

# A LETHAL SUBTLE ENERGY

E. Stanton Maxey, M.D.

### ABSTRACT

Throughout history epidemiology has often provided effective ways of limiting the spread of infectious diseases before their causes became known. Epidemiological studies from many countries now indicate a link between the 50 and 60-Hz electromagnetic fields (EMFs) which accompany electric power delivery and cancers of the blood, brain and breast. Subtle EMFs of only 0.3 to 2 milligauss (mG) are implicated. Significant EMFs occur in 60-Hz systems due to multiple grounding. Electric codes have stipulations against "objectionable" ground currents. Means of measuring, correcting and avoiding subtle but lethal EMFs are presented.

**KEYWORDS:** Cancer, leukemia, lymphoma, central nervous system, astrocytoma, melatonin, electromagnetic fields, EMFs, milligauss, ground currents, electricity, electrophysiology, bioelectromagnetics, power lines, epidemiology

*The fuel of life is the electron, or, more exactly, the energy it takes over from photons in photosynthesis; this energy the electron gives up gradually while flowing through the cellular machinery.*

— Nobelist Albert Szent-Györgyi (1968)

**A**n exploration of lethal subtle energies may properly begin with the electron. The term's etymological root is found in the Greek word *ηλεκτρον*. It means amber and is pronounced i-lek'tron. Ancient Greeks had noticed that amber, when subjected to friction, disturbed dust particles. The amber, having become negatively charged with a surplus of electrons, attracted particles of positive charge and repelled the negative. These phenomena are due to the presence or absence of electrons. Webster defines the electron as a subatomic particle with a negative electric charge of  $1.602 \times 10^{-19}$  coulomb and a mass of about  $9.109 \times 10^{-28}$  gram. Must we not agree that the electron is genuinely subtle in both mass and charge?

No ancient, not by the wildest flight of fancy, could have dreamed of electricity as we think of it today. Can you picture a Greek of two millennia past trying to comprehend monthly electric bills? Modern electricity's history spans scarcely two lifetimes. Barely a century ago scientists were still debating whether or not electricity was an animal substance.

Electricity is now defined as:

*1. A fundamental property of matter, associated with atomic particles whose movements, free or controlled, lead to the development of fields of force and the generation of kinetic or potential energy, and 2. A current or charge of energy so generated.*

For present purposes, let us consider electricity as that flow of electrons which, via high voltage transmission lines and lower voltage distribution lines, streams into our homes and businesses. The current isn't steady. It reverses direction 60 times each second. The flow is accordingly called alternating current or AC. It is also called 60 Hertz, or 60 Hz, as a tribute to the German physicist Heinrich Hertz. Much of the electrified world uses 50-Hz instead of 60-Hz systems. Electrons flow rather like water in a pipe but, being very subtle, they pass through metallic wires of copper and aluminum. The rate of flow is measured in amperes, named after the nineteenth century French physicist André Ampère.

An ampere is defined as:

*The practical unit of current strength; such a current as would be given with an electro-motive force of one volt through a wire having a resistance of one ohm.*

Let us say that you have experimentally set up a 60-Hz one-ampere current in a metal clothes line strung between two poles in your back yard. Fields of force, both electric and magnetic, cylindrically encompass that line. Both fields diminish in proportion to increasing distance from the line. Electric fields are rather easily shielded by metal barriers and will not be dealt with further here. On the other hand, extra-low-frequency magnetic fields, such as those from 50 and 60-Hz systems, penetrate even a cast-iron bath tub with little attenuation. They freely intrude our homes and our bodies. They are biologically active at intensities of one milligauss (mG) or less. The electric clothes line will have a 1-mG field at a distance of 6.5 feet (78.744" to be exact). At thirteen feet the field will be 0.5-mG. This field-to-distance relationship is calculated from the Biot and Savart law in physics.

**W**hat is a milligauss? A *Gauss* is a unit of intensity of magnetic field. The term honors the nineteenth century German astronomer and mathematician Karl Gauss. The Earth has a natural magnetic field of about half a *Gauss*. A milligauss is a thousandth part of a *Gauss* in the same way that a millimeter is a thousandth part of a meter. Accordingly, the terrestrial magnetic field has a strength of about 500 mG. The Earth's magnetic field doesn't alternate like that from power lines. Rather, for all practical purposes, it is constant. There is, however, a very subtle modulation of the Earth's magnetic field called the Schumann resonance. Its intensity is only a small fraction of a milligauss. When recorded on a strip chart the Schumann resonance strikingly resembles a human electroencephalographic tracing.

*Research is to see what everybody else has seen and think what nobody else has thought.*

— *Nobelist Albert Szent-Györgyi (1968)*

**T**he spring of 1974 found Nancy Wertheimer, Ph.D., scrutinizing Denver's residential neighborhoods. She had obtained a list of 1950-1969 leukemia deaths for the four-county area of Greater Denver and was looking for "some kind of pattern." She noticed that death addresses were often close to utility pole transformers. Her survey showed that the leukemia rate was high for the first and second dwellings next to a transformer but decreased for the third house and was low for other neighborhood houses. That autumn a physicist friend, Ed Leeper, suggested that magnetic fields might be the culprit since they, unlike electric fields, are highly penetrating. Leeper gave Wertheimer a crude gaussmeter as a gift that Christmas. Wertheimer's account of what happened next reads like a story book.

*When I got out of my car, I walked to the base of the transformer pole at the alley entrance and switched on Ed's meter. It gave off a loud hum that indicated the presence of a fairly strong magnetic field. I was prepared for that, of course, but when I started walking up the alley, away from the transformer pole, I found that, contrary to what Ed and I had expected, the hum did not begin to diminish until I got past the next pole, at the far corner of the second house lot, from which several wires known as service drops carried current into nearby dwellings. Those were the first service drops that reduced the current load fed into the secondary distribution line by the transformer. As I continued walking past the second pole, a strange thing happened: the hum indicating the presence of the magnetic field dropped off sharply. For a while, I couldn't understand the significance of this. Then it dawned on me that the point where the magnetic field fell off coincided with the pronounced decrease in the leukemia rate I had previously observed at the third house from a transformer.<sup>1</sup>*

Nancy Wertheimer saw identical distribution patterns in both leukemia-death dwellings and high electromagnetic fields. Nobel prizes have honored less momentous observations. Wertheimer and Leeper published their paper, "Electrical Wiring Configurations and Childhood Cancer," in 1979.<sup>2</sup> The paper's import stems from its being the first epidemiological work to significantly link electromagnetic fields (EMFs) to human cancer. This seminal publication has spawned numerous confirmatory studies.

What is the nature of epidemiology? Let us take a lesson from a bit of British history. John Snow plotted death sites during an 1854 English cholera epidemic and saw that most of the dying drew water from the same Broad Street pump. Disease from water was then an outlandish idea. Robert Koch

was eleven years old when authorities shut the pump and the cholera abated. Some years passed before he identified the causative spirillum, *Vibrio comma*.

Between 1798 and 1800 Edward Jenner published three papers showing that cowpox inoculation prevented smallpox. But cowpox inoculation was practiced for more than a century before the intracellular inclusion bodies of the variola virus were described by Giuseppe Guarnieri in 1910.

Unlike the celebrated British examples, contemporary authorities have done nothing to abate EMF-related disease. Instead, they tenaciously hold that remedial action must await scientific consensus on the causative mechanism. By analogy, these authorities are waiting for a juvenile Koch to grow up and discover electricity's *Vibrio comma*, hoping to treat the bacillus rather than clean up the electric power-distribution pump. They will agreeably wait a century for Guarnieri's EMF counterpart. Additional research and prudent avoidance are advocated by bureaucratic regulators at the urging of powerful industrial lobbies.

**A**n abundance of additional research exists now. Numerous EMF epidemiological studies have appeared since 1979 and more are in progress. Here, arranged in order of decreasing magnetic field strength, are synopses of some of them:

1. New York telephone cable splicers received a mean daily EMF exposure of 4.3 mG (milligauss). They had 111% more colon cancer, 165% more leukemia, 100% more brain cancer and 145% more prostate cancer than controls.<sup>3,4</sup>
2. Children with cancer in Stockholm, Sweden, lived in dwellings with EMFs greater than 3 mG more often than controls. Females were 2.3 times and males 1.4 times more likely to live in such dwellings. Increases of 120% for leukemia, 120% for lymphoma and 420% for tumors of the nervous system were found.<sup>5</sup>
3. Los Angeles children with leukemia received 48% more exposure to EMFs above 2.65 mG than a control group.<sup>6</sup>

4. The EPA (Environmental Protection Agency), in a meta-analysis of over 300 scientific papers, noted a link between three site-specific childhood cancers and EMFs above 2 mG. The report states that there is a connection between EMF exposure and leukemia, lymphoma and cancer of the central nervous system.<sup>7</sup>
5. Denver children with cancer lived or were born in dwellings with mean EMFs of 1.7 mG twice as often as controls.<sup>2</sup>
6. Swedish rail workers exposed to 16.66-Hz fields over 25 mG had no increase in cancer while telephone and telegraph repairmen had a 100% increase in leukemia with 50-Hz mean exposure of only .05 to 0.8 mG.<sup>8</sup>
7. No increased cancer risk is observed in proximity to British 50-Hertz distribution lines. The mean EMF exposure was calculated at 0.035 mG.<sup>9,10</sup>
8. An 115% increase in lung cancer death was noted among British persons living within 14 meters of electrical installations.<sup>10</sup>
9. An increased number of large astrocytes appeared in the brains of rabbits reared in substations. Human astrocytoma (an infrequent brain cancer) occurs ten times more often in those occupationally exposed to magnetic fields than in controls.<sup>11,12</sup>
10. Male breast cancer (a very rare tumor), among 227 cases gleaned from the National Cancer Institute, occurred in electricians, telephone linemen and electric power workers *six* times more often than in a control group.<sup>13</sup>
11. The male breast cancer finding has significant implications for females. Lymphoma and cancer of the *breast*, uterus, and brain were 64% more frequent in residents with a mean EMF of 2.5 mG than among controls.<sup>14</sup>

*The exposure of living organisms to abnormal electromagnetic fields results in significant abnormalities in physiology and function.*

— Robert O. Becker

What is a safe level for EMF exposure? Physician Robert Becker is a hero. He was among the very first to recognize the biological impacts, both perils and benefits, of electrical energy. Among his many observations was the early discovery that long bone fractures healed better when subjected to weak currents. The FDA (Federal Drug Administration) approved this use of pulsed EMFs in 1979, ironically the year of the Wertheimer-Leeper report, and such therapy has now found clinical application throughout the planet. Dr. Becker recommends EMF limits of 1 mG as maximum for continuous exposure and 0.3 mG as the theoretical safe level.<sup>15</sup> One manufacturer redesigned its electric blankets in 1989, reducing EMFs 95% to 0.3 mG. Random looping was rejected in favor of placing supply and return circuit elements in close and parallel paths so that their opposing magnetic fields equalize.<sup>16</sup> Human electroencephalographic brainwave entrainment to EMFs of 0.3 mG has been observed.<sup>17,18</sup> Such considerations suggest that an EMF level of 0.3 mG or less is desirable.

The preponderance of epidemiological EMF research is directed toward links to cancer. Might there be other EMF-related disease entities? EMF links to such entities as the electromagnetic-hypersensitivity syndrome, the chronic-fatigue syndrome, autism, the fragile-*x* syndrome, the sudden infant death syndrome (SIDS), Alzheimer's disease, Parkinson's disease, depression, suicide and accelerated AIDS in HIV positive persons have been proposed.<sup>15</sup> Some forty years of medical and surgical practice lead me to believe that cancer will eventually be viewed as an EMF-linked disease, but of less numerical and fiscal significance than the mass of other EMF-linked maladies. As to health-care costs, the chronic Alzheimer patient may live, often with fecal and urinary incontinence, a mindless life lasting decades. Cancer, which kills more quickly, is in some ways more merciful and is often less costly.

**W**hat about additional research? What hypotheses on the functional mechanisms of EMF-related disease appear to warrant continued study? A lengthy consideration of causative mechanisms is beyond the scope of this paper. Nevertheless, some mention of hypotheses is appropriate. Four such appear promising: (1) disruption of cell communication, (2) cell growth mutation via changes in calcium ion flux, (3) activation of oncogenic gene sequences, and (4) disruption of hormonal and immune system controls.<sup>19</sup>

Illustrative of the first category is the report of a doubling of the abnormality rate in chick embryos subjected to repetitive  $\geq 10$ -second EMF exposures during the first 48 hours of incubation.<sup>20</sup> No difference was observed with  $\leq 1$ -second exposures. The authors, employing the principle of biological cooperativity and a mechanism of coincidence detection, proffer an elegant hypothesis that cellular response to an EMF:

*... requires simultaneous activation of several membrane sensors, thereby enabling cells to discriminate against spatially incoherent thermal noise while maintaining susceptibility to correlated external signals.*

**A**n example of the second category is found in the outstanding and extensive research on EMF-modulated calcium ion efflux from the brain by Ross Adey.<sup>21</sup> However, papers attributing cellular neoplastic mutation to calcium ion efflux have not come before me.

The story of melatonin and its hormonal role falls in the fourth category. Galen described the pineal some 2,200 years ago, believing it to be the "seat of the soul." Dictionaries circa 1940 define it as ". . . an appendage of the brain . . ., evidently a remnant of an important sense organ in ancestral forms." Melatonin was isolated from some 250,000 bovine pineals in 1958. Mark Lacy suggested melatonin's role in electron semiconduction by melanin in 1981.<sup>22</sup> Electric blankets were shown to diminish the pineal's production of melatonin in humans by B.W. Wilson in 1988.<sup>23</sup> This may explain electric-blanket-related leukemia since melatonin is oncostatic. By 1991 melatonin was recognized as a nocturnally-produced pineal hormone having a major impact on the reproductive system as well as on other endocrine and nonendocrine organs.<sup>24</sup> The pineal is no vestigial remnant. It may not be the "seat of the soul" but it does play a commanding hormonal role.

These categories fail to catch Szent-Györgyi's vision of electrons delivering cellular energy in multiple petite steps. The metaphor of the television picture tube may help. The image is painted by three fine beams of electrons whose impact on specks of phosphorescent chemical causes light emission. Magnetic fields at the neck of the tube bend the electron beams to scan an array of three different phosphors. They in turn radiate red, green and blue light. If one holds a bar magnet close to the face of the picture tube the colors and

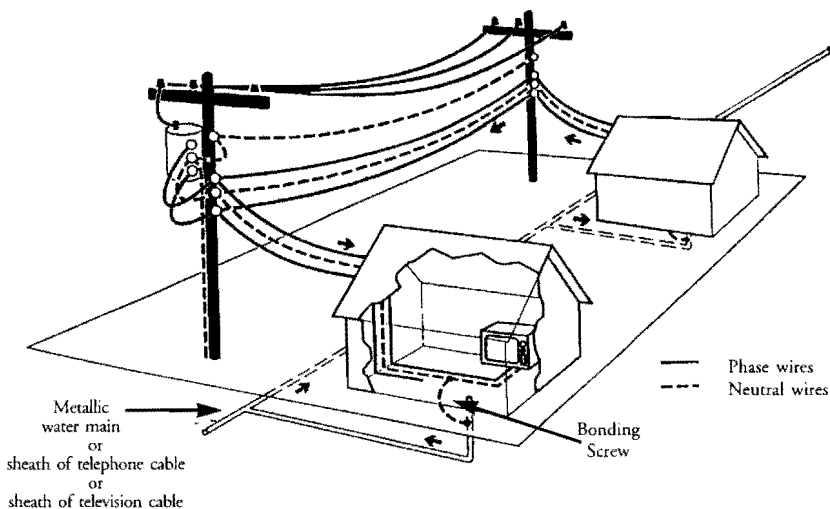


image are blurred. The field from the magnet has warped the trajectories of the electron beams so that they no longer hit the proper target phosphors. The same thing happens in our bodies. Electrons flowing through the cellular machinery are warped from their intended paths by 60-Hz EMFs.

What can be done to effect “prudent avoidance?” Twelve years have passed since the Wertheimer-Leeper report, time enough for some 10,000 children nationwide to develop EMF-related leukemia. Should we not emulate the example of the Broad Street pump and act upon present epidemiological evidence? What can we do?

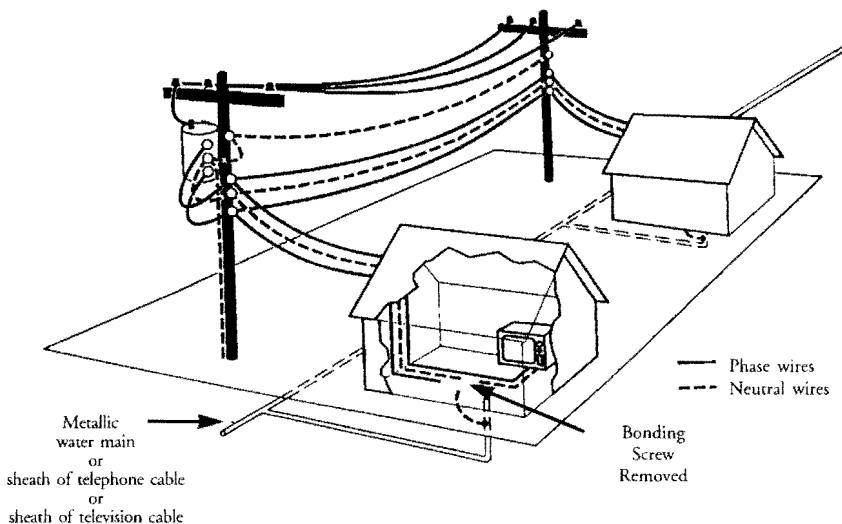
EMF detectors are essential to prudent avoidance. This physician would prescribe them for every household. Milligauss meters cost \$100 and up, kits for the hobbyist \$85 and flashing light sensors \$40. The EMFs of electrical appliances could be checked before purchase. Parents could use such instruments to locate and avoid hazardous zones; areas measuring over 1 mG near clocks, TV sets, computer monitors, microwave ovens, electric blankets and other equipment. Older children could observe EMFs at school. College graduates might consult their physics texts on Biot and Savart’s law. They could then compute the amperages in wiring and plumbing inside walls and floors from the EMFs located by these detectors. Some would remedy EMF hazards by having the bonding screw removed in their circuit-breaker panels. Others would observe hazardous EMFs from underground water, telephone, TV and electric lines. Utilities will sometimes reconfigure power lines to ameliorate the EMFs documented by customers.

**W**hy did magnetic field strength ebb after Nancy Wertheimer passed the second utility pole? Why is there increased cancer along North American 60-Hz distribution lines but not along those in British 50-Hz distribution systems? The answer to both questions is apparent from the physics of EMF generation and the disparity in grounding of the two systems. Figure 1 shows how turning on a 1500-Watt microwave oven creates a far-reaching EMF between adjacent utility poles and inside two houses. The EMF dwindles with increasing distance from radiating wires, falling to less than 1 mG beyond 39 feet. The EMF also fades after the second pole just as Wertheimer observed. Figure 2 shows how simply removing the bonding screw from a circuit breaker panel remedies the menace.



*Figure 1. An objectionable 6-ampere current flows along the arrowed ground path when the 1500-Watt microwave is on. A hazardous EMF over 1 milligauss then exists everywhere within 39 feet of the arrowed ground and utility lines. Source: Electric Power Research Institute; Schematic modifications and legend by author.*

These drawings show how the multiple grounding inherent in WYE<sup>25</sup> distribution systems produces widespread EMFs. The physics is straightforward. When supply and return lines are proximate and carry equal currents, the EMFs of supply currents nullify those of return currents. This occurs in ordinary household extension cords. The Figure 1 legend denotes the EMFs due to 50% of the return current flowing in the return line and 50% in ground paths via water, television and telephone lines. Removing the bonding screw, as seen in Figure 2, simply causes all the return current to flow along a path close to that of the supply current; the EMFs nullify. This ground-current problem is linked to 125-volt appliances. Water heaters and stoves which run at 250 volts do not generate such ground currents as neither the supply line nor the return line is bonded to ground. However, the 125-volt motor in an electric clothes dryer will act just as any other 125-volt appliance.



*Figure 2. Balanced supply and return currents of 12 amperes flow only on close and parallel paths when the bonding screw is removed. The magnetic fields of supply and return currents mutually cancel. Source: Electric Power Research Institute. Schematic modifications and legend by author.*

The British, with no 125-volt system, deliver 240-volt power mostly through buried cables having both a supply and a neutral line inside a steel sheath. The sheath is earthed extensively, but the neutral is earthed only at substations. A potential of only a few volts is expected between neutral and earth at electrical outlets. The result? Since supply and return currents follow close and parallel paths their EMFs mutually cancel.

**M**unicipalities throughout this nation franchise electric and communications utilities under either: (1) the National Electric Code of the National Fire Protection Association or (2) the National Electrical Safety Code of The Institute of Electrical and Electronics Engineers, Inc.

Both have stipulations against objectionable currents in grounding conductors (see Appendix). The meaning of the term "objectionable" is not specified in these codes. Electric utility engineers see the term as applying only to equipment and as having nothing to do with the health menace from EMFs created by ground currents. Municipal bodies have generally been unaware of this stipulation in the electric codes. Their electric inspectors are rarely alert to the EMF health hazard and few of them have ever used a milligauss meter. This must soon change.

**B**onding screws were removed from a number of apartments in a Fayetteville, Arkansas condominium complex over a year ago. The reduction in EMFs was dramatic. A city inspector examined the result. A field engineer from the Arkansas Public Service Commission did likewise. A City Director, who is also an electrical engineer, opined that removal of the bonding screws was a violation of the electric codes. Authorities of both the City of Fayetteville and of Washington County, Arkansas, have since been asked to rule on whether or not the "objectionable" current stipulation of the codes requires removal of bonding screws when the current they conduct produces EMFs over a few milligauss in dwellings. No response has, as yet, been forthcoming.

The question has vast implications. Electric codes already require the mending of a radiating ground current if the EMF menace to human health is sufficient reason to render that current "objectionable." Citizens need only demand that their governments enforce existing codes. Some readers may wish to explore the application of these sections of the electric codes in their own communities.

Ground currents occur in WYE systems in conjunction with high-voltage transmission as well as 125-volt distribution. The high-voltage supply current which feeds distribution transformers returns by two routes; neutral lines and ground paths. This is a natural consequence of multiple grounding. Water mains appear to contribute negligibly as many are non-metallic and lengths of metallic mains are often joined with non-conductive gaskets. Transmission return current flows from distribution transformers both through transmission neutrals *and* via distribution neutrals to the service drops at residences, hence through the sheaths of telephone and TV cables to distant dwellings, hence to

transformers supplying those dwellings and hence back to substations. Significant EMFs are generated all along these circuits since the supply and return ground-current paths do not approximate.

An actual example of EMFs from ground currents in a telephone cable is instructive. Arkansas Highway 265 runs in a north/south direction next to the Paradise Valley golf course in Fayetteville. A power line runs along the easterly side of this highway. Significant EMFs were observed west of the highway, not from the power line but from beneath the surface. Water mains were suspected. However, during earthwork preparatory to some new construction, the offending telephone cable was unearthed. The EMFs showed that a 60-Hz current of 2 to 3 amperes was flowing in the metal sheath of this trunk line. The EMFs from such currents could readily account for the increased cancer observed in telephone lineman and cable splicers.<sup>3,4,25</sup>

An example of EMFs from ground currents in television cables also appeared with the new construction. CATV (Cable Television) service was supplied to some 120 apartments via a cable buried in a trench traversing the golf course. The cable passes down a utility pole from an overhead feeder. Descending the same pole is the neutral of an electric utility loop. The loop energizes a series of distribution transformers which provide normal low-voltage power to some forty dwellings. Measurements at the utility pole show the television cable to be carrying four times more return current than the electric utility's neutral. EMFs of 1 mG intrude bedrooms within 79 feet of the television cable when its 60 Hz current reaches 12 amperes.

**A**n analogous situation was reported by Eugene Preston in 1988.<sup>26</sup> A primary transformer feeder carried 5.8 amperes and the neutral only 2.4 amperes. The 3.4 ampere current imbalance was being carried by a telephone cable which acted as a parallel neutral. The report states the problem lucidly:

*The common practice of solidly connecting grounds from telephone lines, cable television lines, water lines, gas lines, etc. insures that multiple return paths will upset the balance of currents in URD (Underground Residential Distribution) feeders and result in large magnetic fields.*

Such ground currents are prohibited under existing electric codes if their associated EMFs are "objectionable" because they are health hazards. Electric utilities contend that they are not. One electric utility provided a copy of REA BULLETIN 83-1, dated March 21, 1977, from the United States Department of Agriculture Rural Electrification Administration. It reads in part:

*Grounds are provided in distribution systems to relieve the system of abnormal voltages and currents, to stabilize the neutral at or near earth potential, and to provide a low impedance return circuit for a maximum degree of safety to operating personnel and the public. (emphasis added)*

**W**hy is a low-impedance return important? Some of the answer derives from fiscal concerns. Electric utilities purchase electric power and distribute it over their own systems. Some 5% to 15% of the purchased power is lost through heat because of the resistance in electric lines. Lowering the resistance lowers this line loss. A low-impedance return lowers the line loss by lowering the return resistance. The lowered line loss achieved by using ground return circuits makes delivery of electricity more efficient and thus more profitable. The case reported by Eugene Preston achieved a 29% reduction in line loss for the power utility.

*We must guard against both of the prevalent forms of electrophobia: Type A, typified by an unreasonable fear of electromagnetic fields and Type B, characterized by an unreasonable fear of knowledge of the effects of electromagnetic fields.*

— C.J. Montrose

## CONCLUSIONS

1. Our planet's natural electromagnetic environment was instrumental in the evolution of all life on Earth.
2. Electric power has dramatically altered man's electromagnetic environment during the last century.
3. The EMFs of electric power delivery are epidemiologically linked to a high incidence of cancer afflicting principally the blood, brain and breast.

4. The EMFs coincident with 60-Hz power delivery arise mainly from the divergent paths of return currents caused by multiple grounding of neutrals.
5. "Objectionable" ground currents are prohibited under existing electric codes if the cancers associated with 60-Hz EMFs are objectionable.
6. Continuous exposure to EMFs above 1 mG is probably hazardous and below 0.3 mG is probably safe.
7. Milligauss meters are essential to the "prudent avoidance" of hazardous EMFs.
8. Prolonged exposure to EMFs of a few mG is probably less menacing than smoking two packages of cigarettes a day.

CORRESPONDENCE: E. Stanton Maxey, M.D., F.A.C.S. • 2811 Joyce Street • Fayetteville, AR 72703

#### REFERENCES AND NOTES

1. P. Brodeur, Annals of Radiation, *The New Yorker* June 12 (1989), pp 56.
2. N. Wertheimer & E. Leeper, Electrical Wiring Configurations and Childhood Cancer, *American Journal of Epidemiology* 109, 3 (1979), pp. 273-284.
3. G.M. Matanoski, Cancer incidence in New York telephone workers. Poster presented at Contractors Review Meeting, Portland, OR, November 15, 1989.
4. G.M. Matanoski, Electromagnetic Field Exposure and Male Breast Cancer, *Lancet* 337 (1991), pp 737.
5. L. Tomenius, 50-Hz Electromagnetic Environment and the Incidence of Childhood Tumors in Stockholm County, *Bioelectromagnetics* 7 (1986), pp. 191-207.
6. S.J. London, D.C. Thomas, J. D. Bowman, E. Sobel, T. C. Cheng & J.M. Peters, Exposure to Residential Electric and Magnetic Fields and Risk of Childhood Leukemia, *American Journal of Epidemiology* 134, 9 (1991), pp. 932.
7. EPA, Evaluation of the Potential Carcinogenicity of Electromagnetic Fields, Review Draft (1990), pp 3-148 & 3-149.
8. S. Törnqvist, B. Knave, A. Ahlbom & T. Persson, Incidence of Leukaemia and Brain Tumours in Some "Electrical Occupations."
9. M.E. McDowall, Mortality of Persons Resident in the vicinity of electricity transmission Facilities, *British Journal of Cancer* 53 (1986) pp. 271-279.
10. A. Myers, A. D. Clayden, R. A. Cartwright & S. C. Cartwright, Childhood Cancer and Overhead Powerlines: A Case-Control Study, *British Journal of Cancer* 62, 6 (1990), pp. 1008-1014.

11. H.A. Hansson, B. Rozell & S. Stemme, Effects of Experimental Exposure to Power-Frequency Electromagnetic Fields on the Nervous System, In L.E. Anderson, et al., Interaction of Biological Systems With Static and ELF Electric and Magnetic Fields, *Proceedings of the 23rd Hanford Life Sciences Symposium*, Richland, WA, Pacific Northwest Laboratory, (1984), pp.297-305.
12. W. Mack, S. Preston-Martin & J. Peters, Astrocytoma Risk Related to Job Exposure to Electric and Magnetic Fields, *Bioelectromagnetics* 12 (1991), pp. 57-66.
13. P.A. Demers, D.B. Thoomas, K.A. Rosenblatt, L.M. Jimenez & A. McTiernan, Occupational Exposure to Electromagnetic Fields and Breast Cancer in Men, *American Journal of Epidemiology* 134, 4(1991), pp. 340-347.
14. N. Wertheimer & E. Leeper, Adult Cancer Related to Electrical Wires Near the Home, *International Journal of Epidemiology* 11, 4 (1982), pp. 345-355.
15. R.O. Becker, *Cross Currents* (Jeremy P. Tarcher, Inc., Los Angeles, CA 1990), pp. 271.
16. L.M. Roszyk, (retired head of Sunbeam Northern Company's Research and Engineering Department), private communication with author.
17. W.M. Mickajlowskyj, M.M. Krasnohorskyj, K.S. Wojchyshyn, L.I. Hrabor & W.M. Yahor, Toward the Understanding of Weak Magnetic Fields, *Academy of Science USSR, Series B-s-929* (1969).
18. E.S. Maxey, Critical Aspects of Human Versus Terrestrial Electromagnetic Symbiosis, In Biological Effects of Electromagnetic Waves, *Selected Papers of the USNC/URSI Annual Meeting*, Boulder, CO (1975).
19. R. B. Goldberg & W.A. Creasey, A review of Cancer Induction by Extremely Low Frequency ElectroMagnetic Fields, Is There a Plausible Mechanism?, *Medical Hypotheses* 35, 3 (1991), pp. 265-274.
20. C.J. Montrose & T.A. Litovitz, Biological Response to Weak ELF Electromagnetic Fields, *Physics and Society* 21, 1 (1992).
21. W.R. Adey, Cell Membranes: the Electromagnetic Environment and Cancer Promotion, *Neurochem. Res.* 13:671-677, 1988.
22. M. E. Lacy, Neuromelanin: A Hypothetical Component of Bioelectronic Mechanisms in Brain Function, *Physiological Chemistry & Physics* 13 (1981), pp. 319-324.
23. B.W. Wilson, J.A. Morris, R. G. Stevens & L. E. Anderson, Effects of Electric Blanket Use on Human Pineal Gland Function. Preliminary report. In *Proceedings of the DOE/EPRI Contractor's Review, Phoenix, AZ, Oct. 30 - Nov. 3, Washington, D.C., U.S. Department of Energy, Office of Energy Storage and Distribution* (1988).
24. J.R. Reiter, Pineal Melatonin: Cell Biology of Its Synthesis and of Its Physiological Interactions, *Endocrine Review* 12, 2 (1991) pp. 151-180.
25. There are two distribution systems in the USA and Canada, DELTA and WYE. DELTA is "the closed figure produced by connecting three electrical coils or circuits successively end for end, esp. in a three-phase system. (Webster's Third New International Dictionary). The much more common WYE system connects one end of the three electrical coils to a common neutral line which is grounded extensively.
26. T.L. Thomas, P.D. Stolley, A. Stemhagen, E. T. H. Fontham & M.L. Bleecker, Brain Tumor Mortality Risk Among Men With Electrical and Electronics Jobs: A Case-Control Study, *JNCI* 79, 6, (1987), pp. 233-238.
27. E. G. Preston, Magnetic Fields from Underground Residential Distribution Feeders, *Presented at the Forty-First Annual Power Distribution Conference, October 24-26, 1988, The University of Texas at Austin, Austin, TX.*



# APPENDIX

## Codes

Municipalities throughout the United States govern electrical installations through franchising. The franchising requires adherence to one or the other of two recognized electric codes. The pertinent sections of these codes with respect to “Objectionable Current” in grounding conductors follow.

### NATIONAL ELECTRIC CODE OF THE NATIONAL FIRE PROTECTION ASSOCIATION (1990)

#### 250-21. Objectionable Current over Grounding Conductors.

- (a) **Arrangement to Prevent Objectionable Current.** The grounding of electric systems, circuit conductors, surge arresters, and conducting noncurrent-carrying materials and equipment shall be installed and arranged in a manner that will prevent an objectionable flow of current over the grounding conductors or grounding paths.
- (b) **Alterations to Stop Objectionable Current.** If the use of multiple grounding connections results in an objectionable flow of current, one or more of the following alterations shall be made:
  - (1) Discontinue one or more such grounding connections.
  - (2) Change the locations of the grounding connections.
  - (3) Interrupt the continuity of the conductor or conductive path interconnecting the grounding connections.
  - (4) Take other suitable remedial action satisfactory to the authority having jurisdiction.
- (c) **Temporary Currents Not Classified as Objectionable Currents.** Temporary currents resulting from accidental conditions, such as ground-fault currents, that occur only while the grounding conductors are performing their intended protective functions shall not be classified as objectionable current for the purposes specified in (a) and (b) above.
- (d) **Limitations to Permissible Alterations.** The provisions of this section shall not be considered as permitting electronic equipment being operated on ac systems or branch circuits that are not grounded as required by this article. Currents that introduce noise or data errors in electronic equipment shall not be considered the objectionable currents addressed in this section.”

## NATIONAL ELECTRICAL SAFETY CODE (1990 EDITION)

Copyright 1990 by The Institute of Electrical and Electronics Engineers, Inc.

### Rule 92 D. Current in Grounding Conductor

Ground connection points shall be so arranged that under normal circumstances there will be no objectionable flow of current over the grounding conductor. If an objectionable flow of current occurs over a grounding conductor due to the use of multiple grounds, one or more of the following should be used:

1. Abandon one or more grounds.
2. Change location of grounds.
3. Interrupt the continuity of the conductor between ground connections.
4. Subject to the approval of the administrative authority take other effective means to limit the currents. The system ground of the source transformer shall not be removed. The temporary currents set up under abnormal condition while the grounding conductors are performing their intended protective functions are not considered objectionable. The conductor shall have the capability of conducting anticipated fault current without thermal overloading or excessive voltage buildup. Refer to Rule 93C.

•••