STATE OF CALIFORNIA

ENERGY RESOURCES CONSERVATION
AND DEVELOPMENT COMMISSION

In the Matter of:	Docket No. 79-AFC-5
The Application for Certification of PACIFIC GAS AND ELECTRIC COMPANY Re: Geysers Unit 16.	DECLARATION AND WRITTEN TESTIMONY OF DR. ANDREW MARINO SUBJECT: TRANSMISSION LINE HEALTH AND SAFETY

The Staff of the California Energy Commission hereby offers the attached declaration and testimony in the above-entitled matter.

Dated: August 4, 1980

Respectfully submitted,

Steven M. Cohn

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Staff Counsel

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1. PRELIMINARY MATTERS

a. Background of the Problem

In 1873 the English physicist James Clerk Maxwell predicted that light was composed of electricity and magnetism. His idea was that the electric and magnetic parts were inseparably joined; the electric part generated the magnetic part which in turn generated the electric part and so on, resulting in a wave-like motion which moved through space. Some of Maxwell's contempories rejected his theory because is seemed to predict too much--an infinite number of nonlight waves, none of which had ever been detected. But other scientists began searching for the invisible waves, and in 1888 Heinrich Hertz, a German physicist, succeeeded. Using what today would be called a transmitter and receiver, he proved the existence of electromagnetic waves with a frequency of 30 million cycles a second.

Hertz died in 1894, and Gugliermo Marconi, then only 20, read his obituary in an Italian electrical journal. It seemed to Marconi that Hertzian waves had a vast potential in the field of communications; by 1896 he had repeated Hertz's experiments, but with the receiver more than two miles away, not just on the other side of the room. Many successes followed, leading directly to the development of radio, radar, TV, and many other uses for electromagnetic waves.

The birth and growth of the electrical power industry paralleled these developments. Beginning in 1882 under the guidance of Thomas Edison, the industry began the process of systematic electrification; the resulted was a steady increase in power-line construction and in the number of appliances which they served. Electrification gave rise

to environmental electromagnetic fields--electrical entities which, unlike the waves, do not move through space but remain associated with the wire or appliance from which they originated.

The nonionizing portion of the electromagnetic spectrum was ultimately allocated by the government, and 60 cycles a second (Hertz) was reserved for electrical power systems (Figure 1). The portion of the spectrum suitable for wireless transmission (the broadcast frequencies) was divided among different classes of users.

The passage of electricity from a scientific curiosity to a role of importance in society resulted in a profound alteration in the earth's electromagnetic environment. From the origin of life on earth to the beginning of the twentieth century this environment was determined by the sun, and by other cosmic sources and by the geomagnetic properties of the earth itself; it was extremely small even by the standards of today's ultrasensitive instrumentation. But, by the beginning of the last half of the twentieth century, man-made waves and fields were the dominant constituents of the earth's electromagnetic environment.

The state of knowledge of the biological effects of electricity was an important factor in the development of man-made electromagnetic sources. Even before the turn of the century the ability of electricity to cause tissue heating and shock was well known. In the United States--largely for reasons related to the way the medical profession evolved--these became the only recognized biological effects of electricity. As a consequence, from a side effects viewpoint, tissue heating and shock were the only recognized hazards to be guarded

against during the development of the electrical power and communications industries. This approach translated into different precautionary rules for the broadcast and power frequencies. At the power frequency, because the fields alone were physically incapable of causing tissue heating or shock (except under extraordinary circumstances), one needed only to avoid touching a charged wire.

In the Soviet Union, regulation of electromagnetic waves and fields developed very differently. Soviet investigators reported that such waves and fields could affect the central nervous, cardiovascular, and neuroendocrine systems without causing tissue-heating or shock. These results led to the adoption of broadcast-frequency safety levels 10,000 times more strict than those in the United States. The Soviets also adopted regulations governing exposure to levels of power-frequency fields considered to be completely safe in the West.

Beginning in the late 1960s several different lines of investigation in the United States and Europe led scientists to question the assumption that power-frequency fields were always harmless. In less than a decade this effort yielded more than a hundred animal and human studies which revealed the broad outline of a previously unknown sensitivity of living organisms to power-frequency and other extremely low frequency (ELF) fields. My testimony deals with these studies, and their implication for the Geysers 16 transmission line.

b. <u>The History of My Involvement in the Issue of Power Line Side Effects</u>

I work at the Orthopedic Research Laboratory, Veterans Administration Medical Center, Syracuse, New York. Until his recent retirement, the

Director of the laboratory was Robert O. Becker, M.D. In 1961 Dr. Becker founded the laboratory to study the means by which the body regulates and controls its growth and repair characteristics. There were many situations in medicine, for example, where people experienced broken bones, that did not heal properly. In other instances, particularly involving older people and people undergoing prolonged bed rest, the bone tended to dissolve away and the physician was unable to stop or reverse this deterioration. In still other instances, particularly involving the servicemen who received battlefield injuries, it was exceedingly difficult for the physician to cure infections that might develop in the bone. Even beyond all this, Dr. Becker knew that certain life forms had the ability to regenerate entire limbs if necessary. The salamander, for example, whose leg is as anatomically complex as that of a human being, can grow a new leg if the first one is lost. Following an initial series of experiments in the early 1960s Dr. Becker evolved the idea that the control of growth in the body was electrical in nature. His idea was to determine the precise electrical signal which brought about various growth responses. Thereafter, he envisioned that a physician could apply the suitable growth signal when, for whatever reason, it was not supplied by the body. I joined the laboratory in 1965, and during the middle and late '60s we performed many experiments to test and develop these ideas. In 1965 we were able to grow bone in dogs using an electrical signal about one-millionth of that passing through an ordinary light bulb. During the next 10 years this technique for bone growth passed from the animal-study to the human-study phase. We began treating patients for whom the techniques we were developing were the last

resort—these patients had received standard orthopedic treatment and faced limb amputation. Our methods were successful, and ultimately a worldwide clinical testing program began involving thousands of patients. The electrical technique for bone stimulation using these weak currents is now a routine orthopedic procedure.

We developed techniques to cure bone infections in human beings using extremely weak electrical currents. Working thus far only with animals, we have successfully induced partial limb regeneration in laboratory rats. Much of our effort now is devoted to determining the precise electrical signals that trigger or induce the specific kind of growth that is required in each individual case.

During the course of the studies which I have described, in late 1972 and early 1973, we performed some studies which, as it turned out, are relevant to the assessment of risk of people who live near high-voltage transmission lines.

Our method of bone-growth stimulation involved the passage of a very weak electrical current through the bone. To do this, we used small circuits which could be placed in laboratory animals or could be attached to the outside clothing or cast of a patient. In both cases very small wires, normally made of platinum, actually touched the tissue. The electrochemistry of what takes place under these circumstances is complicated, but it was possible to list a number of things that might be important in understanding what was taking place. We formulated this list in early 1972 and planned a series of experiments in which each of the factors could be studied separately. Other sceintists in our laboratory were given responsibility

for performing some of these studies, and I undertook what we called the field studies.

As I use the term "field," I mean either an electric field or a magnetic field. Any time there is a flow of electricity, whether in a wire or through tissue, there is also an electric and magnetic field. My job was to determine whether electric and magnetic fields alone could be involved in some of the effects that we were observing in animals and in human beings, or whether either could possibly produce adverse biological effects. To do this, I designed experiments which used rats and mice that were exposed to electric and magnetic fields. It happened that rats and mice exposed to these fields were in a situation similar to people who live near high-voltage transmission lines. In this case the electric current through the wire sets up an electric and magnetic field which extends outward from the wires for several thousand feet. In the early '70s, however, when we did our first studies, we did not appreciate the relation our work had to evaluating human health risks.

I designed and built an apparatus which created electric fields in the living space of rats and mice; in our first experiments we found that electric fields could produce genetic defects. Later we learned that there were other investigators working in this area, but in 1973 we were unaware of them. We presented our results in September 1973 at a scientific meeting in New York City. Still we did not, in our own minds, relate our experiments to health hazards of high voltage transmission lines; our focus was still on the therapeutic aspects. At the conclusion of the meeting we were approached by Capt. Paul Tyler, a commander in the Navy and a medical doctor. Tyler told us

about a Navy project called Sanguine; it was a plan by the Navy to build a large antenna in Wisconsin. The antenna was to cover about half the state, and its purpose was to permit communications with submarines while they remained submerged. Sanguine would expose many residents in Wisconsin to electric and magnetic fields, the Navy therefore was required to do studies to determine whether there would be a health or environmental hazard.

The Navy funded a number of experiments in the early '70s by various investigators to examine the question of risk. In these studies, investigators placed biological systems, including monkeys, rats, mice, guinea pigs, and even plants, in simulated Sanguine fields to determine if the fields produced any biological changes. The results of some of these studies had been obtained by the Navy towards the end of 1973. Capt. Tyler asked Dr. Becker to come to Washington as part of a small select group to review the results and to give advice to the Navy on how to proceed.

Dr. Becker agreed, and he attended the meeting on Sanguine in Washington, DC, in December 1973. The committee reviewed the Navy research and expressed grave doubts about the safety of the planned project. They said that the research had raised many more questions than it had answered and that the project could not proceed until much more study had taken place. During that meeting, in the process of their discussions and debates, the existence of a link between Sanguine and high-voltage transmission lines was recognized. Sanguine was designed to operate at a frequency similar to that of a high-voltage transmission line, and with a magnetic field of strength

comparable to that of high voltage lines. But the electric field of Sanguine was to be about one-millionth the intensity of that of high-voltage line. Thus, if Sanguine constituted a health risk, it was clear that high-voltage lines were an even greater problem.

After Dr. Becker returned home from Washington, and in response to a newspaper notice of the proposed construction of a new high-voltage line in New York, he sent a letter to the agencies in New York which regulate high-voltage lines; he pointed out that the Navy had research data that might be useful to them in their deliberations. In July 1974, in response to the letter, a staff lawyer of the New York Public Service Commission (PSC)--the state agency with jurisdiction over high-voltage line design and construction--came to our laboratory to talk about the health risks of high-voltage lines. We told him that based on our own studies, the Navy research that Dr. Becker had been privy to in Washington, and studies published in the literature, we felt that there was a risk to health for people who were constantly exposed to the fields of high-voltage lines. The lawyer asked Dr. Becker and me to testify before the PSC in the power line hearing which had initially prompted the letter. Over the next 4 years we served, pro bono, as staff sponsored witnesses and consultants; this included undergoing 17 days of cross-examination.

During the New York hearing, I met PGandE's witness Morton Miller for the first time, and this led to a continuing contact resulting from his opinion of our research. He was employed as a consultant and witness by the Rochester Gas and Electric Company, and at his lawyers' request, I provided him with all my research data, raw data, designs

of my apparatus, and a detailed description of all my laboratory procedures. Dr. Miller also visited my laboratory where he took many photographs. Later, Dr. Miller testified that he had repeated my experiments, with the aid of engineers from the power company, and had verified to his satisfaction that we had done them incompetently. Since then he has sent letters to various journal editors in which he made the same point.

During the New York hearings I received a federal grant to study the possible side effects of power-line fields. My work has concentrated on the effects of these fields on growth, development, and healing. Additionally, we are exploring the mechanism by which the fields can interact with living organisms.

2. THE ELECTRIC AND MAGNETIC FIELDS OF THE GEYSERS 16 TRANSMISSION LINE IN RELATION TO ENVIRONMENTAL 60-HERTZ FIELDS FROM OTHER SOURCES

a. <u>The Geysers 16 Fields</u>

Pacific Gas and Electric (PGandE) has proposed a 60-hertz transmission line system between Castle Rock and Lakeville (the Geysers 16 line) to transmit up to several thousand megawatts of Geysers power. In most instances, a right-of-way containing one or more transmission lines already exists along the proposed route; PGandE has proposed to add additional transmission capacity and to alter the present tower arrangements.

Electrical power carried by transmission lines, such as the Geysers 16 line, does not move through the wires, but through the space adjacent to the wires (1). Sixty-hertz power has a characteristic not present

at higher frequencies, such as those used for radar or TV: the electric and magnetic fields are mutually distinct, and they can be separately produced, measured, or calculated. The Geysers 16 line will thus produce environmental electric and magnetic fields, each of which must be ascertained and evaluated with regard to possible impacts.

Presented in Figure 2 and 3 are the ground-level electric and magnetic field intensities of the Geysers 16 line out to and beyond 6,000 feet from the line. Both figures were calculated using the method described previously (1), employing the assumptions concerning line geometry listed in Appendix B. Fields of both 2-circuit and 4-circuit configurations are given; the two configurations apply to 14 of the 18 different proposed tower arrangements (approximately 78.5 miles). For the remaining portions of the Geysers 16 line (O to P; R to S; S to T; T to U; Exhibit ___. Geysers 16 Draft EIR), the fields produced by the line will be somewhat greater than those listed in the figures.

The electric field of the Geysers 16 line will be at a maximum on the center line directly under the wires, ranging from 4,000 - 7,000 volts/meter depending on the number of circuits (Figure 2). Moving outward from the center line the field first decreases and then increases at about 150 feet to a relative maximum of 300 - 600 volts/meter. Thereafter, the field decreases continuously with distance; it reaches 1 volt/meter at 4,500 and 6,500 feet from the respective center-lines of the 2- and 4-circuit lines. The functional dependence of the Geysers 16 magnetic field is similar to that of the electric field (Figure 3). The maximum magnetic fields are 0.1 - 0.2

gauss; they do not diminish to 400 microgauss until 1,350 and 2,100 feet from the respective center-lines of the 2- and 4-circuit lines. The unusually large zone of influence of the Geysers 16 line is a result of its unique design configuration.

b. Environmental 60-Hertz Fields From Other Sources

Power-frequency electric fields are pervasively in the environment; except in remote areas such as forests, it is difficult to find places where the field is less than 0.1 volts/meter. Typical 60-hertz electric fields emanating from household appliances, measured at a distance of 1 foot, are listed in Table 1. The actual exposure one receives depends on many factors, including the frequency and duration of use of various electrical appliances. Considering the ordinary user distances and the typical duration of use--and excluding electric blankets and high-voltage lines--the average background electric field experienced by each person is probably on the order of 1 volt/meter.

Power-frequency magnetic fields are also pervasive in the environment. The median field at 1,200 locations which we measured was about 400 microgauss. We found that the principal contribution to this field arose from low-voltage wiring and household appliances. Typical magnetic fields measured in the vicinity of such appliances are shown in Table 2.

From a comparison between the Geysers 16 fields and the fields to which people are ordinarily exposed in the environment, it can be seen that, people living or working within about 1 mile of the proposed line

will experience an increase in the level of environmental 60-hertz fields which will be greater than the average fields already experienced.

3. ELF FIELDS IN RELATION TO THE IMPACT ON HUMAN BEINGS

a. Laboratory Studies

A number of animal and human studies have explored the effects of ELF fields on growth, development, behavior, and on the central nervous, neuroendocrine, blood, and cardiovascular systems.

Growth and Development: Knickerbocker et al. (2), at Johns Hopkins University, intermittently applied to mice an electric field of 160,000 volts/meter at 60 hertz. The field was applied to male mice only, for 6.5 hours/day, 5 days/week, for a duration of 10.5 months. During nonexposure periods the mice were mated with nonexposed females and the offspring then reared in a field-free region. It was found that the male progenies, but not the females, were smaller in weight when compared to the progenies of the control males.

Bassett et al. (3), at Columbia University, investigated the effect of a magnetic field on the organization and strength of the repair process that occurs during the healing of a bone fracture. They applied a pulsed field repeating at 65 hertz, with a peak value of several gauss, to dogs that had undergone surgically-induced fractures of the leg bone. It was found that the field accelerated the time course of the repair process. In a subsequent study (4), the field was applied to patients suffering from a bone disease in which the bone fails to heal naturally. Patients exposed for 12 - 16 hours per day for 3 - 6 months achieved a success rate of 73 - 76 percent.

Giarola and Krueger (5), of Texas A&M University, found that exposure of one-day-old chicks to 1.3 gauss at 45 hertz for 28 days depressed their growth rate by 9 - 11 percent as compared with that of the unexposed birds; they observed a similar effect in an electric field of 3,500 volts/meter. In another study (6), Giarola and Krueger found that exposure of egg-laying hens to 1,600 volts/meter at 60 hertz for 16 weeks caused a decrease in egg production.

We continuously exposed three generations of mice to a 60-hertz electric field. (7) Initially, male and female mice were separated into horizontal-field, vertical-field, and control groups. Mice in the horizontal group were allowed to mate, gestate, deliver, and rear their offspring in a horizontal electric field of 10,000 volts/meter. At maturity, randomly selected individuals from the first generation were similarly allowed to produce and rear their offspring while being continuously exposed; the process was repeated to produce the third generation. A parallel procedure was followed for the vertical group--three generations were produced in a vertical electric field--and for the control group. We found that in the first and second generation, males and females reared in both fields were significantly smaller than the comparable control group when compared at 35 days after birth. In the third generation the males exposed to the vertical field were significantly smaller than the controls. In addition, the exposed mice exhibited a higher rate of mortality. In a follow-up study at 3,500 volts/meter (8), using an improved exposure system, we again found that the field caused an increased mortality in each generation; it also caused altered body weights in the third generation. Phillips and his collegues at the Battelle

Institute (9), twice repeated our multigeneration study, using much higher field strengths and different exposure conditions. In their first replicate they found that the males and females were significantly smaller than the respective controls; in the second replicate they were significantly larger than the controls.

McElhaney and Stalnaker (10), of West Virginia University applied 7,000 volts/meter, at 3 and 30 hertz, to the immobilized but intact femurs of rats. They found that the electric field lessened the process of bone resorption which usually occurs in an unused limb; additionally, many of the exposed rats, but none of the controls, developed bone tumors. These results were partially confirmed by Martin and Gutman, of West Virginia University (11); they found that the bone loss which accompanies disuse was lowered by the electric field, but they found no tumors in their study.

Grissett et al. (12), at the Naval Aerospace Medical Reserach Laboratory, exposed 30 monkeys to 20 volts/meter and 2 gauss at 76 hertz. After one year, the field-exposed males were significantly heavier than the control males.

We studied the effect of 60-hertz electric fields of 1,000 - 5,000 volts/meter on the rate of fracture healing in rats.(13) First, a surgically-induced fracture was made in one of the small bones in the legs of 40 rats; half the group were exposed to 5,000 volts/meter and the others served as controls. After 14 days the rats were sacrificed and the fracture sites were examined under the microscope. We found retarded fracture healing in the exposed animals. The study was replicated, and we found the same result. At 1,000 volts/meter we found no effect on fracture healing.

Central Nervous System. ELF fields have been examined from the viewpoint of their effect on the brain by direct means and, in other studies, by means of the behavior modification that results from the exposure.

Lott and McCain (14), at North Texas State University, applied an electric field of 40 volts/meter at 640 hertz to rats; they found a significant increase in brain electrical activity during the 1-hour exposure period. A similar effect was found in chicks by investigators at Penn State.(15)

Fischer and collegues at Graz University in Austria exposed rats to 5,300 volts/meter at 50 hertz for periods ranging from 15 minutes to 21 days.(16) They found that the level of norepinephrine in the brain (an important indicator of brain metabolism) was significantly affected after as brief an exposure at 15 minutes. The norepinephrine level first rose above normal, then, by the 10th day of exposure, fell below normal.

Noval et al. (17), at the Naval Research Laboratory in Warminister Pennsylvania, Bawin et al. (18), at UCLA, and Reisen et al. (19), at the IIT Research Institute, have each reported effects of ELF fields on brain metabolism. Noval's group exposed rats to 0.5 - 100 volts/meter at 45 hertz for 30 - 40 days and found decreased levels of brain choline acetyltransferase. Bawin's group reported that the exposure of chick and cat brain tissue to 5 - 100 volts/meter at 1 - 75 hertz for 20 minutes altered the tissue's binding of calcium (an important element in brain activity). Reisen's group found that 40 minutes

exposure to 155 volts/meter at 60 hertz caused a loss of biochemical function in portions of the brain cells of guinea pigs.

Behavior can be measured in several ways: the time taken for a subject to respond to a visual or audio cue (reaction time), the amount of activity exhibited by a subject, and the proficiency with which trained animals perform their tasks. Friedman et al. (20), at the Syracuse Veterans Administration Medical Center, Hamer (21), at UCLA, Konig (22), at Technical University in Munich, Persinger et al. (23), at Laurentian University in Ontario, Hauf et al. (24), at the Research Institute for Electropathology in Freinburg West Germany, and Gibson and Morony (25), at the Naval Aerospace Medical Research Laboratory, each reported a significant effect of ELF fields on the reaction time of human beings or monkeys. An effect of such fields on animal activity was reported by Moos (26), of the University of Illinois, and by Hilmer, et al. (27), of the University of Berlin. Finally, an effect on trained behavior, in rats, was found by Spittka et al. (28), of the University of Berlin.

Neuroendocrine System. Earlier work had revealed the ability of an ELF magnetic field to function as a biological stressor. (20) We therefore undertook to determine whether an ELF electric field could produce a similar response. We exposed young rats to 15,000 volts/meter for 1 month in 10 separate experiments. (29) We found a variety of statistically significant effects, including depressed body weight, depressed water consumption, increased adrenal and pituitary weights, and altered serum levels of albumin and hydroxycorticosterone. The results indicated that exposure to the field

produced a physiological stress response. Noval et al. (17), independently performed similar experiments at much lower field strengths and reached essentially the same conclusion.

Mathewson et al. (30), at the Armed Forces Radiobiology Institute, exposed rats for 28 days to 0.5 - 100 volts/meter at 45 hertz. Their data revealed a variety of statistically significant effects in the exposed animals, which included changes in blood glucose, hemaglobin and hematocrit, total lipids, triglycerides, and body weight.

It seemed that Mathewson's study confirmed Noval et al. and that the chief difference was the severity of effects. This led to an attempt to delineate the differences in the conditions under which the studies were performed.

The Noval study was performed inside a Faraday cage formed by the steel-wall construction of the facility at which the test and control animals were housed. The possible significance of the shielding was not recognized in the beginning, and it was therefore not incorporated into the design of the Mathewson study. To the extent that Faraday shielding can, of itself, produce biological changes, the shielding may account for the differences between the two studies. Such effects due to shielding have been found in human beings, guinea pigs, and mice.

In the most thorough study of the phenomenon, Wever (31), at the Max Planck Institute in Germany, isolated volunteers in underground bunkers for 3 - 8 weeks and measured the daily periods of their body temperature and activity rhythms. He found that subjects

that lived in a shielded bunker exhibited rhythms whose period was different from those of subjects living in the nonshielded bunker. He also reported that desynchronization--the rhythms no longer rising and falling together--occurred only in the subjects shielded bunker. Both effects ceased when Wever applied 2.5 volts/meter at 10 hertz; this indicated that both the normal electromagnetic environment and the ELF field had a similar influence on the human rhythms studied. Altman and Soltau (32), at the University of Saarbrucken in Germany, exposed guinea pigs to 240 volts/meter at 10 hertz and maintained parallel groups under Faraday conditions and under normal conditions (no field, and no shielding). They found that the shielding produced changes in the blood proteins compared to the normal conditions and that the ELF field caused these changes to disappear. Lang (33), also at the University of Saarbruncker, exposed mice to 3,500 volts/meter at 10 hertz and maintained parallel groups under Faraday and normal conditions. The shielding produced changes in body water content, hemaglobin, and blood sodium levels; the effects were eliminated by ELF field.

Prochwatilo (34), at the Mareyev Institute in Kiev, conducted experiments on the effects of 50-hertz electric fields of 1,000 - 5,000 volts/meter on the neuroendocrine system of rats. He found that after several months exposure iodine metabolism in the thyroid and ketosteriod metabolism in the adrenal gland were both altered. In addition, the microscopic appearance of the thyroid also changed because of the electric field. Similar effects on the alteration of thyroid function were reported by Dumanskiy et al. (35), of the Kiev

Scientific Research Institute; they also found a decrease in blood cholinesterase activity in the field-exposed rats.

Blood. Studies have demonstrated effects of ELF electric fields on the cells and other constituents of blood.(29,35 - 42) Some parameters affected by the field were red blood cell, white blood cell, and lymphocyte concentrations; serum levels of albumin, alpha and beta globulins, corticoids, calcium, glucose, and various enzymes. The conditions under which the studis were performed varied considerably among the studfes. For this reason, and because each of the parameters measured is under the body's hemostatic control--the tendency to return to a normal internal environment--the direction and magnitude of the observed changes varied from report to report.

Cardiovascular System. Blanchi et al. (44), at the University of Turin in Italy, found that exposure to 100,000 volts/meter at 50 hertz significantly altered the electrocardiograms of mice. Gann (45), at Johns Hopkins University, subjected dogs to a small controlled hemorrhage and examined the effect of 15,000 volts/meter at 60 hertz for 5 hours on the dogs' physiological response to the hemorrhage; he found that the blood pressure and heart rate were significantly different in the exposed dogs as compared to the controls (which also experienced the hemorrhage). Fischer et al. (46), at Graz University in Austria, found that brief exposure of rats to 5,300 volts/meter, 50 hertz, caused a significant drop in heart rate.

Beischer et al. (43), at the Naval Aerospace Medical Research Laboratory, exposed volunteers to a magnetic field of 1 gauss at 45 hertz for 1 day; in 9 of the 10 subjects they observed a significant

increase in the level of blood triglycerides--an indicator of possible cardiovascular disease--following the exposure.

General Physiology. ELF electric fields have been reported to alter the rate of cell division in mice (47), impair the ability of rabbits to do work (48); alter the metabolism of rat sperm cells (49), affect muscle metabolism in rats (50), and slow the rate of tumor growth in mice(51).

b. Epidemiological Investigations

Soviet investigators have conducted medical and physiological surveys of personnel occupationally exposed to power-frequency fields. Physical examinations of high-voltage switchyard workers revealed 41 of 45 had some neurological or cardiocascular disorder.(52) No tumors were found, but there were effects on blood pressure, electrocardiograms, and the blood. Another study of 54 workers revealed functional changes in autonomic nervous system which were related to the duration of exposure.(53) Medical surveys of 16 high-voltage substations involving 286 people revealed adverse effects on the central nervous and cardiovascular systems.(54) Similar results were found in 319 people who worked at substations and near power lines. (54) A clinical study of personnel of 330 kilovolt substations revealed a variety of effects of field exposure manifested by alterations in blood pressure and electrocardiogram.(55) The only United States study comparable to these Soviet studies was done by Kouwenhoven et al. (56), of Johns Hopkins University; they found that 2 of 11 workers studied had reduced sperm counts.

Knave et al. (57), at the Swedish State Power Board, found that fewer children were born to exposed high-voltage workers than to controls and that the difference increased with the number of years of exposure. Roberge (58), at Hydro'Quebec, reported that prior to commencement of employment 56 High-voltage workers had approximately equal numbers of male and female offspring; of children conceived thereafter, the number of males was six times greater than that of females.

Wertheimer and Leeper (59), at the University of Colorado, studied the distribution of cancers among children in the greater Denver area. In an attempt to find clues on environmental factors that might heighten cancer risk, they examined the relation between the homes of children who died from cancer and nearby power lines. It was found that the death rate from leukemia, lymphomas, and nervous-system tumors in children was twice the expected rate in homes near substations or other high-current (high magnetic field) wiring configurations.

Many laboratory studies lead to the conclusion that ELF fields, such as the 60-hertz fields of Geysers 16, can alter the function and physiology of the body's regulatory and control systems. Studies of occupationally exposed people suggest the existence of unexpected and adverse health consequences as a result of field exposure; such effects may have also been found among persons living near power lines.

4. ELF FIELDS IN RELATION TO IMPACTS ON NATURAL ECOLOGICAL SYSTEMS

ELF fields have been reported to alter the behavior and orientation of birds, the growth characteristics of Dugesia (flatworms) and Physarium

polycephalum (slime mold), and the metabolism of bees. Experiments have also shown that the fields can be perceived by fish and amoebas.

Several investigators have studied the effects of the electromagnetic field on the Project Sanguine antenna on bird orientation. In pilot studies, Graue (60), of St. Louis University, observed that the headings of homing pigeons were slightly altered in the vicinity of the antenna. In more detailed studies, Southern (61), of Northern Illinois University, constructed cages on the ground directly over the buried antenna to explore the effect of the field on the instinctive directional preferences of ring-billed gull chicks, 3 - 9 days old. When the chicks were released in the center of the cage with the antenna turned off, they showed a directional preference for the southeast; when the antenna was energized the birds dispersed randomly and exhibited no mean bearing. Larkin and Sutherland (2), of Rockerfeller University, carried out radar tracking of individual migrating birds flying over the antenna at altitudes of 80 - 300 meters. They observed that when the antenna was activated, or when its operating condition was being changed (off to on, on to off), departures from straight and level flight occurred significantly more often than when the antenna was turned off. In other radar-tracking studies, Williams and Williams (63), of Swarthmore College, reported changes in the flight direction of migrating birds of 5 - 25° when the antenna was activated. No investigation has yet been made of the effect of duration of exposure, nor has it been determined whether the birds responded to the electric or the magnetic field of the antenna, or both.

Marsh (64), of the University of Iowa, traversely sectioned two species of Dugesia and subjected them to 310 - 420 volts/meter at 60 hertz, applied

along the antero-osterior regeneration axis (normally, the worms will regrow a head or tail, whichever is appropriate to the site). In a significant number of animals the normal regeneration pattern was disrupted, resulting in bipolarity--the production of two heads or two tails in the same animal. In the Physarum experiments, Goodman et al. (65), at the University of Wisconsin, simultaneously applied 0.7 volts/meter and 2 gauss 27 45 - 75 hertz; they observed delays in the rate of cell division and alterations in cell activity in the exposed cells.

Warnke (66), at the University of Saarbrucker, studied the effect of power-frequency fields on the bees. Bee hives were placed on grounded metal plates, and slightly above the hive a cable was strung and connected to a high-voltage generator; Warnke found that the electric field caused grossly abnormal behavior. At 11,000 volts/meter, the bees exhibited great restlessness as recorded by temperature change in the hive. The bees on the hive exhibited a characteristic pose in which the wings were spread, and the flying bees exhibited abrupt movements. The degree of defense of social territory was abnormally increased and some bees, including the queen bee, were herded together and stung to death. Honey and pollen were no longer stored, and the cells which were already filled with honey were emptied. Hives which had been established a short time prior to initiation of field exposure were abandoned a few days after exposure was begun. When the experimenter prevented the queen bee from leaving the hive, the swarm departed without her. In hives which had been well established prior to the initiation of field exposure, all apertures were closed off by the bees, resulting in death of the entire swarm due to lack of oxygen.

In subsequent laboratory studies Altman and Warnke, (67) found that 3,000 - 50,000 volts/meter at 50 hertz caused changes in the metabolism and

activity of bees. Wellenstein (68), at the University of Freiburg, reported that bees from hives under high-voltage lines were more active and more irritable than those from hives several hundred feet from the line. Greenbert et al. (71) also reported that power frequency fields can alter the activity and metabolism of bees.

McCleave et al. (72), at the University of Maine, showed that eels and salmon were able to perceive 0.007 volts/meter at 60 - 75 hertz; this is the most sensitive ELF-induced biological effect yet reported. Friend et al. (73), of the Naval Research Laboratory, found that amoebas exhibited changes in shape and orientation within a few minutes of the application of 1,000 volts/meter at 1 - 100 herts.

The studies point to a susceptibility to ELF electric and magnetic fields in a diverse array of creatures. The significance of this susceptibility in relation to natural ecological systems cannot, presently, be satisfactorily determined. Despite this, the studies suggest that there may be impacts on such systems.

5. INDUCED CURRENT AND THE GEYSERS 16 LINE

The Geysers 16 line will induce a voltage on ungrounded electrically-conducting objects in its vicinity; this includes, for example, cars, buses, bicycles, and people--at 60 hertz the gross electrical characteristics of the human body are similar to those of an ordinary metal. When a person raised to one voltage by the line touches an object at a different voltage, an electrical current will flow through the point of contact. The current comes about because of the physical laws which require the conductors to be at the same voltage. Within about 100 feet of

the line, and depending on the size of the object touched, one might experience a maximum current of 5,000 - 15,000 microamperes (actually there are two currents: a transient current which makes the two voltages identical and a steady-state current which keeps them identical as long as contact is maintained). Currents above 5,000 microamperes are painful, and this fact has long been recognized by the utility industry; it has designed grounding practices to minimize the problem. But when the currents are below about 5,000 microamperes, and hence cannot be felt or otherwise sensed, it has been assumed that they are without any biological consequences. We now know that this assumption is incorrect.

A car parked directly under the Geysers 16 line would yield currents of about 5,000 microamperes, if touched.(74) At 100 feet away, the current would be about 100 microamperes; at 600 - 700 feet it would be about 1 microampere. If the object being touched were 10 times larger--say a tractor-trailer--then the current would be correspondingly greater at each distance. Conversely, if the object touched were smaller--an umbrella or a baby carriage--the current at each distance would be proportionally smaller. It can be seen that within about 2,000 feet of the line, depending on the size of the object touched, its distance from the line, and its degree of electrical grounding, it will be possible to repeatedly experience subliminal currents in the 1 - 5,000 microampere range.

Since the late 1960s, there has appeared a large number of scientific studies describing growth-stimulating characteristics of very weak electrical currents; the most frequently studied tissue has been bone.(75) In these studies, typically, 1 - 10 microamperes is applied for 1 - 3 weeks to a particular skeletal location. The absolute upper limit for these studies

is about 100 microamperes; above that gross tissue distruction occurs. We have used 0.1 - 1 microamperes to heal bone defects in human beings.(76)

The ability of weak currents to alter growth has been demonstrated using conditions of relatively constant exposure--several weeks or more; near Geysers 16, the exposure will probably be intermittent. Also, in most instances, it was direct current, not 60 hertz, that was used to stimulate growth. For these reasons there is much uncertainity in the evaluation of the public-health significance of the subliminal currents induced by Geysers 16.

Many studies have shown the growth-stimulating properties of electrical currents of 0.1 - 100 microamperes, applied for periods of several weeks or more. These currents, which are below the level of perception, are now in routine clinical use under controlled conditions, to combat disease. Similar currents will be induced in people living or working near Geysers 16. It is inadvisable for people to be chronically exposed to this known physiological stimulus; it can be avoided by proper grounding procedures and public education.

6. MECHANISMS OF ELF-INDUCED BIOLOGICAL EFFECTS

It seems generally agreed upon among investigators--both West and East--that the central nervous system (CNS) is the site of the interaction with ELF fields. Somehow, the field is sensed in the brain, and the command for the appropriate adaptive or compensatory response is generated there and transmitted to the other organ systems. Thus, there are several levels at which an ELF bioeffect can be analyzed. One level is that of the brain electrical activity; a change in this activity reflects detection of

the field. A second level is that of brain metabolism, a change in which reflects the transmission of information within the brain from the field-reception area to the area which will originate and control the body's response. The third level is that of the functional state of the body's responding organ systems--the level of the ultimate response to the field.

Adey and co-workers have considered the mechanisms underlying field detection (77): they have suggested that the process occurs at the cell-membrane or molecular level via resonance or cooperative phenomena. We have suggested that at least some ELF-induced bioeffects are whole-system attributes which can not be localized to particular portions of a cell menbrane.(8, 13)

Consider, as an example, the body's response to cold. When an animal is abruptly placed in an unusually cold environment--called a cold stress--a series of biochemical responses occurs which enables the animal, as far as possible, to cope with the changed environment. While the CNS is undoubtedly involved in the detection of, and the response to, the cold stress, there is no unique biophysical process which can be said to be a response to cold. The body's response may be well-defined at the organ level, but this is not true at the cell membrane or molecular level. Much of the available evidence supports the idea that the biological action of ELF fields must similarly be analyzed at the organ level: this includes evidence associated with the perception level (14, 15), the metabolism level (16 - 19), and the organ-response level (20 - 51). Put another way, our theory is that ELF electric and magnetic fields are simply nonspecific biological stressors--like cold, heat, trauma, crowding, and so forth--which can elicit a systemic adaptive response in the exposed organism.

Much work is needed to refine the various theories of ELF-induced bio-effects. No satisfactory synthesis of the data into a complete physical theory seems likely in the near future.

7. THE METHOD OF EVALUATION OF THE HEALLH RISK OF THE GEYSERS 16 TRANSMISSION LINE

Almost all the available studies of ELF bioeffects have been done in the laboratory, usually with animals. Are such studies an appropriate basis upon which to regulate ELF fields from power lines? The National Energy Board of Canada and the Public Service Commission of West Virginia both approved construction of high-voltage power lines with no provision for protection of the public from the electric and magnetic fields. Both agencies reasoned that there were no known biological effects of such fields in people who were regularly exposed to similar fields of other lines. This finding, while technically correct, is hardly surprising because there have been, with few exceptions (59), no studies of the health consequences in such chronically exposed subjects. Under this regulatory approach--known as the dead-body theory--the regulator demands legal evidence of actual harm to exposed subjects. The absence of such evidence--for whatever reason--is construed against the interests of the exposed subjects.

I suggest that the dead-body approach is wrong because it is unfair and unethical. The electrical utility industry, which has resources to conduct epidemiological studies but has failed to do so, should not be allowed to shift the onus to the local land owner who is in no position at all to supply such proof. The dead-body approach, moreover, wrongly presupposes the acceptability of using human beings in an involuntary program of damage

by laboratory studies to be biologically active. In distinction with physiologically inocuous factors--the color of one's socks or the brand name of one's shirt--ELF electric fields greater than 1 volt/meter have produced biological effects in laboratory animals studies under rigorously controlled conditions. For several reasons one cannot directly link specific laboratory effects--changes in growth rate or blood composition, for example--with specific health risks from exposure to Geysers 16. The conditions of exposure, genetic predisposition, variability within the exposed population, and many other factors will all differ greatly between the laboratory and the Geysers 16 line. Despite this imprecision--which is likely to always be with us since the fields are stressors--the Geysers 16 line will present a health risk because it will result in chronic exposure of an uncontrolled human population to a known physiological stimulus in an uncontrolled fashion.

I think that the evidence is very strong that ELF fields are biological stressors.(14 - 19, 20 - 51) A consideration of the kinds of effects which occur in stressed animals reveals even further the difficulties inherent in predicting specific risks with scientific certainty. If an animal is subjected to, for example, a cold stress, then over a few days a number of adaptive changes could be measured and observed. If the stress were maintained, at some point the animal's defenses would break down, resulting in a diagnosable disease. But there is no signature disease for a cold stress. The animal could exhibit almost any disease: an infection, if a viral or bacterial agent were present in the environment; pneumonia, if its respiratory system were already weakened for other reasons; cancer, if it had that kind of genetic predisposition. There are many other similar possibilities. The effects produced by the Geysers 16 line will also

depend on comparably diverse factors because its fields are stressors. The effects will be linked not only with field ssrength and duration of exposure, but also with the predisposition of each subject and with uncontrolled environmental factors. For this reason specific effects could not be predicted with scientific certainty. On the contrary, the true impact of the Geysers 16 line could be assessed only in relation to a comprehensive mortality and morbidity index--that is, in relation to all diseases.

The more familiar notion of the concept of causality seems inappropriate to the likely relation between the Geysers 16 line fields and human disease. In the example of the animal undergoing a cold stress, suppose that a second stress is applied, e.g., that the animal is forced to live in cramped quarters. The expected result in an animal undergoing two stresses is that, whatever disease it is fated to develop when stressed beyond its limit, it will manifest that disease more quickly than if it experienced only one stressor. The question, which stress caused the diseased, has no unique answer--they both did. Near Geysers 16 no one will experience only electromagnetic stress, and many people may experience stress from other sources which is in some sense much greater than that delivered by the line. Thus, the line will be a contributing factor, not a strict cause, of disease.

The limits of the risk of the Geysers 16 line--1 volt/meter, no acute effects--seem clear, but it is extra ordinarily difficult to comparatively assess the magnitude of the risk in relation to other environmental factors. So far as I know, there have been no successful comparative risk assessments involving two different environmental agents; it has proved

possible only to compare levels of the same agent. For the Geysers 16 line there are two zones which can be identified on the basis of the laboratory studies: a high-risk zone surrounding the line and a low-risk contiguous zone reaching outward to the end of the zone of influence of the line. The dividing line between the high- and low-risk zones cannot be chosen with mathematical precision, but in my few it should be no higher than 50 - 200 volts/meter. I base this choice on the following considerations:

(1) Many serious biological effects have been reported in competently performed and relevant laboratory studies involving fields of 5,000 - 100,000 volts/meter. It is therefore necessary to avoid human exposure at these levels and to provide an adequate safety margin. The typical toxicological safety factor in the United States is 100;

(2) Many well done studies have reported undesirable biological effects in animals and people exposed to fields as low as 50 - 200 volts/meter;

(3) The laboratory studies have generally been very limited regarding the number of animals studied and the duration of exposure. When more sensitive studies are performed it seems likely that the risks will be judged to be greater than presently perceived. A practical but conservative approach is therefore warranted.

(4) Almost every laboratory study involved <u>either</u> an electric field or a magnetic field, but not both. Near the Geysers 16 line, however, people will be simultaneously exposed to both fields. The possibility of a synergistic effect of the fields must therefore be accomodated in the determination of a dividing line between permissible and

restricted exposure levels. This consideration should also foster a conservative approach.

(5) The potential problem of induced currents will be significantly reduced if access to regions with fields greater than 50 - 200 volts/meter is restricted.

I think that there ought to be a recognition that the Geysers 16 line is a highway for needed electrical power, but there should be no fiction that this highway is compatible with general human uses. The region bounded by 50 - 200 volts/meter--250 - 575 feet for the 2-circuit line, 425 - 875 feet for the 4-circuit line--should be dedicated to the line, subject only to a few limited uses such as agriculture.

9. THE RULES FOR HUMAN EXPERIMENTATION IN RELATION TO PUBLIC EXPOSURE TO THE FIELDS OF GEYSERS 16

There are different laws in the United States governing human experimentation.(69, 70) The gist of them is that people should not be exposed to a known or suspected physiological stimulus without their consent.

In the low-risk zone of Geysers 16, 1 - 50 volts/meter, there seems no justification, based on the present studies, to significantly restrict human activities. On the other hand, it would be wrong to simply ignore the constant presence of the field and the finite risk that exposure to it entails. The threshold consideration for human experimentation, the presence of a known physiological agent, is satisified in the low-risk zone of Geysers 16. The public should therefore be told of the possibility of a risk; this is precisely what is required if 1 - 50 volts/meter is to be applied to a subject in the laboratory. It would be unacceptable, it seems

to me, to permit this field to be applied via the line to an uncontrolled population because of two technicalities: PGandE is not a federally-supported investigator, and PGandE will probably not closely monitor the reactions in the exposed subjects.

10. SUPPORT FOR FURTHER RESEARCH

Many questions about the health-and-safety aspects of 60 hertz fields remain unanswered. The greatest needs are studies to explore the consequences of long-term exposure to relatively low fields (0.1 - 100 volts/meter) and studies of the basic mechanisms of interactions. This will yield information useful in side effects evaluation and in developing various therapeutic applications of electromagnetic energy. In the United States today, there are no studies of the former type and very few of the latter.

The efforts of individual utility companies to inquire into the side effects of power-lines have been woeful. These have usually been analyses by company doctors (58, 79) or informal surveys by power-company employees. (80) Not surprisingly, these efforts have not turned up any serious problems. The efforts of the Electric Power Research Institute (EPRI) have been worse; since they entered the side effects area, they have been an incubus on progress.

In 1975, EPRI summarily cancelled the research contract of Dr. Donald Gann, at Johns Hopkins University, within months of Gann's report that he may have verified the Soviet finding that power-frequency fields could impair the functioning of the cardiovascular system.(45) Despite the fact that the project expended more than half a million dollars, no final report was

issued; today, it is a nonproject and is not considered by EPRI in its health-and-safety evaluations.(85)

EPRI's next major project was a joint Westinghouse-Penn State effort (81); it was supposed to study the effects of power-frequency fields on growth and brain activity in chicks. When the investigators began to find field-induced changes in the areas (15), the project was redesigned to study the effect of ozone on plants.(82)

One of EPRI's next efforts was a feasibility study; it was concluded that it was infeasible to perform a study to determine whether occupational exposure to power-frequency fields is a health risk.(83) But EPRI has found it feasible to study the effects of the fields on bees.(71) EPRI is presently funding several other studies [including a four-year-old, multi-million dollar pig study at Battelle (84)], but it has consistently refused to release information about almost all of them.

The Department of Energy is currently supporting a research program on the biological effects of power-frequency fields. With the exception of my project, all the studies are being done well above 10,000 volts/meter. The New York PSC will shortly begin a five-year, five-million-dollar program on 60-hertz fields, and it will presumably include some studies in the low-strength range.

There is a pressing need for research support to attract competent and independent scientists into the ELF area. I urge the Commission to make such support available.

11. RECOMMENDATIONS

(1) The right-of-way should be such that the electric field at the edge will be less than 100 volts/meter. 400 2-circuit
650 - 4-circuit

(2) People living within the zone of influence of the line, 1 volt/meter and greater, should be told of the possible risks.

(3) The Commission should fund a laboratory and epidemiological research program to further study the risks of high voltage lines.

STATE OF CALIFORNIA

ENERGY RESOURCES CONSERVATION
AND DEVELOPMENT COMMISSION

In the Matter of:	
The Application for Certification of Pacific Gas and Electric Company Re: Geysers Unit 16.	Docket No. 79-AFC-5
	DECLARATION OF ANDREW A. MARINO

I, ANDREW A. MARINO, declare under penalty of perjury, and if called to testify in the Geysers Unit 16 AFC proceedings would testify, as follows:

1. I am currently on contract with the California Energy Commission as a consultant on the health and safety aspects of exposure to the electromagnetic field of the Geysers Unit 16 transmission line.

2. A copy of my professional qualifications and experience is attached hereto and is hereby incorporated by reference as though fully set forth herein.

3. Based on my review of the NOI, the AFC, data request responses submitted by the Applicant, information submitted at publicly noticed Staff workshops, other documents submitted by the Applicant, other reliable documents and sources, and my professional experience and knowledge, I prepared the attached testimony regarding the possible health risks associated with exposure to the electromagnetic field of the Geysers Unit 16 transmission line.

4. To the best of my knowledge and belief, the factual matters stated in my qualifications and in my testimony are true and correct.

5. The opinions set forth in my testimony are valid and are based on matters which I as a professional reserach biophysicist consider reliable.

I declare under penalty of perjury that the foregoing is true and correct.

Executed this 29th day of July, 1980, at Elbridge, New York

ANDREW A. MARINO

APPENDIX A: REFERENCES; FIGURES; TABLES

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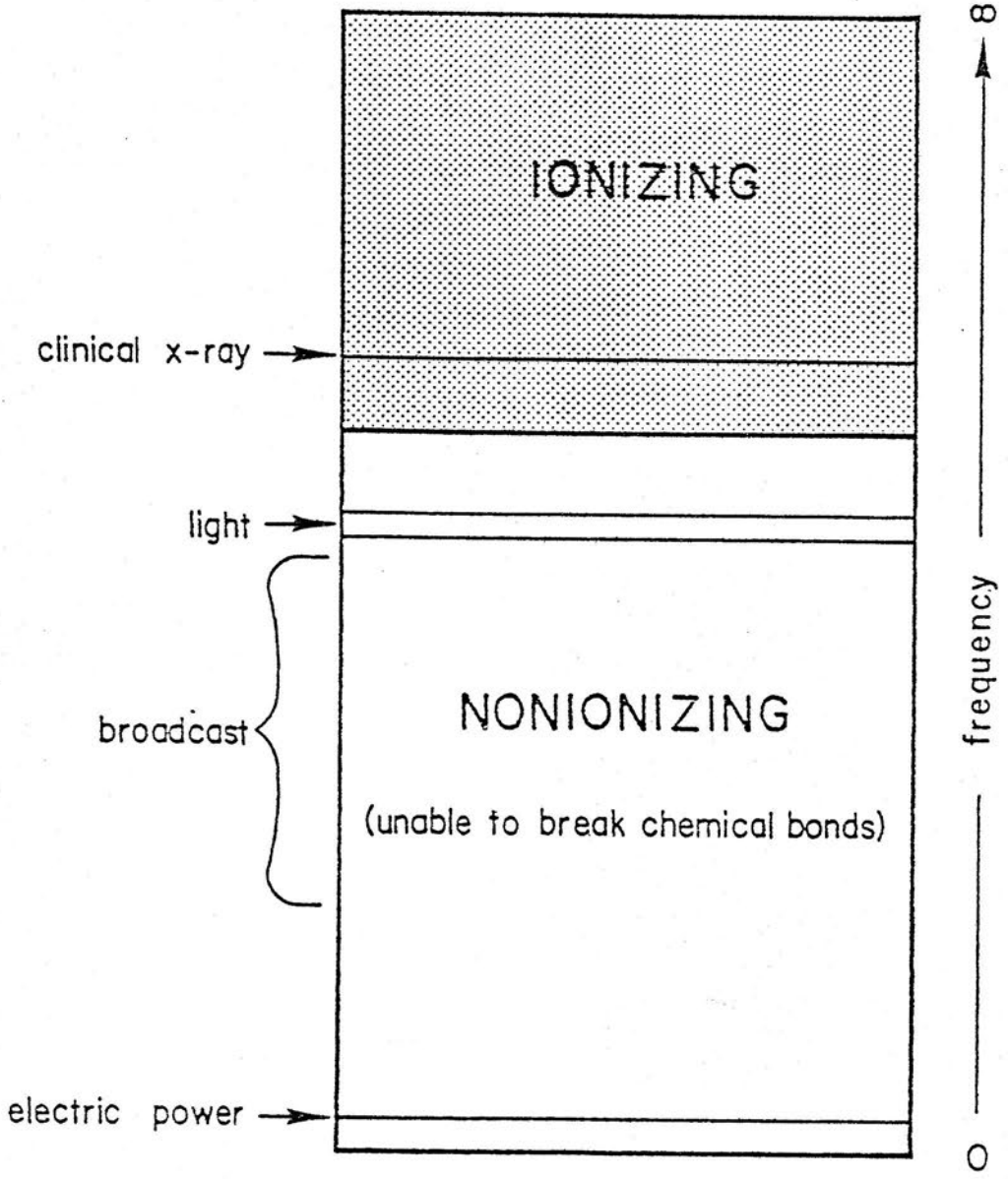


Figure 1. The electromagnetic spectrum is divided according to the way it interacts with matter. It is further divided into frequency intervals called bands. The power frequency, 60 hertz, is in the extremely low frequency (ELF) band (1-100 hertz).

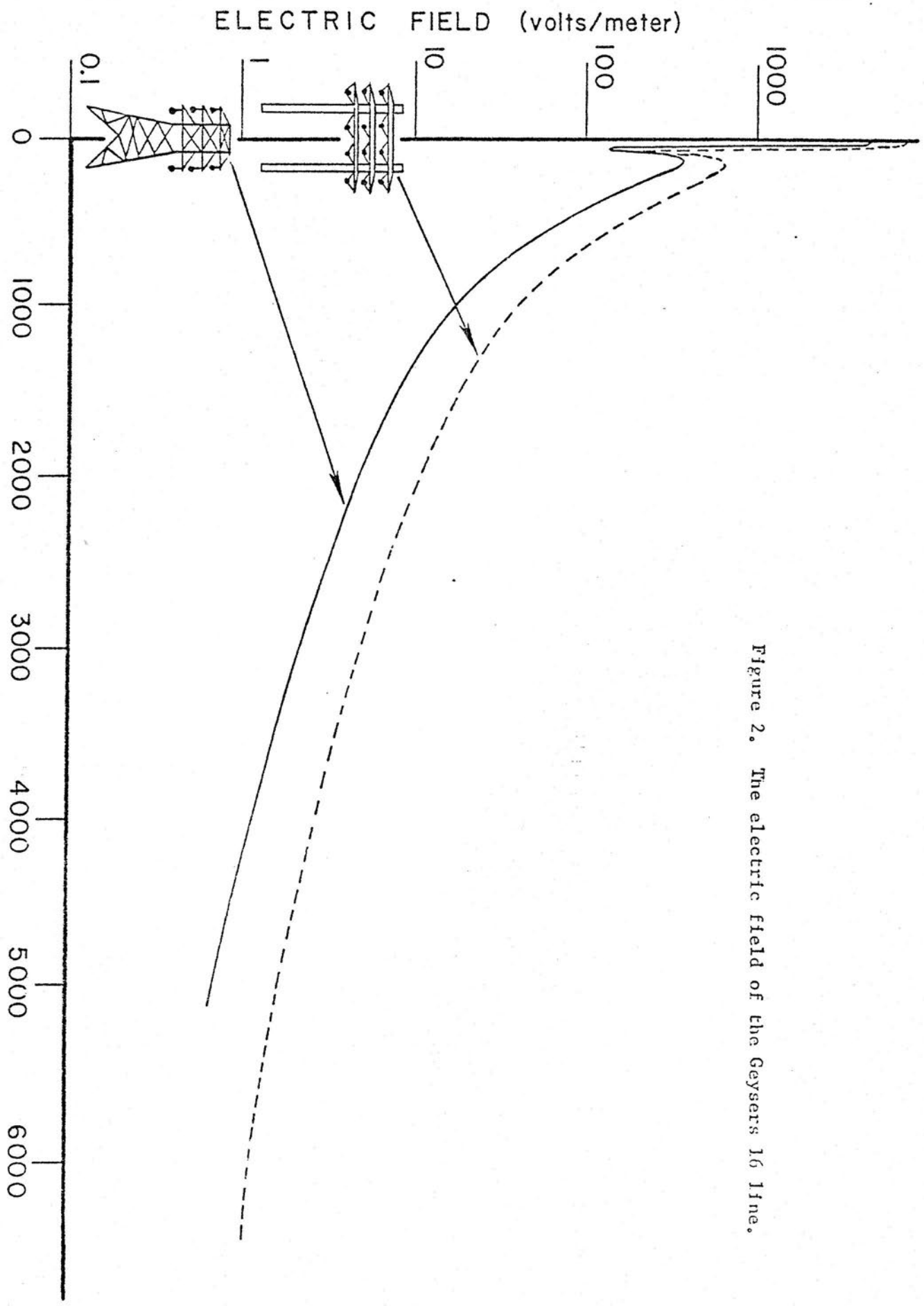


Figure 2. The electric field of the Geysers 16 line.

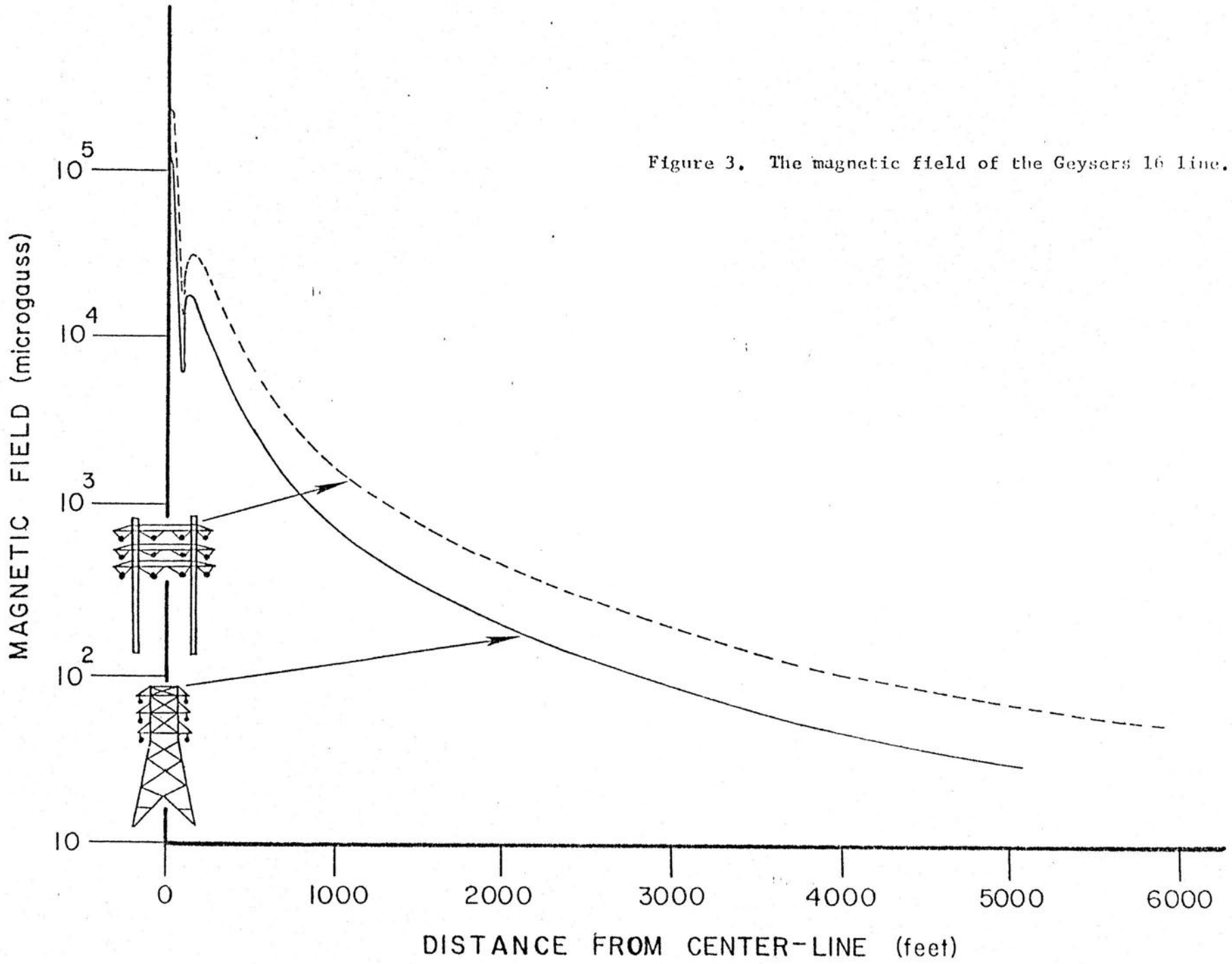


Figure 3. The magnetic field of the Geysers 16 line.

APPLIANCE	ELECTRIC FIELD (volts/meter)
Electric Blanket	250
Broiler	130
Phonograph	90
Refrigerator	60
Food Mixer	50
Hairdryer	40
Color TV	30
Vacuum Cleaner	16
Electric Range	4
Light Bulb	2

Source; US NAVY 1972

Table 1. Power-frequency electric fields of household appliances.

10-25 gauss

Soldering Gun
Hairdryer

5-10 gauss

Can Opener
Electric Shaver

1-5 gauss

Food Mixer
TV

0.1-1.0 gauss

Clothes Dryer
Vacuum Cleaner

0.01 - 0.1 gauss

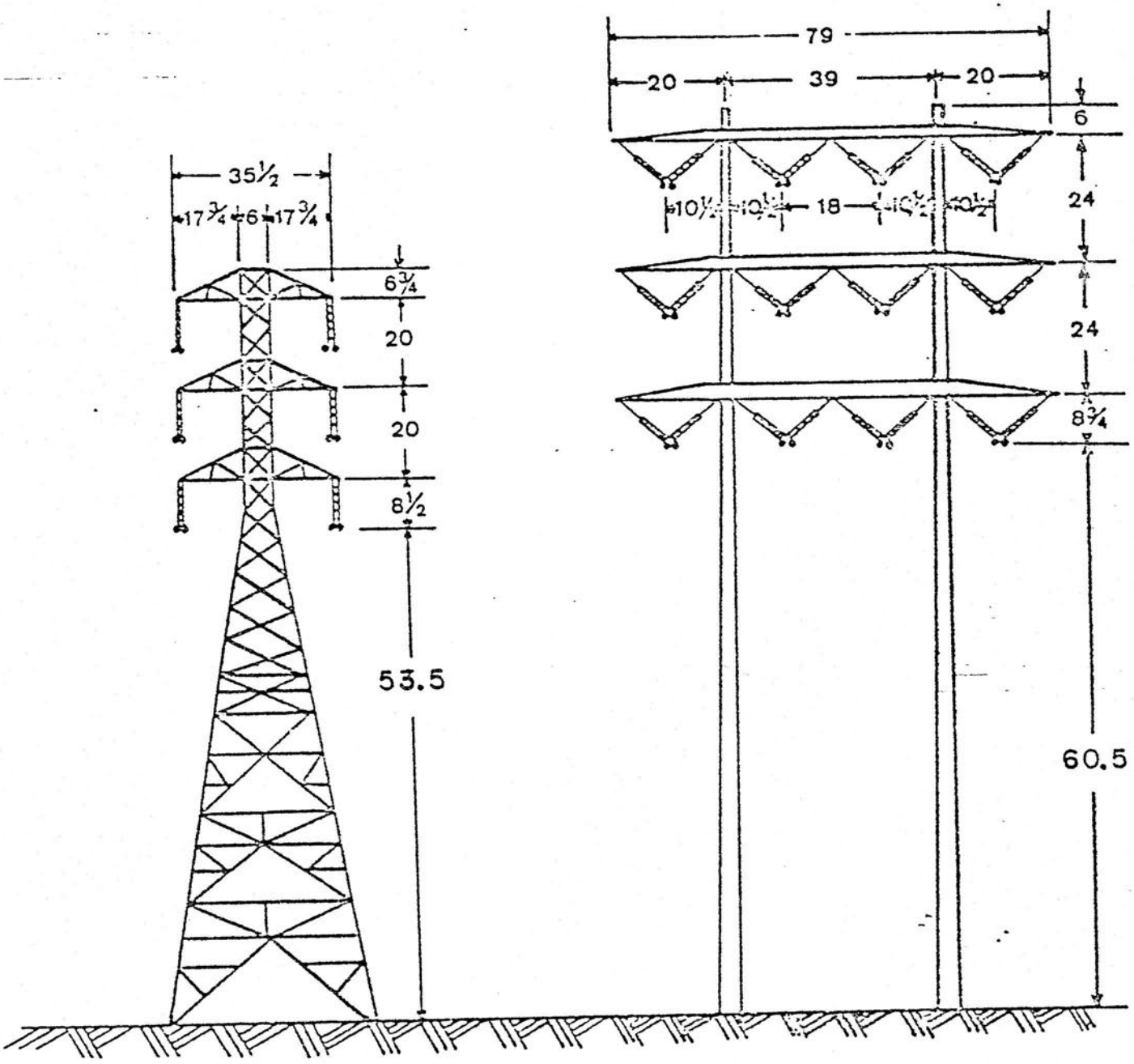
Lamp
Electric Iron

Source; US NAVY
1972

Table 2. Power-frequency magnetic fields on household appliances.

APPENDIX B: GEOMETRICAL ASSUMPTIONS FOR CALCULATION OF THE ELECTRIC AND MAGNETIC FIELDS OF GEYSERS 16.

All dimensions shown in feet



2 Circuit
Lattice Tower

4 Circuit
Tubular Tower

APPENDIX C

CURRICULUM VITAE

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1964 TO PRESENT, RESEARCH BIOPHYSICIST, VA HOSPITAL, SYRACUSE, NEW YORK

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