Health Physics, Vol. 41 (August), pp. 267–277, 1981
Printed in the U.S.A.

0017–9078/81/080267–11$02.00/0
Pergamon Press Ltd.

ENVIRONMENTAL POWER-FREQUENCY MAGNETIC FIELDS AND SUICIDE*

F. STEPHEN PERRY
Albrighton, near Wolverhampton, England

MARIA REICHMANIS† and ANDREW A. MARINO
Veterans Administration Medical Center, Irving Avenue and University Place, Syracuse, NY 13210

and

Department of Orthopedic Surgery, SUNY Upstate Medical Center, Syracuse, New York

and

ROBERT O. BECKER
Department of Orthopedic Surgery, SUNY Upstate Medical Center, Syracuse, New York

(*Received* 7 *May* 1980; *accepted* 12 *November* 1980)

Abstract—We studied the relationship between power-frequency magnetic fields and locations of suicidal deaths in 1969–76 in the West Midlands, England. We found a significant correlation between suicide locations and the measured power-frequency magnetic field strength. Significantly more suicides occurred at locations of high magnetic field strength.

INTRODUCTION

THERE is increasing evidence that environmental power-frequency electric and magnetic fields—60 Hz in North America and 50 Hz in Europe—can produce biological effects in subjects exposed to them. Kouwenhoven found that 2 of 11 workers who serviced high-voltage transmission lines had reduced sperm counts (Ko67). Two Soviet studies found a number of neurological and cardiovascular disorders in high-voltage switchyard workers (As66; Sa67). Knave found that fewer children were born to exposed high-voltage workers than to the controls, and that the difference increased with the number of years of exposure (Kn79). Roberge reported that prior to commencement of employment, 56 high-voltage workers had approximately equal numbers of male and female offspring, whereas, of children conceived thereafter, the number of males born was almost 6 times the number of females (Ro76). Recently, a relationship was found between overhead transmission lines and childhood cancer (Wer79).

Definitive relationships between low-frequency electric and magnetic fields and biological effects have been established in controlled laboratory studies. Wever found that subjects living in shielded bunkers had circadian rhythms different from those of subjects living in non-shielded bunkers (Wev74). The difference was eliminated by a field of 2.5 V/m at 10 Hz. Beischer observed a significant increase in serum triglycerides in 9 of 10 subjects 1–2 days after exposure to a magnetic field of

*This work was supported in part by the National Institute of Environmental Health Sciences, Dept. of Health, Education and Welfare, the Environmental Protection Agency, and the Veterans Administration.

†Author and address for correspondence.

1 gauss at 45 Hz (Be73). Grissett found that a similar field altered the body weight of monkeys following 1 yr's exposure (Gr77).

A major facet of the potential public-health problem posed by environmental electric and magnetic fields is the dearth of knowledge concerning the mechanisms of interaction between the fields and biological systems. This makes it difficult to identify appropriate parameters for study because the fields do not seem to produce specific signature diseases. In addition, there is as yet no definitive evidence for an exposure threshold—either in duration or field strength—for the onset of biological effects, nor has the degree to which these effects constitute a human health hazard been determined. This being the case, pilot studies of various public health indices, such as disease prevalence and mortality, are an appropriate means of identifying factors warranting more detailed investigation, including full-scale epidemiological studies.

During the course of a general medical practice in England, one of us (FSP) observed an apparent connection between depressive mental illness and proximity to high-voltage transmission lines. The investigation of such questions is generally hampered by the unavailability of statistics regarding the incidence of particular mental illnesses. But reliable records for suicides were available, and we therefore undertook a pilot study of the relation between suicide and overhead high-voltage lines. In a 4863 km^2 section of the Midlands of England we found a correlation between the calculated electromagnetic field of such lines and the occurrence of suicide (Re79). The question of whether more or less than the expected number of suicides occurred at locations where the fields were more intense could not be resolved.

The total environmental power-frequency field at any particular location contains contributions from many sources, including high-voltage and low-voltage lines, household wiring, and electrical appliances. This led us to hypothesize that measured fields might exhibit a more definitive link with suicide. The results presented here show that more than the expected number of suicides occurred at locations where the 50 Hz magnetic field was more intense.

METHODS

As before (Re79), the study area consisted of the County of Shropshire, the Mid-Staffordshire Health District, the Parish of Burntwood in Staffordshire and the Metropolitan Boroughs of Wolverhampton, Walsall and Dudley (Fig. 1). Between January 1969, and mid-October 1976, a total of 651 suicide verdicts were reached in this area by the coroner. From the records of the coroners and the police we obtained the following data for each suicide case: date of death; full name; age; occupation; sex; address; and method of suicide. We included in this study only those suicide deaths which occurred to individuals who had resided in the study area for more than 14 days—a total of 598. Pertinent statistical data regarding this group are given in Tables 1–3.

We were interested solely in comparing the measured magnetic field strength at the addresses of the suicides to that measured at the locations of a suitable control group. We were not concerned with how suicides, as individuals, differed from the general population. Since only two of the suicides were under 18 yr of age at their next birthday, the appropriate control group was a random sample of the addresses of the adult population of the study area (Ma70). Voter registration in Great Britain is conducted by a door-to-door canvass within each election district, so that Parliamentary and Local Government Electoral Registers are a virtually complete census of the addresses of the adults residing in the district (Wh77). We therefore used these to derive a series of control addresses; these were chosen at random such that they equalled the number of suicide addresses in each geographical area shown in Fig. 1.

Putative differences between suicides, as individuals, and the general population needed to be considered only insofar as these might affect their choice of residence: suicide victims have personality traits different from the general population which might influence their housing preference. Such individuals may, for example, prefer to live in high-rise apartment buildings more or less often than other persons. Any difference in magnetic field between the suicide and control ad-

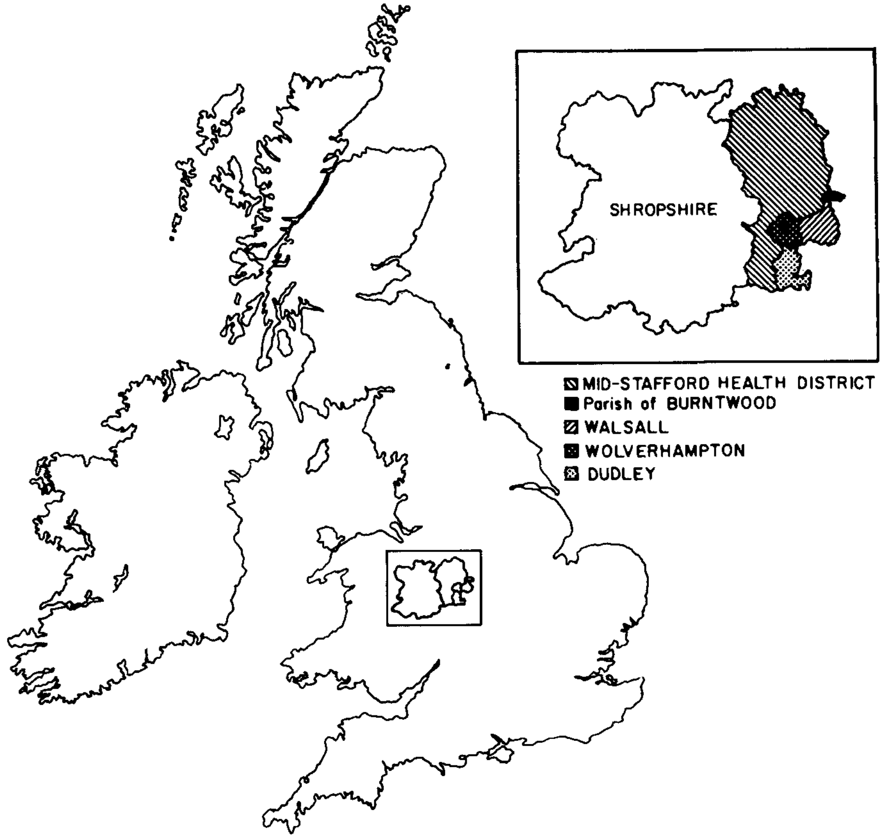

FIG. 1. Study area.

Table 1. Resident suicide verdicts in the study area by sex and year. The study period was 93-1/2 months

Year	Male	Female
1969	45	28
1970	42	28
1971	53	27
1972	43	40
1973	51	34
1974	45	23
1975	44	38
1976 (to mid-Oct.)	42	15
Total	365	233

Table 2. Resident suicide verdicts in the study area by sex and age

Age (years)	Male	Female
15 - 24	30	16
25 - 34	34	20
35 - 44	61	21
45 - 64	149	103
65+	91	73
Total	365	233

Table 3. Resident suicide rates in the study area

Sub-Area	Mean Population (1969-1976)	Number of Suicides	Mean Annual Suicide Rate per Million
Shropshire	345,967	209	77.5
Mid-Staffordshire	301,613	89	37.9
Wolverhampton	268,250	110	52.6
Walsall	271,125	102	48.3
Dudley	296,000	88	38.2
Whole Study Area	1,482,955	598	51.8

dresses might reflect this hypothetical difference in choice of residence, and thus be merely a result of the differences in personality between suicides and the population at large. In order to explore this possibility we classified the addresses in each group as follows: commercial (shop, hotel); institutional (hospital, nursing home, school, military camp); residential (house); residential (apartment); or farm. There were no significant differences between the suicide and control addresses in the resulting distributions (Table 4).

Additional characterizations of the distributions of the addresses with respect to various geographical features were feasible. On large-scale maps (1 mm = 25 m), we plotted the 598 addresses in each group. In a few cases where the deceased resided in a large building or group of buildings such as a hospital or college, the center point of the complex was plotted. We then measured the distances from addresses in both groups to the nearest of each of four prominent features displayed on the maps: schools; major roads; churches; and open water (pond, lake, stream, river, canal, reservoir or well). There were no difference between the distributions for each group with respect to any of the features examined (Table 5). Based on the evidence described, we concluded that there was no difference in geographical distribution or type of housing between the suicide and control addresses. Thus, while we cannot completely foreclose the possibility that suicides may preferentially choose different types of housing than the general population, the available evidence is against this.

Magnetic field measurements were made using a Polytek FB-100 field meter which had a sensitivity of better than 10 μgauss. Each reading was made at 0.5 m from the front door of the residence at 1 m above the ground.

Table 4. Distributions of the Types of Addresses in the Suicide (N_S) and control (N_C) groups among the following categories: House, Apartment, Farm, Commercial (shop, hotel) and Institutional (hospital, nursing home, military camp, school). While there were slightly more farm and institutional addresses in the suicide group, the distributions were not significantly different ($\chi^2 = 5.916$, $p > 0.20$)

Type of Address	N_S	N_C
House	554	559
Apartment	18	22
Farm	14	8
Commercial	2	5
Institutional	10	4
Total	598	598

Table 5. Distributions of suicide (N_s) *and control* (N_C) *addresses in the study area, with respect to distance from the nearest* (a) *school*; (b) *church*; (c) *major road*; *and* (d) *open water. In no case were the distributions significantly different*

A.

Distance to Nearest School (meters)	N_C	N_S
> 1,000	77	92
900 - 999	14	16
800 - 899	18	19
700 - 799	25	21
600 - 699	37	45
500 - 599	57	53
400 - 499	70	56
300 - 399	99	89
200 - 299	98	114
100 - 199	76	72
0 - 99	27	21
Total	598	598

B.

Distance to Nearest Church (meters)	N_C	N_S
> 1,000	64	74
900 - 999	15	14
800 - 899	20	24
700 - 799	25	20
600 - 699	38	40
500 - 599	71	66
400 - 499	60	62
300 - 399	84	77
200 - 299	99	98
100 - 199	97	90
0 - 99	25	33
Total	598	598

C.

Distance to Nearest Major Road (meters)	N_C	N_S
> 1,000	46	53
900 - 999	16	14
800 - 899	11	14
700 - 799	11	9
600 - 699	25	23
500 - 599	35	39
400 - 499	52	38
300 - 399	60	59
200 - 299	75	76
100 - 199	130	125
0 - 99	137	148
Total	598	598

D.

Distance to Nearest Open Water (meters)	N_C	N_S
> 1,000	0	2
900 - 999	5	4
800 - 899	5	3
700 - 799	12	5
600 - 699	30	30
500 - 599	31	30
400 - 499	60	52
300 - 399	62	79
200 - 299	120	144
100 - 199	162	157
0 - 99	111	92
Total	598	598

All of the 1196 addresses (598 suicides and 598 controls) were visited. At 8 of the suicide and 4 of the control addresses the residence could not be positively identified and these 12 addresses were dropped from the study. Thus magnetic field measurements were made at 590 suicide and 594 control addresses—a total of 1184 locations. Because the flow of current through the distribution system fluctuated at different times of the year, of the week, and of the day, the suicide and control addresses were visited alternately (Table 6). As can be seen, the magnetic field measurements for each group were made equally with respect to the month of the year and the time of day. Because domestic current consumption rises on weekends, the slightly larger percentage of control measurements made on Saturdays and Sundays would have tended to bias the results against a finding that the magnetic field was higher at the suicide addresses. There were no significant differences between the two groups as regards the times at which the measurements were made.

RESULTS

The magnetic field strength measurements ranged from 10 to 15,000 μgauss, with a mean of about 800 and a median of about

Table 6. Times of measurement of the magnetic field strength. There were no significant differences between the suicide and control addresses ($P > 0.05$ m χ^2). (a) By months of the year (1979). (b) By days of the week. (c) By hours of the day

A. By Months of the Year (1979).

Month	Number of Addresses Suicides	Controls
Feb. - Mar.	100	100
April	200	198
May - June	290	296

B. By Days of the Week.

Day	Number of Addresses Suicides	Controls
Weekdays (M-F)	390	372
Weekends	200	222

C. By Hours of the Day.

Time	Number of Addresses Suicides	Controls
0800-1200	169	177
1200-1600	231	228
1600-2000	190	189

400 μgauss. The data were not normally distributed, so, for analysis, we arranged the values for both the control and suicide groups in order of magnitude of measured magnetic field strength, and performed several independent tests on the resulting distributions.

We found that 305 of the 590 suicide measurements fell above the median of the combined groups, compared to 257 of the 594 control measurements, implying that the magnetic field strength at the suicide addresses was greater than that at the control addresses ($p < 0.02$, extended median test, Table 7).

A large-sample two-tailed Mann-Whitney U-test (corrected for tied data) also indicated that the field strength at the suicide addresses was significantly greater ($U = 196{,}651.5$ for $z = 3.66$, $p < 0.0002$).

We divided the data into 11 groups (Wa43); the resulting population within each group is listed in Table 8. We found that the distributions of suicide and control addresses were significantly different by a χ^2 test ($p < 0.001$).

Even though the data were not normally distributed, it was appropriate to perform a t-test to examine the magnitude of the effect (Di57; Me73; Sn67). The mean and S.D. for the suicide addresses, 867 ± 1320 μgauss, was significantly higher than that of the controls, 709 ± 1110 μgauss ($p < 0.5$, 2-tailed t-test).

Table 7. Numbers of measured field strength values falling above and below the median of the combined suicide and control groups. There were significantly more suicide than control measurements above the median ($p < 0.01$, χ^2 test with continuity correction)

	Number of Addresses	
	Suicides	Controls
Above Median	278	232
At Median	54	51
Below Median	258	311
Total	590	594

Table 8. Distributions of suicide and control addresses with respect to measured magnetic field strength. The distributions are significantly different ($p < 0.001$, χ^2 test). Cells equal to or greater than 1 but less than or equal to 5 may be used in computing χ^2 under the conditions applicable here (Di57; Co52). The distributions are significantly different, however, even if such cells are not allowed (if the last two lines of the table are combined, $\chi^2 = 31.9$, $p < 0.001$)

Magnetic Field (microgauss)	Number of Addresses	
	Suicides	Controls
0 - 199	38	65
200 - 399	220	173
400 - 599	97	125
600 - 799	55	73
800 - 999	32	51
1000 - 1199	28	21
1200 - 1399	22	15
1400 - 1599	26	12
1600 - 1799	7	6
1800 - 1999	4	1
$\geq$ 2000	61	52
Total	590	594

Several possible transformations of the original data ($x^{1/2}$, x^2, $1/x$, $\sin^{-1} x$, $\ln x$) all showed significant differences between the two groups. Of these, $\ln x$ best approximated a normal distribution. The mean of the natural logarithm of the field strength at the suicide addresses, 6.20 ± 0.97, was higher than that of the control group, 6.00 ± 0.87 ($p < 0.001$, 2-tailed t-test).

All tests indicated that there were more suicide than control addresses at higher magnetic field strengths. To further examine this, we defined "very high" and "high" magnetic fields as those fields above 1500 and 1000 μgauss respectively. If magnetic field strength were not related to suicide, the numbers of suicide and control addresses within these ranges would not differ, but in each case they did (Table 9). The proportion of suicides found in the high field and very

Table 9. Numbers of suicide and control addresses with "very high" (≥1500 μgauss) and "high" (≥1000 μgauss) measured magnetic field strength. There were more suicide than control addresses in both cases ($p < 0.01$, high field; $p < 0.05$, very high field; χ^2 test with continuity correction)

Group	Magnetic Field Strength (Microgauss)			
	Very High Field		High Field	
	≥1500	<1500	≥1000	<1000
Suicides	93	497	148	442
Controls	67	527	107	487

high field regions was 40% greater than the corresponding proportion of controls (0.251 vs 0.180, high field; 0.158 vs 0.113, very high field).

DISCUSSION

Significantly more suicides than expected occurred in the higher magnetic field strength ranges (Tables 7–9). This effect could not be ascribed to different housing preferences among suicides as compared to the general population: as we noted earlier, the available evidence indicates that there were no differences in geographical distribution or type of housing between the suicide and control addresses. We believe this to be the first demonstrated correlation between human behaviour and environmental power-frequency fields.

The median value of the measured field strength was about 400 μgauss, while the median of the calculated fields arising solely from overhead high-voltage transmission lines was about 50 μgauss (Re79). These data suggest that low-voltage wiring and/or household appliances were the principal source of the environmental magnetic fields.

Low-frequency magnetic fields have been linked to childhood cancer (Wer79), altered human behaviour (Gi74), and elevated serum triglycerides—both in a survey of exposed workers (Pr73) and in a follow-up laboratory study (Be73). Low-frequency magnetic pulses of precisely tailored electrical characteristics—rise-time, peak amplitude, decay rate, duty cycle—have been used experimentally in the successful treatment of bone disorders (Ba77), and are now in clinical use. Thus the impact of low-frequency magnetic fields can be very broad, involving the major organ systems, including bone and the cardiovascular and nervous systems. This suggests that different physical or cellular mechanisms of interaction may be operative under the various conditions of exposure. For now, we think that the most fruitful approach to the understanding of field-induced biological effects involves the stress hypothesis (Se50): the field acts as a biological stressor, eliciting a systemic reaction which depends on, among other factors, individual predisposition and the presence of other stressors (Ma79; Ma80a; Ma80b). The stress hypothesis is less mechanistic than typical biophysical theories, but yet sufficiently broad to embrace the known field-induced effects.

It is enlightening to consider, at least to a rough approximation, the strength of the internal fields induced by the external magnetic fields which we measured. Let us model a human being as a sphere of tissue with radius r (more appropriate geometries do not significantly alter the following analysis). An external magnetic field of magnitude B and angular frequency ω will induce a maximum electric field inside a human being of

$$E = \omega r \mathrm{B}/2.$$

The earth's magnetic field is of the order of 0.5 gauss, but has zero angular frequency and thus induces no internal electric field. Our median measured magnetic field, however, will result in an internal electric field of about 0.94 mV/cm (assuming a radius of 1.5 m).

Two controlled laboratory studies have shown that applied low-frequency electric fields of 3.5–4.0 V/m can alter behaviour in humans and monkeys (Ha68; Ga70). Employing the spherical model, it can be shown that the maximum induced electric field—now the coupling is capacitive, as compared to the inductive coupling in the case of the applied magnetic field—is of the order of 3×10^{-4} mV/cm (assuming a conductivity of 0.1 μ/m). Thus the induced electric field present inside the suicide victims was greater than that associated with established behavioural effects. Because many other laboratory studies could be similarly cited (Ma77), calculations such as these clearly establish the plausibility of a biological impact of low-frequency magnetic fields of the order of 400 μgauss, based on the existence of biological effects found under controlled conditions which produced equivalent internal electric fields.

The magnetic field measurements were made outside each residence, which may have resulted in a narrower range of value than was actually present. The highest measured field was about 15,000 μgauss, but, for example, fields near typical household appliances such as hair dryers and television sets are on the order of 10^6–10^8 μgauss (Fa72). These fields are not, however, representative of chronic exposure. Considering that the magnetic fields present in the working environment are even greater, it seems clear that further studies, focussed on individuals routinely exposed to high magnetic fields, are warranted.

Compared to the natural background, the present ambient electromagnetic environment has been thoroughly altered by modern power and communications systems. This makes it impossible to establish disease baselines with respect to which the true impact of these fields could be ascertained, thus rendering assessment of the public-health impact of environmental electromagnetic fields very difficult. The situation is further complicated because it appears certain that such fields act upon the organism systemically, with the outward manifestations—change, effect or disease—largely determined by individual predisposition. Despite this, we found a correlation between environmental power-frequency magnetic fields and suicide; this suggests that the impact of such fields may be considerable.

Any population will include some individuals less capable than average of adaptation to environmental fields. Although we remain uncertain as to the physiological impact of these fields—and of any protective adaptation mechanisms which may have developed—we consider that our findings, in conjunction with other reports of the vehavioural and physiological effects of low-frequency electric and magnetic fields, indicate a need to take the electromagnetic environment into account when designing new public facilities such as hospitals—particularly those offering long-term care for psychiatric disorders.

Our study area was mix of both urban and rural regions, which tends to enhance the degree to which our results might be indicative of the situation in other areas, at least in industrialized countries. We must, however, caution against a too generalized interpretation of our results. This pilot study clearly demonstrates an association between environmental power-frequency magnetic field strength and suicide, but equally clearly, more detailed, large-scale epidemiological studies will be needed before any definitive conclusions can be drawn regarding the degree of this relationship and its public-health significance.

Acknowledgements—We wish to thank H. M. Coroners, the Police and the Staffs of the Local Authority Planning Departments in all regions of our study area for the very great assistance given to us from 1976 onwards. We wish also to acknowledge the ready co-operation of the Central Electricity Generating Board (Midland Region) and the Midlands Electricity Board during the earlier stages of our investigation.

REFERENCES

As66 Asanova T. and Rakov A., 1966, "The State of Health of Persons Working in the Electric Field of Outdoor 400 kV and 500 kV Switchyards", *Gig. Tr. Prof. Zabol.* **10**, 50–53. (Available from IEEE, Piscataway, NJ, as Special Publication 10.)

Ba77 Bassett C. A. L., Pilla A. A. and Pawluk R. J., 1977, "A Non-operative Salvage of Surgically-resistant Pseudarthroses and Non-unions by Pulsing Electromagnetic Fields", *Clin. Orthop. Rel. Res.* **124**.

Be73 Beischer D. E., Grissett J. D. and Mitchell R. E., 1973, "Exposure of Man to Magnetic Fields Alternating at Extremely Low Frequency", Naval Aerospace Medical Research Laboratory, Pensacola, Rep. 1180. (Available from NTIS as Ad 770140.)

Co52 Cochran W. G., 1952, "The χ^2 Test for Goodness of Fit", *Ann. Math. Stat.* **23**, 315–345.

Di57 Dixon W. J. and Massey Jr., F. J., 1957, *Introduction to Statistical Analysis*, 2nd End (New York: McGraw-Hill).

Fi72 Final Environmental Impact Statement for the Sanguine System: Fact Sheet, 1972, Department of the Navy, Washington, D.C.

Ga70 Gavalas R. J., Walter D. O. and Adey W. R., 1970, "Effect of Low-level Low Frequency Electric Fields on EEG and Behaviour in *Macaca Nemestrina*", *Brain Res.* **18**, 491–495.

Gr77 Grissett J. D., Kupper J. L., Kessler M. J., Brown R. J., Prettyman G. D., Cook L. L. and Griner T. A., 1977, "Exposure of Primates for One Year to Electric and Magnetic Fields Associated With ELF Communications Systems", Naval Aerospace Medical Research Laboratory, Pensacola, Rep. 1240.

Ha68 Hamer J. R., 1968, "Effects of Low-level Low Frequency Electric Fields on Human Reaction Time", *Commun. Behav. Biol.* **2A**, 217–221.

Kn79 Knave B., Gamberale F., Bergstrom S., Iregren A., Kolmodin-Hedman B. and Wennberg A., 1979, "Long-term Exposure to Electric Fields", *Electra* **63**, 41–54.

Ko67 Kouwenhoven W., Langworthy O., Singewald M. and Knickerbocker G., 1967, "Medical Evaluation on Man Working in AC Electric Fields", *IEEE Trans. Power Appl. Sys.* **PAS-86**, 506–511.

Ma70 MacMahon B. and Pugh T. F., 1970, *Epidemiology: Principles and Methods* (Boston: Little & Brown).

Ma79 Marino A. A., Cullen J. M., Reichmanis M. and Becker R. O., 1979, "Power Frequency Electric Fields and Biological Stress: A Cause and Effect Relationship", in: *Biological Effects of Extremely Low Frequency Electromagnetic Fields* (Edited by R. D. Phillips, M. F. Gillis, W. T. Kaune and D. D. Mahlum), pp. 258–276 (Washington, DC: U.S. Dept. of Energy).

Ma77a Marino A. A. and Becker R. O., 1977, "Biological Effects of Extremely Low Frequency Electric and Magnetic Fields: A Review", *Physiol. Chem. Phys.* **9**, 131–147.

Ma77b Marino A. A., Berger T. J., Austin B. P., Becker R. O. and Hart F. X., 1977, "*In Vivo* Bioelectrochemical Changes Associated with Exposure to Extremely Low Frequency Electric Fields", *Physiol. Chem. Phys.* **9**, 433–441.

Ma80a Marino A. A., Reichmanis R., Becker R. O., Ullrich B. and Cullen J. M., 1980, "Power Frequency Electric Field Induced Biological Changes in Successive Generations of Mice", *Experientia* **36**, 309–310.

Ma80b Marino A. A., Cullen J. M., Reichmanis R. and Becker R. O., 1980, "Sensitivity to Change in Electrical Environment: A New Bioelectric Effect", *Am. J. Physiol.* in press.

Me73 Mendenhall W. and Scheaffer R. L., 1973, *Mathematical Statistics With Applications* (N. Scituate, MA: Duxbury Press).

Pr73 Proceedings of the Ad Hoc Committee for the Review of Biomedical and Ecological Effects of ELF Radiation, 1973, Dept. of the Navy, Washington, DC.

Re79 Reichmanis M., Perry F. S., Marino A. A. and Becker R. O., 1979, "Relationship Between Suicide and the Electromagnetic Field of Overhead Power Lines", *Physiol. Chem. Phys.* **11**, 395–404.

Ro76 Roberge P. F., 1976, Study of the Health of Electricians Assigned to the Maintenance of Hydro-Quebec's 745 kV Stations, Hydro-Quebec, Montreal, Canada.

Sa67 Sazonova T., 1967, "A Physiological Assessment of the Work Conditions in 400 kV and 500 kV Open Switchyards", in *Scientific Publications of the Institutes of Labor Protection of the All-union Central Council of Trade Unions*, Issue 46, Profizdat. (Available from IEEE, Piscataway, NJ, as Special Publication 10.)

Se50 Selye H., 1950, *Stress* (Montreal: Acta).

Sn67 Snedecor G. W. and Cochran W. G., 1967, *Statistical Methods*, 6th Edn, (Ames, IA: Iowa State Univ. Press).

Wa43 Waugh A. E., 1943, *Elements of Statistical Method* (New York: McGraw-Hill).

We79 Wertheimer N. and Leeper E., 1979,

"Electrical Wiring Configurations and Childhood Cancer", *Am. J. Epidemiol.* **109**, 273–284.

Wev74 Wever R., "ELF-effects on Human Circadian Rhythms", in: *ELF and VLF Electromagnetic Field Effects* (Edited by M. A. Persinger), pp. 101–144, (New York: Plenum Press).

Wh77 *Whitaker's Almanack*, 1977 (London: Whitaker).