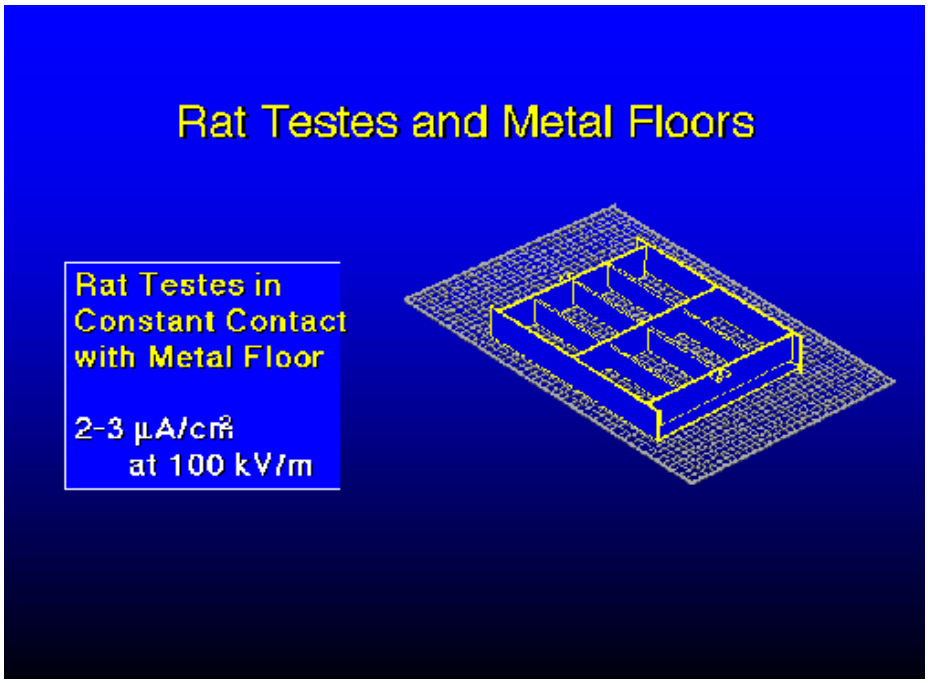
This is a typical rat in one of Battelle's experiments. They were big, and they lived in small boxes. These conditions are not appropriate for asking whether EMFs are stressors. It's like experimenting on the people who lived in the Warsaw ghetto.

Slide 5:



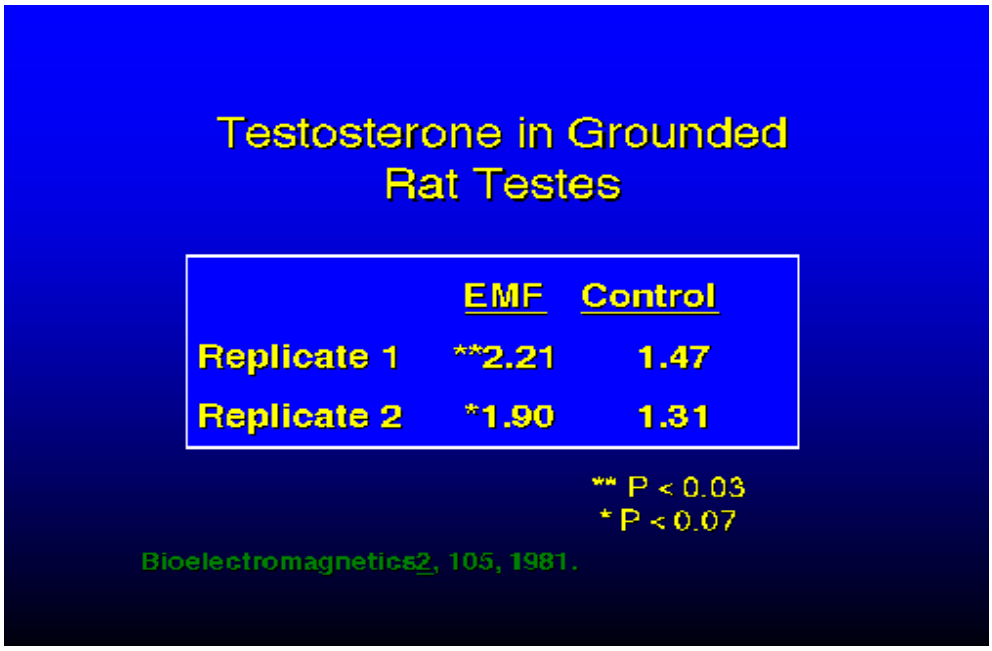
Battelle's failure to follow the NIH guidelines resulted in exactly the kind of housing-induced stress effects that the Guidelines were designed to avoid. For example, rats confined in the Battelle housing units for 120 days had increased body weight compared with their weight after 30 days in the units. But the average weights of the adrenal and pituitary glands of the 120-day rats actually decreased, indicating that the rats were seriously stressed due to chronic crowding. Animals subjected to such chronic crowding are simply not suitable subjects for use in EMF studies because the stress produced by the crowding almost guarantees that the animals will be unresponsive to the EMFs.

Slide 6:



There is another aspect of the way Battelle's animal housing conditions jeopardized the data. TheBattelle investigators used metal screening as the floor in their animal housing units. The floor was electrically grounded and, given the anatomy of male rodents, was in frequent contact with their testes. In the rodents that were exposed to the EMF this combination of male rodent anatomy and grounded flooring resulted in the passage of an electrical current through the testes of the rats and mice. The current was too small to be perceived by the animals, but the situation produced two fundamental problems. First, any changes observed in the exposed animals could have been due to the electrical currents, rather than the EMF. If that were true, then the results of the study would have been irrelevant with regard to health risks of powerlines because the passage of electrical current through testes is not a problem there. Second, the cage design clearly affects male and female rats differently, thereby greatly complicating evaluation of the implications of the results for human beings.

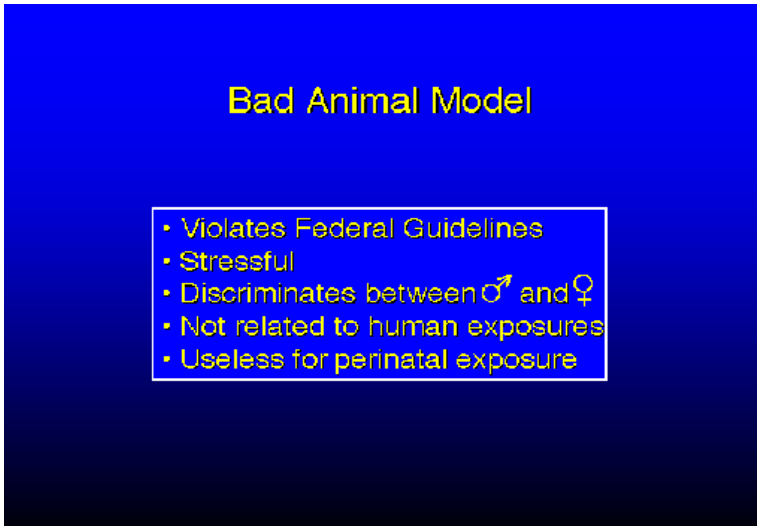
Slide 7:



Is there any evidence that the electrical current that passed through the testes of the male rats produced any effects on the testes? Battelle investigators found that testosterone, which is manufactured in the testes, was consistently reduced in animals that were exposed to an EMF for 120 days.

Slide 8:

It can be seen, therefore, that Battelle employed a bad animal model. The housing conditions violated federal guidelines and resulted in animals that were chronically stressed and therefore useless for assessing the effects of EMFs. Further, the model discriminated between males and females in the sense that the method of housing rather than the EMF could produce different effects depending on gender. Finally, the model was seriously defective for breeding experiments because the grounded metal floor completely prevented the normal nesting behavior of rats and mice during and immediately after birth of the young.



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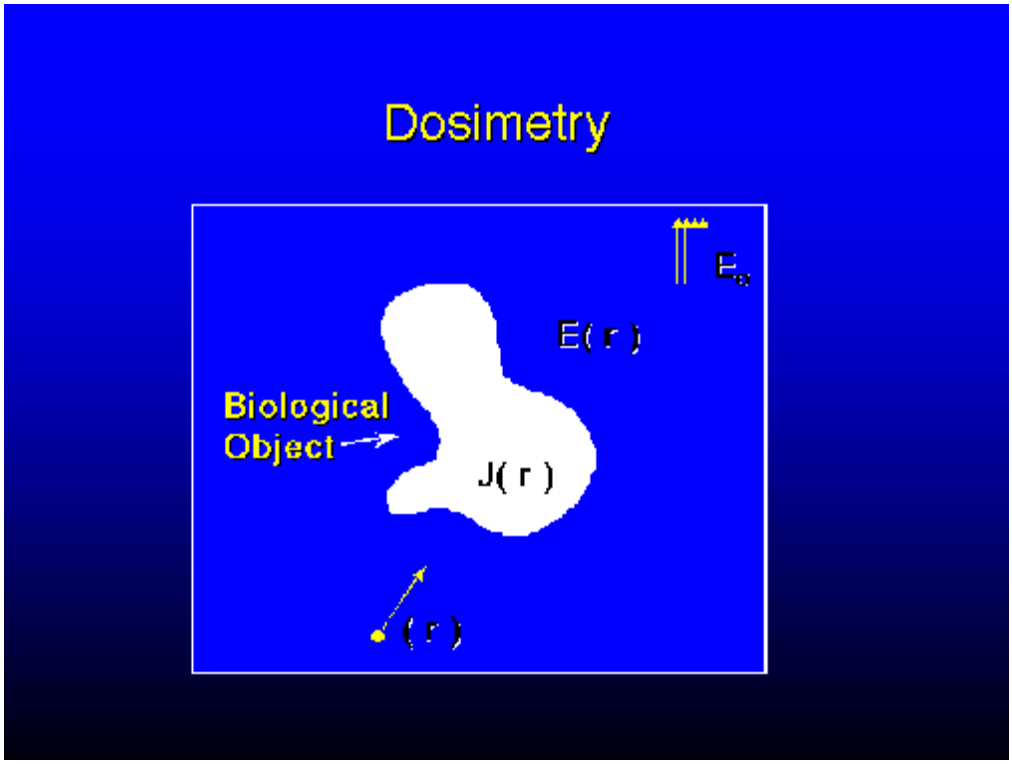
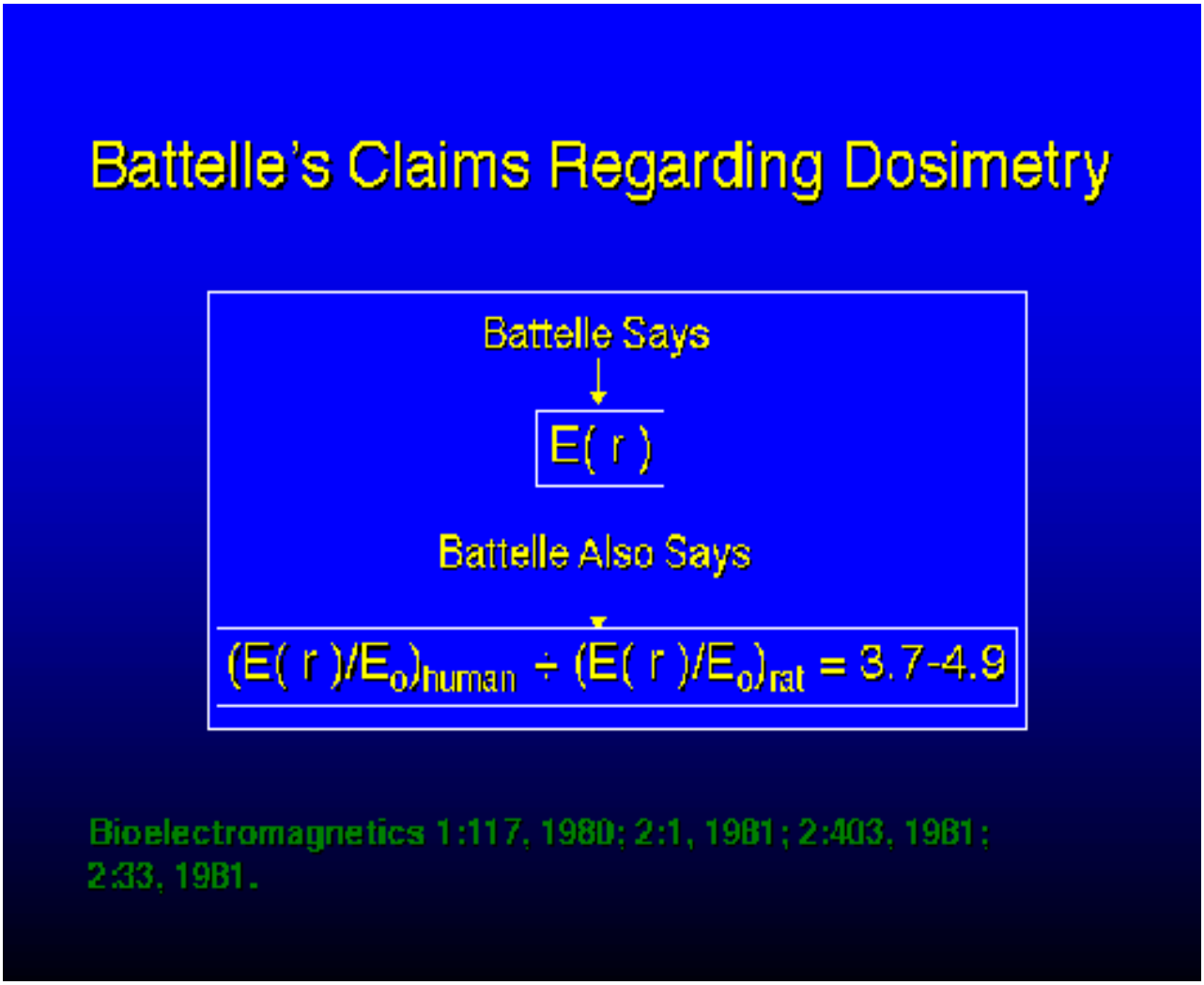


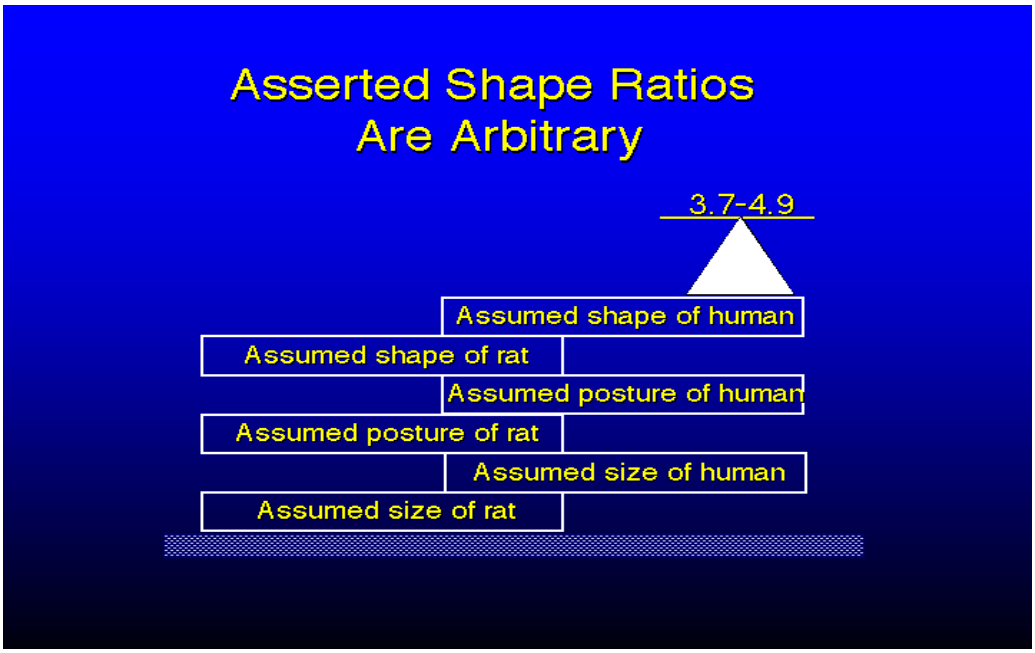
I would now like to discuss the issue of dosimetry, by which I mean how that amount of exposure in the animal experiments should be related to the amount of exposure experienced by human beings along the right-of-way of high-voltage powerlines. Following the approach of the Battelle investigators, let us consider three quantities: $\mathbf{E}_o$, the electric field applied to an animal (determined as the voltage applied to a pair of parallel plates divided by the distance between them); $\mathbf{E}(\mathbf{r})$, the electric field in the vicinity of the animal (which is imagined by the Battelle investigators to be materially different than $\mathbf{E}_o$); and $\mathbf{J}(\mathbf{r})$, the current density inside the animal.

Slide 10:



Battelle investigators claim that even though **E(r)** can't be reliably measured, it can be calculated. They say that they have performed these calculations and have shown that human beings distort the applied EMF 3.7-4.9 times as much as rats. Consequently, they claim, in order to evaluate the effect of an EMF on human beings, one must consider the effects of an EMF about 5 times stronger in animal studies, if the test animal is a rat.

Slide 11:



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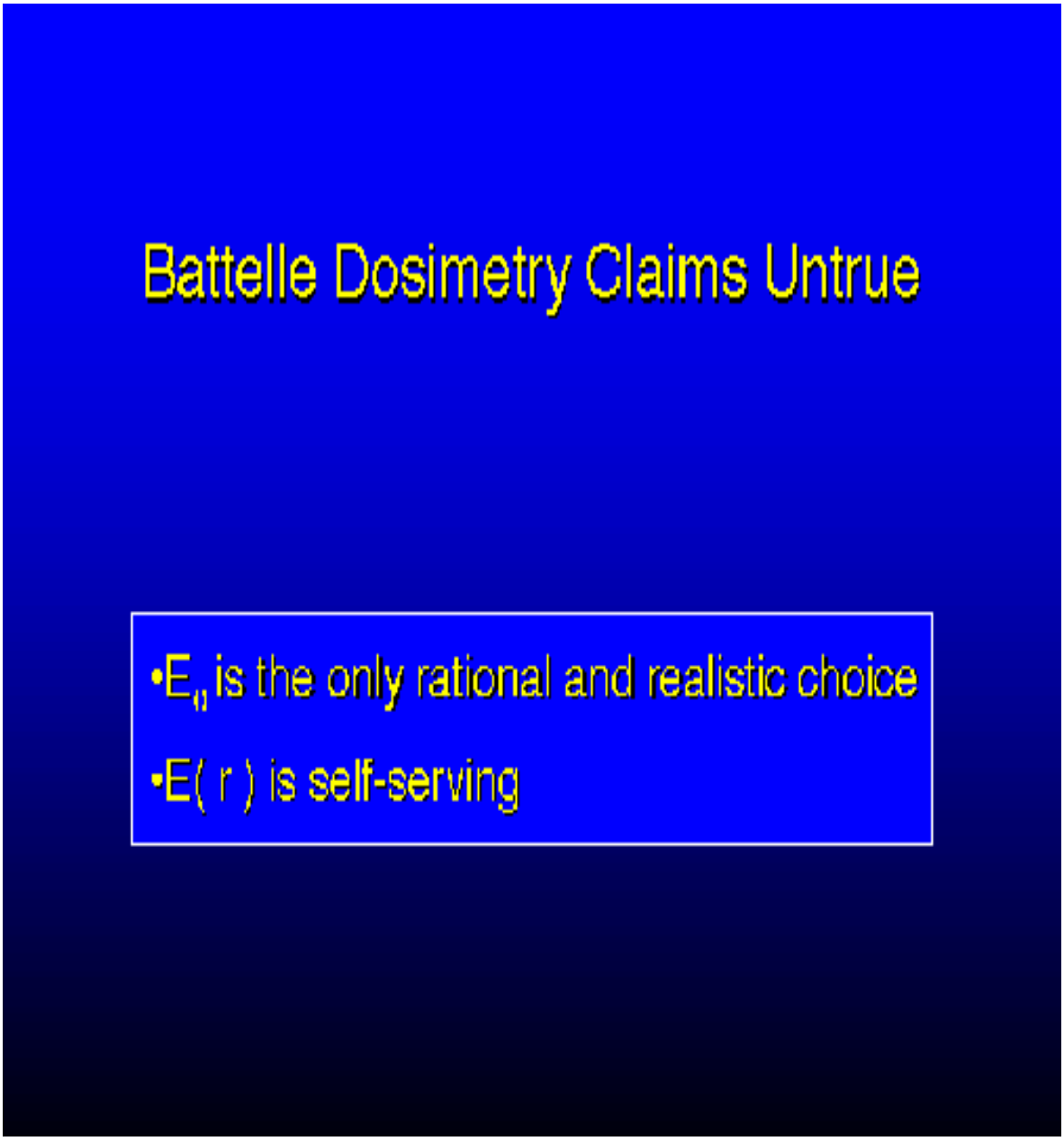
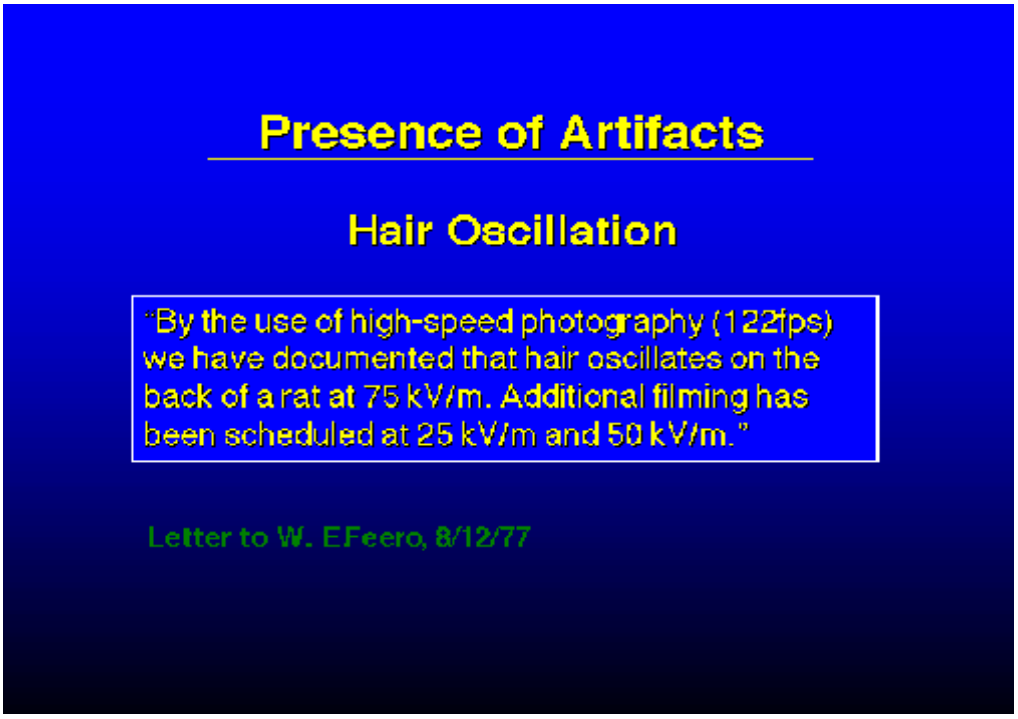


It seems to me, therefore, that Battelle's claim that it can calculate a meaningful value for **E**(**r**) is self-serving in the sense that it tends to enhance the perception of the precision and reliability of their work, particularly so I think among scientists who are not well versed in the intimate details of the politics and economics of the powerline EMF health-risk dispute. The truth is that **E**$_o$, the applied EMF is the only rational choice for comparing experiments involving different animals and for evaluating their implications for human health risks, based on the present state of our knowledge.

Slide 13:



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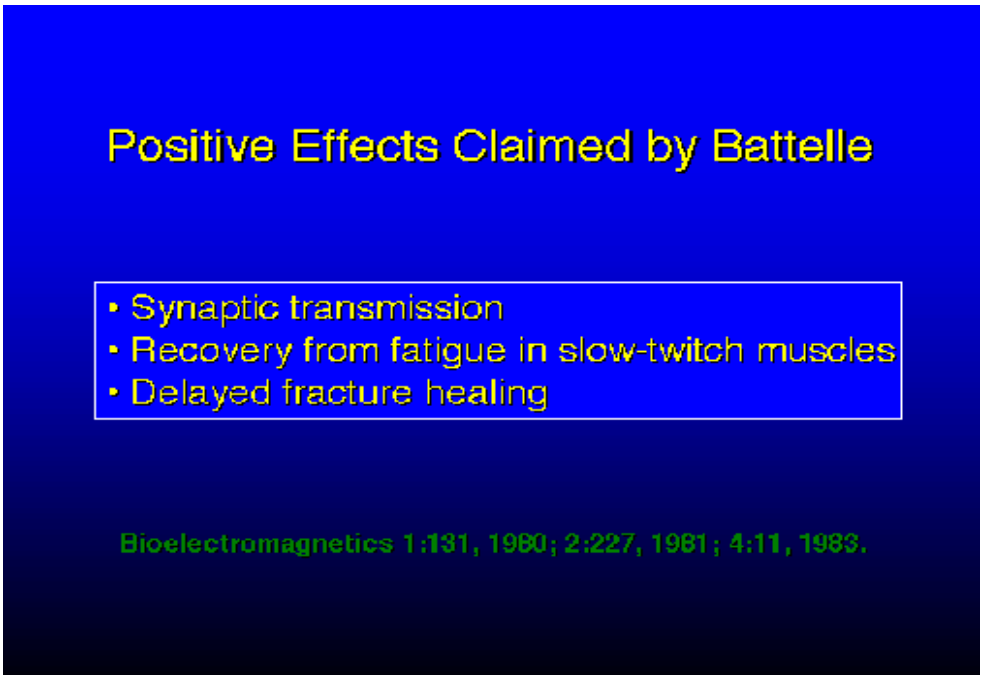
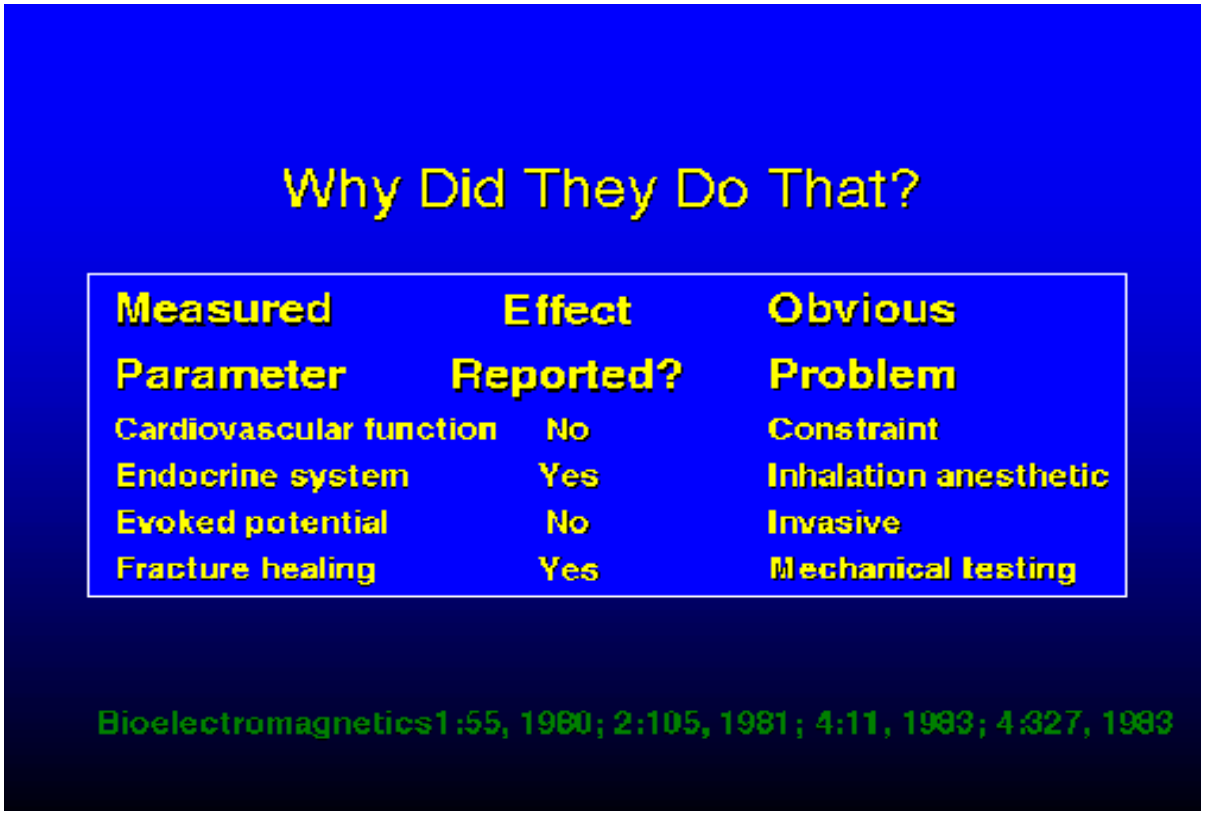
Slide 14:



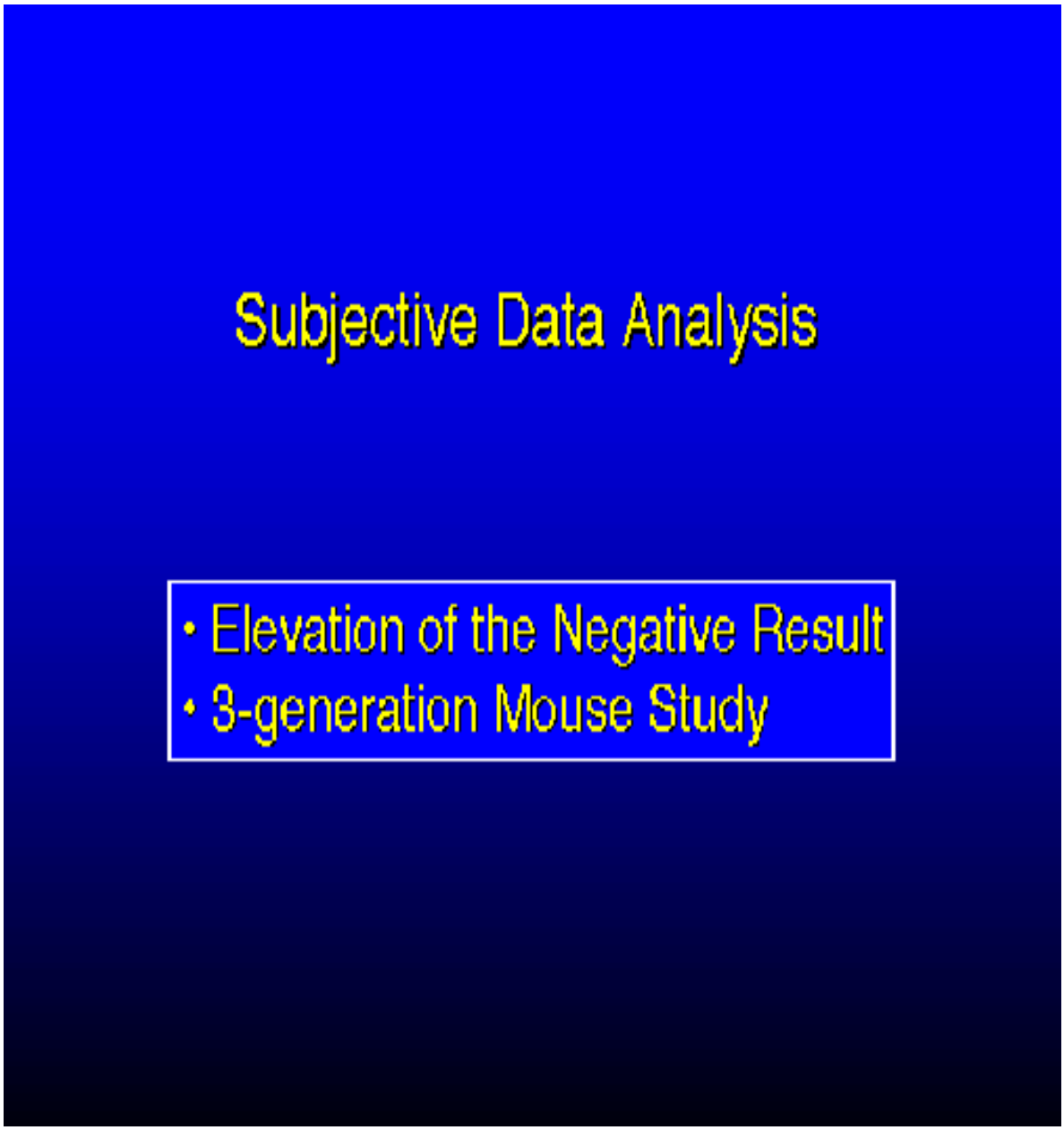
Although the Battelle studies have been mostly negative, the Battelle investigators did claim to find some positive effects due to EMF exposure. But because these effects were observed in animals that were being continuously stimulated by hair vibration it is impossible to decide whether the effects were directly due to the EMF, or were indirectly caused as a result of the response to the continual irritation of hair vibration. Consequently, even the positive studies done at Battelle have dubious value with regard to evaluating human health hazards from powerline EMFs, because human beings are not entirely covered by hair.

Slide 15:



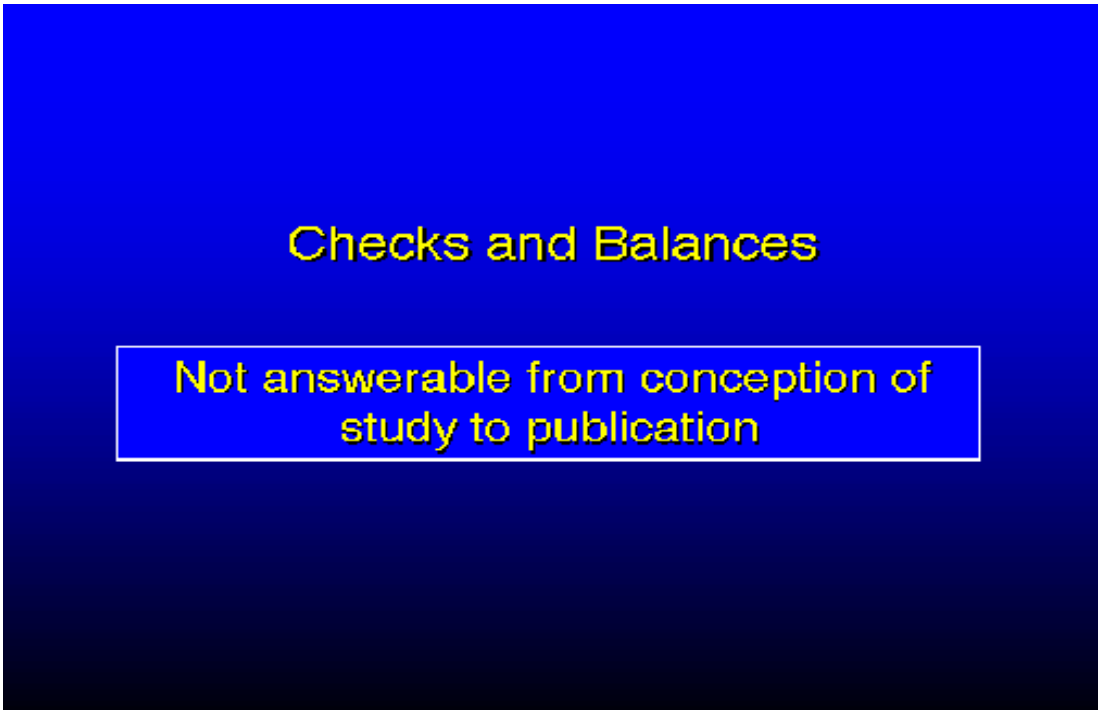
The details regarding how the Battelle investigators performed particular experiments reveal major shortcomings that simply destroy their value for most purposes, especially for evaluating human health risks. For example, in a study of cardiovascular function they measured heart rate under conditions that almost certainly affected heart rate, thereby obscuring any potential effect due to the EMF. In a study involving effects of the EMF on the endocrine system, they killed the animals using an inhalation anesthetic, which almost certainly affected the values of the endocrine parameters that were being measured in relationship to EMF exposure. In a study in which evoked potentials were measured, the Battelle investigators used invasive electrodes, something that is never done when the technique is used to study the nervous system in human beings. In a study involving fracture healing, the Battelle investigators chose a hopelessly insensitive method of evaluating the effect of the EMFs.

Slide 16:



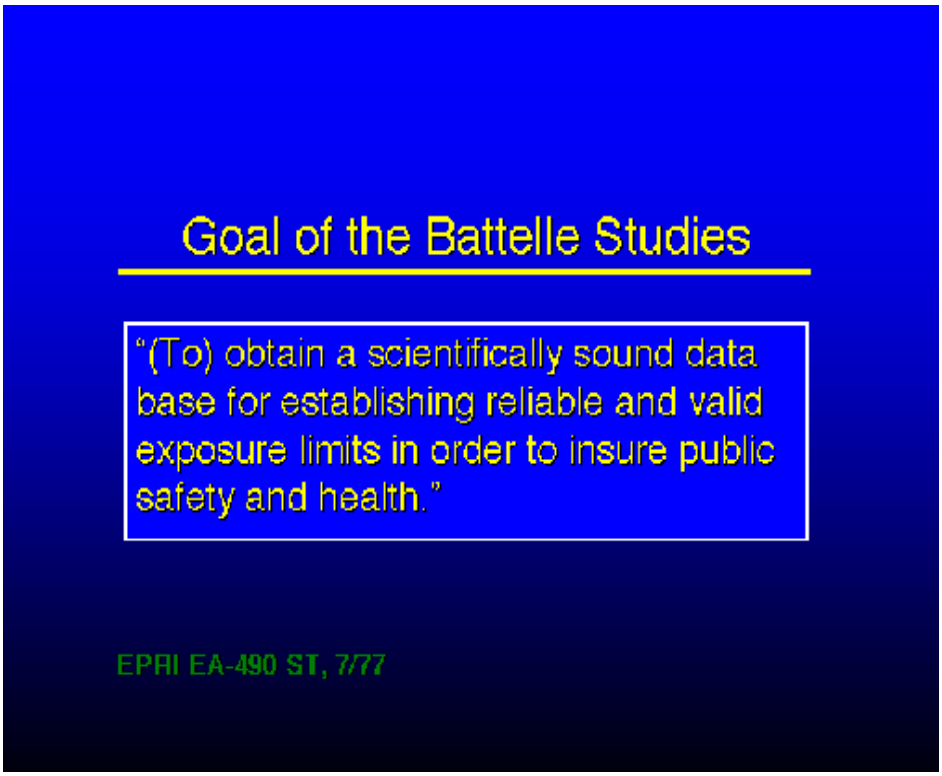
The Battelle investigators can also be faulted in the way they analyzed their data. The bulk of their work has been negative, and at this meeting as well as many previous meetings they have interpreted these negative results to suggest that powerline EMFs do not give rise to health hazards. But this conclusion is wishful thinking, not valid analysis, because most of the studies should have been negative in view of the conditions under which they were performed. Even studies that were actually positive were made to be negative by virtue of the way the data was analyzed. For example, in a study involving the exposure of mice to EMFs that was repeated twice, the Battelle investigators found statistically significant effects in both cases, but in opposite directions relative to the corresponding controls. What they did was average the results and claim that no effect was found.

Slide 17:



How did all of these shortcomings in the Battelle studies come about? The Battelle investigators had to satisfy their study sponsors, not a panel of their scientific peers, regarding the study design and conduct. Additionally, the Battelle studies were intended, from the beginning, to be done in secret and only partially disclosed. I think these were the main reasons.

Slide 18:



In summary, the explicit goal of the Battelle studies was to evaluate the health risks of powerline EMFs.

Slide 19:

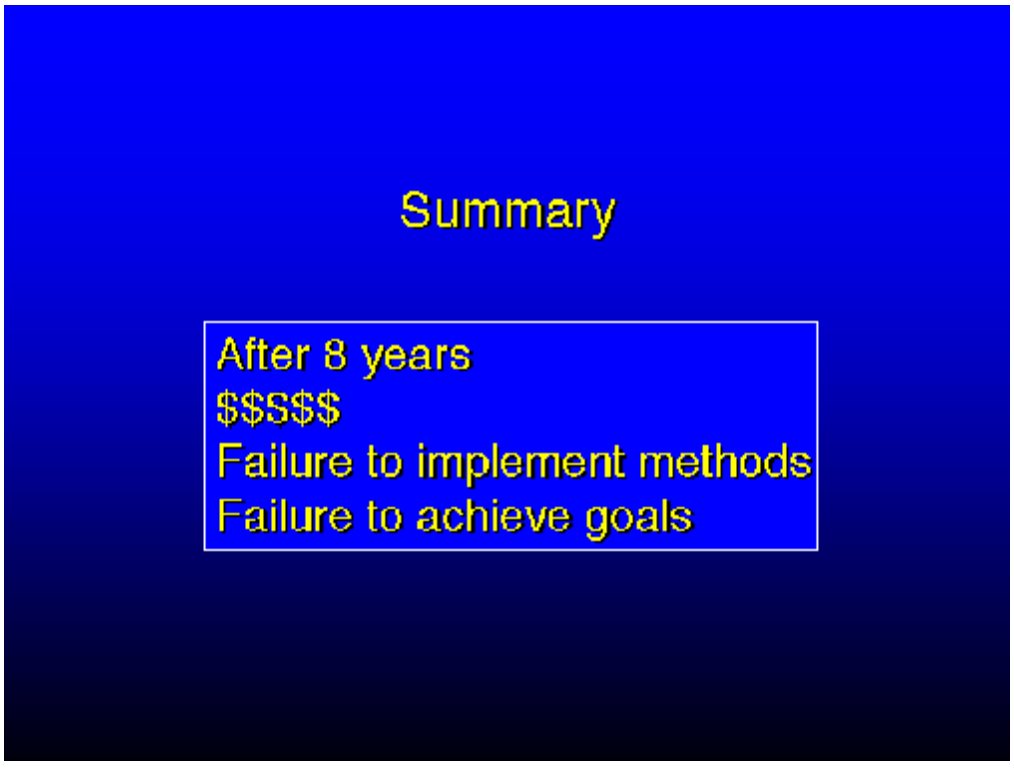
To accomplish this, the Battelle investigators held themselves out as experts who could design and

conduct experiments that eliminated defects that they perceived in the studies of other scientists which led some to claim that powerline EMFs were health risks.

Slide 20:

The Battelle studies were supported by prodigious sums of money from the power industry. Battelle probably spent more money for its EMF research than was spent to perform all other previous EMF studies, combined.

Slide 21:



After many years and many dollars, the Battelle investigators have failed to conduct reliable

experiments and failed to achieve their goal of providing a data base to evaluate powerline EMF health risks.