

ALASKA LEGISLATURE SPECIAL COMMITTEE / SUBJECT FILES 86 / 2

988 SCOMM44: HOUSE POWER ALTERNATIVES STUDY COMM. 1979-80

electrical engineers for lines carrying similar voltages.

I pointed out this discrepancy to Richard Tell (Electromagnetic Radiation Analysis Branch of the Environmental Protection Agency) in a letter dated January 13th of this year and drew these facts to his attention: In the CIGRE paper by Korobkova et al² maximum field intensity figures on roads under 750 kv lines of 22 kv/m are reported (see page 4). On page 5 the statement is made that "at 750 kv switchyards there is practically no area with the intensity lower than 10 kv/m." On page 6, Figure 4 (curve 3) shows a graph of field intensity versus distance to the conductor of a 500 kv line. This graph is reproduced below (Figure 1). It shows a maximum intensity reading beneath the outer conductor of 22 or 23 kv/m and this occurs when the conductor is about 10 meters away. I understand this to mean that the line in this case is approximately 33 feet minimum height above ground. Citing from "Rules and Regulations on Labor Protection,"³ page 9, work carried out on the ground in the zone of influence of a 750 kv transmission line without the use of protective measures is permitted in the span of the transmission line and close to anchor and corner towers for no more than ten minutes. If work is off the ground at height, it must be carried out using protective measures. Since the field that they allow their workers to be exposed to for a maximum of 10 minutes is 20 kv/m, we can reasonably assume that they believe fields of this intensity occur within the span as designated. They include a diagram of the areas which I have reproduced below (Figure 2).

These statements show quite clearly that the Russians were measuring field gradient intensities as high as 22 kv/m under both 750 kv and 500 kv lines. Maximum levels actually measured by electrical engineers in the United States are 10 kv/m under 765 kv lines and 8 kv/m under 500 kv lines. There appears to be a difference of a factor of more than two between the U.S.S.R. and the U.S. readings.

Some of this discrepancy may be accounted for by differences in line design. For example, the Russian lines are somewhat lower than our lines. It is difficult to quantify this factor precisely because there is not enough firm information available on the height of the Russian lines that were in service at the time these studies were being conducted. The only indication that we have of height is the one previously mentioned - a 500 kv line which appears to have a minimum height of about 33 feet. Our 500 kv lines have theoretical minimum heights of 35 - 37 feet under maximum load and temperature conditions. However even when lower clearances of this order of magnitude are taken into consideration there still remains a significant discrepancy, a factor of somewhere between 1.5 and 2.

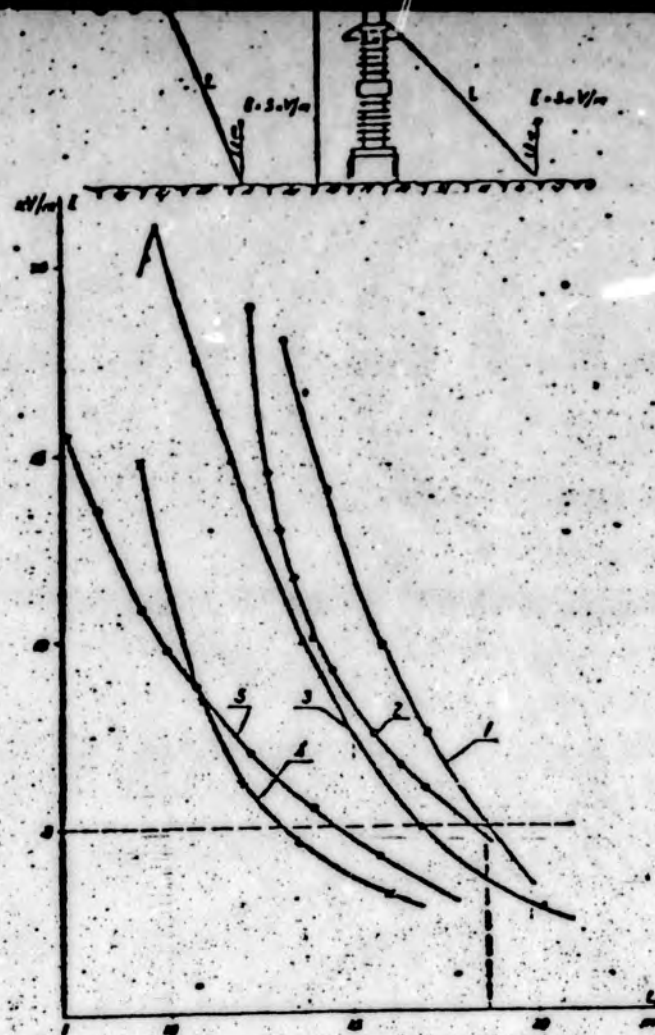


Figure 1. Dependence of intensity on distance to live parts of equipment and buses : 1 - at a 500 kV air c-b, BB-500 ; 2 - at a 500 kV c-b, BB-500 ; 3 - on the roads ; 4 - at a current transformer ; 5 - at a disconnector. From Korobhova et al, p.6.

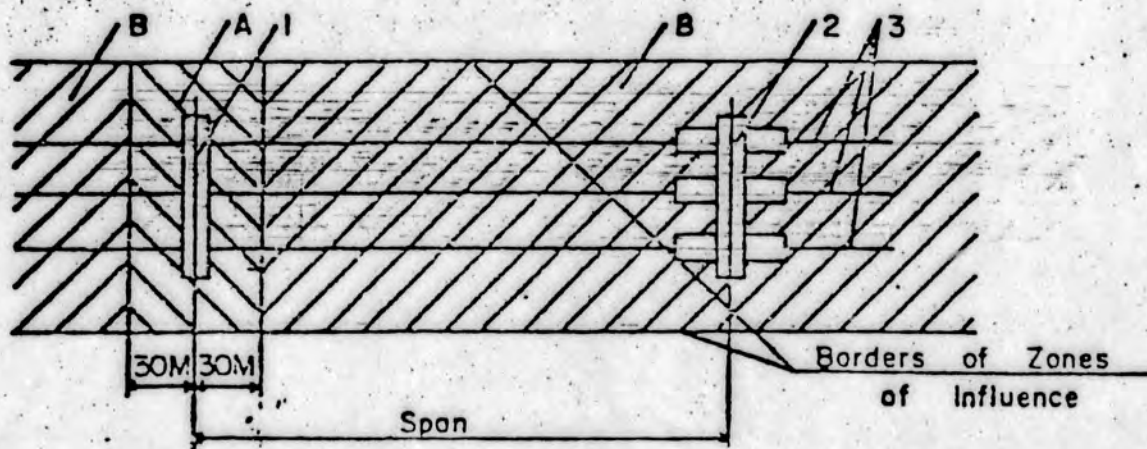


Figure 2
DIAGRAM OF 750 kV TRANSMISSION LINES WITH ZONES OF INFLUENCE

- 1--intermediary tower
- 2--anchor or corner tower
- 3--conductors

A--zones in which work is permissible without protective measures for durations of no more than 180 minutes (distances given in the diagram)

B--zones in which work is permissible without protective measures for durations of no more than 10 minutes

From "Rules and Regulations on Labor Protection," P. 9.

As I commented in my letter to Mr. Tell, it is important that this difference be resolved if we are going to consider the significance of the Russian studies as they apply to our own lines. And in his response of February 3rd, he agreed that an important discrepancy does appear to exist.

Since that time I have made a number of field gradient measurements under 765 kv lines, duplicating as closely as possible with the instruments available to me, the Russian measuring techniques as well as those of our engineers. I now believe that the discrepancy between the two sets of figures can be very simply explained on the basis of the different methods used in measuring the fields in the U.S. and the U.S.S.R.

It is stated in the Russian reports that the strength of the fields in their substations and under their lines was determined by measurements with an especially designed field gradient meter. The meter itself and the manner in which the readings were taken is described in detail. Theoretical calculations do not appear to have played any part in the determination of the field gradient by the Russian scientists. There is only one reference in the five reports to theoretical field strengths and this one reference indicates that their theoretical understanding of the spacial distribution of the electric field differs significantly from ours. On page 5 of the Morozov and Gromov paper the following statement is made: "...data from calculations and measurements of the distribution of the electric field on high voltage lines shows that field intensity is proportional to the square of the distance from the source of the field (conductor, connecting bus, etc.)" Even assuming that the authors mean "inversely proportional" this statement does not correspond with our theoretical formula for field gradient. It also indicates that their field gradient measurements increased in intensity fairly rapidly as height above ^{ground} increased - much more rapidly than occurs in our field gradient readings which do not alter much until more than half of the distance between the ground and the conductor has been traversed.

To measure their fields the Russians used a small ungrounded meter held by an observer on a short handle at 1.8 meters above ground. This meter is described in the report by Morozov and Gromov.⁴ In Figure 3 below I reproduce their sketch of the meter. On page 2 of their report they specify that the handle of insulating material is 250mm long and they say that "the operator holds the instrument by the handle and inserts it into the measured area." The height at which the instrument is held is described as 1.8 meters above ground (see "Rules and Regulations on Labor Protection," p.4).

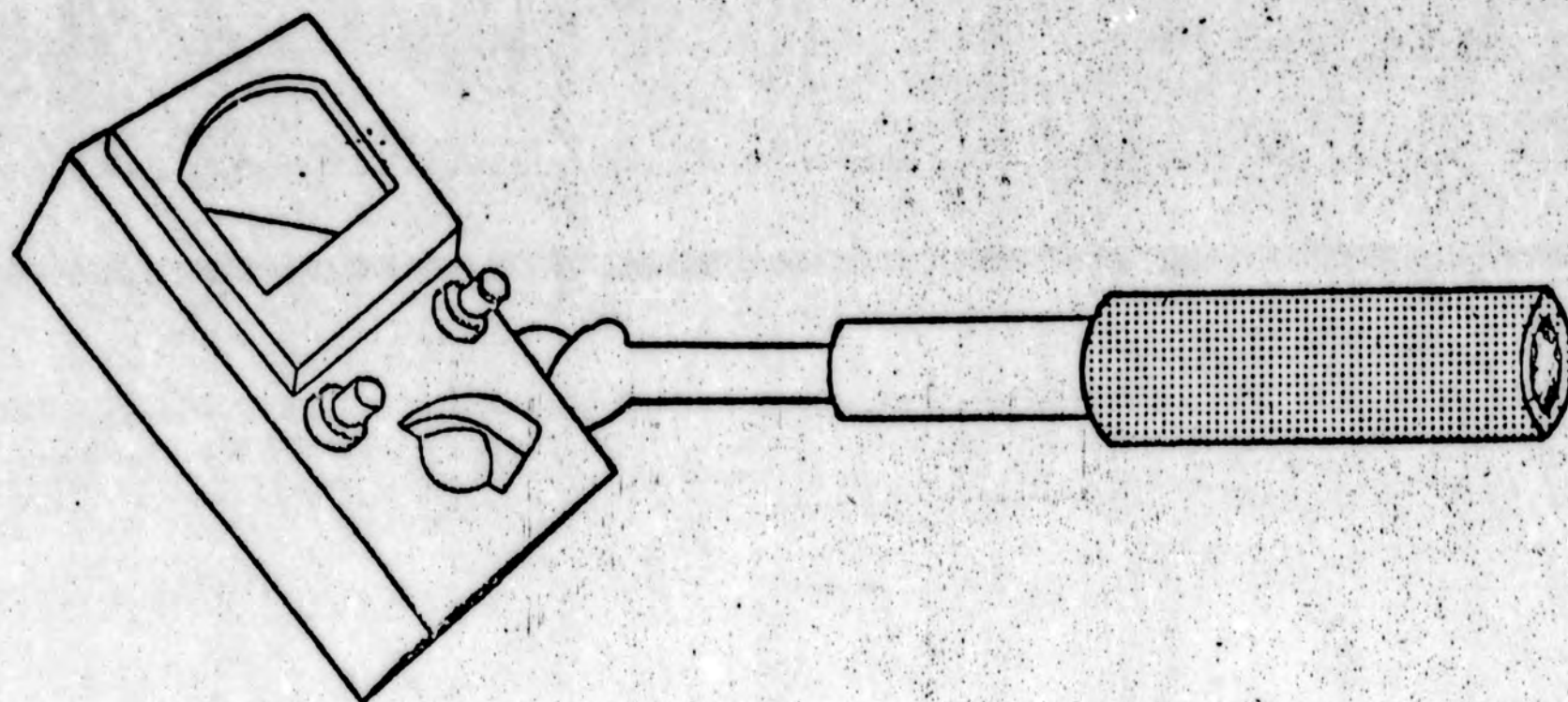
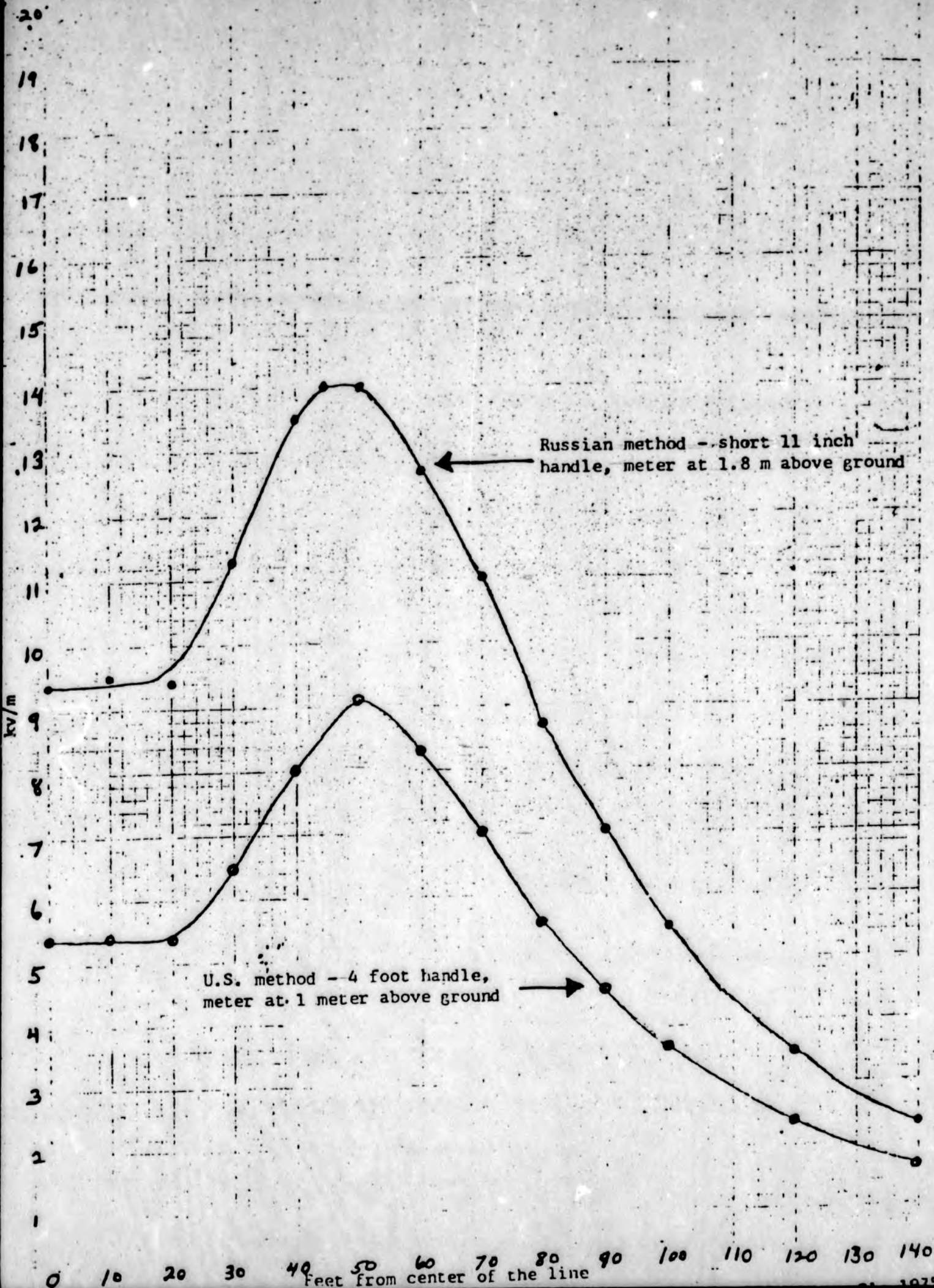


Figure 3. AN INSTRUMENT FOR THE MEASUREMENT OF THE INTENSITY OF ELECTRIC FIELDS OF 50 HZ
From Morozov and Gromov, p. 7.

A handle of 250mm (about 11 inches) is so short that the observer holding the instrument cannot avoid causing considerable concentration of the field by the presence of his body. I found that a Monroe meter (Model 238A-1 Portable Differential AC Electric Fieldmeter) held in close to the meter (thus simulating an 11 inch handle) and raised to a height of 1.8 meters above ground gave readings anywhere from 1.5 to 2 times higher than the same meter held out on its full 4 foot long handle at approximately one meter above ground. Figure 4 shows a field profile under a 765kv line with readings taken according to the standard U.S. method (on a 4-foot long handle at one meter above ground) and according to the Russian method (using an 11 inch handle with the instrument held at 1.8 meters above ground). In the short handle configuration the position of the hand is extremely important. The hand itself, of course, must occupy part of the 11 inch handle. If the hand is moved several inches nearer the body of the instrument the readings increase by as much as 50%. For the measurements in Figure 4 the hand was placed as far away from the meter as possible on the 11 inch handle. The readings taken by the Russian method average 1.6 times the readings taken by the U.S. method.

It is also interesting that the height at which the Russian measurements are made tends to magnify the discrepancy between the two ways of measuring electric field gradient. If the observer crouches down and holds the instrument in the short handle position at one meter above ground, the readings for field gradient are 1.26 times higher than those taken when the full handle is used. In other words the presence of the observer has a more perturbing effect on the field at 1.8 meters than it does at one meter (an observation that would also be predicted by theory).

It seems apparent to me that the Russians were measuring a more perturbed field than the U.S. engineers measure and this accounts for a large part of the discrepancy in the two sets of readings. The Russian method of measuring electric fields was valid within their own frame of reference as long as all their results were based on this same technique. A reprint just released of a paper given in February 1975 at a US/USSR exchange meeting in Washington indicates that Soviet scientists are revising both their measuring techniques and their theoretical calculations to bring them more in line with accepted international procedure.¹¹ However these recent changes do not alter the fact that the field measurements which were used as the basis of their health studies from 1962 to 1972 were made in the manner I have described above. Therefore, in order to relate the conditions of these studies to fields



created by our lines, a correcting factor of approximately 1.6 must be applied. For example the Russian safety regulations state that 25 kv/m is the maximum field to which people should be exposed at all. If we multiply this maximum figure by 1/1.6 or .6, we would obtain a limiting field gradient of 15 kv/m.

There is also another factor which must be taken into account. The frequency of the AC current in Russia is 50Hz while ours is 60Hz. For a given field intensity, the higher frequency causes a 20% larger charging current to run in the bodies of people exposed to these fields and since current is thought to be the principal cause of biological influence, we must apply a factor of .8 to arrive at the biologically equivalent field. Here are the Russian standards with these two correcting factors applied:

Russian field intensity in kv/m	same fields measured by U.S. method	biologically equivalent fields kv/m	maximum permissible time in field in 24 hours
5	3	2.4	unlimited
10	6	4.8	180 minutes
15	9	7.2	90 "
20	12	9.6	10 "
25	15	12	5 "

It should be remembered, of course, that the actual size and characteristics of the Russian meter are slightly different from the Monroe meter which we used and this may affect the degree to which the field is perturbed. In order to determine the exact factor between the fields measured by the U.S. and the U.S.S.R. techniques, the Russian instrument should be used according to their method and compared directly with ours over a range of field strengths. However the charts and graphs above do give at least a rough estimate of the way our field gradients would compare with the fields to which the Russian workers were exposed and which were used as the basis of their Rules and Regulations on Labor Protection. It is apparent from the figures that the fields experienced under our 765kv lines fall well within the range of intensities which were found to cause biological effects. A graph of theoretical ground level gradients (Figure 5 below) shows maximum intensities of 13 kv/m and gradients at 100 feet from the center line (the edge of a typical right-of-way) of approximately 5 kv/m. It is significant, too, that the Russians emphasize that people exposed to these fields for the maximum times must not also be subjected to transient shock currents. People walking and working under our

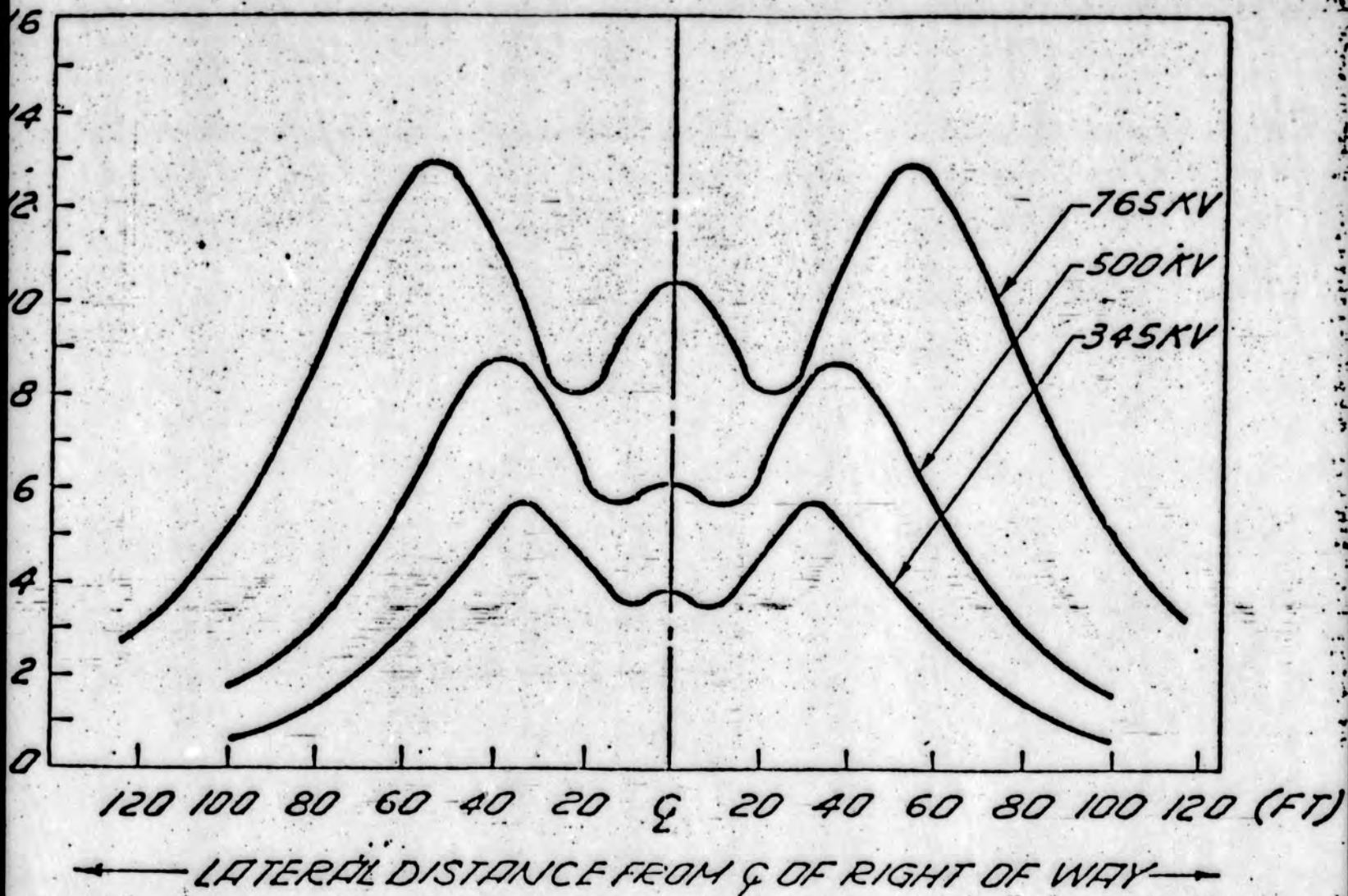


Figure 5. Typical Electrostatic Ground Gradient Profiles of Various EHV Lines
From E.S. Zobel and F.J. Dormady, Charles T. Main, Inc. Report of Tests with
Fluorescent Tubes to indicate Electric Field Strength Under 500 kv Transmission
Lines, Colstrip Project - 500 kv Transmission Lines, "March 1975, p. 11.

lines complain frequently of transient shocks from farm machinery - even leaves of corn and blades of grass.

Charging Currents

A more direct and more fool-proof way of estimating the biological significance of alternating electrostatic fields is by determining the amount of charging current that runs in the bodies of people exposed to EHV fields. I have measured currents as high as 200 microamps in the body of a 6-foot man standing with both arms raised at the strongest point of the field under a 765 kv line. With one arm raised the maximum current was 160 microamps. These measurements were made with the man standing on an insulating pad and holding one electrode of an ammeter between the thumb and forefinger. The other electrode was grounded. At the edge of the right-of-way (100 feet from the center line) body currents of 100 microamps were measured.

The CIGRE report by Korobhova et al states that studies of the biological influence of charging currents were being carried out in the U.S.S.R. (see footnote, p.2). "Preliminary data show that a 80-120 microampere current flowing through a man for a long time unfavorably affects him." The current levels measured under a 765kv line were within or considerably above this U.S.S.R. danger level. Again these current measurements indicate that the fields under our lines would be considered by the Russian scientists to be biologically significant.

The CIGRE paper by Schneider et al¹, reported current levels that are similar to the ones I have cited above. This group of German scientists found that a man standing on the ground with one hand raised would have a charging current of 18 microamps for each kv/m of unperturbed field gradient, so at the maximum point under the 765kv line where we measured 9.1 kv/m the total charging current flowing in his body would be 162 microamps. At the theoretical maximum of 13 kv/m the current level of 230 microamps would be anticipated.

Measurements made by Bonneville Power Administration and reported by T.D. Bracken⁷ yielded an average value of 16 microamps per kv/m for a 1.75m man with arms held at his side. Bracken also noted that the charging current is directly proportional to the square of the height of the person exposed to the field. Although the experiments on which this relationship was based did not consider heights above 2 meters or differently shaped objects, the implication is strong that a taller object in the field - e.g. a man on a horse

or a piece of farm machinery would sustain a higher body current (see Figure 6).

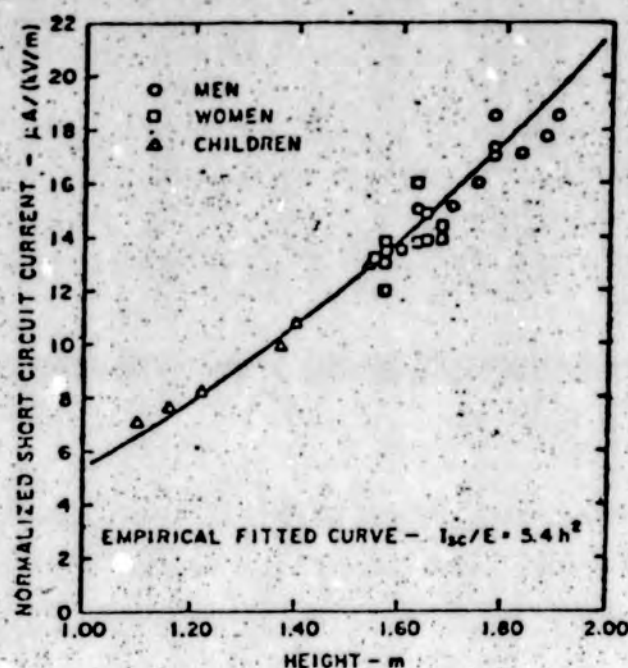


Fig. 1. Normalized short circuit current versus height for persons.

From T.D. Bracken, p. 7.

Putting all these facts together, it seems clear that a person walking or working under the main span of the 765 kv lines now in operation in the United States would have continuous ~~displacement~~ currents of 100 to 200 microamps in his body, and under special circumstances the amounts could be greater. These levels are significantly higher than the amounts considered safe by the Russians. Definitive research on this subject has not (to my knowledge) been conducted in this country. I believe that this health question should be answered before more of these lines are built.

Ozone Generation by Lower Lines

Over the past few years a number of field investigations of ozone levels under 765 kv lines have been made and have shown no appreciable increase over ambient ozone levels. However, at the time these tests were conducted the 765 kv lines were being operated at levels 8 to 10% below the rated voltage and, since corona discharge and the associated formation of ozone are threshold phenomena, this relatively small difference in operating voltage makes an enormous difference in the amount of ozone production that would be expected. When these lines are run at 690 kv or 720 kv corona loss would be negligible except under certain conditions such as rain or snow, and when there is considerable water vapor

present in the air less ozone is formed per kilowatt hour of corona loss. Under these circumstances it would be very surprising if monitoring for ozone near a "765 kv" line energized at about 700 kv would show significant increases in levels above ambient.

It is interesting, however, that at Oak Ridge National Laboratory ozone measurements at the edge of a right-of-way for two 500 kv transmission lines recorded ozone concentrations of 210 and 230 parts per billion on April 6, 1972, at 9:30 and 9:40 A.M.⁸ These figures were ten times the ambient levels. The Oak Ridge report suggested that these levels were caused by temperature inversion. Obviously, if a temperature inversion can cause a ten-fold increase in concentrations at ground level then a very considerable amount of ozone must be generated by the line and normally carried off by the surface winds. Such amounts generated by thousands of miles of lines would add significantly to the ozone concentrations in our atmosphere, concentrations which are already dangerously high during a large number of days.

It is apparent from purely theoretical considerations that the maximum levels are not likely to occur directly under the line but quite a little distance down wind.¹⁰ The ozone, being hot when formed, rises and then is blown by the wind, reaching ground level at some distance from the line. Even in the lightest of winds (about 2 miles per hour) the maximum concentration would occur about 300 feet from the line. Only when the wind blows parallel to the line would it be reasonable to expect higher levels under the line itself. When the wind is transverse to the line the maximum concentration is inversely proportional to wind speed. Temperature inversions and very light winds provide the most favorable conditions for elevated ozone levels.

The fact that ozone is formed in high electric fields can be very simply demonstrated in the following manner. Take a grounded needle point or a fine wire mounted in a teflon cylinder (to protect it from the wind) and attach this cylinder to the intake tube of a Mast ozone meter. Now mount this probe in the electric field created by a power line. (We used a wooden tripod.) At a certain field intensity the ozone meter readings suddenly begin to rise. In fact one has to watch very carefully because the level recorded by the meter rises so quickly that it can go off scale and saturate the meter. The field intensity at which this occurs has quite a definite threshold which is different for each different type of needle or wire. By standardizing on one type of probe this method provides a check on the field gradient readings,

a check which has the advantage of being independent of any calibrating procedure. This experiment also demonstrates the threshold characteristics of ozone formation in high electric fields and raises the possibility that ozone is not only created on the surface of the conductors themselves but may also be formed on any sharp edges on the towers, on barb wire fences under the lines, perhaps even on the tips of branches and leaves that project sharp conducting surfaces into the electric field.

Need for a Definite Study

It was reported to me by Richard Tell that on May 12th of this year Indiana and Michigan Electric Company and Ohio Power Company raised the voltages on some of their 765 kv lines; so now there is an opportunity to make more meaningful studies of lines carrying this voltage. The question of ozone production by EHV lines could be answered if an impartial study were conducted by a government agency such as the EPA. A line that is known to be operating at 765 kv to 800 kv should be continuously monitored for at least six months using six ozone meters deployed in the following manner:

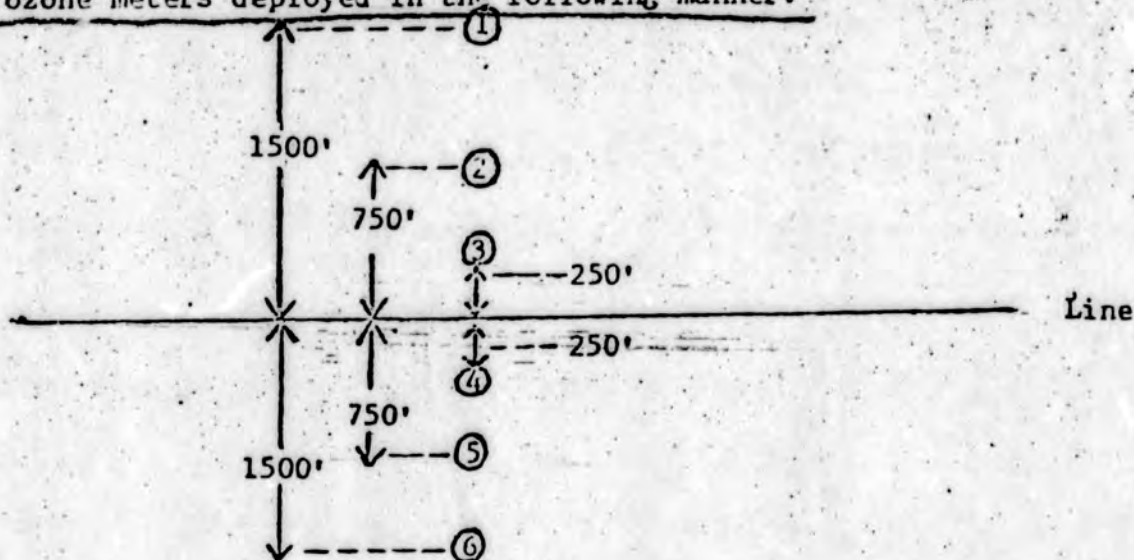


Figure 7

and speed,

Wind direction, temperature, and humidity should also be recorded and the data analysed for upwind, downwind, and parallel to line conditions. Sulfur dioxide filters should be used and at least one instrument to monitor nitrogen oxide levels downwind of the line.

Although ozone is one of the most important products of corona discharge, it certainly is not the only one and it would be unfortunate if the

interest in ozone formation obscured the need to consider the other products of electric discharge. Monitoring for NO and NO₂ near power lines has been given only token consideration. To my knowledge only a few spot checks have been made. Furthermore, the question of what happens in rain or humid air is still unanswered. In these conditions ozone production per kilowatt hour of corona discharge drops very sharply. It is extremely likely that another chemical reaction is absorbing this energy. The most obvious candidate is the formation of hydroxyl radicals and atomic hydrogen from water molecules. Hydroxyl radicals are known to be very active biologically and may serve a function similar to that of hydrocarbons in the formation of toxic smog.

Since all of these questions have important implications for the health of people living near the big transmission lines, a really serious attempt should be made to answer them before allowing construction of the thousands of miles of extremely high voltage lines that are planned for the next few years.

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Source References

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Original Contributions

ELECTRICAL WIRING CONFIGURATIONS AND CHILDHOOD CANCER

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Wertheimer, N. (Dept. of Preventive Medicine, U. of Colorado Medical Center, Box C-245, Denver, CO 80262), and E. Leeper. Electrical wiring configurations and childhood cancer, *Am J Epidemiol* 109:273-284, 1979.

An excess of electrical wiring configurations suggestive of high current-flow was noted in Colorado in 1976-1977 near the homes of children who developed cancer, as compared to the homes of control children. The finding was strongest for children who had spent their entire lives at the same address, and it appeared to be dose-related. It did not seem to be an artifact of neighborhood, street congestion, social class, or family structure. The reason for the correlation is uncertain; possible effects of current in the water pipes or of AC magnetic fields are suggested.

electricity; electromagnetic fields; leukemia; neoplasms

Electrical power came into use many years before environmental impact studies were common, and today our domestic power lines are taken for granted and generally assumed to be harmless. However, this assumption has never been adequately tested. Low level harmful effects could be missed, yet they might be important for the population as a whole, since electric lines are so ubiquitous. In 1976-1977 we did a field study in the greater Denver area which suggested that, in fact, the homes of children who developed cancer were found unduly often near electric lines carrying high currents.

In our modern power delivery systems, high-tension wires carrying current at

voltages up to several hundred kilovolts (kv) deliver power to distribution substations where the voltage is stepped down, resulting in proportionately higher current in the medium-voltage (usually 13 kv, wire-to-wire) primary lines. These latter radiate out from the substation to distribute power through a neighborhood. Then, at the local transformer, the voltage of the primaries is stepped down once more to produce the 240 volt current which is carried along the secondary wires to service drops which bring the power to the customer's house. The current flow will always be greatest in the wires directly issuing from the substation or the transformer. At these points the voltage has been stepped down and "transformed" into current. And it was particularly homes close to these transforming points that were over-represented among our cancer cases.

Because our findings appeared to relate to high current rather than voltage, we looked into the magnetic fields induced by current flow. Magnetic fields penetrate the human body (and buildings, etc.) readily. They are not easily shielded, but

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Abbreviations: AC, alternating current; HCC, high-current configuration; Hz, hertz; LCC, low-current configuration.

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The authors thank the Colorado Department of Vital Statistics and Dr. John Cobb of the University of Colorado Preventive Medicine Department for their facilitation of this research.

TABLE 1
Daytime measurements of 60 Hz magnetic fields (in RMS gauss) in Colorado in 1976-1977

	75 cm above ground, under wires				75 cm above ground over buried plumbing which serves:		
	Large primaries (N = 64)*	High tension (N = 22)*	Thin primaries (N = 51)*	First span secondaries (N = 84)*	Second span secondaries (N = 73)*	First span homes (N = 160)*	Second span homes (N = 104)*
Maximum measurements	.035	.020	.008	.005	.004	.013	.008
Median measurements	.007	.0033	.0022	.0017	.0009	.0015	.0010
% >.0030 gauss	73.4%	54.5%	35.3%	20.2%	6.8%	22.5%	10.4%

* N = no. of sites studied.

† First span secondaries are those nearest the transformer; second span wires are further "down-stream" from the transformer (see text). First- and second-span homes are homes near the respective types of secondaries.

they can be cancelled by balancing the currents that produce them. Such cancellation occurs in electric wires, where the return current tends to balance the supply current. However, the cancellation is imperfect because the wires are often separated in space and, more importantly, because some of the return current does not flow through the wires at all, but returns instead through the ground, and particularly through the plumbing system to which most urban electrical systems are grounded at each house.

This results in a locally imbalanced current, both in the distribution wires and in the plumbing. That imbalanced current produces a 60 hertz (Hz) magnetic field which, though small (table 1), is nonetheless orders of magnitude larger than the 60 Hz field found in nature (about 10^{-8} gauss (1)). The ground-current flows not only in the street plumbing, but also through the pipes in the house. Current which enters the plumbing at one house can flow through several homes before it returns to the distribution wires, because the plumbing provides a continuous, low-resistance path between houses.

The ground-current produces a magnetic field within the house (localized near the plumbing) which appears to be related roughly to the types of wiring configurations nearby (see table 1). This relationship between wires and plumbing is to be expected because, other things being equal, the greatest unbalanced current tends to occur where the total current in the wires is greatest, and the unbalanced portion of the current must detour through ground paths such as the nearby earth and plumbing.

A number of household appliances and power tools also produce magnetic fields, but in comparing the fields from appliances with those from power lines, it is important to note that most appliances present approximately a magnetic dipole source, with fields falling off roughly as the inverse cube of the distance, while a

wire with unbalanced current will have a field falling off only as the inverse of the distance. For instance:

	1 cm	15 cm	1 m	3 m	30 m
Electrical drill	13 gauss	.12	.001	< .0001	< .0001
Electrical range (4 burners on high)	1 gauss	.04	.0015	< .0001	< .0001
Wire carrying 15 amperes	3 gauss	.2	.03	.01	.001

In the literature there are listings of 60 Hz magnetic fields produced by appliances which appear quite high. These should not be misinterpreted: They are apparently due to the use of measurements taken "as close as possible" to the appliance. Our measurements indicate that magnetic-field exposure to the whole body from normal use of household appliances rarely exceeds .001 to .002 gauss for any extended period, while the ambient fields in a house due to nearby distribution wires or plumbing may sometimes reach those levels, or more, for hours or days at a time. If magnetic-field exposure is responsible for our finding, it may be that, above some minimum threshold, duration of continuous exposure is more important than strength of exposure *per se*. There is some precedent for such a threshold effect in the literature on direct current (DC) magnetic fields (2).

Our field measurements showed that, on the average, those types of wires associated with cancer in our study exhibited high magnetic fields (compare tables 1 and 3). However, the readings varied considerably over time; and because our observations were all made in good weather and during work-day hours when domestic current is minimal, because current-flow had most probably altered since the time of our subjects' residency, and because it was rarely feasible to go close to the house to take a measurement, no attempt was made to take systematic measurements at our study homes. Rather this study is based on the potential current flow suggested by differ-

ent wiring configurations (nearness and size of wires, closeness to origin of current, etc.).

Experimental work on physiologic effects of low-level, extremely low frequency magnetic fields is limited. It has been recently reviewed (3). Among the positive reports are decreased mitosis in slime molds (4), decreased growth of seedlings (5) and chicks (6), decreased *in vitro* growth of embryonic tissue cells (7), and a number of behavioral and physiologic changes in rats (8). All these results are for fields considerably higher (.5-30 gauss) than the 60 Hz fields generally found near power lines; however, the findings reported often appear to be unrelated to dose over the range studied. Prolonged exposure to the .001-.1 gauss range most pertinent to wiring effects has not been explored experimentally.

Two studies suggest that a relatively strong AC (alternating current) field may interfere with growth of implanted tumors in animals (9, 10) except where the tumor tissue is exposed to the field *before* implantation. In this latter condition, tumor "takes" were increased (9).

To explore occupational exposure to AC magnetic fields, we analyzed data from a USPH publication on occupation by cause of death (11). All those occupational categories which seemed likely to include men frequently exposed to AC magnetic fields were grouped together and found to have, as a group, a cancer rate significantly higher than the total population. The "exposed" categories included: power station operators; stationary engineers; linemen and servicemen, telephone, telegraph and power; motor-men, street, subway and elevated railway; electricians; and welders and flame cutters. The

standard mortality ratio for cancer for these categories combined was 115, a significant increase over the ratio of 100 for all occupations ($\chi^2 = 24.5, p < .0001$). For other "natural causes" of death this same group showed a standard mortality ratio of 102 ($\chi^2 = 1.8$, not significant). While this crude analysis in itself proves nothing, it underlines the fact that the harmlessness of AC magnetic fields is still unproven.

METHODS

Our cases consisted of persons dying of cancer in Colorado before age 19 in the years 1950-1973, who also had a Colorado birth certificate. Only subjects with addresses occupied from 1946-1973 in the greater Denver area were used. Controls for these cases consisted of next Denver-area birth certificates, chosen both from the files organized by birth-month and county (*file 1 controls*), and from the alphabetical search-listings, which list all Colorado births alphabetically within several wide spans of years: 1939-1958, 1959-1969, and 1970-1974. These latter were called *file 2 controls*. If the next birth certificate was that of a sibling it was skipped.

Birth addresses were those listed on the birth certificates. "Death" addresses were obtained for both cases and controls by searching for parents in city directories

for the two years just prior to diagnosis of the case. For cases who could not be traced, the address on the death certificate was used. For controls, if the *file 1 control* could not be traced, the *file 2 control* with most similar birth date who could be traced was used. There were no significant differences in the proportion of "high-current configurations" (HCC's as defined below) shown by the *file 1 controls* used (21 per cent HCC), the *file 2 controls* used (23 per cent HCC) and the unused extra controls (25 per cent HCC), so it seems unlikely that our method of selecting controls biased our findings.

In all, 344 cases met our criteria. Thirty-nine of these were born before 1946, and 33 had a birth address which was lost because it had been demolished or was not adequately specified. Only death addresses were analyzed for these 72 cases and their respective controls. Similarly, 16 cases had no usable death address, so only birth addresses were used for these cases and their controls. Table 2 gives a summary of how many persons and how many addresses were available for cases and controls.

The procedure was simply to visit the birth and "death" addresses of each case and each control, and to draw a small map of the electrical wires and transformers in the vicinity. Primary (13 kv) wires were categorized as either "large-gauge" (built

TABLE 2
Distribution of persons and addresses available for analysis, for cases and controls, in a study of electrical wiring configurations and childhood cancer in Colorado in 1976-1977

Residential status	Cases		Controls	
	Persons*	Addresses*	Persons	Addresses
Stable	109	109	128	128
Moved, birth and death addresses available	147	294	128	256
Only birth address	16	16	16	16
Only death address	72	72	72	72
Totals	344	491	344	472

* Tables 3, 4, and 9 present data on total addresses, tables 5, 6, 7, 8, and 10 present data on total persons. Tables presenting data on persons are generally broken into total persons with an available birth address ($N = 272$) and totals with an available death address ($N = 328$).

to carry high currents) or "thin" depending on whether they were clearly larger than the secondary wires. Distances were measured from the part of the house nearest the wires to the wires, with a rollatape.

Three types of homes, because of their proximity to high-current wires, were considered to have "high-current configurations" (HCC's): 1) homes less than 40 meters from large-gauge primaries or an array of six or more thin primaries; 2) homes less than 20 meters from an array of 3-5 thin primaries or from high-tension (50-230 kv) wires; and 3) homes less than 15 meters from "first span" secondary (240 volt) wires. *First span secondaries* were defined as those secondaries which issued directly from the transformer and had not yet lost any current through a service drop occurring beyond the transformer pole. The span of secondary wires separated from any transformer by at least one intervening service drop (ignoring those drops directly attached to the transformer pole) were called *second span secondaries*. First span wires will have more current running through them than second span wires because the first span must carry current for all the drops that mark its distal end *plus* whatever current the second span requires.

All other configurations were considered "low-current configurations" (LCC's). In addition, where first span wires could be seen to be carrying current to no more than two single family homes, on the average (on both sides of the block), those wires were called *short first span* wires and, because they carried current for so few homes, they were always considered LCC's, regardless of distance. Houses situated beyond the pole at the end of a secondary line ("end poles" in tables 3 and 4) were considered the extreme example of LCC homes, because they had no distribution wires at all running past them.

Since the Denver area has been growing fast, many new primary wires have been installed to accommodate increased power demands. Many of these new installations are of a style easily distinguished from older wires. For addresses occupied before 1956 (20 years prior to our field work) we noted that only 59 per cent of the primary wires found near our study homes were of the "old fashioned" types which had been in use at the time of our subjects' occupancy. (Actually 71 per cent of the primary wires observed near pre-1956 case addresses were "old fashioned," but only 49 per cent of the wires near pre-1956 control addresses were of the older types that could have been in use in those early years.) Where the more modern wiring was observed, we could not tell whether it represented new installations or replacement wiring, but we did know that it could not have been there in its present form in the pre-1956 years. Therefore, we decided to treat all primary wires seen near homes occupied before 1956 as unreliable, and to code such homes strictly according to their more stable secondary-wire configurations.

This adjustment did not critically affect our findings. Proximity to primary wires was most strongly associated with cancer for recent addresses, and the association (as expected) was weaker in the older data. But the association was still significant when all years were considered and no adjustments made: For birth addresses, 31 per cent of the 272 cases and 22 per cent of the 272 controls had homes near (unadjusted) primaries, a difference significant beyond the .025 level by Chi-square. For death addresses the figures were 29 per cent of 328 cases and 19 per cent of 328 controls, significant beyond the .01 level.

RESULTS

General configurations. Table 3 shows how many cancer and control homes exhibited the various wiring configura-

tions. It can be seen that the most striking difference between cases and controls was found for subjects who had only one address from birth to death. This might be because, for subjects who moved, the effects of configurations at one address were diluted by effects of configurations at other addresses.

Table 4 indicates that the greater the exposure to current expected from a given wiring configuration, the greater the excess of cancer found in homes where that configuration was observed.

Type of cancer. The breakdown according to type of cancer (table 5) shows a fairly similar excess of HCC's in cancer cases for all categories but one, the death addresses of cases with "other tumors."

Such a wide association with different types of cancer is not characteristic of known carcinogens such as ionizing radiation; thus the broad association observed here suggests that the HCC-cancer relationship may not be a causal one. The most likely alternatives are that it is due to some artifact, or that it reflects some effect of HCC's on the body's general ability to resist cancer.

Onset age. As table 6 shows, the HCC-cancer relationship was observed in both young and older subjects. The fact that the relationship held for the birth as well as the death addresses of older subjects would seem to suggest that the effects of HCC exposure can be long delayed. However, a closer look at the data showed that

TABLE 3
Wiring configurations at the homes of cancer cases and controls, Colorado, 1976-1977

Type of configuration*	Stable residence:		Moved residence:			
			Birth address		Death address	
	Case	Control	Case	Control	Case	Control
Substation <150 m†	2	0	2	0	2	0
Large primaries <40 m	14	6	14	13	38	17
High tension <20 m	0	0	0	1	1	0
Thin primaries <20 m	13	10	11	4	17	11
1st span secondaries <15 m	19	10	26	11	23	20
Total HCC's	48	26	53	29	81	48
1st span secondaries >15 m	33	43	53	57	66	51
"Short" first span wires	6	11	9	4	11	19
Second span secondaries	20	33	40	40	51	66
End poles	2	15	8	14	10	16
Total LCC's	61	102	110	115	138	152
(% HCC)	(44.0)	(20.3)	(32.5)	(20.1)	(37.0)	(24.0)
	$\chi^2 = 14.4$		$\chi^2 = 5.4$		$\chi^2 = 7.6$	
	$p < .001$		$p = .02$		$p < .01$	

* All six cases within 150 m of a substation were also less than 40 m from large primaries.

† HCC = high-current configuration; LCC = low-current configuration.

TABLE 4
Cancer related to the amount of current expected from different wiring configurations, Colorado, 1976-1977

Wiring configuration	Expected current	Total addresses:		
		Case	Control	% cases
Substation	Very high	6	0	100.0
Other HCC	High	176	103	63.1
LCC except end poles	Low	289	324	47.1
End poles	Very low	20	45	30.8

TABLE 5
Wiring configurations and type of cancer, Colorado, 1975-1977

Residence	Type of wiring configuration*	Leukemia		Lymphoma		Nervous system tumors		Other	
		Case	Control	Case	Control	Case	Control	Case	Control
Birth address	HCC	52	29	10	5	22	12	17	9
	LCC (% HCC)	84 (38.2)	107 (21.3)	21 (32.3)	26 (16.1)	35 (38.6)	45 (21.1)	31 (35.4)	39 (18.7)
Death address	HCC	63	29	18	11	30	17	18	17
	LCC (% HCC)	92 (40.6)	126 (18.7)	26 (40.9)	33 (25.0)	36 (45.5)	49 (25.8)	45 (28.5)	46 (27.0)

* HCC = high-current configuration; LCC = low-current configuration.

23 (66 per cent) of the 35 older cases born at HCC's were also living at a HCC (usually the same address) within two years of their cancer onset. Only three (20 per cent) of the 15 older controls born at HCC's were living at a HCC within two years of the "death" date. Thus the HCC-cancer relationship observed in the birth addresses of older subjects can be largely attributed to a HCC residence near the time of cancer onset, and there is no need to posit a long-delayed effect of HCC's.

Urban-suburban differences. Since cancer may show a different incidence in urban and non-urban areas, it seemed important to rule out the possibility that a difference in urbanization between cases and controls was the significant variable in this study, and simply carried the HCC differences with it, spuriously. This seemed unlikely, intuitively, because the field work was done one neighborhood at a time, and on none of the 22 days of field work did the individual day's results fail to show a preponderance of HCC's in the case addresses.

A more formal survey shows that, although there was a slight excess of suburban addresses in the controls, it was not statistically significant. Furthermore, the cases showed more HCC's than the controls independently in three areas: in old Denver, in the more recently developed Denver areas (as estimated from a planning department publication (12)), and in the Denver suburbs (see table 7).

Socioeconomic class. The literature reports an excess of leukemia in families of higher socioeconomic class (13). Our data, dealing with all types of childhood cancer, show only an insignificant trend in this direction. It seemed possible that our method of choosing controls might have biased our control group against lower-class controls, since only controls who could be traced in directories were used. However, a check on the discarded controls showed that upper and lower

class controls were discarded equally often, while Class III controls were somewhat disproportionately retained. There was no significant difference in the per cent of discarded and retained controls showing a HCC and, as table 8 shows, the association between HCC's and cancer was observed within each social-class group. It therefore seems unlikely that some spurious relationship to social class explains our findings.

Family pattern. The literature reports an excess of first siblings and older mothers among children with leukemia (14). In our total sample of childhood cancer cases, a trend towards both more first siblings and older mothers was noted, but neither was statistically significant. Furthermore, the HCC-cancer relationship holds to approximately the same degree within each maternal-age

and sibling-order category tested, so we see no clue in these variables as to why the relationship between HCC's and cancer should exist.

Traffic congestion. A recent report (15) suggests that cancer may occur unduly often near heavy-traffic routes. Our data did show a mild excess of case-addresses near such routes; case-addresses were more likely than control-addresses to be found within 40 meters of streets having a daily traffic count of 5000 vehicles or more on the 1960 Department of Highways traffic map. However, once again, a significant excess of HCC's in cancer cases was found independently for addresses on heavy-traffic routes and for other addresses. (For heavy-traffic routes, 53 per cent of 74 case-addresses showed HCC's against 30 per cent of 48 control-addresses; for other locations, 35 per cent

TABLE 6
Wiring configurations and cancer onset age, Colorado, 1976-1977*

Residence	Type of wiring configuration†	Cancer onset 0-5 years		Onset 6-18 years	
		Case	Control	Case	Control
Birth address	HCC	66	40	35	15
	LCC	103	129	68	88
	(% HCC)	(39.1)	(23.7)	(34.0)	(14.6)
Death address	HCC	68	37	61	37
	LCC	105	136	94	118
	(% HCC)	(39.3)	(21.4)	(39.4)	(23.9)

* Case-control differences are significant by Chi-square ($p < .01$) for each category in the table.

† HCC = high-current configuration; LCC = low-current configuration.

TABLE 7
Wiring configurations in different neighborhoods of cancer cases and controls in Colorado in 1976-1977*

Residence	Type of wiring configuration†	Old Denver		Newer Denver		Suburban	
		Case	Control	Case	Control	Case	Control
Birth address	HCC	42	26	27	9	32	20
	LCC	77	91	40	44	54	82
	(% HCC)	(35.2)	(22.2)	(40.3)	(17.0)	(37.2)	(19.6)
Death address	HCC	49	24	35	19	45	31
	LCC	62	77	49	55	88	122
	(% HCC)	(44.1)	(23.8)	(41.7)	(25.7)	(33.8)	(20.3)

* Case-control differences are significant by χ^2 ($p < .05$ or better) for each category in the table.

† HCC = high-current configuration; LCC = low-current configuration.

TABLE 8

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Father's occupational class* at subject's birth, related to wiring configurations at birth residences of cancer cases and controls, Colorado, 1976-1977

Type of wiring configuration†	Classes I and II		Class III		Classes IV and V	
	Case	Control	Case	Control	Case	Control
HCC	19	9	49	30	33	16
LCC	34	41	98	111	39	65
(% HCC)	(35.8)	(18.0)	(33.3)	(21.3)	(45.8)	(19.8)
	$\chi^2 = 3.2$		$\chi^2 = 4.7$		$\chi^2 = 10.8$	
	$p < .10$		$p < .05$		$p \approx .001$	

* Class categories follow the schema provided in "Mortality by Occupation Level and Cause of Death," Vital Statistics Special Reports 53: #5, 1963, and are as follows: Class I: Professional. Class II: Technical, Administrative and Managerial. Class III: Clerical, Sales, and Skilled Workers. Class IV: Semi-skilled Workers. Class V: Laborers.

† HCC = high-current-configuration; LCC = low-current configuration.

TABLE 9

Increase of cancer cases within 40 meters of heavy-traffic routes, as related to the presence or absence of nearby* primaries, Colorado, 1976-1977

Type of subject	Near primary wires		Not near primaries	
	Traffic routes	Other locations	Traffic routes	Other locations
Cases	32	84	42	333
Controls	9	53	39	371
(% cases)	(78.0)	(61.3)	(51.9)	(47.3)
	$\chi^2 = 3.3$		$\chi^2 = 0.4$	
	$.05 < p < .10$		Not significant	

* "Nearby" primaries here means that the primaries were near enough to the house to qualify it as a high-current configuration (HCC).

of 417 case-addresses showed HCC's against 21 per cent of 424 control-addresses).

In fact, the excess cancer we found on heavy-traffic routes seems to be related to the frequent presence on such routes of primary wires carrying especially high currents. Table 9 shows that the excess of cancer cases on high-traffic routes occurred to a significant extent *only* where primary wires were nearby.

Sex distribution. Many cancers, including leukemia, occur more frequently in males than females. This is reflected in our data where 57 per cent of our cases were males, as compared to 49 per cent of the controls. The excess of HCC's among cases was significant for both males and females when the sexes were analyzed separately, but the trend was stronger in

the males; 51 per cent of the 197 male cases had a HCC at their birth- or death-address, or both, while 45 per cent of the 147 female cases had such an address. This compares with only 28 per cent of the 168 control males and also 28 per cent of the 176 control females.

It is interesting that significant male excess among our cancer cases appeared to be confined to two categories: 1) cases whose birth address had a lower current configuration than the death address, and 2) cases with stable address who developed cancer after at least one year of postnatal life at a residence situated near primary wires (table 10).

Because these two categories were chosen from a number of ways we might have categorized the data, they must remain suspect until a replication confirms or

TABLE 10

Sex distribution of cancer cases in a study of electrical wiring configurations and childhood cancer in Colorado in 1976-1977

Type of address	Males	Females	% male	Significance*
Birth address had lower current configuration than death address	28	14	66.7	$\chi^2 = 4.0, p < .05$
Stable residence at HCC† involving primary wires	22	4	84.6	$\chi^2 = 11.1, p < .001$
Other cases with any HCC address	56	48	53.8	$\chi^2 = 0.5$, not significant
Other cases with no HCC address	91	81	52.9	$\chi^2 = 0.5$, not significant

* An expected value of 50 per cent male was used to calculate the chi-squares.

† HCC = high-current configuration.

disputes them. However, we chose these categories for a reason: We hypothesized that males might be excessively susceptible to HCC's at all ages, including prenatally. (It is of interest here that male rats appear especially susceptible to experimental magnetic fields (8, p. 182) (16), as do embryos (17).) If males are more susceptible, they might frequently be aborted when pregnancy occurs at a HCC, but pregnancy at a LCC would allow the most susceptible males to be born and then to develop cancer later when exposed to a situation with higher current nearby. This hypothesis is consistent with the male excess in category 1 above.

Category 2 is presumed to provide a potentially similar situation: Where primary wires are found running near a house (in 1976), it is always possible that these wires were first installed or were "beefed up" at some time *after* the subject's birth. Or if they were present all along, the current they carry may sometimes have increased with time. If any of these things happens, the postnatal current flow near the house will be increased over the prenatal flow, even without a change in residence. Should this happen, the susceptible male who escaped abortion during pregnancy might develop cancer, and this would explain the male excess in category 2.

Substations. Power carried at higher voltage is stepped down to produce increased current at two points in our electrical distribution system: at the distribution substation, and again at the neighborhood transformers. As indicated, cancer cases were found in excess close to the "first span" wires issuing from the transformers. An even stronger trend was found for substations.

None of the 702 control addresses visited (including our unused extra controls) was within 150 meters of a substation. This is to be expected since probably less than one home in 1000 in the Denver area is that near a substation. What is surprising is that six of 491 case addresses were found within 150 meters of a substation and, in each case, less than 40 meters from the large primary wires issuing from that substation. These six are shown in table 3. Each cancer case had lived at the substation address within three years or less of his illness. Although these numbers are small, they are striking.

Blind studies. It should be noted that our Denver-area study, being exploratory, was not done blind. This could lead to error, although our observations were reasonably unambiguous. To check just how reliable our coding was, an assistant observed and coded 70 case and 70 control addresses randomly chosen from those previously coded by the principal inves-

tigator. The assistant did not know the case-control status of the addresses she coded. Her coding agreed with ours in 128 (91 per cent) of the 140 instances. In five of the 12 instances of disagreement, the assistant's judgment favored the hypothesis of a HCC-cancer correlation, while ours did not. In seven instances, the reverse was true.

Also, a blind study was done (for birth addresses only) in Colorado Springs and Pueblo. This study showed the same correlation as the Denver study, similar in degree but less significant due to the smaller numbers; 32 per cent of the 65 cases and 18 per cent of the 65 controls showed HCC's. The correlation was strongest for cases with onset before six years of age, possibly because many of the older cases had been gone from their birth addresses for many years before their cancer onset.

DISCUSSION

It is not clear *how* residence near a HCC might affect the development of cancer, but several possibilities should be considered:

1) Some association of both cancer and HCC's with a third factor may spuriously account for our correlation. Although we found no indication of such a third factor in our analyses of social class, neighborhood, congested streets, or family make-up, the possibilities have not been exhausted.

2) The magnetic fields produced by wire currents may somehow directly "cause" cancer. There is, however, no independent evidence or theoretical understanding which seems to support this possibility. The evidence concerning mutagenic effects of extremely low frequency magnetic fields, for instance, is ambiguous, but probably negative (18).

3) Carcinogenic activity may be associated with some *indirect* effect of the HCC's. For example, fields around power

lines might change some ambient environmental carcinogen, such as particles which emit ionizing radiation. (However, the fields near domestic wires are too weak to make this seem probable.) Or the increased current flowing in the plumbing might locally affect the drinking water. (There is often a small amount of lead in copper water pipes, for instance, due to imperfect soldering. And lead in the water supply is correlated with cancer, at least geographically (19). However, it is not clear that AC current in pipes could affect this small amount of lead enough to make a difference.)

4) AC magnetic fields might affect the development of cancer indirectly, through some effect on physiologic processes. It is conceivable, for instance, that contact-inhibition of cellular growth, or the basic immune reaction of recognizing "self" from "not self," involves electrical potentials occurring at cell surfaces. Against an electromagnetic background different from that provided during evolution, any such cell mechanism might be altered.

Whatever the basis for our observed correlation, it should be emphasized that, although the risk of cancer appears to be increased for children living near HCC's, it is rarely increased by a factor of more than two or three. Therefore, if in the general population one child in 1000 is likely to get cancer before age 19, no more than two or three in 1000 living near a HCC would be expected to get it. The practical significance of the correlation, if any, lies in the high prevalence of HCC's, not in any very high risk posed by most HCC's.

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Bradley Westfall
Route 1 Box 434
Rudolph, Wisconsin 54475

March 17, 1979

Gloria Woida

C. U. R. E.

Saulk Center, Minnesota 56378

Dear Mrs. Woida:

Effect of EHV line on cattle reproduction

As a background: My father purchased this basic farm for dairying in 1934 and added 20 acres, then I added 38 acres and 120 acres and now have sold the 120 acres so as to maintain the last (original) 146 acres. The farm was basically a dairy farm throughout the years. Though we started artificial breeding in 1955 and started a hereford herd through artificial breeding to consume the extra feed we were producing and to take up the extra barn space during the winter. In 1970 we started in to the purebred Simmental beef for sale as breeding stock using the hereford herd as foundation animals. This was a very successful venture in the beginning as we sold the first two open one year old heifers for \$2700.00 and prices for other simmental breeding stock continued to be great. I added some excellent holstein milk cows to the original guernsey herd when my father retired in October of 1975. The milking herd was sold individually between October and December of 1977. The Simmental herd that remained was sold as a group in March of 1978. We now only cash crop our land except for four animals, two simmental steers, a simmental heifer, and a guernsey heifer from which we hope to keep ourselves in beef and milk.

During 1968 and 1969 we experienced our first breeding problems with our dairy and beef animals. Abortions, (abortions in late pregnancy were the only ones we were aware of and looking for at this time), sterile (apparently, but could have been caused by early abortions which we were not looking for), and weak or crippled calves. We blamed the poor conceptions on the A. I. technician and weak calves on the bulls the A. I. stud kept. The veterinary checked for all possible causes that he could think of and always sent samples of blood and tissue for testing to the state lab at Madison, Wisconsin. We never found an infectious cause and our herd has always been calfhood vaccinated for Bangs. Because of the problems we began looking for another artificial breeding organization. None other had good service in the area at the time, so I went to the ABS technician school. From April 1, 1970 on I did all the A. I. work in our herd and for a time worked for American Breeders Service. The results were tremendous and I thought we had solved the problems. First service conceptions started out at 75% and climbed to a high of 90% for the first two years. Then all our problems emerged and kept getting worse no matter what we tried. The cattle turnover because of abortion caused sterility was getting to great. Calf losses from abortions were also cutting into our replacement calf numbers and we redoubled our efforts to find a infectious cause, but to no avail. The discovery of what we think is now our problem came quite accidentally when we had to move our cattle to new late fall pastures during the dry falls of 1975, 1976, and 1977. The cattle one week after being in the new pasture would cycle normally and we again had as high as 90% first service conceptions. The only difference was that they were never under the EHV lines that were in and along their normal summer pastures. The good breeding records would hold while they were in the barn during the winter. This breeding difficulty was

disastrous for our beef operation as very few cattle calved in the spring and calves were not at the right age when they were supposed to sold or ready for breeding. The dairy herd calving intervals were too long to make them worth continuing as a dairy herd. We then proceeded to sell both herds as quickly as possible.

Looking back we found that the herds had been in the pastures under the power lines in 1968 and 1969 then out during 1970 and 1971 and back in these same pastures from 1972 until sold. The cattle were not in the pastures with the EHV lines, 1970 and 1971, because of crop rotation and reseeded of these pastures. This is 345,000 volt transmission line and is across and along our fields. The breeding problems and problem calves that we blamed on the A. I. technician and the A. I. Stud were apparently caused by the presence of the transmission line. As the same problems resumed from the summer of 1972 into the present. The two heifers we currently have would not breed this summer and they were still in the pasture under the EHV lines. Cattle less than 3 months pregnant * would abort when put from the barn into the pasture during the Spring. Less than 2% would become pregnant (including virgin heifers) during the time under the EHV lines and carry calves to full term. This as opposed to 70% to 90% previously. Uneven and false cycles were persistent and didn't change until the cattle were removed from the pasture to another or put in the barn when conception would again jump to 70% - 90% range.

We believe that a state or national study or studies should be done under controlled conditions. Without the influence or possibly even the knowledge of the electric utilities until completion.

Our Simmental beef herd is in another part of the state and will be checked by myself for the breeding and calving results the past year. They will be a good control group for confirmation of my conclusions. I must stress here that I have absolutely no doubts about the effects of EHV transmission lines to my cattle. I will present my breeding records and interpret them for anyone that wants to take the time or pay my travel expenses to their location and I will lecture or give speeches if they wish and show our veterinary expenses which were unusually high during this period per animal.

Big power generation plants require EHV lines. So to eliminate the problem of EHV transmission lines, small plants should be built by cities or counties and operated without a profit, a true public utility. I feel the only safe transmission line is one that a small bird will perch up on.

Sincerely,

Bradley H. Westfall
Bradley H. Westfall

BHW/bw

Additional reference: Louise Young, 755 Sheridan Road, Winnetka, Ill. 60093
KNOWLEDGE of study done on small animals.

Study supposed to have been completed by the Ohio Department of Agriculture.

Study on humans up to 1000 feet from EHV power lines supposed to have been printed in Newsweek during June or July 1978.

* Some cows would abort at 7 months with some visible malformations after becoming pregnant, during the winter.

QUALITY CONTROL WORKSHEET

Date: 2-19-65

Page: of

By: BHW

DESCRIPTION FRED & BRADLEY WESTFALL FARMS NEAR RUDOLPH — RED IS POWER LINE RIGHT-OF-WAY, BLUE IS POLES, TOWER & CABLES OF E.H.V. LINE. TELEPHONE LINE ALSO SHIRTS SQUARE MILE PERIMETER.

1 TO HIGHWAY 34 WOOD-PORTRAGE COUNTY LINE ROAD

2
3
4
5
6 YOUR COMMENTS ON LOWER
7 HALF OF LETTER AS TO POSSIBILITY
8 OF DUSTING IN THIS AREA NOW
9 WOULD BE APPRECIATED TO
10 BE RECEIVED BEFORE FEB. 26, 1965.

11
12
13 THANK YOU

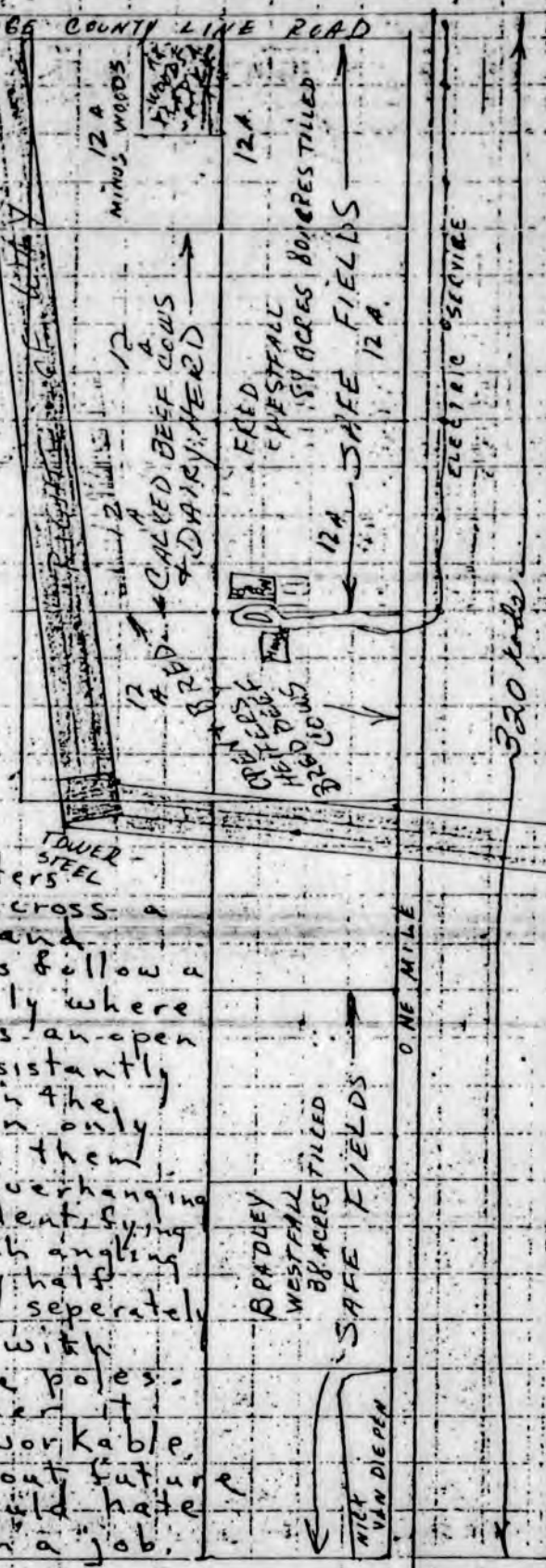
14 MILES CROP DUSTING SERVICE

15 83 WEST LINCOLN AVENUE
16 HARTFORD, WIS. 53027

17 BRADLEY H. WESTFALL

18 Such a proposed highline would
19 really spoil future aerial pest-
20 icide application on your land.
21 We thread (fly under, between, or
22 over) a lot of wires around perimeters
23 in our work but wires angling across a
24 field is a downright miserable and
25 dangerous situation. When wires follow a
26 perimeter fence we know exactly where
27 they are but when they angle across an open
28 field they are impossible to consistently
29 pinpoint because ones eyes lie in the
30 same horizontal plane. We can only
31 go by the poles and must give them
32 plenty of berth because of the overhanging
33 wires and lack of a surface identifying
34 line like a fence. Then too, such angling
35 wires would increase the flying by half
36 again in order to work the plots separately
37 and even coverage is affected with
38 considerable overlap around the poles.
39 If the tower were in the corner it
40 would make the land at least workable.
41 My advise would be to forget about future
42 aerial applications. I would hate
43 Rudolph to put a new pilot on such a job.

44 HIGHWAY "C" TO RUDOLPH



B 23 REC'D
B HW

10M 7-43

THE KILLER ELECTRIC

Is your electric toaster hurting your sex life? Don't laugh, it isn't funny! This investigation details the damage being done to your body and mind—from impotence and headaches to cancer and deformed children—by the invisible electric pollution in the air around you. Even more terrifying, the Pentagon and Kremlin are locked in a secret arms race to create electric weapons that may turn future conflicts into a war of wizards.

An investigative report by Lowell Panto

Electricity all around you lives a life of its own in the wires behind your walls, waiting like generals to do your bidding. Light the house, turn on the television, cook your food, keep you warm at night. The only problem, civilian scientists are now discovering, is that the electromagnetic radiation emitted by all our uses of electricity may be slowly killing us—much as atomic radiation would.

This is no all-pipe to the Pentagon or the CIA. They have spent more than twenty years, and many millions of dollars, studying how electric mind control and other means of electric warfare could be used against all enemies, foreign and domestic. The Soviet Union has done likewise, and the U.S. and USSR have long been locked in a secret war involving the use of these new weapons of electromagnetic radiation (EMR)—which now promise to give nations possessing them the power to alter the weather, generate earthquakes, and even disrupt the thought processes of entire enemy populations. Is this why the evidence of electric shock to our health has been suppressed?

Nobody is sure when the Electric War began, when weapons using EMR

were first used by one nation against another. Perhaps it was begun unknowingly when the British first aimed primitive radio beam (radio emits short electromagnetic waves—microwaves) toward attacking Nazi ships. But a major battle of the war began in 1943, when the CIA agents, using electronic devices, made a routine sweep of the U.S. Embassy in Moscow for buggering devices and discovered that the Soviets were beaming powerful microwave radiation at the building. Technically, the attack was an act of war; the embassy is legally U.S. territory, and to attack it is the same as invading New York City or Los Angeles. What the hell were the Russians doing? Using the beams to pick up voice vibrations on window panes? Using the microwaves to a great extent, testing devices hidden deep in the walls? Or were they using American diplomats and their families as guinea pigs in some unknown experiment?

That microwaves could be harmful was well known. Soldiers had died from walking too close to the beams of powerful radars; their brains melted like hamburgers, the blood in their eyes cooked hard. Even in smaller doses this energy vibrating in the electromagnetic spectrum between the

wavelengths of ordinary radio waves and visible light could induce nausea, vomiting, and strange buzzings in the head. And it could kill sperm, as was believed by many Navy radar technicians who sold "treatments" to shipmates bound for shore leave; the trouble was, as researchers have found, such microwaves deform the genetic material in sperm, and this leads not to no babies, but to grossly deformed ones. The U.S. Navy has for many years used its powerful radar beams to "paint" Soviet trawlers with microwave radiation.

But U.S. military experts prior to 1963 had assumed that the destructiveness of microwave radar beams depended on their power, their intensity. Certainly men working right near radars could develop vision-destroying cataracts as the clear fluid in their eyeballs—biochemically similar to the white

of an egg—was cooked to opaque whiteness by repeated microwave exposure. A few experts had quietly fretted during the Fifties that some touring fairs in praise of "progress" were treating the public to displays of how, with unshielded microwave beams, eggs could be fried before their eyes. "Pass your hand through the invisible beam," onlookers were told. "It's not dangerous unless you feel heat." As a youngster I remember doing that at one of those fairs; I remember, too, sneaking repeatedly into a downtown shoe store where, under an ever-on fluoroscope, I could see the bones inside my feet. With each viewing I built up to a dose of radiation now recognized as potentially lethal. (Thomas Edison's assistant died from demonstrating this invention too many times.) But that was the feeling back then, that in small doses all such radiation was harmless.

This was what confused the CIA about the radiation into the embassy they would code-name Moscow Signal: it was not powerful enough to do great harm, at least not by U.S. Public Health Service standards. The Soviet beam apparently reached an average intensity of four milliwatts per square centimeter within the embassy; the U.S. health standard, set almost arbitrarily and based on the estimate of the American electrical industry, called ten milliwatts per square centimeter a safe dose. But the Soviets, who have elaborately researched the effects of EMR for thirty years, considered a dose one-thousandth the size of the U.S. standard to be dangerous to the human body and set strict standards, limiting the number of minutes a worker was permitted near high voltage lines, large power transformers, or radar equipment. By Soviet standards, the U.S. Embassy was receiving a severely dangerous dose of EMR; by U.S. standards the same radiation was insignificant.

The CIA was aware of what the Soviets were doing, but it chose to disclose nothing to State Department workers who, along with their children, were being incessantly irradiated. Instead, the CIA instituted a study it called Project Pandora, named for the woman of Greek mythology who defied the gods and opened the box that unleashed disease and pestilence into the world. The name would prove prophetic.

Under Pandora the CIA began irradiating monkeys and other animals with microwave radiation of the same intensity and on the same wide array of frequencies as the Moscow Signal. The full results of these tests, some of which were done at the Walter Reed Army Institute of Research in Washing-

ton, D.C., have never been made public. But a few civilian scientists in the U.S., doing similar studies, have replicated results reported by Soviet research: that even at these low levels, EMR can disturb heartbeat and biorhythms, can cause convulsions and disorientation, can alter the chemical composition of the blood, can induce cancer, and can cause deformed births.

Under Pandora the CIA used ruses to gather samples of blood and genetic material from people working at the embassy in Moscow. Those tests, reports science writer Paul Brodeur in his excellent book on microwaves, *The Zapping of America*, showed "lots of chromosome breaks," an indication that the people were suffering genetic damage likely to cause mutations in their unborn children, abnormal development in their young children, and cancer in all.

In 1973, a full decade after the CIA discovered the Moscow Signal, columnists Jack Anderson and Les Whitten broke the story. They reported that the CIA feared the radiation was being used to brainwash U.S. diplomats, or at least to impair their efficiency, as the Pandora experiments had shown that it could warp the minds of laboratory monkeys.

As reporters looked into the situation, and as embassy employees fearfully sought medical consultation, an ominous picture emerged. Like his two predecessors, Ambassador Walter J. Stoessel, Jr. had come to Moscow in good health. Now he suffered from nausea, dizziness, and headaches, and was known to be bleeding periodically from his eyes. He would soon be transferred to a new post amid reports that he was suffering from leukemia, cancer of the blood. The two ambassadors before him, Charles Bohlen and Llewellyn Thompson, both died of cancer.

The Department of State ordered blood tests of all embassy employees. The tests revealed that on average their blood "lymphocyte count was 40 percent higher than the count in other foreign service personnel," and that other indexes of blood chemistry were also wildly abnormal. Soviet scientists have published studies that show this change in the white blood cell count to be caused by microwave bombardment and that it foreshadows a host of serious symptoms. The State Department refused to blame the increase on the microwaves—which by then the White House had officially protested—and it described the alteration in blood chemistry as beneficial, for white cells work as part of the body's immune system. The unusually high counts, however, suggest that the bodies of the embassy employees were fighting against

HOME ON THE ELECTRIC RANGE

We've all seen signs warning the wearers of heart pacemakers to stay out of places where microwave ovens are used. But we all have natural pacemakers that order our heartbeat, regulate our sense of time and space, and keep our mind and moods stable. The invisible "electric smog" emitted by household appliances subtly affects our natural pacemakers, leaving us irritated, exhausted, unable to think clearly, and sometimes even ill.

The most common sources of electronic radiation are things run by electric motors. Inside those motors electromagnetic energy jumps across thousands of tiny gaps every second, so every motor, to a greater or lesser degree, is bombarding you with pulsating electric pollution.

Consider a partial list of everyday items with electric motors or spark gaps:

- Automobile motor
- (especially the ignition system)
- Motorcycle
- Moped
- Elevator
- Power lawn mower
- Trucks
- Electric saw
- Electric trains
- Chain saw
- Air conditioner
- Washing machine
- Electric carving knife
- Electric hair dryer
- Electric toothbrush
- Electric clock
- Record player
- Electric refrigerator
- Garbage disposal
- Dishwasher
- Automatic garage door opener

unseen invaders, perhaps the body's own irradiated cells, that unless checked might become cancers.

Why weren't they told? Many angry embassy employees wanted to know, and several are now suing the government for imperiling them. But, in fairness to the CIA, the reason is simple enough, apart from its desire to decipher Soviet motives by analyzing this action. The microwave level was, by U.S. standards, entirely safe. To admit its hazard could have far-reaching consequences, for right now millions of Americans live and work with more radiation than was beamed at the Moscow embassy. Those in the thousands of high-rise buildings in hundreds of U.S. cities, those at nearly eye level with television station transmission antennas and microwave relay horns, are daily irradiated with far more microwave energy than were the Moscow victims.

"It's the biggest can of worms, environmentally and politically, we'll face in this century," a Rand Corporation consultant told me. "Our whole society, our culture, our machinery—they're all electric. And from the Pentagon point of view, all our radars, satellites, communication systems—all the stuff we need for national defense—it's all high-power electric. So what happens if you come along and show people that their TV set will give them cancer and kids with two heads? A lot of them are going to say, 'Unplug the damned electricity.' But we can't unplug it! The whole momentum of our civilization is toward more electricity, not less. It holds us together like a giant electromagnet. Turn off the power and we crash into a million incoherent pieces."

A few scientists now have begun to utter the unspeakable—that there is a serpent in our electric Garden of Eden, that instead of living better electrically, as the advertisements promise, we may die quicker. Recall that we used to speak of "Better Living Through Chemistry," a slogan used by the explorers of inner landscapes via LSD, a fad that lost popularity when the government issued reports showing that lysergic acid caused chromosome damage and could cause deformed births. But it's one thing to quit an entertainment like LSD and quite another to unplug the electric lifeblood of our whole technology.

Soviet scientists hypothesize that the human body has its own natural resonant frequencies. After all, our brains and central nervous systems interact with each other and the environment through exchanges of electrical impulses. We are both senders and receivers of electric energy. Thus, it stands to reason that when electrical energy emitted nearby is on wavelengths resonant

with ours, we will "feel" the signals as symptoms—buzzing, heat, headache, impotence, disorientation, nervousness, illness. Such are the felt symptoms of EMR exposure found by Soviet research.

Each year the amount of electricity used in the United States increases by about 5 percent, and much of that ever-growing total seeps back into the environment as electric smog, a vast and swelling invisible garbage dump of electromagnetic radiation in which we all must live.

When electricity was first being introduced, many people resisted it as dangerous. The reason: it was said that if you removed the light bulb from its socket, electricity would "leak" into the room. Likewise, when radio made its debut, stories held that people with fillings in their teeth found themselves "receiving" local stations.

It is now clear that these tales were somewhat correct. Electricity does "leak." Wherever it flows through wires, whether high-voltage lines or the wiring in your home, it generates radio-frequency electromagnetic fields that extend far beyond the wire itself. Wherever it flows through complex circuitry, as in your television set or stereo equipment, a wide range of such radio frequency energies may be emitted.

And the notion that people can be resonant with some of these frequencies is also apparently correct, although those critical wavelengths and the sensitivity of the receiver will vary widely from person to person.

In school most of us were taught to perceive ourselves essentially as *chemical* beings made up of so many grams of iron, so many pounds of calcium, so many gallons of water. "Rendered down, you are worth \$2.38 for your constituent chemicals," the science teacher would say—a figure now bolstered by inflation and by the discovery that we include some rare amino acids worth \$800 an ounce. As chemical beings we were taught to take chemical drugs to cure sickness, to change moods or to charge our metabolism.

But our science teachers may have failed to teach us we are also *electric* beings. A chain of electrical impulses enables your eyes to scan this page and your brain to decipher the meaning of the squiggles on this paper. The poet Walt Whitman knew it more than a century ago. "I Sing The Body Electric," he wrote. And so it is.

Religious figures have for millennia been portrayed in art with halos, fields of light or energy, surrounding them. In 1939 the Soviet researcher Semyon Kirlian discovered a method of photography that makes visible the pattern of electricity that is emitted by all objects,

more brightly by living things than by inanimate objects. By studying changes in these Kirlian "aura" photographs, Soviet investigators have claimed that they can predict the emergence of several illnesses for which no other physical symptoms are detectable and that they can show what seems to be a transfer of electrical or "bioplasmic" energy from the hands of a psychic healer into the body of an ailing patient.

Precisely what such photographs show is debated by scientists, but it is clear that some electrical phenomena involving the body are being recorded on film and they seem to change markedly when the subject is intoxicated or sober, sick or well, calm or angry. This "aura" or electric body seen in the photographs can extend several inches beyond the surface of the skin, and it tends to flare most brightly—as one might expect—at juncture points in the body's own telephone exchange and intercom, the central nervous system. (These points also correspond precisely to those the Chinese have targeted for countless centuries in the practice of acupuncture, which is based on the idea that health is restored by removing blockages in the body's invisible energy circulatory system.) It is clear, too, that this mysterious electrical field

MICRO-TIDAL WAVE

Microwaves, which mounting evidence now shows can cook your goose in small doses just as they cook your rump roast in the slightly larger doses in home microwave ovens, have begun to pervade our lives. No longer limited to the military, airport, and police speed-trap radars, their sources around the home include:

- Automobile motors
- Microwave ovens
- Television sets
- (color and black and white)
- Stereo equipment
- Citizens Band radio transmitters
- Amateur radio transmitters
- Soldering irons
- Telephones and their wiring
- Electric wiring
- Diathermy devices

In some of the above, the dose of microwaves given off is small, but recent evidence shows that tiny doses can have lethal and perhaps cumulative effects—each exposure doing a permanent bit of genetic damage to your body's cells. The Consumers Union, publishers of *Consumer Reports* magazine, has refused to give ratings to any microwave oven because such ratings would encourage people to buy them at a time "when nobody is really sure what a safe dose of microwaves is."

interacts with the environment.

Our grandparents read by candlelight and heated their homes with firewood or coal, much as people have done for thousands of years. We are the first generation to live in an environment intensely charged with human-made electricity, which we have plugged in and turned on without knowing what effect it could have on the evolution of our species. As a result, the body of a human living today in New York or Los Angeles, Houston or Cleveland, Detroit or Philadelphia, Boston or San Francisco, Minneapolis or St. Louis, Chicago or Washington, D.C., or any of a hundred other great cities of the post-industrial world is dosed daily with up to 100 million times more electromagnetic radiation than our ancestors soaked in from sunlight and starlight. Who can doubt that this has a large, and probably negative, effect?

"Man may soon enter an era of energy pollution of the environment comparable, in public health and ecological implications, to the chemical pollution of today," warned the White House Office of Telecommunications Policy in March 1973, the same year the CIA's Project Pandora became public.

The question is, at what point do we say the threat is great enough to begin pulling out the plugs — and whose plugs do we pull? Microwave ovens, for example, are deemed safe by the U.S. Public Health Service if they leak microwaves into their surroundings at a level 25 percent more intense than the Moscow Signal. But though they may leak that much when new, in everyday use the shields may be damaged, the seals worn, the doors loosened, and as a result the ovens would pour more invisible radiation out at a rate a hundred times higher than the U.S. safety standard, 100,000 times higher than the Soviet safety standard. Thus, the Consumers Union, publishers of *Consumer Reports*, has refused to approve any microwave oven because, say they, "nobody is really sure what a safe dose of microwaves is."

That statement may be imprecise. The Pentagon and CIA may know. So may the electrical industry. But for them to say it is to invite explosive political protest and a tidal wave of lawsuits from radar technicians, pilots, and others whose health has been damaged by exposure to what they were told was harmless EMR radiation. Three such lawsuits by radar-involved workers have already been won, based on evidence by New York University ophthalmologist Dr. Milton Zaret that cataracts can be caused by supposedly "safe" microwave doses.

As of 1972, wrote investigative reporters Joel Griffiths and Richard Ballantine, the typical city-dwelling Amer-

ican already gets a constant dose of electromagnetic radiation of at least ten milliwatts per square centimeter, the maximum level called safe by the Public Health Service. This is from microwaves ricocheting off buildings, from radio and television transmitters, and from power lines above or under the streets. The amount increases yearly as we use more and more electricity. And the evidence increases yearly that this accumulation of radiation has a cumulative effect on our bodies, just as atomic radiation does. When genetic material is mutilated or destroyed, it does not merely disappear. Damaged organ or brain cells remain, weakening or damaging the whole living organism.

Electricity does 'leak.'

Wherever it flows
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high-voltage lines or
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that extend far beyond
the wire itself.

Microwaves are the most dramatic form of EMR pollution: you can cook with them and hence kill with them, as a California woman recently proved by savagely putting her pet dog into her microwave oven for punishment. The poor dog, said reports, "exploded."

But energy radiating anywhere along the electromagnetic spectrum can have severe effects. Recently, for example, farmers in Minnesota followed the lead of protesters in Upstate New York and Illinois in opposing construction of high-voltage power lines near or over their land. "We're being asked to live with an unknown danger so people in the city can have more dumb gadgets," one farmer shouted at a line of police brought to thwart threatened attacks on the construction crew, an event covered on network television. Among the risks of power lines are these: vast amounts of electrical energy radiate around the wires, enough in many cases to light an unconnected neon bulb held in bare hands — as science writer Louise B. Young demonstrated on the cover of her 1973 book, *Power Over People*, a study of the disregard many electric companies have for the health and well-being of people living near their power lines. Because these lines are subject to natural forces, they often develop weak points where more than

a million volts of electrical potential may be radiating off the wires — enough to severely shock a farmer driving a tractor underneath, enough to shock a child in the playgrounds the City of Los Angeles thoughtfully built underneath high-voltage lines "so as not to waste this valuable space."

Power lines also change the electrical charges in the air, and medical evidence shows the impact this has on human health. We tend to feel vibrant, alive, full of bounce and energy when breathing air in which the molecules carry a negative electrical charge — negative ionization, this is called — a condition commonly found near waterfalls, near the ocean surf, and high in mountains. Conversely, we tend to feel sick, weak, depleted, and depressed when the air is positively ionized, a common condition during hot and humid or hot and dry days. In parts of the world where annual hot winds bring heavy positive ionization of the air — in Arabia and parts of Switzerland, for example — the laws for centuries have dealt more gently with those whose crimes took place during the months of "craziness" carried by the winds, write Fred Soyka and Alan Edmonds in their book, *The Ion Effect*.

High-voltage lines positively ionize the air around them, thus impairing the health of living things nearby. But with modern technology we have learned how to bring such "devil winds" into our homes and workplaces as well, with the flip of a switch. Where electrical elements are used for heating — in ovens, air conditioning systems, hair dryers, and radiant heaters, among other places — we fill the air with ions that deplete the body's own vital electricity. We make ourselves restless, tired, irritable, and often unable to relax and think clearly.

But the greatest problem with power lines is in that question of what I call "bioresonance." For those whose bodies are resonant with some of the emissions of nearby power lines, a host of health problems can result: fatigue, headaches, impotence, and other maladies.

Research done at the University of California in Los Angeles by neurophysiologist Dr. Ross Adey, for example, showed that the kind of simple power lines that carry electricity to apartments or homes like yours often generate an electromagnetic field that reaches for several hundred yards beyond the line itself and that can oscillate at seven Hertz (cycles per second). Dr. Adey experimented with monkeys, training them to perform simple tasks repetitively precisely every five seconds. He then put the monkeys in a room into which was beamed a very

(continued on page 102)

THE KILLER ELECTRIC

(continued from page 44)

low intensity radio signal of seven Hertz frequency. The results: the monkeys' sense of time and rhythm was wildly distorted by the signal, which was considerably milder than the Moscow Signal. When West German researchers did similar experiments with humans, their subjects reported intense feelings of time disorientation, some reporting that a twenty-four-hour period in a room permeated with seven Hertz electromagnetic waves felt like the passage of sixty hours. Perhaps 200 million or more North Americans live within, or in the course of a typical day travel through, such electrical fields, fields which interact with their own body electricity and influence their biorhythms in subtle ways. It is so much a part of modern civilization that we never question it. We are all, so to speak, on the same drug and all perceiving the same distorted reality. We are trapped in an electric spider web of our own making, a web on which we depend even as it threatens our health and well-being and our survival as a species.

What can harm us accidentally can also be used deliberately as a weapon against selected people. The awesome thing about the Moscow Signal was not only its microwave energy, but also its oscillation—a fact seldom mentioned. These were not continuous microwave beams that the Soviets aimed into the U.S. Embassy. They were pulsed beams, either turned off and on or frequency-shifted so they would "flicker" at rates between one and fifteen Hertz. The significance: this is the frequency range of normal human brain waves—Alpha waves range from eight to twelve Hertz, Beta from twelve on up, Theta from four to seven Hertz, and Delta from one to four Hertz. By pumping electrical energy into people's heads in this way, using energy already resonant with the electrical wavelengths of their central nervous systems, it seems likely that mental and biological distortions and disorientations could be produced. "Brainwashing" was the word invoked by journalists Jack Anderson and Les Whitten to describe the CIA's concern over these signals, and it seems apt.

In CIA research with human subjects, it was found that each person has critical frequencies that unlock doors in the mind to tranquility, to bliss, to anxiety, to disorientation, and to intense pain. The Pentagon had long known that such responses could be tapped in a person. The Navy, after all, had

The Soviets, who have elaborately researched the effects of electromagnetic radiation for thirty years, considered a dose one-thousandth of the size of the U.S. standard to be dangerous to the human body.

funded extensive research by Yale University physiologist Dr. José M.R. Delgado and others who showed that such reactions could be induced in any brain to which you could attach electrodes. In his book, *Physical Control of the Mind: Toward a Psychocivilized Society*, published in 1969, Dr. Delgado waxed eloquent about how he could gently shock into goodness any wrong-thinking individual. But the CIA went further, finding that you could change a person's mind without attaching electrodes to the frontal lobes at all. Through Project Pandora's research, the CIA took a long step toward electrical control of the mind and opened further the dark box of a future psychocivilization.

But the Soviets have researched electromagnetic radiation effects far longer than have the CIA or Pentagon, and in October 1976 they began an experiment that dwarfs anything the U.S. military has contemplated. The Soviets began tampering with Earth's magnetic field.

From a configuration of four incredibly high-powered transmitters, three of them laid out in a giant triangle with points in cities northwest of Moscow, the Soviets began to send out coordinated radio pulses. The signals disrupted shortwave radio broadcasts and amateur wave bands throughout the world and stirred controversy and protest.

The Soviets were testing a theory set forth by the eccentric genius Nikola Tesla, revered as the Slavic Thomas Edison. Tesla invented the Tesla coil, much of the theory behind television, and the technology of alternating current. He also claimed to be in communication with people from Venus. Shortly after the turn of this century, Tesla theorized that by using coordinated radio impulses it should be possible to manipulate the part of Earth's magnetic field that resides at the edge of space up in the ionosphere by gen-

erating giant electric standing waves. These waves, said Tesla, could then be manipulated to change the course of giant wind patterns, like the jet stream, that shape our weather. By 1976 the Soviets were prepared to try any idea that promised to redeem their worsening weather; by all indications the planet had been growing colder since the Forties and was threatening a new ice age that would all but destroy the Soviet Union as a world power. As I predicted in my book, *The Cooling*, in 1976, weather problems would soon force the Soviets to try some desperate technological gamble, and they did.

In December 1976 the Soviets launched three new satellites to coordinate the signals from their ground-based transmitters. The impulses that followed were a classic experiment based on the frequency wavelengths Tesla theorized. The jet stream, already distorted by decades of expanding cold air over the Arctic, locked into the odddest bend of this century—far north in the Pacific, bringing record winter warmth to Alaska, and far south over the eastern United States, bringing snow for the first time ever seen in Miami, Florida, and in the Bahamas. Weather was remarkably good that winter in the Soviet Union, which until then had suffered repeated crop failures in the Seventies and had been forced to beg food from the United States.

As the 1977 winter approached, the Soviets began a new series of configured high-energy transmissions. On November 21, a new huge wave stretched along Earth's ionosphere from the western tip of Alaska to northern Chile in South America. Rain returned to California after two years of record drought, flooding towns, while waves tore apart beachfront homes. In many parts of the eastern U.S., cold records set the year before fell, as did a number of buildings under the weight of never-before-seen snowfall. Hurricane-force winds tore across Europe, killing dozens of people and bringing bizarre snowfall to Spain and southern Italy.

But during that time, earthquakes seemed to erupt everywhere on the planet, one of nine-point-one magnitude in the Indian Ocean being the strongest ever recorded. Dr. Andrew Michrowski, an expert on Tesla who works as a technologies specialist in the office of Canada's Secretary of State in Ottawa, told me, "The Soviet experiment got out of their control. They created these giant changes in the Earth's magnetic field, but then they could not

dissipate the standing waves, although they tried to neutralize them with new waves. But this is the reason for both the crazy weather and the earthquakes—and the airquakes, too."

Airquakes are strange booms first heard off the northeast coast of the United States in December 1977. They are, Michrowski believes, experiments by the Soviets in how to use coordinated radio pulses to generate an incredible release of electromagnetic energy in one spot of the Earth's magnetic field—"like an explosion," he told me. I would prefer to accept Pentagon explanations that the booms came from jet airplanes or swamp gas or flying saucers or something else. But when these booms happened, many smoke detectors in the region were triggered, detectors that react to ionization, to a

IONIC MAN

A growing number of scientists agree that the state of human health reflects the electricity in the air you breathe, on its "ionization." Where the fine dust and molecules in the air carry a negative electrical charge, our bodies feel vigorous, alert, full of energy. Where the air carries a positive electrical charge, the body tends to feel depleted, exhausted, and a person is more likely to be irritable, headache, and disoriented. (The body will also age more rapidly in a positive ion environment and is more likely to develop cancer.)

In parts of the world where annual hot winds bring heavy positive ionization—in Arabia and parts of Switzerland, for example—the laws for centuries have dealt more gently with those whose crimes came during the months of "craziness" the winds carry.

With modern technology, we have learned how to create such crazy, positively-ionized air in our own homes and workplaces, bringing madness and sadness as near as the electric switch. Among the things that flood our environment with positive ionization are:

- Power lines
- Electric air conditioning, including fans
- Electric heaters, especially radiant-type
- Electric broilers and ovens
- Hair dryers
- Electric hair curlers
- Television sets
- Electric blankets
- Electric heating pads
- Electric toasters
- Sunlamps

For that Special Woman Swinging Heart with Diamond Sparkle



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G-8-78

We are the first generation to live in an environment intensely charged with human-made electricity, which we have plugged in without knowing what effect it could have on the evolution of the species.

rapid change in the electric charges in the air. "If I'm right," says Michrowski, "the Soviets are on the verge of a breakthrough into a new weapons technology that will make missiles and bombers obsolete. It would allow them to destroy up to five American cities in a day just by sending out radio impulses. They could also induce panic or illness in whole nations."

The U.S. has had its own opportunities to study such phenomena, and what has been reported seems to confirm Tesla's theories. A U.S. high-energy transmitter in Antarctica studied by Stanford University physicist Dr. Robert Helliwell does indeed generate a "rain of electrons" from the ionosphere, in effect a new magnetic flux. And just as Tesla predicted, in some configurations its signal becomes amplified by realignment of the planet's own magnetic field. Unacquainted with Tesla's work, Helliwell expressed surprise that the "signals were somehow amplified up to a thousand times" by unexpected natural forces during his experiments.

The U.S. Navy, worried for years at its inability to communicate in an emergency with submarines submerged on the far side of the planet, has tried repeatedly to build a foolproof buried radio system with antennas dug in over thousands of square miles. The system, variously called Project Sanguine and Project Seafarer, has, by public protest, been prevented from being built in Nevada, Texas, Michigan, and Wisconsin. As proposed, it would use very high power on Extremely Low Frequencies (ELF), in the Hertz range of human brainwaves. A prototype was built in Wisconsin, but it, too, came under fire when Senator Gaylord Nelson (D., Wisconsin) forced the U.S. Navy to reveal its suppressed test data showing abnormal blood chemistry in nine of the ten men who had worked on it. Some of these men showed the same symptoms as per-

sonnel in the Moscow embassy. Spearheading the protest against Sanguine, environmentalists also produced evidence that its transmissions would be powerful enough to disrupt the migrations of birds, the mating habits of squirrels and other animals nearby, and even the reproductive cycle of plants.

The Navy has been reluctant to discuss precisely how Sanguine is supposed to work, but this much is evident: it is supposed to fill the entire cavity between the ionosphere above the Earth and the planet's stony mantle with electrical impulses capable of reaching a submarine twelve thousand miles away under thousands of feet of water. To believe it can do this, the Navy must know something the public does not, something about the nature of a type of radio transmission generally assumed to be disruptive to the environment. They want to saturate the entire planet's environment with such transmissions, and that should give us pause.

We should pause, too, at the tales of "satellite killers" used to cloak what the U.S. military knew about the December 1976 Soviet satellite launches and concomitant news stories about the development of "particle beam" death rays. We and the Soviets have indeed been in a race to develop ray weapons, but as a former Pentagon consultant myself, I have reason to suspect that neither laser light nor intense beams of particles are at the cutting edge of U.S. research. Both methods are too subject to the oddities of the atmosphere, to thermal bending effects, clouds, and the like. People have forgotten that the laser — light generated by energy-stimulation of the right sorts of atoms — has an older brother. Two years before discovery of the laser, Hughes Aircraft scientists in California announced development of the working prototype of the maser, a device that stimulated atoms to emit an incredibly powerful beam of microwaves able to "shatter material." Suddenly nothing more was said about the discovery, and virtually nothing to this day has appeared discussing it. This seems odd, for a maser beam could slice through the clouds and mirrored surfaces that would thwart lasers, particle beams, and the like. It makes one wonder, doesn't it? But somehow I can't quite clear my mind about how to put all these puzzle pieces together. Perhaps the Electric War is already over, and somebody else has won. □

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Trouble on the Land:

Confrontation on the Prairie

PAUL DAVID WELLSTONE and LAMONT TARBOX

Farmers in western Minnesota are up in arms. Their anger is directed not against low crop prices or bad weather, but against a more tangible enemy that may be just as hard to beat. The farmers are fighting two large electrical utilities — Cooperative Power Association (CPA) and United Power Association (UPA) — that want to build a power line across prime crop lands and, in some cases, virtually over the roofs of their homes.

The proposed line is part of a huge effort by the utilities to meet the expected demand for electricity in Minnesota in the 1980s. The plan is to strip-mine coal in North Dakota, build electrical generating plants there, and then send the power to Minnesota's Twin Cities, Minneapolis and St. Paul, through gigantic overhead transmission lines. The project is expected to cost CPA-UPA at least \$800 million.

The transmission line towers, if built, will rise 150 feet above the ground and cross 8,000 acres of Minnesota farmland. The size of the line and the volume of current flowing through it pose special problems not associated with smaller power lines. The Minnesota Department of Natural Resources (DNR) says deer will not pass under the line and birds will not nest near it because of the build-up of static electricity in the air; therefore, all state-owned wildlife areas have been exempted from the proposed route.

The farmers are indignant because the same concern has not been extended to them. They fear the massive electrical current will cause significant chemical reactions in the air around the line, creating dangerously high con-

centrations of ozone. They also have other worries: Large pieces of equipment, buildings, and fences may have to be grounded to prevent a build-up of static electricity and to keep current from jumping from the line to the ground. Advanced irrigation systems may be rendered useless, and aerial spraying may have to be curtailed. The towers may enhance the risk of serious accidents whenever heavy machinery is used. The line may create a noticeable noise that bothers livestock, and decrease the value of the farmlands. And the farmers are deeply disturbed about the way the utilities have tried to steam-roller permission to construct the line from local and state officials.

The farmers have responded in their own way. Citizens' groups involving hundreds of families have sprung up in several counties. Farmers have testified at local and state hearings. They have raised large sums of money to hire a battery of lawyers to explore all possible legal means of stopping the line. They have persuaded the state legislature to pass a new law covering the routing of future power lines. They have even obstructed the work of utility survey crews in the fields, destroyed equipment, and gone to jail to keep the line off their lands.

The utilities have the upper hand in the courts, and see no need to compromise. But they have underestimated the farmers all along, and the fight is not over. If the farmers lose in court and the utilities proceed with construction, there will be more confrontation on the prairie.

Farmers here and throughout the Midwest are conventionally regarded as conservative, but their conservatism is of a special sort, based on the life they lead and their productive relationship with the land. Their ownership of land and responsibility for its successful cultivation foster an independence not found in most other segments of today's America. They value hard work, independence, self-sufficiency, and self-reliance. Farming is more to them than a livelihood. It is the source of their lifestyle

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and the legacy they hope to pass on to their children. Some farmers perceive the land as a "sacred trust" they hold for themselves, their children, and the rest of the nation. To threaten their land is to threaten everything they have, everything in which they believe.

Though farming encourages independence, experience has taught them the value of collective action. They have had organizational experience in the Farm Bureau, the National Farmers Organization, and various fuel, fertilizer, and marketing cooperatives. But the strongest inducement to collective action has come from the common perception of the threat posed by the utility companies. One farm woman, Carolyn Koudela of Douglas County, told us, "We've been told the farmer is about the most independent person there is. But when it comes to something that's going to bother them, or hurt their welfare or their family's welfare, they can join together faster than anybody or any labor union or anything else."

The story of how the opposition to the power lines organized itself bears her out. The utilities' plans first came to the farmers' attention in the summer of 1974 when Jim Nelson, a farmer in Grant County, heard about them at a county commissioners' meeting. At the meeting, the utilities made their request for permission to build a power line through the area, and Nelson discovered that the line was to be routed right across the top of his home. The commissioners took no action at that meeting.

The next day, Nelson went to Jerry Bates, a neighbor who sold crop insurance and knew many people in the country. "Between the two of us, we started a kind of chain reaction thing of notifying everyone along the route," Nelson recalls. Initially, they contacted farmers who were to be right under the line. The utility companies held an "informational meeting" ten days later, and 100 farmers crowded into the Grant County courtroom to voice their opposition. One week later, Nelson and his neighbors had formed their own organization, No Power Line (NPL), with an initial membership of 150. At the first meeting, each family contributed \$25 or \$50.

Farmers in neighboring counties also organized. In Stearns County, a few farmers heard that a power line might be coming through and that a township official had a map of the proposed route. They borrowed the map, made a copy, and began to inform their neighbors that the line would cross their land. The farmers of Stearns County quickly organized and formed an organization, Keep Towers Out (KTO).

Pope County, located between Grant and Stearns counties, turned out to be the center of protest. For one thing, Pope County commissioners were opposed to the line and effectively used a zoning ordinance to delay consideration of the companies' requests for permits. Farmers formed their own organization, Towers Out of Pope Association (TOOPA), in late February. The president, Harold Hagen, expressed the group's position in *The Pope County Tribune*. "TOOPA aims to completely eliminate the power line from coming through the country. We aren't

against a power line going to the metro area, but we want the line to go through areas less suitable to agriculture."

Members of each of these groups began attending county commission, zoning board, and planning commission meetings in their own areas. Sometimes farmers from one county traveled to meetings in other counties to testify against the line and show their support for their fellow farmers. NPL discovered that the zoning ordinance in Pope County was helpful to farmers there, so it obtained passage of a similar ordinance in Grant County.

In March 1975, the various county groups joined together in a multi-county organization, Counties United for a Rural Environment (CURE). Each county had one representative on the board of CURE, and Harold Hagen of TOOPA was elected president. CURE hired a lawyer and began to consider legal strategies, though most of the farmers concentrated on attending local meetings, where they tried to prevent local officials from granting the utilities permission for the line.

The response varied. Stearns County officials were inclined to support the power companies from the start, and farmers were unable to stop officials from granting the necessary permits. In Grant County, farmers won enough support from local officials to pass the new zoning ordinance and hold extensive hearings — some of them attended by as many as 200 citizens. But the county commissioners were not opposed to the line, and it seemed likely the utilities would be granted permits, though with some restrictions: keeping the line 500 yards from farmsteads; barring construction during muddy times of the year, and requiring that all topsoil be carefully replaced.

In Pope County, the commissioners stood fast in opposition to the line throughout the permit proceedings. The farmers had won support from people living in the small towns of the county. Without a permit in Pope County, the whole project was threatened — so the utilities came up with a strategy that was, in effect, an end run around local authorities and made local opposition easier to overcome.

In April 1974, the Minnesota legislature passed a Power Plant Siting Act, which provided that the Minnesota Environmental Quality Commission (MEQC) would make a final determination on power line routes after extensive public hearings. The Act required a "certificate of need" from the Minnesota Energy Agency; hearings to establish a twenty-mile wide corridor that would contain several possible routes for a power line; hearings to determine the actual route of the line, and an environmental impact statement. But even though the Act was passed before the line was built in western Minnesota, the utilities managed to keep the power line outside its jurisdiction; they claimed that since construction in North Dakota had preceded the legislation, they had a "grandfather privilege" to adhere to the old arrangements of local approval for the line.

The companies did not expect the determined opposition they continued to encounter. Local officials dragged their feet, and it seemed likely that Pope County would refuse to grant permits. In April 1975, the utilities

'People have distrust for government now that has never existed before'

reversed their earlier position toward the Minnesota Environmental Quality Commission, renounced their right to be "grandfathered," and asked the MEQC to take over consideration of the line. The Commission accepted jurisdiction and the struggle shifted from the county to the state level.

MEQC established a forty-nine-member Citizens Advisory Committee and held hearings during the summer and fall of 1975. At the same time, farmers in northern Grant County and Douglas County formed two new organizations, Preserve Grant County (PGC) and Save Our Countryside (SOC). These groups were prompted by fear that other farmers' organizations would succeed only in moving the power line off its original target and onto farms elsewhere. All of the farmers' organizations mistrusted the state agency. As the MEQC held hearings around the state, the farmers followed, attending every meeting. In one case, they discovered that the transcript of a hearing omitted two-thirds of the testimony presented, most of it in opposition to the power line. The farmers suspected MEQC was playing the power companies' game.

In late September, the Citizens Advisory Committee made its recommendation. Harold Hagen, president of CURE, described it this way: "It's not far enough north to suit most of us but with the guidelines we had it was the best we could do. . . . We were limited by the outside boundaries established by the EQC and our route runs pretty much along the northern edge of that boundary. . . . If we didn't pick anything we would have lost the opportunity for input into the issue." But on October 3, MEQC rejected the corridor chosen by the Citizens Advisory Committee and chose a path close to the one requested by the power companies.

In December, MEQC announced the precise route of the line, and six months later — in June 1976 — the power companies began survey work. The anger that had been building up among farmers exploded when the survey crews appeared on the land. Farmers gathered around the crews and turned on chain saws so the surveyors could not hear each other. Others parked their grain trucks to obstruct the surveyors.

"It was a spontaneous reaction," Harold Hagen says, "that came right in the neighborhood when someone felt that here is something that shouldn't be and he gave a call and soon there was a network of calls and the people just sort of rolled in from all over in a matter of just short minutes." Fighting erupted wherever the crews tried to work. Because of these confrontations, Governor Wendell Anderson intervened and persuaded the power companies to halt survey work, at least temporarily, in Stearns County.

When the companies resumed surveying in other counties in September, farmers again blocked their work. In Pope County, a local judge issued an injunction against the farmers' civil disobedience and ordered the sheriff to enforce it, but the sheriff and the county board said they did not have the manpower to control the demonstrations. There was speculation the governor might send in the National Guard.

In January 1977, the new governor, Rudy Perpich, made several "mystery trips" to visit farmers in western Minnesota. He conferred with members of CURE and CPA-UPA, and they agreed to meet with an arbitrator. The meetings broke down in March, however; the farmers walked out because the power companies had begun condemnation proceedings in North Dakota and parts of western Minnesota.

Since March, the struggle has moved into the courts. A three-judge panel appointed by the state supreme court ruled against the farmers, and in August the state supreme court heard arguments from both sides. The court has not yet decided the case, but the farmers plan to appeal to the Federal level, if necessary, and will continue their legal battle as long as they can. Pending a final court decision, construction on the power line has stopped, but many farmers in the area are not optimistic about the long-range prospects. John Tripp, one of the farmers, says, "People have a distrust for government now that has never existed before."

They also have a new appreciation of the effectiveness of collective action and militant protest. Jim Nelson, one of the younger farmers, says, "I'm part of the generation that opposed the Vietnam war fairly seriously, and civil disobedience was a big part of that. . . . I never did it myself, but it was always acceptable to my generation." Dennis Rutledge says the farmers' protest movement "showed that we were strong in our convictions but also sensible and law-abiding citizens as much as the law was going to let us be. The law had stepped on us and forced us to that hill out there, but we weren't going to go so far as to seriously break the law. We were only going to break it enough to show that we were serious. And that's exactly what we did."

Still, some farmers are talking about shotguns and dynamite. One of them says, "I think it would be a big blunder on the part of our state government to try and force the line through here. We might have another Attica." Another farmer explains, "There are two varieties of resistance at that point, one of which is substantially more honorable than the other. One is the civil disobedience type of thing, and the other is the dark-of-night type of thing. And they are both good possibilities." □

Powergate
or
Beyond the Limits of Legitimate Authority

In western Minnesota, over 100 persons have been arrested for alleged illegal activities while protesting the construction of a 800 KV DC powerline from North Dakota to Delano, Minn. Their resistance has revealed gross illegal actions by the courts, state agencies, and the utilities. Misuse of this authority has furthered an energy policy that was conceived in deceit, is potentially dangerous to those who must bear its ill effects, and will lead to the development of a centralized energy system controlled by a few. Ironically, the persons protesting the illegitimate construction of this line are the ones formally being charged with illegal actions.

Two licenses must be granted by state agencies before a utility can begin construction of generation and distribution facilities. United Power Assn. (UPA) and Central Power Assn. (CPA) of Minnesota obtained the first of these, a Certificate of Need, from the Minnesota Energy Agency (MEA) after construction had already begun and without establishing sufficient need. The utilities were issued the second of these, a construction permit, from the Minnesota Environmental Quality Board (MEQB) without adequate public participation or transcripts.

According to law, a utility must apply for and receive a Certificate of Need before applying for a corridor designation and a construction permit.¹ By requiring this, the State of Minn. through the MEA insures its citizens against abuse from private corporations providing public services. The Certificate of Need was not issued by the MEA until April 2, 1976 while UPA/CPA had applied for their construction permit on Dec. 9, 1975.

The MEA is required by law to establish its own statistics to evaluate need independent from those of the utilities.² Dr. Paul Steinbeck, Energy Facility Analyst of the MEA wrote the following in an open letter dated Jan. 31, 1978 that

The Energy Agency rules containing assessment of need criteria (EA6 00, 300, 900, 1000) do not mention an Agency forecast. This makes them illegal. The Agency has not established a forecast of energy need for the days of peak demand for any electric service area. Because there has been no Agency forecast and illegal criteria were used, the Certificate of Need granted is void as a consequence of such illegal process.

Not only has the MEA failed to provide the legally required statistics, but it has yet to establish a forecasting approach whereby such statistics may be acquired. While these utilities insist the need for electricity from this line is immediate and urgent, Northern States Power has delayed completion on five of its major generation facilities due to lack of need.

Extreme irregularities surround the issue of cost as it relates to the Certificate of Need. Energy Agency Regulation 611 requires the applicant to

In regard to the selection of the entry point, there were no public hearings held or transcripts made. The MEQB sent a letter to the North Dakota Public Service Commission stating:

We have learned that a substantial portion of the right-of-way from the point of crossing westerly has been acquired. Because of this fact, the Commission would be compelled to accept this route. . .

Furthermore, UPA/CPA did not apply for exemption from North Dakota law until Sept. 4, 1975. Two months prior, at a public meeting of the MEQB on June 10, opponents of the line were informed that the point of entry had already been fixed, and the line was exempt from N. Dakota law. This application for exemption was denied by the N. Dakota PSC the following March. When taken to court concerning this, the Supreme Court again ruled in favor of the MEQB. A three judge panel set up to hear appeals concerning the powerline controversy wrote a memoranda relative to this case. "Early in the proceedings, before the corridor was even designated, it was generally known where the anticipated point of entry would be located."⁷ Somehow the court is able to justify this blatant illegality and write a bit farther on in their memo, "We cannot find in the record that any decision was arbitrary, capricious, or contrary to existing law."⁸

The MEQB is obligated under law to keep a complete record, including official transcripts of all proceedings leading to the issuance of a construction permit.¹⁰ On July 12, 1976, the MEQB stated that the transcripts of the hearings in Paynesville and Litchfield on April 13 and 14 of that year had been destroyed. The next month, they reopened the public hearings to compare tapes made by a local resident, Virgil Fuchs, with the official transcript. In October, the Office of Hearing Examiners for the State certified that the official transcripts failed to contain all of the testimony from these hearings.

As a result of their findings, a very interesting and unusual transcript was entered into the records. Judge Kennedy of Stearns County ordered the MEQB to transcribe the testimony contained in the Fuch's tapes into the official transcript. This corrected transcript contains over 150 gaps and "unintelligibles" regarding testimony given by farmers concerning the effect of the line upon their lives and livelihoods, as well as testimony given by expert witnesses as to effects on health, noise levels, television and radio interference--the very information the hearings were designed to collect:

The Supreme Court again ruled in favor of the MEQB despite other additional violations of Statutory law. The panel of three of judges found the transcripts were "in substance a complete record", while citing the case of Reserve Mining Co. vs. Herbst, "Decisions of administrative agencies enjoy a presumption of correctness, and deference should be shown by the courts to the agency's expertise." The

UPA/CPA is currently under scrutiny concerning its involvement in a highly centralized energy coordination system known as the Mid-continent Area Power Pool (MAPP). MAPP is composed of fifty-five municipal, public and private electric utilities in the upper Mid-west. They have testified many times that the electricity from this line will be used by their own 33 member co-operatives and that the proposed construction was not for the purposes of profit. The UPA/CPA system plugs into the MAPP network of transmission lines, and power is sold back and forth between the members.

The licenses discussed in the previous pages have been issued by state agencies to UPA/CPA. Statutes require that applications for these permits contain a "statement of ownership of the line and an affidavit that the applicant is authorized to act on behalf of the owner."¹² Mn. RCF Sec. 19.01 also requires that the conditions under which those who are subject to services shall be joined as a party in the action. UPA/CPA has signed a contract committing their line for use by other MAPP members. This contract calls for fees for the use of the line. The voting system within MAPP allows CPA only 6% of the vote. And there is no limitation on use of the line by members of MAPP only.

This brings us to the most publicized of all the illegalities--those alleged to have been committed by the people protesting this line. These people are defending the right of all persons to health, safety, and control over their own lives. They are in direct conflict with those few who intended to build a powerline for their own interests. Those few are supported by the courts, the government, and the law enforcement officials. The conflict has only just begun, the powerline will not be built, and the people of western Minnesota will emerge victorious!!

Footnotes:

- 1) Cert. of Need Hearings Dec. 4, 1975
- 2) Supreme Court Powerline Decision 1977.
- 3) Cert. of Need Hearings Dec. 4, 1975.
- 4) Supreme Court Powerline Decision 1977.
- 5) Mn. Statute 116C.55 subd. 2.
- 6) " " 116C.55, .58, .59, .06, .60, 15.0419.
- 7) Supreme Court Decision 1977. p. 45.
- 8) Ibid
- 9) Mn. Stat. 116 C.06, subd. 2, 116C.50, 15.0418, 15.0419, 15.0421.
- 10) Docket No. CU-TR-1
- 11) Mn. Stat. 116C.6 1
- 12) Mn. Reg. MEQB (g) (2).

Biological Effects of Static and Low-Frequency Electromagnetic Fields: An Overview of United States Literature

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Prepared by

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**BIOLOGICAL EFFECTS OF STATIC AND
LOW-FREQUENCY ELECTROMAGNETIC FIELDS:
AN OVERVIEW OF UNITED STATES LITERATURE**

EPRI EA-490-SR

Special Report

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FOREWORD

As part of its program of research on biological effects of electric fields, EPRI is sponsoring research on large animals at the BATTELLE Pacific Northwest Laboratory. A parallel project using small animals is being sponsored by ERDA at the same location. Together these two efforts make the research study the largest ever performed in this field.

In preparation for a visit of Soviet scientists also performing research in this area, the Principal Investigator of this study, Dr. Richard D. Phillips, and his colleague, Dr. William T. Kaune, were asked to prepare an overview of United States literature on biological effects of electromagnetic fields at powerline frequencies. This review appears on the following pages. Both the ERDA and EPRI project managers believed that this brief and timely overview would be of sufficient interest to warrant early publication as a joint EPRI/ERDA document.

W.E. Feero, Project Manager
ERDA

H.A. Kornberg, Project Manager
EPRI

PREFACE

This document was prepared for the US/USSR Scientific Exchange Program, Problem IV, Topic 2 on the Biological Effects of Static and Low-Frequency Electromagnetic Fields. The purpose of the exchange is to evaluate current knowledge and to develop cooperative research programs with the Soviet Union to assess the possible health hazards of exposure to static and low-frequency electromagnetic fields. Following an exchange of national literature surveys, of which this document is a part, there will be an exchange of visits by experts of both countries. Six experts from each country will then meet in a joint workshop to review the state of knowledge and current research on this topic and propose a cooperative research program to solve unanswered problems. The cooperative research program proposed at the joint workshop will be initiated in 1978.

Both authors are participants in the Exchange Program, Topic IV.2, and are being provided support by the Electrical Energy Systems Division of Conservation, Energy Research and Development Administration. Funds to prepare this report were provided by the Energy Research and Development Administration and the Electric Power Research Institute.

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BIOLOGICAL EFFECTS OF STATIC AND LOW-FREQUENCY
ELECTROMAGNETIC FIELDS: AN OVERVIEW OF UNITED STATES LITERATURE

by

Richard D. Phillips and William T. Kaune

INTRODUCTION

There has been a rapid growth of power and communication systems in the United States over the last several decades and this growth is expected to continue. With this growth there has been an increasing level of static and low frequency electromagnetic fields to which people and other life forms may be exposed. Recently, questions have been raised concerning possible deleterious effects of exposure to such fields. Of particular concern has been the large electric, low magnetic fields in the vicinity of power transmission systems and the small electric and magnetic fields produced by communication systems. In recognition of this concern and need for definitive information, a number of new research projects have been initiated to assess the potential biological effects of static and low-frequency electromagnetic fields. The goal is to supplement our current knowledge and obtain a scientifically sound data base for establishing reliable and valid exposure limits in order to insure public safety and health.

Several major symposiums and reviews of the literature on the biological effects of static and low-frequency electromagnetic fields have been published in recent years (Bridges, 1975a,b; Sheppard and Eisenbud, 1977; Liboff and Rinaldi, 1974; Llaurodo, Sances and Battocletti, 1974; Persinger, 1974; Kornberg, 1976; Bridges, 1977; Antoian, 1977; Benedick and Greenberg, 1974). These symposiums and reviews cover a broad area of research interests, ranging from interactions of biological systems with naturally occurring electromagnetic fields arising from atmospheric electricity and geomagnetism to biological responses to directly applied electrical currents. The scope of this overview will be more limited; it will focus on past and ongoing research in the United States concerned with the biological effects of static and low-frequency electromagnetic fields produced by power transmission systems and low-frequency communication systems. The fields produced by these systems, particularly by the power transmission systems, are the highest 60-Hz fields to which people and other life forms may be exposed.

POWER TRANSMISSION SYSTEMS

60-Hz Electromagnetic Fields

There are currently more than 40,000 circuit miles of overhead AC (60 Hz) transmission lines in the United States operating at extra-high voltages (EHV), 345 to 765 kV (Anon, 1975b). Typical values of the maximum vertical electric fields at 4 feet above ground level under EHV transmission lines range from 5 to 9 kV/m (Bridges, 1975a; Anon, 1974;

Anon, 1975b; Bracken, 1976). The corresponding ground level magnetic fields do not depend on the transmission line voltage but on the line current, spacing between phases, and height above ground. At midspan under a typical 765-kV transmission line, the ground level 60-Hz magnetic field is about 0.3 Gauss for a current of 2000 amperes in each phase (Bridges, 1975a).

The total current induced by the electric field between ground and a man standing in electrical contact with ground, known as the short-circuit current, is about 16-20 $\mu\text{A/kV/m}$ (Anon, 1975b). Magnetic fields produce circulating electric currents in the body with the current density reaching its maximum value near the surface of the body (Guy, 1976). Based on estimates from calculations on models, the current density from the magnetic field at the hips of an erect man under a 765-kV transmission line ($E = 9 \text{ kV/m}$, $B = 0.3 \text{ Gauss}$) would be about 10% of the current density induced by the electric field (authors).

The situation is somewhat different in EHV switchyards where the electric fields are not uniform and can range from typical values of 2 to 9 kV/m (Anon, 1975b) to as high as 14.6 kV/m (Miller, 1974). Total body currents induced in switchyard workers and live line maintenance workers can be appreciably higher than those occurring in persons standing under transmission lines (Barnes, 1967; Miller, 1967).

Appreciable research has been conducted on the induction of currents in humans and animals by 60-Hz electric fields (Anon, 1975b; Bracken, 1976; Barnes, 1967; Deno, 1975; Miller, 1967; Anon, 1972a; Anon, 1972b; Deno, 1977; Phillips, 1976a; Kouwenhoven, 1966). Induced currents from

transmission lines are too low to represent a serious shock hazard. At least 5 mA are required to produce a shock which is disabling and 60 mA or more is needed to cause fibrillation of the heart in adult humans (Keesey and Letcher, 1970). Currents of this magnitude would flow through the body only in fields greater than 350 kV/m and 4 MV/m, respectively (Deno, 1977). Several reports have summarized the effects of AC shocks on humans and animals (Reilley, 1977; Dalziel, 1968), and the subject will not be reviewed in this paper.

Secondary shocks, or spark discharge shocks, resulting from touching objects at different potentials have been studied by a number of investigators (Anon, 1975b; Bracken, 1976; Anon, 1972a; Phillips, 1976a; Reilley, 1977). Although such shocks are not life threatening and do not appear to produce permanent harm, they may produce a general stress response with repeated experiences which could account for some of the biological effects of electric field exposures reported in the literature.

Exposure to high-strength 60-Hz electric fields can produce nerve stimulation, due to piloerection and hair oscillation, and a tingling at the body surfaces next to clothing. These sensations become annoying to a small percentage of people starting at field strengths of about 8-10 kV/m (Zaffanella, 1972; Anon, 1975b). It has been suggested by several scientists that some of the reported biological effects of 60-Hz electric fields, particularly in furred animals, may be responses to this hair stimulatory effect (Bridges, 1975a, 1977; Antoian, 1977; Kornberg, 1976).

good.

In 1962 studies were initiated by the American Electric Power Company on safety practices, field intensities, body currents and working environments related to high voltage transmission lines. In one of these studies medical examinations were conducted over a 9-year period on 11 linemen working on 138 and 345 kV transmission lines (Kouwenhoven, 1967; Singewald, 1973). Four of the men regularly worked on live lines while wearing conducting clothing and gloves, exposing their heads to 60-Hz electric fields up to 470 kV/m. The other men worked mostly with hot sticks and were exposed to maximum fields of 70 kV/m. During the period, seven extensive medical examinations were conducted at Johns Hopkins Hospital. No significant changes of any kind were found.

As part of the research program sponsored by the American Electric Power Company, a study was made (Knickerbocker, 1967) to determine whether exposure of mice to high-strength 60-Hz electric fields over a long time period affected reproductive ability or produced tissue damage. Twenty-two male mice were exposed to 160 kV/m for 6.5 hours/day, 5 days/week, for 10.5 months. An equivalent number of animals was sham exposed. All exposed and sham exposed male mice were bred to nonexposed virgin females during the nonexposure periods. Exposure to the electric field had no effect on reproductive ability. Body weights of the exposed and control mice did not differ. Gross and microscopic pathological studies made at the end of the experiment showed no relevant lesions. The only observed effect of electric field exposure was that the male progeny of the exposed animals had a lower body weight than male progeny of control animals. No differences were observed in the female progeny.

Few other studies were made in the 1960s to assess the biological effects of 60-Hz electric fields on experimental animals. Moos (1964) examined the effects of 60-Hz fields at 0.8 to 1.2 kV/m on activity of mice. In a series of five experiments involving alternating exposure (field-on) and control (field-off) periods ranging from 1 day to 1 month, Moos reported mice were more active during the dark period with the field on than with the field off. Results of daylight activity between field-on and field-off conditions were not consistent. In a second study, Moos investigated the effect of electric field exposure on the mortality response of mice previously treated with 900 R of ionizing radiation. No significant effect was observed.

good

In a recent study (Marino, 1976a) mice were allowed to mate, gestate and rear their offspring for three successive generations while being exposed to 60-Hz electric fields. Mice exposed to 15 kV/m vertical electric fields exhibited decreased body weights at 35 days postpartum and increased mortality rates during the first week after birth for three successive generations. Mice exposed to 10 kV/m horizontal electric fields exhibited decreased body weights for two successive generations but not increased mortality rates. The authors suggested the depressed body weights and increased mortality rates may have resulted from the microcurrents the animals experienced during exposure while eating and drinking.

comes from adrenal gland

In another study (Marino, 1976b) body growth, serum proteins and serum corticosterone levels were measured in rats after continuous exposure to vertical, 60-Hz electric fields at 15 kV/m for 30 days. In

Serum albumin was lower in the exposed rats. Serum corticosterone levels of exposed rats appeared to be lower than levels in controls in three experiments, but no measure of variance was made to allow an estimate of significance. When exposed animals were subjected to cold stress, the serum corticosterone levels in both experimental and control groups rose markedly and equally. This suggests the exposed animals were not suffering from the general adaption syndrome as a result of chronic exposure to a nonspecific stressor.

Marino et al. (in press) reported on a total of 10 experiments which suggested exposure of rats to vertical, 60-Hz electric fields at 15 kV/m for 30 days may result in decreased corticosterone levels, increased serum albumin and serum glutamic oxaloacetic transaminase, increased pituitary and adrenal weights, decreased water consumption and decreased body weights. However, only the decrement in water consumption was regularly demonstrated, suggesting the animals may have received shocks or perceived current flow when they drank during exposure. The other results were inconsistent.

Gann and LaFrance (1976) examined the cardiovascular response of dogs to controlled bleeding (10 ml/kg over 3 minutes) after a 5-hour exposure to 60-Hz electric fields at 15 kV/m. The cortisol secretion response to ACTH was not affected by exposure to the electric field. Several cardiovascular changes were observed at the end of the bleeding. Mean arterial pressure fell 5.9 mm Hg in the control group and 16.0 mm Hg

in the exposed group. Arterial pulse pressure fell 0.9 mm Hg in the control group and 10.9 mm Hg in the exposed group. Heart rate decreased about 9 beats/min in the control group but increased about 57 beat/min in the exposed group.

Several studies have been made on the effects of 60-Hz electric fields on in vitro preparations. Bassett and Herrmann (1968) reported an increased DNA and collagen production in cultures of fibroblast cells exposed to 100 kV/m. Gann and LaFrance (1975) exposed cultures of rat subcutaneous areolar cells to 60-Hz electric fields at 200 and 600 kV/m. Cell morphology and regenerative rates were not affected in the cultures exposed to 200 kV/m, but growth stopped and the cells died in the cultures exposed to 600 kV/m within 7 days after the start of exposure. Durfee et al. (1975) found cell growth was inhibited in cultures of embryonic chicken fibroblasts exposed to 60-Hz electric fields at 1 and 10 V/m. A similar inhibitory effect was observed in embryonic chicken kidney cells exposed to 60 Hz at 1 V/m, but not at 10 V/m. Growth rates of cultures exposed to 75 Hz at 1 V/m were also inhibited, but at 10 V/m growth rates were enhanced in both types of tissue cultures.

Several surveys of limited scope have been made to examine the influence of 60-Hz electric fields from EHV transmission lines on farm crops and animals. Busby et al. (1974) questioned 18 farmers on land near a 765 kV line. Responses by the farmers indicated no alterations in crop productivity, cattle, hogs, or in dairy production of grazing animals could be attributed to the electric fields from the transmission

line. Ware (1974) surveyed 125 farmers on land near a 765-kV transmission line and 116 reported no problems related to the grazing of their animals.

There is currently a lack of unanimity by U.S. scientists as to whether or not 60-Hz electric fields associated with transmission lines produce any adverse biological effects. Results from earlier studies are somewhat conflicting and contradictory. The need for additional biological research to clarify the situation has been recognized. This fact, in conjunction with the development of ultra-high-voltage (UHV) transmission systems capable of transmitting power at 1100 to 1500 kV, has led to the initiation of a number of new research projects to obtain definitive answers concerning possible health hazards of these low-frequency electromagnetic fields.

A major research project is in progress at Pennsylvania State University to investigate the ecological influence of electric fields. A number of experiments have been made to evaluate the effects of 60-Hz electric fields on meadow voles and birds (Bankoske, 1976). Exposure of meadow voles to 50 kV/m for 4 weeks had no effect on body weight, activity, behavior, or on the progeny of exposed voles born both during and after the exposure period. Results of the avian studies were mostly negative. Short-term exposures of developing chicken embryos to fields as high as 67 kV/m had no significant effect on hatchability, time to hatch, hatching weight, early weight gain, activity or gross behavior. Chronic exposure of newborn chicks to 40-80 kV/m for 8-22 days had no effect on growth or

electroencephalogram (EEG) patterns. Activity of chicks was found to be depressed for about 1 week after removal from a 22-day exposure to 40 and 80 kV/m. A transitory enhanced growth rate was observed in male chicks during a 20-day exposure to 40 and 80 kV/m, but no significant effect on weight was observed at the end of the exposure period. Similar results were reported by Krueger et al. (1972) where body weights of chicks exposed to 3.4 kV/m at 60 Hz or 3.6 kV/m at 45 Hz did not differ from controls at the end of a 28-day exposure period.

In another study by Krueger et al. (1975a), fecundity of chicken was investigated after males and females had been exposed to 60-Hz electric fields at 16 kV/m for 84 days. Egg production was reduced in exposed hens. No effect was observed in fertility, hatchability, gross embryonic morphology, sex ratios, or egg shell quality.

Durfee et al. (1975) exposed chicken eggs to 60- and 75-Hz electric fields at 1, 10 or 3600 V/m throughout the holding and incubation period. No significant effects were observed on hatchability, embryonic mortality, memory consolidation or posthatching body weights.

Carter and Graves (1975) exposed chicks to 60-Hz electric fields at 0, 40 or 80 kV/m continuously from 1 day after hatching until 22-24 days after hatching, at which time electroencephalograms (EEG) and electrocardiograms (ECG) were made. Detailed evaluation of the EEGs did not disclose any significant differences among treatment groups. Heart rates of birds exposed to 40 or 80 kV/m were significantly higher than those of unexposed controls, with the 80 kV/m group having a significantly higher rate than the 40 kV/m group. The authors also investigated the heart rate

response of the birds to auditory stimuli, a broody hen call and a 500 Hz tone, but no clear differences in responses among treatment groups were evident.

Three major research projects have recently been started at Battelle, Pacific Northwest Laboratories. One project is concerned with possible ecological effects of a 1100-kV transmission line test facility and the other two projects are laboratory studies designed to investigate the biological effects of 60-Hz electric fields on small and large animals. In the small animal study (Phillips, 1976b), a large multidisciplinary research team is conducting a comprehensive series of screening experiments on rodents to cover areas of hematology, serum chemistry, immunology, central nervous system function and structure, neurophysiology, animal behavior, endocrinology, pathology, bone structure and function, cardiovascular function, metabolism, prenatal and neonatal growth and development, and teratology. The large animal project (Phillips, 1976c) will involve continuous exposure of miniature swine to 60-Hz electric fields over several generations with routine measurements made relative to reproduction, growth and development, behavior, hematology and serum chemistry. In addition, any effects observed in the small animal study will be evaluated in the miniature swine.

Several experiments of the Battelle studies have been completed. Acute exposure of swine to large 60-Hz electric fields produced no gross behavioral effects (Phillips, 1976a). A field of 50 kV/m produced hair stimulation (piloerection and hair oscillation), and preliminary data was obtained that indicated swine may perceive the presence of electric fields at 30-35 kV/m. In the small animal studies (Phillips, al., 1977),

heart rate measurements were made on rats after exposure to 60-Hz electric fields at 80 kV/m for 8 hours/day for 5 days. No effect was observed at the end of 8 or 40 hours of exposure. In another experiment it was found that rats spend more time in the shielded (unexposed) side of a two-compartment shuttle box than in the unshielded (exposed) side at fields of 90, 105 and 130 kV/m, but no side preference was observed at lower field strengths.

Several other research projects have been initiated recently to evaluate possible biological effects resulting from exposure to 60-Hz electric fields (Kornberg, 1976). The effects of electric fields on bee behavior and honey production under natural conditions are being studied. An epidemiological study of health of linemen and switchyard workers is now in progress. Another research group is investigating the effects of electric fields on cardiac pacemakers implanted in nonhuman primates. Scientists at the Brain Research Center in Los Angeles are investigating the effects of 60-Hz electric fields on animal behavior and on central nervous system function. A study at Battelle is being made to examine genetic effects of 60-Hz and static electric fields on bacteria and fruit flies.

It is anticipated that results of these and other studies will help clarify the current uncertainties about the possible biohazards of electric fields and provide the baseline data needed to establish criteria for safe exposure limits for humans and other life forms.

Static Electric Fields

Electrical power in the United States is transmitted primarily at 60 Hz. The only EHV direct current (EHV-DC) transmission system currently

in operation is the ± 400 kV Celilo-Sylmar Intertie between northern Oregon and southern California. Little meaningful biological research has been conducted that simulates exposure to such a system. Factors in addition to the static electric and magnetic fields must be considered, such as ion currents, air ions, and possibly ozone. Studies are in progress at Bonneville Power Administration to characterize EHV-DC systems for subsequent biological investigations (Bracken, in press).

Several biological studies concerned with electrostatic fields have been published. Lott and McCain (1973) investigated the effect of a static electric field at 10 kV/m on the EEG and hypothalamic electrical activity of rats as indices of the animal's perception of the field. During exposure EEG activity increased and posterior hypothalamic activity appeared to *govern* decrease. No significant effects were noted in ECGs, respiratory function *all vital* or rectal temperature. *signs*

Marino et al. (1974) exposed groups of rats for 30 days to static electric fields at 0.3 to 19.7 kV/m. Vertical (0.6-19.7 kV/m) or horizontal (0.3-9.8 kV/m) exposures had no effect on growth rate or final body weight. Changes were reported in the serum protein fractions of rats exposed to vertical fields: albumin was elevated in groups exposed to 2.8, 5.6 and 19.7 kV/m; alpha and gamma globulin fractions were depressed in the group exposed to 19.7 kV/m; beta globulins were elevated in the groups exposed to 5.8 and 19.7 kV/m. It is not known if these changes are significant, since measurements were made from pooled blood samples and no estimates of population variability could be made. The authors also noted an unexpected

incidence of secondary glaucoma in animals exposed to vertical fields. This glaucoma only affected the right eye and was not observed in controls or in the group exposed to horizontal fields. It is possible the secondary glaucoma could have developed from pre-existing uveitis commonly found in a small fraction of laboratory rats.

In another experiment (Marino, 1974), female mice were injected with Erhlich ascites tumor cells and then exposed to horizontal static electric fields at 8 to 11 kV/m for 14 days. More chromosomal abnormalities in tumor cells were observed in exposed than in control mice. No host animal cells showed chromosomal abnormalities.

There is a need for additional research on the possible bioeffects of exposure to static fields, particularly with respect to exposure to DC transmission systems. For the latter studies potential sources of bioeffects need to be identified and appropriate exposure systems need to be designed to simulate in the laboratory the environment under an EHV-DC transmission line.

COMMUNICATION SYSTEMS

Considerable biological research has been conducted in conjunction with the development of an extra-low-frequency (ELF) communication system known as Project Sanguine. The system will transmit signals at 45-75 Hz from a grid antenna system buried in the earth. The electric field strength in the ground and air above the antenna grid is about 0.07 V/m, decreasing with distance from the grid. The magnetic fields above the lines are about 0.13 Gauss. A detailed description of the antenna system has been reported by Baker (1974).

Although the electric and magnetic fields that would be produced by this communication system are small, there has been considerable concern about possible effects on biological and ecological systems. A comprehensive research program to assess possible bioeffects of exposure to low-level electromagnetic fields at low frequencies was started in 1968 and still is in progress. Rozzell (1974) has summarized the research program, and results from studies completed to date have been compiled into three large volumes (Anon, 1975a, 1977a) and also have been summarized (Anon, 1977b).

An abbreviated summary of research studies and results on physiology, growth and development, behavior, genetics and biochemistry is given in Tables I-V.

Except for the studies by Coate et al., (1970) and Noval et al., (1976), no effects were observed in the physiology studies (Table I). The only significant effect observed by Coate et al. was a higher lactation index in the second generation of the exposed group than in the control group. The meaning of this difference is unclear. In the study by Noval et al. (1976), exposed rats gained weight at rates 20-30% slower than controls and had less abdominal fat. Reduced choline acetyltransferase in the brain stem and elevated liver tryptophase pyrrolase were also noted in the exposed animals. Mathewson et al. (1977) were unable to confirm these findings in a subsequent study.

Coate et al. (1970) investigated the effects of low frequency electromagnetic fields on germination, growth and development of corn, buckwheat and sunflowers. Although no effects were found on corn or buckwheat,

seedling growth of sunflowers was retarded (Table II). Rosenthal et al. (1975) repeated the experiment with sunflowers and were unable to confirm the results of the earlier study.

A series of experiments have been made on the response of the slime mold Physarum polycephalum to 60- and 75-Hz electromagnetic fields (Table II). The time interval between successive mitotic divisions of exposed cultures was appreciably longer than that of controls after 90-120 days of exposure (Goodman, 1975, 1976a; Marron, 1975). Sexual and asexual life cycles were not affected, but a retardation in reversible protoplasmic streaming was observed. Apparently the changes were not permanent; cultures removed from the electromagnetic field recovered in about 30-50 days. Additional studies were made at lower field strengths, five- and twenty-fold weaker, and no effects were observed.

In another experiment, Goodman et al. (1976b) investigated mitotic rate, protoplasmic streaming, respiration in microplasmodia, and glucose transport across the cell membrane of Physarum polycephalum exposed to 45-, 60- and 75-Hz sinusoidal or modulated 76-Hz electromagnetic fields at 0.14-0.7 V/m and 0.4-2 Gauss. They found the mitotic cycle was lengthened, the shuttle streaming period was slowed, and the rate of respiration was depressed. Also, modulated fields appeared to induce the alterations sooner and at lower intensities than sinusoidal waves.

No behavioral effects have been observed in rats, pigeons or primates exposed to 45-75 Hz electromagnetic fields at strengths up to 100 V/m and 10 Gauss (Table III). However, some marine animals do perceive electric fields in water at about 10-20 V/m (Coate, 1970). Turtles that perceive such fields will leave the field area and fish orient their bodies to

minimize the head-to-tail potential difference (Coate, 1970). The perception threshold for amoeba is about 500 V/m at 1-100 Hz (Friend, 1975). Significant membrane disturbances occur at twice this level, and the amoeba starts to become elongated in a direction perpendicular to the applied field at levels above 1000 V/m. Other marine animals, such as shrimp, snails, crabs, scallops, etc., perceive current densities between 1-50 mA/cm², depending on the species and frequency of the field (Straub, 1972). McCleave et al. (1974) found that Atlantic salmon (Salmo salcer) and American eels (Anguilla rostrata) detect ELF electric fields at 0.007-0.07 V/m but not magnetic fields at 0.5 Gauss. Neither activity nor circadian rhythm were altered by electromagnetic fields at these levels.

Gavalas-Medici et al. (1970, 1976) demonstrated a frequency-dependent effect of electromagnetic fields on schedule-controlled behavior of primates. The interresponse times of monkeys in lever press responses in an operant behavioral task were significantly shorter and less variable during exposure to 7-Hz fields at 10 V/m than during no field (unexposed) time periods. No effects were observed at any frequencies tested at 1 V/m, nor at 60 nor 75 Hz at 10 V/m. The effect at 7 Hz appeared to be dose dependent, with higher field strengths producing even shorter interresponse times. At 56 V/m, a significantly shorter interresponse time was observed at 75 Hz, but not at 60 Hz.

In an early study, Coate et al. (1970) reported an increased sex-linked lethal mutation rate in fruit flies exposed to low frequency electromagnetic fields (Table IV). Subsequent studies by Bender (1976) and Mittler (1971, 1972) failed to confirm this finding. No cytogenetic effects were observed in bacteria (Coate, 1970) or plants (Miller, 1976).

Bawin and Adey (1976) exposed in vitro preparations of cat and chick brain tissues to 6-75 Hz electric fields at 5-100 V/m for 20 minutes and observed a reduced calcium efflux at 6 and 16 Hz. Thresholds were about 10 and 50 V/m for chick and rat tissues, respectively.

Several studies have been made to evaluate possible effects of electromagnetic fields on human psychobiology and performance. In one study (Beischer, 1973) 10 subjects were exposed to 1 Gauss at 45 Hz for periods up to 24 hours. A large battery of physiological and psychological tests were made throughout the study. No effects were seen except for elevated serum triglycerides in 9 of the 10 exposed subjects at 24 to 48 hours after the exposure period. Similar trends were not seen in any of the 5 control subjects. In a second study (Gibson, 1974) psychomotor performance tests were made on human subjects exposed to 1 Gauss at 45 Hz for 24 hours. There were no significant performance decrements attributable to the exposure.

A number of studies and surveys have been made at the Sanguine Test Facility in Wisconsin over the last 9 years to evaluate possible effects of the electromagnetic fields on the ecosystem in the area. No adverse effects have been produced on plants (McCormick, 1971; Rosenthal, 1976b), soil arthropods or annelids (Greenberg, 1972, 1973, 1974a), local birds or mammals (Seale, 1976), nor on wood lice, redworms, earthworms, slugs or red-backed salamanders (Greenberg, 1974b, 1976). A clinical evaluation was made on personnel working at the Sanguine Test Facility and no effects attributable to the electromagnetic fields were found (Krumpe, 1974).

Some effects on bird orientation were noted on pigeons (Graue, 1974), ring-billed gull chicks (Southern, 1975) and migrating birds (Williams, 1976). Pigeons and some migrating birds changed their flight orientation slightly when close to the energized antenna.

CONCLUSIONS

Based on a long history of experience with electric fields by the utility industry, it appears that intermittent and repeated exposures to strong 60-Hz electromagnetic fields from present power transmission systems have no obvious adverse effect on the health of man. It has been recognized recently that this belief must be tested by carefully designed and executed experiments under laboratory conditions where precise control can be exercised over coexisting environmental factors. A number of studies have been initiated in response to this need to evaluate possible effects from both acute and chronic exposures.

Considerably more attention needs to be paid in future studies to the details of the interactions of an animal and its environment with applied electric fields. For example, it has now been shown that rats individually housed in close proximity to each other can have their short-circuit currents reduced by about 35% due to mutual shielding (Phillips, 1977). The possibility of transient discharges between an animal and its watering system has existed in many past studies. In addition, substantial steady-state 60-Hz currents may pass between certain kinds of watering systems and a drinking animal. Watering systems must be designed to eliminate these artifacts, reducing these currents as much as possible and quantitatively documenting

any residual current. Animal exposure systems must be carefully designed and surveyed to insure that they are free of corona discharge and ozone formation. Finally, one must be alert for the possibility of stress-induced biological effects due to hair stimulation or other forms of electric field perception; the mechanisms of these phenomena and their physiologic effects have yet to be fully elucidated.

All past experiments exposing animals to electric fields have been characterized by simply reporting the unperturbed field strength; that is, the field strength with no animals present. In many cases, details of how this quantity was determined were not given. However, the electric field strength at the surface of the body is the relevant quantity for determining the induced currents and fields inside the body and for understanding surface phenomena such as hair stimulation. This quantity depends not only on the magnitude of the unperturbed field but also on the shape of the animal body and its orientation with respect to the applied field. Since the shape and orientation of an erect human in a given field is very different from that of a laboratory animal, detailed measurements of the perturbed field and induced currents in the animal must be made before results obtained with that species can be translated to the human situation.

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TABLE 1. Summary of Physiology Research

Test Subject (Investigator)	Electromagnetic Field			Exposure Time	Parameters Examined	Results
	Electric (V/m)	Magnetic (Gauss)	Frequency (Hz)			
Dogs (Coate, 1970)	10, 20 plus 0.5 mA current	1, 2	45, 75	16 h/d, 5 d/w, for 3 weeks	Behavior, body weight, EEG, ECG, testis, eyes, clinical chemistry, hematology, pathology, body temperature, blood pressure	No effect
Rats (Coate, 1970)	10, 20	1, 2	45, 75	16 h/d, 5 d/w, for 3 weeks	Fertility, reproduction and development	Increased lactation index exposed rats in second generation
Rats (Noval, 1976)	0.1-100	--	45	30-40 d	Body weight, brain and liver enzymes	Reduced growth rate, reduced amount of abdominal fat, reduced choline acetyltransferase (brain stem) and elevated liver tryptophane pyrrolase
Rats (Mathewson, 1977)	0-100	--	45, 60	28 d	Body weight, hematology, serum chemistry, pathology	No effect
Mouse (Krueger, 1975)	100	--	45, 75	to 36 d	Body weight, blood chemistry, susceptibility to virus infection	No effect
Mouse (Beischer, 1975)	--	1	45	1-7 d	Body weight, liver weight, liver tri- glycerides, behavior, pathology	No effect
Primate (Grissett)	20	2	72-80	1 yr +	Body weight, blood chemistry, ECG, EEG, body temperature, respiration rate, blood pressure	No effect to date. Study still in progress.

FUEL SUPPLY FOR THE COAL CREEK GENERATING STATION
OF
THE COOPERATIVE AND UNITED POWER ASSOCIATIONS

By

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The environmental impact of high voltage lines

LOUISE B. YOUNG and H. PEYTON YOUNG

"Man may soon enter an era of energy pollution of the environment comparable, in public health and ecological implications, to the chemical pollution of today."

This prediction was made in a report to Congress by the White House Office of Telecommunications Policy in May 1974. The principal sources of the energy pollution described in this report are radio and television transmitters, radar installations, microwave ovens, and electrical power lines. Of all these sources, electric power lines have received the least attention and, considering the thousands of miles of extremely high voltage lines which are now being planned for the near future, this source of energy pollution should receive immediate and careful consideration.

The largest transmission lines that are being built and operated today carry 765,000 volts (765 kilovolts) and lines are under development that will carry 1,500 kilovolts and even 2,000 kilovolts. There are two important health hazards associated with these lines: (1) air pollution resulting from chemical reactions that take place in the corona discharge, and (2) electromagnetic effects, particularly the strong electric field that exists in the vicinity of these lines. This article will consider only the latter problem. The first is very interesting and important, but is so complex that it should be dealt with separately in another article [1].

Extremely high voltages—carried on bare, unshielded conductors—pass overhead in many places no more than 40 feet above roads and farms and cause very strong electrostatic fields in the space around these lines. There is a very high voltage difference between one point in space and another point, say a meter away. The potential difference between these two points may be as high as 50,000 volts under a 765 kilovolt line. This alternating electrostatic field in air induces 'charging currents' in all objects near the line. There are small but continuous currents running through the ground, the plants, the rocks, the farmer on his tractor.

The presence of the electric field can be dramati-

cally demonstrated by walking in the vicinity of a transmission line holding an ordinary fluorescent bulb. The bulb will light up without cords, but without metallic connections to ground, and this will occur at a considerable distance off the right-of-way. Many people have their back to their gardens, and the fields where they work many hours a day in regions where light bulbs will light up in your bare hand.

What does it do to living things to spend a great deal of time in such intense electric fields as are subjected to electric currents running continually through them? Considering the importance of the question, one might assume that it had been thoroughly investigated by the power companies before such lines were built. But a search of the scientific literature reveals that this subject has not been adequately studied. The few research papers that have been done show that there are probably profound effects caused by these fields.

About 10 years ago when American utility companies were starting to use extra-high-voltage transmission, two studies were conducted by the power companies. In one experiment they exposed male mice to strong electric fields for 6½ hours a day over a 10½ month period [2]. These mice were bred at regular intervals with females that had not been exposed. The number and size of the progeny produced were considered to be measures of latent effects which might have been passed on to the exposed fathers. The average size of the progeny was found to be significantly smaller than normal. It was also noted in the report that the exposed mice tended to sleep more than the control mice. On the basis of these findings, the scientists recommended that further studies be conducted, but no follow-up studies have been reported in the literature.

It is a significant fact that in this experiment the female and baby mice were never exposed to the electric fields. Fetuses and very young animals are known to be especially sensitive to radiation. Furthermore, since each mating involved one animal that had not been exposed, any recessive genetic changes due to the electric field would have been masked by genes that had not been affected by exposure.

The other study conducted by the power com-

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FUEL SUPPLY FOR THE COAL CREEK GENERATING STATION
OF
THE COOPERATIVE AND UNITED POWER ASSOCIATIONS

It is indeed a pleasure for me to speak to you today regarding the fuel supply for the Coal Creek Generating Station being built by the Cooperative and United Power Associations near Underwood, North Dakota. The CU project is an exciting story about the coal and electric power industries working together to solve a critical national problem -- the energy shortage -- through research, new technologies, financial innovation, and imaginative management. The North American Coal Corporation and The Falkirk Mining Company are proud to be a part of this project.

The entire fuel requirements of the Coal Creek Generating Station will be provided by The Falkirk Mining Company under a Coal Sales Agreement which was executed with the Cooperative and United Power Associations on July 1, 1974. This Agreement provides for the delivery of up to 6 million tons of coal annually over a 35-year term, with production commencing in 1978.

The Falkirk Mining Company is an Ohio corporation qualified in North Dakota, and is a wholly-owned subsidiary of The North American Coal Corporation, which is based in Cleveland, Ohio. North American is the second largest independent mining company and the ninth largest coal producer in the United States.

Since 1967, North American's Indian Head Mine near Beulah,

North Dakota, has produced the entire fuel requirement of the UPA's generating plant near Stanton, North Dakota, via daily unit train shipments.

Today, I will outline the activities and progress of The Falkirk Mining Company, as well as the financial and management techniques being employed to provide the fuel supply to the Coal Creek Generating Station. Furthermore, since Falkirk's operations in North Dakota reflect the coal industry's Western activities, I will also briefly survey the promise and problems associated with this Western coal development and how we are working to solve them.

Let's begin by looking at the reasons why we are in North Dakota together.

The United States Bureau of Mines estimates that 44 per cent of the nation's total recoverable coal deposits underlie the three Northern Great Plains States of North Dakota, Montana, and Wyoming. We estimate that North Dakota alone has about 25 billion economically surface-mineable tons of coal with today's technology.

Our current national energy shortage is stimulating coal development on the Northern Great Plains. The United States, with only 6 per cent of the world's population, consumes about 35 per cent of the global energy output. The shortage of domestic oil and natural gas, which increases our dependence on imported oil, continues to worsen despite reduced total energy demand resulting from the economic recession. It must be pointed out, however, that while the recession lowered energy use; economic recovery will boost it.

The national interest clearly dictates the need to shift our energy base from gas and oil to coal and nuclear. And with atomic power's delays and uncertainties, coal -- our most abundant energy source -- has become vital. Coal deposits comprise 88 per cent of our United States indigenous energy reserves. Yet, the coal industry supplies only 18 per cent of our current energy needs. Clearly, coal's role is due to expand dramatically -- particularly in the West.

National Electric Reliability Council figures show that between 1950 and 1973 coal consumption by utilities has escalated from 100 to 375 million tons. The Council projects that utilities will need 700 million tons by 1983. The National Coal Association shows total coal demand leveling out at 1.5 billion tons by 1985. Because of Federal air quality standards and coal industry economics, the West must supply much of this coal.

Eastern and Midwestern electric utilities cannot obtain sufficient quantities of low-sulphur coal from Appalachia. To meet pollution control regulations, steam coal users must blend lower-sulphur Western coals with established high-sulphur Eastern supplies.

Further, coal industry costs are skyrocketing in the East. The Federal Coal Mine Health and Safety Act of 1969 has typically increased underground mining costs \$2.50 to \$3.00 per ton. Its effect on Western surface mining has been negligible.

Western surface-mined coal also has the advantage of being capital intensive rather than labor intensive. Of the total cost of thin-seamed

Eastern underground-mined coal, 50 to 60 per cent is comprised of labor costs. This compares to 20 to 35 per cent labor-related costs for Western surface-mined coal. While the productivity of typical Western surface mines is 100 to 130 tons per man per day, the productivity of the typical Eastern underground mine is only 8 to 15 tons of coal per man per day.

You may ask why it is advantageous to be capital intensive rather than labor intensive. First, wage and benefit increases repeatedly won by labor have increased the cost of Western surface-mined coal by only half the cost increase for Eastern underground mined coal. This margin continually widens with the passage of time because of the labor intensiveness of Eastern underground mining. Furthermore, most Eastern underground-mined coal is produced from operations which have been organized by the United Mine Workers of America. In my opinion, this Union has brought unwarranted disorder to the industry. To wit, my Company alone lost over one million tons of production in 1974 at our Ohio and Pennsylvania operations due to illegal, unauthorized wildcat strikes by the UMWA. To put this lost tonnage figure into perspective, our Company produced only 11.3 million tons of coal during the year. This Union must accept its responsibilities to manage and govern its membership. Four major coal companies, including North American, recently filed suit in Federal court to make the UMWA International Union immediately liable for all illegal future strikes at any of our mines.

Within this context, new coal utilization technologies -- extra

high voltage electrical transmission, gasification, liquefaction, solvent refining -- are also contributing to making coal's Western move possible. Until recently, North Dakota's lignite could only meet local needs. Its high moisture content and resultant low heating value makes it impractical for shipment to distant markets. Now extra high voltage transmission (particularly DC) and coal gasification are close to reality. The transporting of Western coal to distant markets in railroad cars and barges will rapidly become obsolete. Gasified coal in pipelines or electrified coal via wire is the Western coal marketing concept of the immediate future. This will make Western coal competitive with other fuels over wide sections of the United States.

At North American, we are basing our growth on the development of these new coal utilization technologies. North American and its subsidiaries -- The Coteau Properties Company and The Falkirk Mining Company -- currently have under lease over 300,000 acres of proven, economically-mineable North Dakota lignite reserves. These reserves are currently estimated to contain about four billion tons of coal, much of which is earmarked for gasification by the American Natural Gas Company.

The developments in North Dakota represent a new direction for North American and signal the change within the coal industry. More than 90 per cent of our production last year originated from underground mines in Ohio and Pennsylvania. Since 1967 we have been producing only slightly

more than one million tons annually in North Dakota. As you know, at that time our Indian Head Mine began supplying the United Power Association's generating station near Stanton, North Dakota.

When coal gasification and extra high-voltage transmission become realities, North American's operations in North Dakota will be the major factor in our Company. This development, however, cannot be fully realized without the solution of many complex problems.

What are our problems? Some we share with other industries, such as material shortages. We face long delivery lead times. For example, two large excavator manufacturers are now building five 100-yard draglines for us, and yet we cannot receive delivery of the first of these machines until 1978.

Accompanying the critical need for capital equipment is an equally critical skilled labor need. Competent technicians in every phase of this specialized industry are in extremely short supply.

The availability of skilled labor is not the only labor problem which could deter the development of the coal deposits of the Northern Great Plains. Large labor unions, such as the United Mine Workers of America, the International Union of Operating Engineers, the International Brotherhood of Electrical Workers, and Progressive Mine Workers, have their sights on coal development in the West, which has been relatively free of labor strife.

Our Indian Head Mine, which is located some 30 miles west of the