BEFORE THE
STATE OF NEW YORK
PUBLIC SERVICE COMMISSION

CASE 26559 - Rochester as and Electric Corporation and Niagara Mohawk Power Corporation: Pannell Road to Volney and Oswego to Sterling Transmission Facilities

October, 1974

Prepared Testimony of
Andrew A. Marino, Ph.D., J.D.
Veterans Administration
Hospital
Syracuse, New York

Q. Would you state your name and business address?

A. My name is Andrew A. Marino. My business address is Veterans Administration Hospital, Irving Avenue, Syracuse, New York.

Q. Would you summarize your educational and professional background?

A. I received a bachelor's degree in physics from St. Joseph's College, Philadelphia, Pa., in June 1962. I received my master's and doctorate in physics from Syracuse University in 1965 and 1968 respectively. My field of specialization is biophysics. Since September 1964 I have been employed full time by he VA Hospital as a research biophysicist. Our laboratory is devoted to the study of the interaction of electricity and biological organisms. During he course of my employment, I have co-authored approximately 20 scientific publications. In May 1974 I received a J.D. degree from the College of Law of Syracuse University.

Q. What is the purpose of your testimony?

A. I will describe the biological effects of extremely low frequency (ELF) electric fields which have been reported in the literature. I will discuss the biological effects which we have observed in rats at 60 hz and 150 rms-volts/cm. On the basis of these results, I will propose a tentative safety level for chronic exposure to electric fields at 60 hz of 1.5 rms-volts/cm.

I will discuss the biological effects of ELF magnetic fields.

On the basis of the research discussed above I will advise against construction of the transmission line as proposed.

Q. Would you describe any reports which deal with biological effects of very low frequency fields?

A. In 1968, McElhaney, Stalnaker and Bullard reported inter alia, the effect of electric fields of 3 hz and 30 hz on rat femurs. Their aim was to determine whether the deterioration of bone that occurs during prolonged non-use could be ameliorated by the application of electric fields. They placed insulated metal plates over and under the right leg bones of rats and held them in place by means of a plaster cast. Wires were brought out through the cast and connected to voltage sources. At each frequency an electric field of approximately 70 rms-volts/cm was applied to the animal's leg in situ. The rats were given the electric field treatment for one hour every twelve hours for 28 days, after which they were sacrificed and the right and left femurs were removed and studied. The left femurs were not immobilized. Six sham immobilized rats, six rats exposed at 3 hz, and five rats exposed at 30 hz survived the experiment and were evaluated to determine the effect of the electric field. It was found that all five of the 30 hz rats developed tumors as did two of the six 3 hz rats. No tumors were seen on the sham immobilized legs and none were seen on non-immobilized legs.

Unfortunately, the nature of the reported tumors was not described and this point has not yet been resolved. Further, the data seemed to suggest that the electric field at 30 hz lessened the osteoporotic effect of immobilization.

Also in 1968, Hamer (2) showed that electric fields of 0.04 rms-volts/cm at frequencies in the range of 2 to 12 hz can affect human reaction time performance. Employing 27 human volunteers, each being tested at two frequencies with the range, he showed that the average period of time for the subjects to respond to an audio cue was longer at the higher of the two frequencies. The result shows that not only does the presence of the weak electric field affect the subject's ability to organize a response to its environment, but also that this phenomenon is frequency sensitive.

In 1971 a Soviet group described the effect 50 hz electric fields of 200 rms-volts/cm had on the rate of division of cells in the eye and the liver of mice (3). Prior to electric field exposure, 12 mice were injected with a substance which suspends the process of cell division after it has begun. Half the mice were then exposed to the electric field for four hours, following which all 12 mice were sacrificed. The percentage of cells in the liver and corneal epithelium of each mouse that were in the suspended state of division was determined. It was found that on the average there were three times as many suspended-state cells in the experimentals as in the controls. This indicates that the tissue from the exposed mice was three times more active than that of the control mice. This effect was produced after four hours of exposure.

A recent demonstration of the effect of ELF fields on biological systems is the work of Bassett, et al. (4). They built simple circuits which were energized by small 24 volt batteries. The circuits powered coils which were mounted on the legs of dogs who had been given fibular osteotomies (surgically performed bone fractures). The dogs were divided into two groups; 20 in the first, and 19 in the second. The first group were all exposed to pulses of 1 millisecond duration repeating at 1 hz. This arrangement produced a peak field within the dogs of 0.002 volts/cm. The second group of dogs were exposed to pulses of 150 microseconds repeating at 65 hz. This arrangement produced a peak field within the dogs of 0.020 volts/cm. The authors found a decidedly beneficial effect in the second group of exposed dogs. After 28 days of continuous exposure, the organization and strength of the repair process in the fractures had increased significantly. That is, the 65 hz circuit was found to augment bone repair.

The biological effect described by Bassett et al. was produced by subjecting the animals to a time varying magnetic field, which in turn induced an electric field. That is, both fields were simultaneously present in the animals, and it is therefore not possible to state categorically that the effect was due solely to the electric field. The authors designed the experiment so as to produce a bulk electric field, believing that the electric field would be the biologically active field. Nevertheless, the possibility remains that the magnetic field may have played some role.

Q. Are there other reports in the literature dealing with biological effects associated with electric fields at low frequencies?

A. In 1964 Moos (5) exposed mice to an average field of 10 volts/cm at 60 hz and studied the effect on their activity. The data appears to show that the mice were more active when the field was turned on, and the author stated that no definite conclusions were possible but that it appeared that a trend had been established.

Some time prior to 1967, the American Electric Power Company became concerned with the question of safety in live line working (6). Therefore the American Electric Power Service Corporation entered into a research agreement with the Johns Hopkins Hospital to study the effect of electric fields on human beings (6). As part of this study, the effects of 345 kV 60 hz fields on 11 linemen were studied over 42 months (7).

The linemen were given periodic physical examinations. An ophthalmologist and otolaryngologist a urologist and a neuropsychiatrist were consulted. The laboratory survey consisted of a complete hematological study and blood chemical studies. Thyroid and kidney functions were evaluated. Electrocardiograms and electroencephalograms were recorded and studied. Hearing was tested, and x-rays of the chest and hands were obtained at each examination.

The authors found no significant changes of any kind in the general physical examination. The men remained healthy. There was no change in the cardiovascular function or respiratory system. No malignancies were found and there were no significant changes in any of the laboratory studies. The consultants found no disease states which could be related in any way to the transmission line exposure. Eye and hearing examinations showed no changes. The psychiatrist could not detect any significant changes in emotional status in any of the men that could be related to this study. The urologist did find that two of the men had reduced sperm counts, but the morphology and motility of the sperm were normal.

There are several difficulties with the report described above. The stated conclusions were not supported by data, making objective analysis difficult. Furthermore, there is a comparable Soviet study involving more subjects that reached the opposite conclusion (8).

The Soviet group studied the state of health of 45 persons (including 4 women) who worked in 400 kV and 500 kV switchyards. Each worker was exposed to the fields from 2 to 5 hours per day, and the average exposure period was about 4 years per worker.

The Soviet group performed complete clinical studies of peripheral blood, x-rays of the chest and electrocardiography, in addition to general physical examinations and histories. Of the 45 subjects, 41 presented some type of subjective disorder, most frequently neurological and cardiovascular, occurring during and shortly after field exposure. Symptoms subsided some hours after exposure ceased, and in general the severity of the symptoms was proportional to the length of the time of exposure. Approximately 30% of the male subjects reported decreased sexual vigor. The authors believed that the reported symptoms were due to autonomic nervous system dysfunction. Physical examination, while failing to show any organic pathology, did reveal instability of the pulse and blood pressure, tremors of the extremities, and hyperhidrosis. Accompanying this, the EKG showed bradycardia in 14 subjects and slowed atrioventricular conduction in 10 subjects, while laboratory studies of the peripheral blood showed only mild changes from normal (except for marked spherocytosis found in 17 of 28 subjects in whom this examination was done).

The Soviet group concluded that their observations gave leave to assume that being in a high voltage electric field of commercial frequency is an adverse influence upon the working person. This is manifest by disorders of the functional state of the nervous and cardiovascular systems.

The Soviet study presents some data, but I do not feel it justifies a more precise conclusion than that power frequency electric fields can affect maintenance personnel. Indeed, that appears to be precisely what they did conclude.

There is one difficulty common to both the American and Soviet studies; namely, under the procedures employed, it is most difficult to establish an exact cause and effect relationship.

In the typical laboratory experiment all parameters are controlled except for the suspected causative parameter which is varied in a precise fashion. Parameters which reflect the suspected effect are then monitored. In this way the two may be logically related. In both studies described above, however, there was no control in this sense. The possibility, therefore, exists that causes other than the field exposure may have been involved.

The Soviet medical study of switchyard personnel (8) led to a physiological study of the work conditions in 400 kV and 500 kV open switchyards (9). Two groups of operating personnel were formed for purposes of study. Group I was composed of persons working under electric field exposure of not more than two hours daily. Group II contained persons exposed not less than five hours daily. In all, 54 persons were studied by the following tests: temperature, pulse, blood pressure, critical flicker fusion frequency (CFF), speech and motor performance error (determined by reaction time testing) and the strength-duration curve and optical stimulation frequency of the adductor pollicis. Essentially no differences were noted between Groups I and II in body temperature, pulse, arterial blood pressure and CFF. Changes were, however, noted in the strength-duration curves of motor function, with Group II showing an increase in excitability at the end of the field exposure period, and an increase in the latent time in the reaction time tests. Error in speech and motor performance increased with exposure in both Groups, but more so in Group II. The author concluded from the data that the electric field influenced primarily the autonomic nervous system, and that the extent of functional changes was directly related to the duration of the exposure.

In another part of the Johns Hopkins study (10), 22 mice were exposed to electric fields of about 1600 volts/cm at 60 hz for two months over a 10½ month period. The 22 mice and an equal number of controls were studied both at the gross level and histologically over several generations. The results of the study were largely negative, except that the male progenies of the exposed mice were slightly smaller in weight.

Kruger et al. (1) exposed egg-laying hens to a maximum full-body electric field of 16 voltslcm for 16 weeks. During the first and second four week period, egg production by the exposed animals was significantly lower than that of the controls. During the third and fourth week period there were no significant differences. The results suggest that while the long-term (greater than 16 weeks) egg-laying capacity of the hens was not altered, some presently unknown physical process resulted in a decrease in production over the short-term (less than 8 weeks).

Q. You have described some reports showing biological effects at less than 200 volts/cm, and other reports which are largely negative (7, 10). Is that not contradictory?

A. Not at all. It simply means that some scientists observed effects under the conditions they employed, while others, under different conditions, found no effect. The thesis that emerges is that low frequency electric fields can influence and affect biological systems. These reports do not stand for the proposition that effects will always be found. On a more general plane, it may also be said that many of the biological effects of electric fields are subtle and easily missed. The reports describing biological effects due to electric fields are mostly of recent vintage. They correspond roughly to the time frame in which the relationship of man to his environment, both natural and artificial, is being re-examined.

Q. In your own research have you studied the effect of electric fields on biological systems?

A. Yes.

Q. What is the purpose of your electric field research?

A. The basic purpose of our laboratory is to elucidate the physical basis by which a biological organism controls its growth processes. The ultimate aim is to restore the ability to regenerate limbs in those species, such as man, which have lost that capability during the course of evolution. We believe that electrical factors are crucial in growth phenomena. Many publications have emanated from our laboratory on this subject. In one such publication, the ability of electric currents to grow bone in dogs was described (12). This experiment has since been repeated by others and it is now possible to grow bone in humans. When the results are analyzed in detail however, some important problems are presented. We do not know if the observed effects are due to the actual current that flows, the electric field that causes the current, or if it is related to chemical species that are created at the implanted metallic electrodes. Therefore the decision was made to design experiments to study each physical process separately. This was the motivation for our electric field experiments.

Q. Would you describe your electric field experiments?

A. In our experiments, we employ male Sprague-Dawley rats. They are housed in plastic cages and cared for according to normal animal care procedures. Throughout the entire volume to which the rats have access and slightly beyond, an electric field is created by energizing the plates of a suitably mounted capacitor. The rats are 21 days old when the exposure is commenced and it is continuous for 30 days with only momentary interruption to change the bedding material. We have many other electric field experiments, but I believe that the results obtained with this experimental system would be those that are relevant for the purposes of this hearing.

Q. Please describe the results of your work.

A. Following thirty days of exposure to a 60 hz electric field of 150 rms-volts/cm, the rats were weighed and then sacrificed by decapitation. The blood was collected and the extracted sera were pooled and prepared for various studies. A minimum of 12 rats were used in preparing both the experimental pools and the control pools.

By three different criteria, the experimental group differed from the control group.

The average weight of the experimental rats at the end of 30 days was less than that of the controls.

The distribution of blood proteins in the experimental rats was altered.
The average serum concentration of the steroid 11-hydroxy-corticosterone was lowered in the experimental rats.

Q. Were these experiments repeated?

A. Yes, they were repeated three times and the results were the same. The results are given in Tables 1–3 on pages 4-6 of Exhibit _______ (AAM-1).

Q. How do you interpret these results?

A. The results establish that 30 day chronic exposure to 60 hz fields at 150 rms-volts/cm causes certain specific quantifiable biological effects.

Q. Do the changes you have described, taken as a whole, indicate sickness or disease?

A. The medical and biological significance of our work will be described by Dr. Becker.

Q. Based on your work, is it possible to compute a safety factor for chronic exposure to 60 hz electric fields?

A. Compared to the pervasiveness of 60 hz fields in the environment, only a very modest amount of research has been performed. It is therefore not possible to establish a safety factor with the desirable precision. It is possible, however, to make a reasonable beginning. Title 21 of the Code of Federal Regulations, Section 121.5, reads in part: "…the following safety factors will be applied in determining whether the proposed use of a food additive will be safe. Except where evidence is submitted which justifies use of a different safety factor, a safety factor in applying animal experimentation data to man of 100 to 1 will be used; that is, a food additive for use by man will not be granted a tolerance that will exceed 1/l00th of the maximum amount demonstrated to be without harm to experimental animals."

We believe that it is reasonable to employ this safety factor of 100 to 1 in evaluating permissible chronic human exposure to 60 hz electric fields. Since we have found biological effects at 150 rms-volts/cm, the utilization of the 100 to 1 safety factor would yield a tentative safety level of 1.5 rms-volts/cm at 60 hz.

Q. How does the proposed tentative safety level compare with the electric field strength to which the general public is exposed normally?

A. I have made no measurements personally; however, the following values are listed in the Fact Sheet for the Sanguine System (13).

Appliance	Electric Field
Incandescent light bulb	0.2 volts/cm
Electric range	0.4 volts/cm
Clock radio	0.15 volts/cm
Color television set	0.30 volts/cm
Hair dryer	0.50 volts/cm
Food mixer	0.60 volts/cm
Refrigerator	0.90 volts/cm
Broiler	1.30 volts/cm*
*measured 30 cm from device)	

Based on these values, it appears that the ambient electric field at 60 hz would be considerably less than the proposed safety level.

Q. Are you familiar with any safety regulations in foreign countries dealing with exposure to commercial frequency fields?

A. I have read the document entitled "Rules and Regulations on Labor Protection at 400, 500 and 750 kV AC substations and Overhead Lines of Industrial Frequency," as translated by Dr. G. Guy Knickerbocker. The Rules were issued jointly in 1971 by the Ministry of Health and the Ministry of Energetics and Electrification of the USSR.

Q. What is the substance of the Rules and Regulations?

A. According to the Rules, working conditions are not limited or controlled where the electric field is less than or equal to 50 volts/cm. If the electric field is greater than 250 volts/cm, all work must be done with the worker protected by screening or some other device. For fields between the two values, the permissible duration of field exposures without protective measures is limited as follows. At 250 volts/cm, 5 minutes; at 200 volts/cm, 10 minutes (9) at 150 volts/cm, 90 minutes; at 100 voltslcm, 180 minutes. Thus for instance, after spending 90 minutes in an electric field of 150 volts/cm, the worker must spend the remaining portion of the 24 hour period in an electric field of less than 50 volts/cm.

The Soviet Rules and Regulations were prompted by the Soviet reports of 1966 (8) and 1967 (9) previously discussed (14). I do not know if the Rules have been changed or updated in response to subsequent reports (1, 2, 3, 4, 5, 7, 8, 11).

Q. Can you relate the results you have obtained, including the proposed tentative safety factor, to the 765 kV transmission line presently under consideration?

A. Yes, because the proposed transmission line would create a spatial electric field distribution of considerable strength.

Q. Have you made calculations of the spatial electric field distribution that would be created by the proposed transmission line?

A. Yes.

Q. Would you explain what led to these calculations and their result?

A. Our experiments were designed with no thought of their possible relevance to power transmission systems. Subsequently, we observed the biological effects described above. During the course of routine literature searches, we became aware of reports which showed that maintenance personnel performing live line work were exposed to electric field strengths much higher than that involved in our work (7,15). We therefore did some crude calculations of the electric field distribution that would result from the recently approved Volney-Edic transmission line because the only design information available to us at that time was the February 1972 Environmental Impact Statement by Niagara Mohawk filed with the Public Service Commission in Case 26251, and it did not contain this information. Our calculations indicated that the proposed safety level would not be achieved until some distance beyond the right-of-way. We notified Niagara Mohawk, the Public Service Commission and the Department of Environmental Conservation of our general findings, and proceeded to do a more detailed calculation, employing design data of the presently proposed line. The details of the calculation are presented in Appendix 1 on pages 10–14 of my Exhibit. Based on this calculation we computed the electric field profile for the proposed transmission line. The general pattern at ground level is given in Figure 1 on page 1 of my Exhibit. A more precise view of the tail of the curve is given in Figure 2 on page 2 of my Exhibit. We found that the proposed tentative safety level would not be achieved until at least 329 feet from the center of the right-of-way. This is 204 feet beyond the edge of the right-of-way.

Q. Figure 4-11 in the Application to the Public Service Commission for a Certificate of Environmental Compatibility and Public Need in Case 26559 shows a maximum electric field profile. How does it compare with the one that you have calculated?

A. It is essentially identical. For instance, the calculation which yielded Figure 4-11 predicts that the proposed tentative safety factor of 1.5 rms-volts/cm would not be achieved until at least 337 feet from the center of the right-of-way. This is within 3% of our calculated value.

Q. Why do you say “at least” 329 feet, to use your figure, and 337 feet to use the figure of the applicants?

A. For several reasons. First, both calculations describe only the ground level electric field. The electric field above the ground at any lateral distance will be greater than that at ground level. For instance, Miller (15) has measured the electric field at ground level and at 6 feet above the ground due to a 345 k transmission line. He found that at the lateral distance which. corresponds to the peak electric field the field t a height of 6 feet was nine times stronger than the field at ground level. It should be noted that this ratio depends on the particular transmission line under consideration. Nevertheless it is true that the electric field above ground level will be greater than that at ground level for any given lateral distance. Thus if a 1.5 rms-volts/cm limit were to be adhered to, the outer limit of lateral distance would be somewhat greater than 329 or 337 feet.

Secondly, while I believe that both calculations are internally correct, there is a question in my mind concerning whether they accurately describe the real world. That is, the record does not show actual measurements of the electric field profile of a prototype of the proposed transmission line. It is certainly conceivable that the mathematical predictions of the electric field profile might be in error, and I believe that the direction of that error would be such as to predict a lower value of the electric field than would be measured, at least for lateral distances greater than 100 feet. Lastly, the lateral distance at which any particular electric field is achieved is a function of the height of the transmission line above the ground. For example, calculations show that for a height of 50 feet, 1.5 rms-volts/cm occurs at 329 feet or 337 feet, but for a height of about 50 feet, the electric field doesn’t decrease to 1.5 rms-volts/cm until about 434 feet from the center line.

Q. How would you determine the actual electric field that is created by a 765 kV transmission line?

A. It seems to me that a complete set of measurements should be made on an already existing transmission line or an experimental prototype. The electric field at different heights for each lateral distance should be ascertained under different weather and topographical conditions and for different soil conductivities. From a biological viewpoint, the data would be usable directly if one were interested in knowing at what lateral distance a specified electric field occurred.

Q. Would you summarize your testimony with regard to the electric field due to the proposed transmission line?

A. Yes. The calculations predict that the electric field will decrease to 1.5 rms-volts/cm at 329 or 337 feet measured laterally from the centerline. I believe that these distances are in error in that they are too small. There is nothing in the record, of which I am aware, that would establish what the actual electric field will be (as distinguished from the calculated electric field) at any distance. Thus the record does not show at what lateral distance the electric field will actually have decreased to 1.5 rms-volts/cm.

Q. Is there a generally accepted scientific theory which could explain the biological effects of electric fields at very low frequencies and very low strengths at the molecular or cellular level?

A. No. It is only recently that such effects have been described and no coherent theory has yet evolved. Perhaps some history of the field will be helpful. The older view of the interaction of electricity with biological organisms generally does not take into consideration the fact that the organism is alive. For instance, radiation of sufficient energy to produce ionization in muscle tissue will do so regardless of whether the animal is alive or not. In this view, any effects due to energy which could not produce ionization because the frequency was too low, were attributable to heating of the animal tissue. There is now a competing viewpoint, one which we happen to accept as correct. In this latter view (see, for example, ref. 16), cells in the body exist in equilibrium with their immediate electrical microenvironment. Certain changes in this microenvironment result in an information transfer into the cell which is capable of controlling the cell function. Thus, in this view, a given cell may be "triggered" to differentiate, or build bone, or increase protein synthesis, or decrease its hormone output (17). The environmental change can be exceedingly small because its function is to convey information to the cell, which itself is the source of the energy for the process. Thus, in theory, a heretofore considered “small” electrical stimulation could produce a biological effect.

Q. Could you particularize this theory to a more concrete biological situation?

A. Yes. I will describe the application with which I am personally involved. Piezoelectricity is a property of some materials by which when these materials are squeezed, they generate a voltage. The property is well-understood to physicists. It turns out that many tissues in the human body are piezoelectric , including bone and other tissues containing the protein collagen19. We have a working hypothesis that the voltages generated during walking or other movements may control he function of the cells of bone (20). That is, there is reason to believe that changes in the normal voltages that appear on the bone surface may trigger cells to build or resorb bone, depending on their magnitude and polarity.

Q. Assuming that this control system exists, could it be affected by 60 hz electric fields?

A. Yes, 60 hz fields could interact with cells directly, or they could affect cells indirectly. This latter possibility is the subject of some most interesting research. I have defined the piezoelectric effect as voltage that results from squeezing the material. According to the laws of physics, every material that is piezoelectric must also exhibit the converse piezoelectric effect. That is, when a voltage is applied to the material, it becomes “squeezed” or speaking more technically, it is strained. Straining creates a distribution of electric charge on the surface of the material which may be measured as a voltage. This surface charge, or voltage, may convey or transmit information to cells in the immediate area, thereby affecting, or controlling their function. Thus in theory, electric fields applied to a living system may affect that system. McElhaney's experiment, discussed above (1), was predicated on this theory. Norton's work on bone explants tissue culture is also based on this idea (21). Both have described biological effects.

Q. Returning to the electric field profile of the presently proposed line, which you present in Figures 1 and 2 on pages 1-2 of your Exhibit, would you explain how this profile would affect a man, from the viewpoint of electric current?

A. Yes, at any lateral distance, the man would be exposed to an electric field of the intensity indicated in Figure 1. The field would induce throughout his body a small electric current proportional to the strength of that field.

Q. Can this current be calculated or measured?

A. Yes, both are possible. An excellent calculation has been published (6). I have applied that calculation to the case of a man in an electric field profile shown in Figure 1. The results are given in Table 4 on pages 7-8 of my Exhibit. During the course of our experiments we have measured the induced current in rats for fields up to 200 volts/cm. The results are given in Figure 3 on page 3 of my Exhibit. As can be seen, the mathematical model employed very accurately predicts the induced currents in the rat and I would assume therefore, that the predictions of the model for a man would be similarly accurate, if a man were similarly exposed.

Q. Can the question of biological effects of electric fields be approached via the study of biological effects of electric currents?

A. It would be seriously wrong to equate the question of biological effects of electric fields to that of the biological effects of electric currents.

Q. Would you explain the last statement?

A. In our research, the entire animal is subjected to an electric field. Similarly, a man near a transmission line is completely immersed in an electric field. Even if one were perfectly sure that current below a certain level applied to the body through a limited surface area was completely without biological effect, one could still not predict whether a full-body electric field, of strength which produced a total body current at the "safe" level, would or would not cause a biological effect.

Q. Are you saying that the only way to determine whether full-body exposure to electric fields causes biological effects is to do an experiment at the particular electric field strength in question?

A. Yes. The most brilliant scientists and engineers could not answer the question by extrapolating from experiments in which currents are locally administered. Furthermore, only the crudest data are presently available concerning what is a "safe" level of electric current.

Q. Are the currents which you have calculated as shown in Table 4, “steady-state” currents?

A. Yes. They are rms steady-state values. That is, they take no account of transient effects. Transient over-voltages can occur in a transmission line due to switching and lightning (22). Very little is known concerning the physiological effects of these short-lived phenomena.

Q. What is a magnetic field?

A. It is a region of space in which a force would be exerted on a charged particle which moved through it. The field can arise from atomic currents, as from a magnet, or from currents moving in a wire. With reference to the latter case, the frequency of the magnetic field would be the same as that of the current in the wire which creates it.

Q. Can magnetic fields affect biological organisms?

A. Yes (23, 24). That much is clear. This area is, however, in its infancy and the reports tend to be preliminary. This is particularly true if the question is restricted to magnetic fields of low strength, and frequency comparable to that associated with the transmission line. In 1973, Beischer and his colleagues described the effect of exposure of man to magnetic fields alternating at 45 hz (25). A total of 13 volunteers were involved in the study. All were confined to a specially constructed platform for one week, during which ten subjects were exposed to a magnetic field of 1 gauss for up to 22.5 hours. A large battery of physiological and psychophysiological tests were given throughout the confinement period. The results were negative with one exception; a significant increase of serum triglycerides was observed 1 to 2 days after exposure in 9 out of 10 men exposed to the magnetic field. Similar trends were not seen in the five control subjects.

This phenomenon was induced by a magnetic field of magnitude, frequency and direction, comparable to that associated with the transmission line. Dr. Beischer has indicated to me that his only reservations concerning the validity of the triglyceride effect is the relatively small number of subjects involved. In his report he states “in summary, the results of this pilot study suggest that an alternating magnetic field of 45 hz and 1 gauss strength may cause a time-delayed increase of serum triglycerides in man. It should be emphasized that the number of subjects was small and that a final assessment depends on establishment of the threshold for the effect and the field strength-biological effect relationship."

For a discussion of other low strength magnetic field effects and their significance, I would refer you to Dr. Becker's testimony.

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

A. I would recommend against construction as proposed. The level of the electric field which would be produced at points beyond the right-of-way would exceed what I feel is a reasonable safety level for about 268 feet beyond the right-of-way on both sides. Also, the level of the magnetic field on the right-of-way may cause biological effects in people exposed to these fields. In my opinion, common wisdom dictates that these effects should be studied further before the proposed line is constructed.

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

A. They apply proportionately. That is, if one lowers the current that flows, one lowers the magnetic field associated with it. If the voltage is lowered, then the electric field at any point in space is lowered by the same factor. Regardless of how a company designs or operates its transmission lines, I do not think reasonably arrived at safety levels for electric and magnetic emanations should be chronically exceeded.

Q. Would you state for the record whether the conclusions you have reached apply equally to a + 400 kV d-c overhead transmission line or an underground 345 kV transmission system with the same power transfer capability as the proposed line?

A. I have not analyzed the d-c case and therefore cannot comment on it. With reference to an underground 60 hz power system, elementary laws of physics show that it is possible to shield a conductor which is carrying a voltage so that the electric and magnetic fields at points beyond the shield are greatly reduced. The biological hazard would then be reduced proportionately.

Q. Does this conclude your testimony?

A. Yes.