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

November 24, 1976

#### **REBUTTAL TESTIMONY OF ANDREW A. MARINO**

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**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 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.

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 7247-15). 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-I0ff), 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 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 of 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.