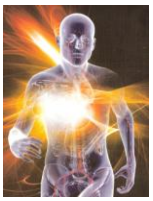
Electropathic Stress in Animals and Man



By Donald Hillman, Ph.D., Professor Emeritus, Michigan State University

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Electropathic stress is a neuroendocrine (nerve and hormone) response of the central nervous system (CNS) which consists of the brain and spinal cord of animals and humans. Exposure of peripheral nerve sensors near the surface of the skin are the first-order protection of the exposed victim. The CNS receives, sorts, and notifies the autonomic nervous system (ANS) of invading environmental electrical interferences The ANS is largely responsible for maintaining homeostasis (i.e., keeping physiological parameters such as heart rate, blood pressure, blood sugar, red and white blood cells, and hormones within a tolerable range for the individual). The hypothalamus, an extension of the brain stem, and the pituitary gland at the base of the brain with its abundance of stimulating hormones largely controls other glands and most functions of the mammalian body through the ANS, neurotransmitters, and feedback from responsive sensors and organs throughout the body. Electrical Interference with electrical and electronic equipment is well known in the industry, but little attention is given to effects on man and animals. A brief review of scientific evidence for electropathic stress follows.

Electropathic Stress pertains to the illnesses and pathological conditions (suffering, disease, and enduring pain) of humans and animals when exposed to excessive electricity such as contact current and electric and magnetic fields (EMF).

- The Electric Field "E" refers to the voltage/meter^2 "height^2" of the subject above earth.
- The Magnetic Field "B" refers to the flux density of the magnetic field which is based on flux or flow of current in amperes per square meter. For estimation of Tesla, the permeability and permittivity are related to free space of air. Permeability of air: $\mu = 4\pi \times 10^{-7}$ (a constant) which is multiplied by Amp/meter and frequency (f) to determine magnetic field "B".
- The permeability of biological tissue to a magnetic field is essentially the same as air [103, 109] thus a measure of current density (C = amps/m^2) at the point of exposure is a reasonable estimate of the relative magnetic field in which the subject is immersed. Magnet fields are proportional to current flowing through a circuit "flux" whether the conductor is air (wireless), earth, wire, or biological tissue.
- Direct effects of EMF independent of the CNS may occur by changing polarity and thresholds of some parameters such as sodium, potassium, and ATPase (enzymes), or cell membrane permeability. [12]

Stress is composed of three common elements: stimulus, reaction-response, and result or consequence [20].

- **First is the energy stimulus, i.e., the pressure or strain exerted upon the recipient**.
    a. In the mechanical world stress or strain is measured in pounds per square inch (psi), lbs/sq ft, (or kilograms per square meter).
    b. In the electrical world, electrical pressure is measured as Volts; an electric field, (E-Field) is Volts/meter.
    c. Current is the flow of electricity through a circuit, measured as amperes of electrons per second.

[1] ***Shocking News*** (dba) is a registered publisher of science-based information dedicated to public awareness of electric and magnetic fields (EMF) in the living environment and their effects on the health and welfare of humans and animals. Editor is Don Hillman, Ph.D., Professor Emeritus, Department of Animal Science, with help from wife Mary, MA, Michigan State University, East Lansing, MI. Don is a member of the American Society of Agricultural Engineers and The American Dairy Science Association. Telephone: (517) 351-9561.

Current is somewhat comparable to gallons of water per minute flowing through a pipe or a river. One ampere is 6.25×10^{18} electrons per second. One ampere is one Coulomb, and the intensity of current is amperes per square meter (A/m^2).

d. The intensity of a magnetic field is flux density (symbol B) or flow of fluctuating current from a magnetic field. One milliGauss (mG) is equivalent to 0.1 microTesla (μT). One mG is equivalent to 79.5 milliAmperes (mA)/m; or 1 A/m = 12.57 mG. Then, 1A/m is equal to 4 x pi (3.1416) a constant for permeability of free space (air), about equal to permeability of biological tissue [105, 111].

e. Electric and magnetic fields are invisible, and imperceptible by touch except for those people who are electro-hypersensitive (EHS), and MF is often outside of the normal frequency range for hearing; although some power lines sing, and others rattle or vibrate. Thus most people are unaware when they are exposed to EMF.

f. Biological systems respond to Current (I), Voltage is often measured as a way to estimate current flowing through resistive conductors using Ohm's Law: E=IR; R decreases as frequency (cycles/second) of the voltage E increases allowing more I to permeate biological tissue.

- **The Second Element of Stress is Internal, in the Animal Nervous System and Glands that Control Most Functions of the Body.** It begins with signals to the brain and spinal cord, the Central Nervous System (CNS) i.e.,
    a. a neural-endocrine (nerve and glandular reaction) that results in a physical response involving muscles, such as movement of a foot (shifting or kicking), a switch of the tail, or hunching of the back or bristling, characteristic of the "Fight or Flight" responses and the General Adaptation Syndrome [121,122].
    b. physiological effects such as a change in blood pressure, heart rate, body temperature, perspiration, respiration rate, hormonal secretion – either physical stress such as physical injury or trauma, electric shock, hemorrhage and pain occur, and of course
    c. psychological stress resulting from fear of threats or anger is similar. These occur during events such as separation of offspring from its mother, unfamiliar surroundings or addition of new members to the herd or flock which may cause temporary stress in the course of determining the new rank in authority, called the pecking order.
    d. chemical changes in blood or tissue now provide scientific bases for psychological-neurological disturbances of people and animals to environmental stress that were previously described as "It's all in your head," by uninformed psychotherapists and physicians [12,13,20,81].

  In the animal industry, stress may be caused by environmental effects such as extreme temperatures, e.g., heat stress – cold stress, sudden sharp and even chronic noise at certain frequencies or intensities; the trauma of milking machines failing to operate properly thus irritating the teats, mistreatment of animals, and certain abrupt or unbalanced dietary changes may result in endogenous (internal) stress, i.e., belly ache, or nutrient-electrolyte imbalance not readily apparent to attendants, or the stress of prepartum, parturition or calving, may result in changes in the health and susceptibility of animals to common environmental invasions of foreign microbes, viruses, or diseases [15,24,26,101,109,116,128].

- **The Third Element of Stress is the Product, Result, or Consequence** of all the above which may be measured in the health and performance of the animal or human. Essentially all neuro-endocrine integrated physiological systems of the mammalian body are affected by stress, either directly or

indirectly in one species or another. Stress has been shown to affect the function of each of these systems:

a. Neurological response to environmental stimulation, interferences and toxins, that cause changes in behavior, cognitive – knowledge, perception, memory, judgment – and illness or neuromuscular tremors, and tingling sensation of hands or muscles when exposed to the stimulant [43,49,53,55,64,72,73,75,86,91,94,110,126,138]
b. Energy metabolism – utilization of glucose, deposition and mobilization of stored energy as glucagon and fat, and enzymatic phosphorylation of energy transfer through cell membranes, e.g., cAmp>ADP>ATP, and disposal of waste products. May include inanition, appetite, diabetes and obesity [12,20,22,and 66].
c. Cardiovascular and Respiratory – heart rate, heart rhythm, arrhythmia, blood pressure, blood viscosity, blood cell counts, bone marrow, anemia, function of the lungs including lung cancer [10,16,17,18,20,28,33,35,36,64,72,104,118,120,132,134,135,142,148].
d. Mineral and electrolyte deposition in bone, calcium flux, collagen formation, utilization and excretion including kidney function and body water control [1,12,13].
e. Immune system – hormonal and leukocyte response to invading foreign substances, i.e., bacteria, viruses, phages, and injury thus providing protection from allergies, infectious diseases and cancer [10,12,41,88,95,106,107,123].
f. Reproduction – disruption of normal estrus cycles or ovulation of females, and reduced sperm count of males have been demonstrated. Impaired development and embryonic death of embryo and fetus, and malformation of offspring have been attributed to electrical interference [2,10,61,85,86].
g. The mean reduction in net revenue from 1-day increase in adjusted calving interval was $4.7 (Canadian) per cow in dairy herds [108].
h. Low frequency (ELF) EMF exposure (1.98-3.28 μT) below a 380 kV electric transmission line altered CD8 (lymphocyte surface antigen), circadian rhythms, and Leukocyte Differentiation Antigens CD4/CD8 ratio and numbers in Italian cows compared to controls [128].
i. In laboratory animals the response of 20 immune parameters including cytotoxic T lymphocytes of the spleen, thymus and bone marrow, and sub-class immature cell numbers and immunoglobulins exposed to 60 Hz EMF was real when Chaos statistical methods were applied, but nonlinear, therefore ordinary Analysis of Variance averages failed to detect significant differences that were real for individuals [90,91,92,98].
j. In humans exposure of fathers to EMF working in a high voltage switchyard resulted in chromosomal aberrations of lymphocytes and sperm cells and a significantly greater number of congenitally malformed offspring [99,100,106].
k. Leukemia, chondrosarcoma, and renal carcinoma increased in male children of men exposed to occupational EMF. No effects were seen in female children of EMF exposed men [106].
l. Leukemia of children increased linearly as EMF in the living environment increased from 0.1 to 0.2 to 0.3 and 0.4 microTesla (μT) in meta-analysis including some 65 studies [141].
m. Leukemia was 4.3 times greater in children with 0.4 μT EMF in their bedroom than those with 0.1 or less μT [76].
n. Host-hormonal responses can proliferate and exacerbate certain microbial infections of the animal, i.e., microorganisms interact with host endocrine systems, augmenting disease processes and possibly playing a role in development [88].

Now, let us examine the consequence of some temporary, normal, natural events that cause changes in the stress hormone cortisol and associated changes in milk yield, fat disposition, and immune responses of cattle.

Effects of Stress and ACTH on Milk Production and Cortisol in Milk

Movement of Cattle by Trucking: Effects of the stress caused by the excitement of trucking dairy cows from one farm to another were investigated in a herd of 39 cows in Wisconsin [19]. The stress of shipping cows 100 miles from one dairy to another increased cortisol in blood and milk and decreased milk production.

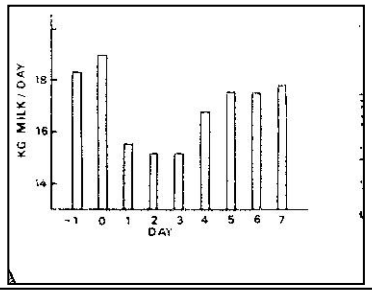

Figure 1. Effect of ACTH injection on Milk Production of 5 Cows an indication of the effect of stress.

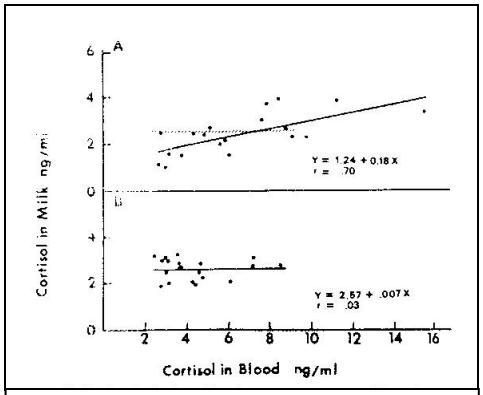

Figure 3. Cortisol in Milk was a function of cortisol in blood of cows subjected to stress of moving.

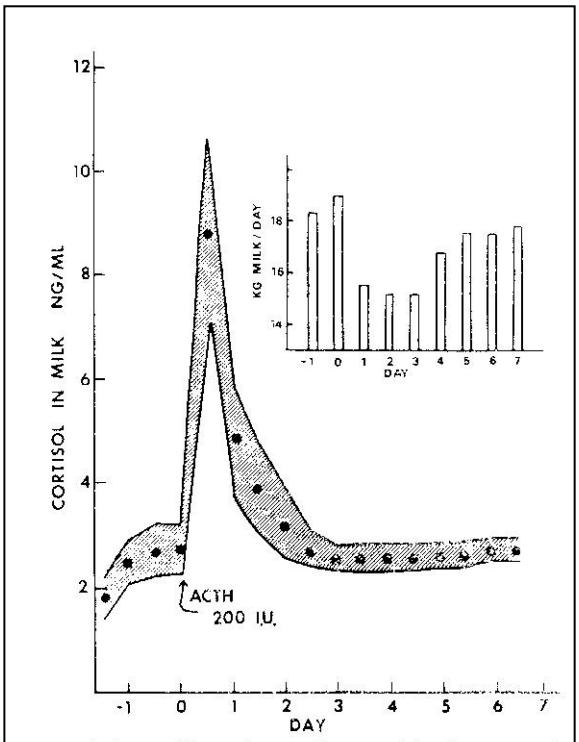

FIG. 2. Effect of 200 IU ACTH injection on cortisol in milk and on milk production of 5 Holstein cows. The shaded area represents one SE about the mean which is denoted by (•). Average milk production of the group is shown in the inset.

Similar temporary effects of the stress of cattle Moved to a new location while some cows were simply merged into a new facility nearby were demonstrated by investigators at North Carolina State University, Raleigh, NC.

- Milk production of Merged and moved cows was decreased at first milking, but subsequent milk yields were similar to yields pre-relocation.
- Milk fat percentage was decreased for 3 days for Moved cows but was unchanged for merged cows. Across groups, older cows and cows in late lactation tended to have the greatest decreases in milk yield.
- Corticosteroids in serum were increased in merged cows for 2 days after relocation. No changes in somatic cell count or percentage of heats were detected with relocation.
- Detrimental effects of herd location were slight and indicate that dairy herds can be moved without adversely affecting production traits [140].

Administration of 100 i.u. ACTH decreased milk production -7.5% in 2 days and -23% in 10 days while 200 i.u. decreased milk production 30%; and the extent of milk decline was correlated with the percentage reduction of circulating eosinophils during experiments at University of Reading, England, reported by D. B. Flux et al., J. Endocrin. 10:333-339, (1954).

Stress at Calving Alters Corticosteroids, Leukocytes and Increases Risk of Infections

- The stress accompanying labor pre- and post-calving (parturition) and rapidly increasing milk secretion has been clearly shown to cause dramatic changes in corticoids and lymphocytes (leucopenia) in blood of healthy cattle as published by Michigan State University Animal Scientists, Priesler et al. [109]

Heat Stress and Hot Weather Affected Health and Production of Cattle

- A blood neutrophylic leucocytosis of cows in low-voltage current and significant decrease in segmented neutrophils, increase of lymphocyte counts and decrease in monocyte count is consistent with the response of blood cells to environmental-heat stress of cows in Arizona associated with stressing conditions associated with stimulation of the hypothalamic-pituitary-adrenal axis.
- Modest increases in somatic cell counts of milk were associated with corticotrophin injections and environmental-heat stress [143,146].
- Positive correlations were recorded between blood leucocytes and somatic cell counts of milk in mastitis-free cows.
- Investigators noted "the diminished ability of high Milk Quality Test (MQT) cows to mobilize leucocytes following corticotrophin injection, [143] and blood leukocyte changes occurred after ACTH [49,50].

Similarly, stress of environmental temperature affected cow performance: Cows calving in January and February produced 17% more milk, 7% more fat, were 14% more efficient in use of gross energy, and breeding efficiency having (-32 days open) than cows calving in July and August. Cows exposed to 20 days of maximum temperature > 27°C in the first 100 days of lactation averaged 27% higher in gross efficiency (kg milk/MCal of estimated net energy) than cows exposed to 40 to 87 days > 27° Celsius, according to Cornell U. and USDA workers (McDowell, et al., *J. Dairy Sci*, 1976).

Effects of Electrical Stress on Behavior, Health and Milk Production of Dairy Cattle

The decrease in milk and milk-fat during stress of Wisconsin and North Carolina herds corresponds to decreases in milk fat reported for cows subjected to electrical stress in experiments at Cornell University, New York as follows:

- **In Complete Lactation Experiments** milk fat was lower for every group exposed to 1-, 2-, and 4-volts electricity than from cows in the 0-Volt group [37]. (Note: Fat% was miscalculated for the 2-V group, Table 2, in the published article).

In studies of "Cow Sensitivity to Electricity During Milking," investigators reported

- "Milk fat was lower when currents were applied to first lactation cows and significantly lower for multiple lactation cows, and
- "somatic cell counts were lower for the multiple lactation cows, and higher for first lactation cows when currents were applied, but neither were significantly different," according to Aneshansley et al [3].

Statistically significantly different ($P < .05$) numbers of average somatic cell counts (SCC) in milk due to treatments are difficult to achieve since minimum numbers are in the 100,000/ml (milliliter) range and average about 200,000 in normal herds. Thus, large within-group variation requires very large sample size or numbers of cows at each treatment to be statistically significant, because statistical significance depends on sample size as well as differences and variances between means. Few experimental data have the necessary cow numbers for SCCs to be significantly different between treatments, meaning probability of random error less than 5%.

Electropathic stress enhances and exacerbates the stress of calving and results in similar changes in blood corticoids and leucocytes of cattle exposed to excessive EMF.

Excessive Electrical Exposure enhances, exacerbates, and proliferates bacterial, viral and macrophage infections of cattle and other animals [10,11,17,18,21,43,44,65,68,72,77,80,90,107,116]. All animals and humans carry a few microbial or even cancer cells in their bodies. The body's defense system destroys its enemies or keeps them within the limits of the individual's tolerance to maintain homeostasis under ordinary circumstances. But, under acute or chronic stress the immune defense system may be impaired and foreign invaders cause damage to a particular function of the Autonomic Nervous System (ANS): cardiovascular, metabolic, gastrointestinal, urinary water and electrolytes, reproductive and mammary system, or immune response and defense system that is most vulnerable. Therefore, Electropathic Stress (EPS) affects impairment of several body functions. EPS should not be considered a single system interference, as we shall see in reports of other investigators [84, 85].

Induced Current from Electric and Magnetic Fields – Stress in dairy cattle is normally measured in terms of impaired milk and butterfat production, impaired reproduction, mammary infections, and growth of young cattle. In other animals raised for food, i.e., beef cattle, sheep, hogs, and poultry, growth or body deposition of protein, fat, and connective tissue are economic considerations. Interference with reproduction, body defense mechanism, and increased infectious mastitis or somatic cell count (SCC) in milk are common complaints of dairy farmer victims of EPS [5,6,7,22,30,37,40,41,49,50,51,54,61,68,80,81,84,91,92,112,149,150].

In controlled experiments, milk fat secretion was affected in groups of Holsteins exposed to 10 kV/meter electric field and 30 microTesla magnetic field for 28-day periods, according to reports of investigators at the University of Montreal, Quebec, Canada [21,22]. The exposure was equivalent to standing under a 735 kV AC transmission line carrying a maximum load of 2000 amperes current and was presumed to be the worst-case scenario for electrical exposure of cattle in a specially constructed exposure chamber similar to cattle exposed at pasture or a barn under overhead transmission lines.

During the first experiment with 28-day periods, milk yield per cow was not significantly different, but milk fat % tended to be higher, thus 4.0% fat-corrected milk was higher from cows while exposed to electric and magnetic fields (EMF). Cortisol levels in blood were not significantly different when the overhead electric current was On or Off, although progesterone levels in blood were increased significantly by EMF during the first 28-day experiment [21].

In a second 28-day switchback experiment with cows exposed to EMF versus no exposure:

- **milk yield decreased 4.97%, fat-corrected milk decreased 14%, and fat yield decreased 16%, while dry matter intake increased 5% [22].**

Milk and milk-fat production were decreased from cows exposed to contact current and induced EMF compared to cows during nonexposure in the four different experiments cited above.

Also, cows decreased milk production 11-17% during exposure to 5.0 mA intermittent contact current in short-term trials at a USDA-ARS experiment station [82].

Because decreased fat test of milk has been, generally, associated with a shift in availability of short-chain fatty acids (acetic > propronic, and butyric) produced by microbial fermentation in the cow's rumen, the question about effects of EMF on microbial fermentation in the rumen of cattle remains unanswered. Sources of fiber, and buffering compounds such as baking soda and magnesium oxide, added to diets have been shown

to maintain butterfat content of milk of cows fed high carbohydrate-low fiber diets.

Electrical Effects on Midwest Dairy Farms – Our studies of 1705 cows in five farm herds for 517 days revealed that milk production decreased as currents from the 3rd harmonic, 180 Hz; the 5th harmonic, 300 Hz; the 7th harmonic, 420 Hz; the 42nd harmonic, 2520 Hz; and Triplen Harmonics increased daily as in Figure 4. The figure shows effect of average daily harmonic current (green bars) and effects of maximum daily harmonic current (red bars) on milk produced per cow per day [61; and see references in Figure 4].

- The 42nd harmonic (2520 Hz) accounted for decreases averaging about -13 pounds milk per cow daily (-13 lb or -5.9 kg). This was the most milk loss of the low current harmonics in our data.
- Maximum daily harmonic currents of the 3rd Harmonic accounted for decreases of -9 pounds (4.08 kg) milk per cow per day.
- The 5th harmonic accounted for -2.5 lbs. (1.13 kg) milk per cow daily.
- The 7th harmonic accounted for -6.5 lbs (2.95 kg) decrease of milk per cow daily from the data set.
- Power quality was highly variable on farms at different times and different locations. Our data were based on within-herd changes in power quality and corresponding changes in milk production.
- Differences in management or breeding practices were not a consideration since they were relatively constant within herds and differences, due to time of year, days, or number of cows milking, were removed by multiple regression analysis as independent variables.

Similarly, a west-Michigan herd charged with cow-contact voltage ranging from 2.5-6.7 VAC, DC peaking at > 13 VDC, and AC frequencies > 613.38 Hz [102] that resulted in decreases of milk production from 85 to 43 lbs/day at 150-Days-In-Milk average, decreased conception rate from industry average 51% to 21% and losses of circa 300 head over a five-year period resulting in financial disaster while the utility investigators could not find any harmful voltage [93]. Results were comparable to the Minnesota dairy farm response from isolation of the ground wire [4,5,6].

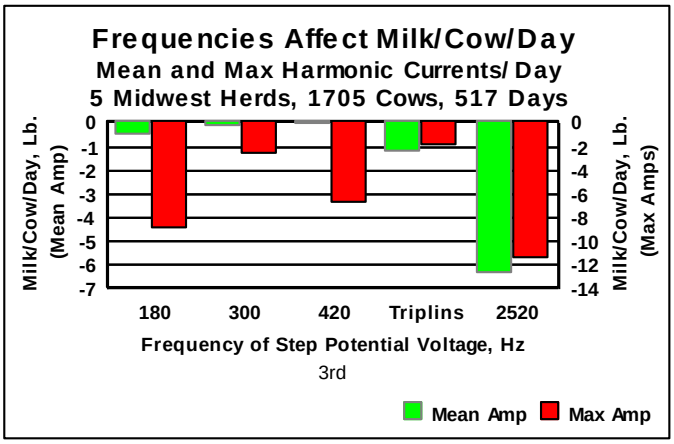

Figure 4. Effect of Harmonic Currents on Milk Production of Dairy Herds in Wisconsin, Michigan, and Minnesota, Hillman, et al., ASAE presentation No. 033116; Amer. Dairy Sci. Assoc., Paper No. 223, and Canadian SAE-SCGR Paper N0. 03-505 (2003).

However, electrical stress increases epinephrine and cortisol, the adrenal hormones that inhibit production of insulin, increase glucagon (stored glucose) released from the liver and muscle and tends to increase blood sugar similar to effects of diabetes mellitus. While blood sugar is known to increase when cattle are fed high

CHO-low fiber diets, a direct effects of EMF on blood sugar has not been reported in cattle, but are known in laboratory animals [20] and humans [12].

Thirdly, Blood Hormones Respond during Experimental Electrical Stress of Cows – Cows subjected to 0, 4, and 8 mA (0.004-0.008 A) of current under controlled conditions in New York resulted in:

1. Increased cortisol (adrenal hormone) in blood of cows subjected to electricity compared to nonexposed controls.
2. Increased heart rate and blood pressure of cows at 2 and 4 mA of current [83], and cows subjected to 4 and 8 mA current [38,41].
3. Delayed release of oxytocin from the pituitary gland of cows in the New York experiments [40]. This research was perhaps the most direct "cause and effect" research showing effect of electrical stress on hormonal changes of dairy cattle.

We analyzed the data (Figure 5) from Gorewit et al. [41], in a multiple regression model to estimate changes in blood cortisol per mA exposure (0, 4, and 8 mA) and minutes of exposure (0-18 min). Blood cortisol increased linearly Y = 3.385 + 0.462 ng / mA current (P = 0.0002). Cortisol also increased linearly Y = 3.385 + 0.519 ng / minute (P = 7.160e-08) as time of exposure increased (0-18 min). The interaction: $Y_{cortisol}$ f 4.772 + 0.025 (mA × T_{min}), was linear (P = 0.05). Interaction (mA × T) accounted for 94.7% of cortisol variation using the average values reported. Baseline cortisol increased during milking; electrical exposure caused a synergistic effect. Cortisol is released from the adrenal gland when ACTH (adrenocorticotropic hormone) is released from the pituitary by electrical stimulation of peripheral nerves. Similarly, oxytocin release from the pituitary stimulates excretion of milk (milk release) from the mammary gland upon stimulation of the udder by suckling, or by massaging of the udder in preparation for machine-milking. Impaired milk let-down, i.e., incomplete milking, was a common complaint of dairy farmers raising the stray voltage issue. Epinephrine administration significantly reduced milk yield in heifers and cows but did not inhibit oxytocin release in response to milking. Investigators found that as little as 50 μg epinephrine inhibited mammary blood flow to the udder by as much as 90% [39].

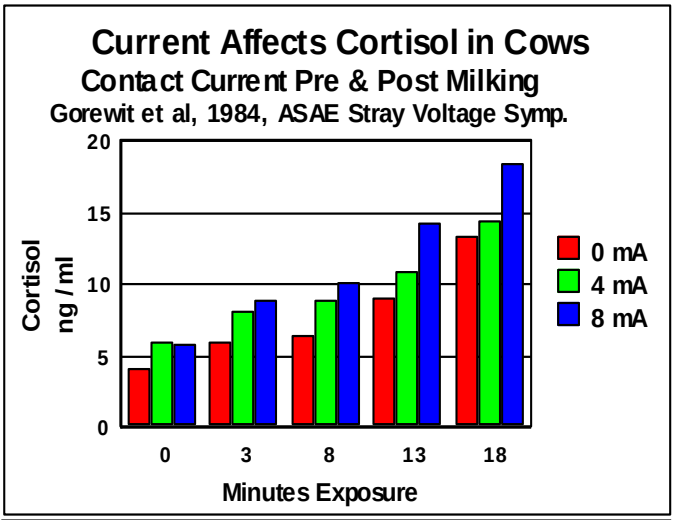

Figure 5. Cortisol in blood increased in cows subjected to 4 and 8 milliamps electrical current, Gorewit et al 1984.

Again in 1986, USDA investigators had published Correlation of Indices of Stress with Intensity of Electrical Shock for Cows [83]. In the abstract authors noted**, "Electric shock is commonly used as a paradigm of**

stress. Cows have a higher tolerance to electrical shock than other species. To test this tolerance, seven lactating cows were shocked biweekly for 10s [seconds] 0, 2.5, 5.0, 7.5, 10.0, and 12.5 mA current, 60 Hz. At lower mA, cows became tense and showed limited movement. As mA increased, cows became more agitated. The experiment was terminated because of the severity of behavioural responses."

We plotted the data from Table 3 of the USDA-ARS report [83] in the Figures below for glucocorticoids, heart rate, and epinephrine of the seven cows used in the electrical experiment. Heart rate increased 2 Beats/minute per 1 mA increase of current immediately after 10 seconds of shock as mA increased and was significantly different from baseline at 10 mA. However, the plotted data indicate a trend toward increased heart rate beginning at the lowest level of current and increasing linearly as current increased. Similarly, considerable variation in glucocorticoid and epinephrine content of blood suggest that the adrenal hormones were affected but the number of observations per treatment were too small and the variation too wide to be statistically significant. In contrast, cortisol, heart rate, blood pressure and oxytocin were significantly affected by 4 and 8 mA current in the report of Gorewit et al., 1984 [42].

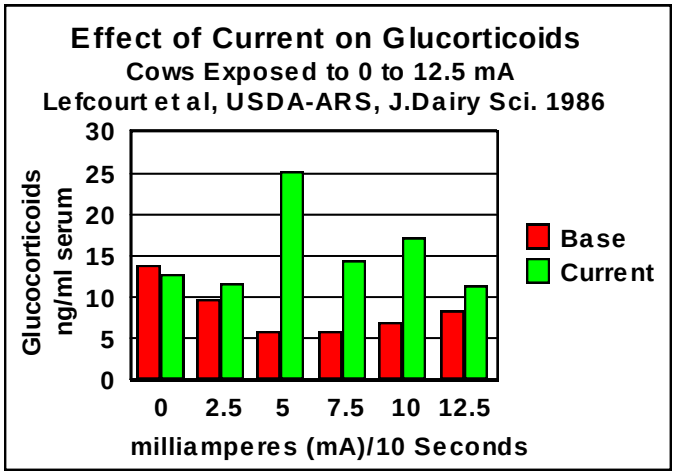

Figure 6. Adrenocorticol hormones in blood of cows increased at every level above 0 to 12.5 mA of exposure to 60 Hz current for 10 seconds in USDA-ARS experiment.

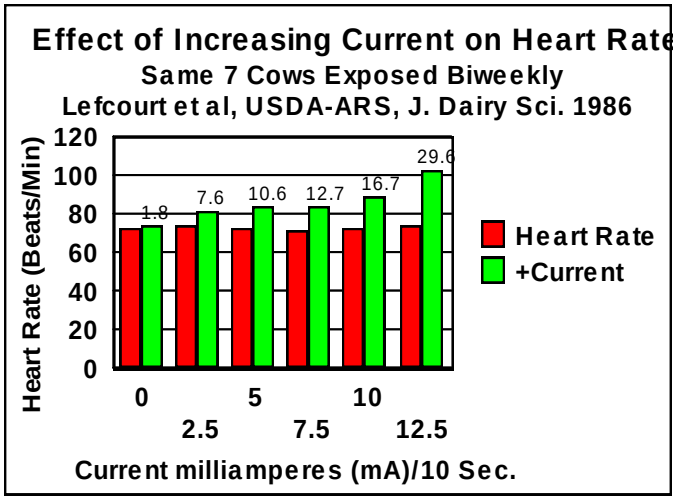

Figure 7. Heart Rate of Cows Increased at every level of 60 Hz current above 0 to 12.5 mA. The average increase was 2 beats/minute per each mA increase current, in experiments by USDA-ARS in 1986.

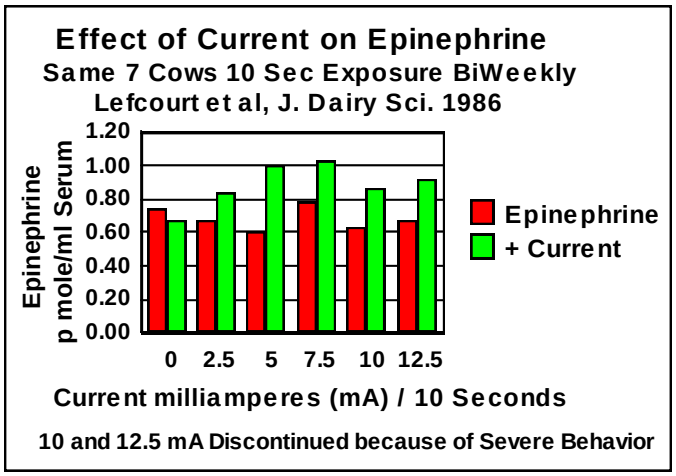

Figure 8. Epinephrine (Adrenalin) increased at every level of 60 Hz current above 0 to 12.5 mA for 10 seconds in experiments at USDA-ARS.

However, Peak minus Baseline glucocoticoid mean level was 13.8 peak -12.7 base or very little different at 0 treatment; standard errors for P-B for glucocorticoids were 2.6 times larger than baseline SE. The actual data from Table 3 of Lefcourt et al. [83] are plotted in the figures presented and seem to indicate notable and quasi-linear effects of electrical shock on adrenal glucocorticoids, heart rate, and epinephrine in blood.

Norepinephrine was unaffected by shock or recannulation in this experiment. Epinephrine doubled in two exceptional cows at 10 mA. The two exceptional cows showed consistent glucocorticoid responses, had consistently elevated baseline heart rates and prolactin and were the only cows not shocked at 12,5 mA due to severe behavioural responses. It should be noted that 2 of 7 experimental cows represented 28.6 % of the sample that would not tolerate the 10 and 12.5 mA current. Thirty percent would be about equal to the cull rate every year for most dairy farms. The data were in Table 3 (page 837 of the article) [83].

The authors indicated that there were no significant differences between treatments. "However, **area under the [glucocorticoid] response curve was significantly different from zero (P < .01) at 5.0 and10.0 mA.** The P-B [Peak (-) Baseline] glucocorticoids were significantly different from zero (P < .05) at all current intensities, including 0 mA [the difference at 0 suggests some stress due to the excitement of the procedure or slight differences in cow response on different days].

Authors explained why the study was conducted, "Considering the recent concerns of animal welfare groups, it is imperative that farmers be able to demonstrate that current management practices do not unduly "stress" the animals. To make this demonstration requires that stress be defined."

The USDA data showed that acute electrical exposure of cattle for 10 seconds bi-weekly resulted in differences in heart rate and glucocorticoids that were associated with increasing current, but these differences were considered unimportant by the authors. Ten-second exposures are a poor representation of chronic effects on cattle exposed continuously or intermittently for a lifetime on some dairy farms as reported by farm investigators [4,5,22,61,65,70,80,102,129,131].

Action of Neuroendocrine Factors on Glucose Homeostasis

"In short, cortisol is an important diabetogenic, anti-insulin hormone. Its primary hyperglycemic and lipolytic and secondary ketonic actions are usually exhibited only when its secretion is greatly stimulated by stress [12]."

The adrenal hormones and neurotransmitters released during stress influence carbohydrate metabolism, either by their actions on the primary organ of glucose production – the liver, or by their actions in insulin-sensitive organs of glucose utilization: muscle and adipose (fat) tissue, according to G. J. Taborski and D. Porte, Jr., Veterans Administration Medical Center, and University of Washington, Seattle, WA [20, Chapter 24].

The acute or minute-to-minute regulation of glucose acts by cellular mechanisms that are usually already expressed in liver, muscle, and adipose tissue, whereas the permissive, long-term regulators usually induce or enhance cellular expressions of enzymes in the pathways of carbohydrate metabolism, i.e., the CREBS cycle.

A New Assay for measuring the stress effect on phosphorylation of protein kinases has been invented by Randal Tibbetts and Yuling Shi [133] at U. of Wisconsin, and patented by WARF, the Wisconsin Alumni Research Foundation, Inc. This may be an important breakthrough for determining presence of environmental stress, such as electricity, on causes of cardiovascular disease, diabetes, and impaired immunity resulting in proliferation of morbidity and mortality of cancer and other diseases.

ATP Energy Receptors Altered

Low frequency (ELF), low energy pulsing electromagnetic fields (PEMFs) alter the expression and the functionality of adenosine A_{2A} receptors in human neutrophils. The effect was also dependent on intensity, time, and temperature [139]. Sensitivity to EMF of the energy transduction enzymes ATPpase, ATP, ADP, AMP, and creatine, and to temperature, light, high frequency sound, and centrifugation were first demonstrated in nerve cells in 1964 [66]. Impairment of cyclic AMP-ATP metabolic energy transfer across cell membranes may partially account for the fatigue and neuroendocrine dysfunction of persons and animals exposed to excessive PEMF [20,55,60,84,92,117,138].

Electrotaxis – Finally, the effects of extremely low frequencies (ELF <1 to 60 Hz) and low-amplitude electric fields (EF) (0.1-10 V/cm) causing electrotaxis (or galvanotaxis), i.e., movement of species- and cell-type-specific cells migrating to either the anode or cathode, as in laser magnetic healing, may be a factor in EMF-induced cardiovascular disease. Limited data indicate human vascular cells migrate toward the anode, whereas bovine aortic endothelial cells move to the cathode. During movement, ruffled membranes, lamellipodia and filopodia are formed preferentially in the direction of the anticipated electrotaxis migration. Delineation of the possible role of electrotaxis on electropathic stressors such as coronary occlusion or blood viscosity will require further research in areas open for exploration. DC EMF triggers the separation of charged membrane components [34]. Also, DC mixed with AC decreases the threshold for fibrillation [111]. DC voltage commonly corresponds in magnitude but opposite (-sign) to AC-peak-peak distorted voltage from power lines.

***Sympathetic nervous system* – Epinephrine**: The adrenal hormone epinephrine (EPI) has an acute glycogenolytic effect at the liver, which increases hepatic glucose production and therefore the plasma glucose level. The action of EPI is rapid, producing a transient increase of glucose production that then returns to a near basal rate despite continued EPI administration. Thus EPI is the immediate response to electrical shock, whereas the glucocorticoids respond to chronic stress over a longer period of time – 1st increasing and

eventually decreasing blood glucose, and the catecholamines, norepinephrine (NE) and dopamine, modulate effects of excessive stress [20] and may account for the apparent adaptation observed (Aneshansley et al. [3]).

Understanding underlying causes is necessary for knowing how to prevent diseases that have been observed to occur in 25 to 50% of cows in problem herds exposed to excessive electricity. Such stress proliferates post-calving infections of the reproductive tract and mammary gland corresponding to changes in blood as observed by Daniel Hartnell, DVM, et al. [54] in Minnesota who from many measurements observed that the cows could not receive more than 0.25 VAC at contact points in a farm herd, but measured 100 to 120 mA current in the primary neutral ground wire during a power outage (electricity was off) indicating current was from off-farm sources, and similar current when the power was back on. Current in the secondary neutral was 18-20 mA AC. We measured similar low voltage (0.12-VAC, but 100-200mA current at radiofrequency >100MHz in an insulated watering tank from which cows were reluctant to drink water and produced abnormally low quantities of milk [62].

Stress Effects on Health-Defense Mechanisms of Cattle and other Animals

The finding by Hartnell et al. [54] that changes in blood occurred to cattle exposed to electricity on farms concurs with other reports: Induction of lymphopenia caused luteal dysfunction in cattle [2]. Apparently, lymphocytes serve a multifunctional role in reproduction and defence of the organism. Maternal and early life stress impairs immune function of offspring [11], weak amplitude-modulated EMFs affect calcium release from brain tissue [1,13], increase stress proteins in DNA [14], affect blood pressure and somatosensory perception via dopamine [20,36], increase Interleukinen IL-1, and decrease IL-2 in cattle, and stimulate lymphocyte activity [15] promote chromosomal aberrations of living cells [7,25], proliferated erythroleukemia and inhibited maturation of mouse Friend cells *in vitro* [24], increased lymphoproliferative and myeloproliferative disorders in people living near high voltage transmission lines [64,77,85,86], caused changes in blood glucocorticoids and leukocytes in cattle and laboratory animals [31,42,49,50,91,112,128].

Micro nuclei of peripheral blood erythrocytes of cows near (in front of) a radar tower were six times higher than in control herds remote from the tower in Latvia, indicating cows exposed to communication signals are at risk for erythrocytic anemia [7]. The Skrunda Radio Location Station (RLS) releases radio-frequency (154-162 MHz) and pulse signals. Micro nuclei arise from chromosomal fragments or chromosomes that are not incorporated into daughter nuclei at the time of cell division. The peripheral blood micro nuclei test is used to evaluate acute clastogenic effects and assess chronic damage of chromosomes as prescribed in The Collaborative Study Group for the Micro Nucleus Test in 1992. The investigators chose cattle for the micro nuclei test because Cows live in the same environment as Man [7]. Other investigators have studied the effects of electromagnetic radiation as reviewed by McCann et al., 1993; on microbial systems (Juutilainen and Limatainen, 1986, and chick embryos 1987); on plants, pine trees, (Balodis, 1996, and Schmutz et al., 1994 as noted in the report of Balode) [7]. Impaired reproduction and fetal development were reported in laboratory animals [10,20] and a risk factor for cancer in humans and human cells [11,77,86,94,95,101, 116,135,147,149,150].

The EMF – Heart – Cortisol Connection – Cortisol in blood, heart rate, and blood pressure increased, and release of oxytocin was delayed when dairy cows were exposed to 4.0 and 8.0 mA contact current compared to no exposure in controlled experiments [42]. Heart rate is controlled by response of the autonomic nervous system to various environmental stimuli, i.e., trauma, excessive heat (heat stroke), cold, sound, light, and mental perceptions such as fear and elation. Electrical contact current and induced energy from electric and magnetic field (EMF) exposure may now be added to the list of heart rate and blood pressure environmental stimulants in respect for 25 or more articles published in credible scientific journals [64].

Cytokines are important communicators between stress and response of lymphocytes – Electrical stress of cows was demonstrated when cows subjected to 1mA current for two weeks had increased levels of Interleukin-1 and decreased Interleukin-2, and changes in cortisol and Immunoglobulin in blood compared to untreated controls [112]. The data provide further evidence that electrical exposure poses a danger to defense mechanism of the bovine. Cows were affected at 1mA current flowing through the body, raising the issue of appropriate EMF thresholds to prevent electrical interference with defense mechanisms of the animal.

A cascade of events occurs in the immune system of animals when IL-1 is released, as described by Bradford P. Smith in *Large Animal Internal Medicine*. The finding that Il-1 and Il-2 in cattle respond to 1 mA electric current is an important breakthrough in understanding how extraneous electricity impairs normal control of diseases, and also implies a new basis for electrical exposure standards by the animal industry. A review by Italian immunology investigators described some important signaling pathways which drive bidirectional communication between the immune and nervous systems during infection [15]. Particular emphasis is placed on pro-inflammatory cytokines, immunomodulator hormones such as glucocorticoids (GCs), growth hormone (GH), insulin-like Growth hormone Factor-1 (IGF-1) and leptin as well as nutritional factors, and cytokine-HPA regulation, IL-6GCS-Zn, cytokines-GH/1GF-1, IL-6GH-Leptin and thymus activity. The thymus gland is believed responsible for preparation of T-lymphocyte and killer lymphocyte "cytotoxic cells" [15].

Research with laboratory animals (mice, rats, guinea pigs, etc.) has shown that interleukin-1 is one of the key indicators of the immune response to stress, infection, or antigenic challenge.

- IL-1 has been reported to stimulate hypothalamic-pituitary-adrenocortical hormone secretion.
- IL-1 was reported to stimulate ACTH and to inhibit prolactin secretion by pituitary cells in culture and to stimulate CRF.
- **Corticotropin Releasing Factor, or (CR Hormone),** a 41-residue peptide (protein) is believed to be the principal compound permitting access to central pathways that govern pituitary-adrenal responses to stress according to Paul E Sawchenko, The Salk Institute, La Jolla, California, in *STRESS* [20].
- CRH receptors are found throughout the brain and spinal cord, and the peptide is synthesized in many peripheral cells, including immune cells. CRH has other important central nervous system functions related to or independent of stimulating ACTH release.
- CRH causes central arousal, increased sympathetic nervous system activity, and increased blood pressure.
- In contrast, CRH decreases reproduction function by decreasing the synthesis of gonadotropin-releasing hormone (GnRH) and gonadotropins and by inhibiting sexual behavior.
- CRH also decreases feeding activity and growth.
- CRH may also regulate β-endorphin and its analgesic action.
- Finally, in immune cells, CRH stimulates release of cytokines and also augments their activity on target cells. CRH circulates at very low plasma levels bound to a specific protein [12].
- Application of cytokine technology [15] and a new assay for stress protein kinase activity in blood or other tissue [133] offer promise as additional diagnostic tools for the veterinary and human medical professions when traditional protocols fail to provide plausible basis for prevention or treatment [53,128].

The pituitary gland located at the base of the brain secretes hormones that control or regulate most functions of the body in conjunction with other organs, signals and communicates with the brain in a feedback system that promotes homeostasis within the tolerable genetic limits of the individual. When the tolerable limits are exceeded, the organ's function fails, or the organism breaks down and chaos proceeds.

The pituitary gland secretes:

- ACTH (adrenocorticotropic hormone) the hormone that stimulates adrenal cortical hormones, i.e. cortisol, corticosterone, aldosterone, and others and is a major factor affecting availability of glucose, a primary energy source for most species of mammals, and influences enormous effects on lymphocyte activity (12,20).
- TSH Thyroid stimulating hormone, regulates secretion of thyroid hormones – thyroxin T_4 and triiodothyronine T_3 – which control metabolic rate or utilization of body energy.
- STH – Somatotrophic Hormone, Growth Hormone, influences growth of body cells, and increases milk production – synthetic bovine somatropin (bst) was commonly used by some dairymen to stimulate milk production of cows from early 1990s until recently.
- LH – Luteinizing Hormone promotes development of "yellow bodies" at the site of egg eruption on the ovaries and secretes progesterone and other hormones following ovulation.
- FSH – Follicle Stimulating Hormone regulates the growth, pubertal maturation reproductive processes, and sex steroid hormone secretion of the gonads of either sex. Secretion of LH and FSH are stimulated mainly by a single hypothalamic hormone –
- GnRH gonadatropin-releasing hormone, or LHRH luteinizing hormone-releasing hormone – regulate the secretion of reproductive hormones.
- PRL – Prolactin, the hormone that initiates milk production
- ADH – Antidiuretic Hormone, controls kidney function and body water content.
- OCT – Oxytocin hormone causes milk ejection and aids in parturition of the newborn.

In practice, treatment of cows with GnRH and prostaglandins F2-alpha reduced interval to first ovulation and first detected estrus and increased the proportion of cows with three or more ovulations before first service from 57% for saline treated controls to 83% and decreased number of services per conception during experimental trials at Kansas State University. The practice of forcing ovulation of cows with a functional corpus luteum on the ovary is now common on dairy farms. In stray voltage trials GnRH and Prostaglandins $F_{2\alpha}$ were used on all cows that were not pregnant within 50 days after calving at Cornell University. That may have reduced variation due to electrical treatments so that no differences in reproduction were found due to electricity [37].

The increased cortisol in cows concurs with results obtained when rats were exposed to 0.5 W/kg for periods of one year or longer [10]. Blood cortisol of all rats was equal at the beginning but cortisol of exposed rats increased above controls shortly after the experiment began. By the end of the experimental period cortisol was lower in exposed rats compared to controls. The cortisol pattern was a typical adrenal response to stress finally resulting in adrenocortical fatigue as in Addison's disease of humans. While the rats used in the Guy experiments were gnotobiotic (germ and virus free), 18 of the exposed rats had cancers of the pituitary, adrenal, and thyroid glands and only five of the controls had cancer [10].

In earlier experiments, serum corticoids (corticosterone) were depressed 31.7 %, while albumen levels increased 28.2%, and body weight was 6.6% lower in rats when exposed overhead to 150V/m, 0.68 µA, 11.1 $\mu A/cm^2$ for 30 days compared to controls [91].

Similarly, Imaida et al. [74] found that mean levels of corticosterone, ACTH, and melatonin were higher for rats exposed to near field TDMA modulated 929.2 MHz RF EMF at 50 pulses/s, 0.33 duty cycle, than for unexposed controls. The experiment was repeated with rats exposed to TDMA modulated 1.439 GHz RF EMF whole body SARs 0.680-0.453 W/kg for 90 minutes per day, 5 days/wk for 6 weeks. Significant increases were found in the serum levels of corticosterone, ACTH and melatonin in the RF EMF group compared to the sham group.

Experimental data with intact live animals support the hypothesis that pituitary, adrenal, and pineal glands are affected by 60 Hz current [42] and modulated, pulsed signals as produced by cell phone signal generators [8,32,81] . Levels of exposure were below FCC (Federal Communications Act of 1996), permissible EMF radiation levels while animal health was impaired [53,89,90].

Melatonin, a hormone secreted from the pineal gland, is associated with the function of the circadian clock which regulates sleeping, and many related functions of the body. Melatonin concentrations are higher during darkness and decrease during daylight. Melatonin is believed to produce strong oncostatic, immunological, and antioxidant functions in the blood. EMF exposure has decreased melatonin concentrations in blood, or urinary excretion of its metabolite, in humans sleeping under an electric blanket [146], and electrical workers exposed to 60 Hz magnetic fields while working in substations or on 3-phase conductors, women exposed to visual display units (computer monitors) during office work, in dairy cattle exposed to overhead EMF [21,22,65,85] and in laboratory trials [72,73,95,112].

Neuroendocrine stress characterized by the hypothalamic-pituitary-adrenocorticol response mechanism is perhaps most critical because of the influence of chronic stimulation of cortisol on numerous physiological reactions [12,20]. Cortisol increases heart rate and blood pressure, a sympathetic nervous system response, increases metabolic rate in early stages of prolonged stress, depresses in later stages, increases blood glucose, increases fat storage, increases appetite, and attenuates insulin release by pancreatic isle cells.

Veterinarians may need to consider electricity as a cause of IL-1 release when other common pathogens cannot be found as a common cause of impaired health using the time-tested diagnostic protocol that would ordinarily find the culprit. Veterinarians and medical doctors may need to add an ammeter, gauss meter, or other electrical meter to the diagnostic instruments in their black bag.

Electropathic Stress Effects on Humans

We measured effects of EMF radiated from the utility's neutral-to-ground wire below the living room floor on heart rate and blood pressure while sitting on the living room sofa. Heart rate and blood pressure increased in proportion to (1) EMF (mG), (2) voltage potential induced on the body, and (3) current (mA) exposure as measured with oscilloscope, and (4) measured changes in heart rate and blood pressure while exposed to the electrical current induced from the power line [59,61,64].

Secondly, a farmer developed heart arrhythmia and hypertension while working near 46-kV Transmission lines constructed 12 feet from his grain storage and machine-shed. Local doctors could not differentiate the cause of his cardiovascular impairment. However, a cardiovascular surgeon and electro-toxicologist in Dallas, Texas, administered a small electromagnetic challenge of 2-4 mG and recorded the changes in heart rate, arrhythmia, blood pressure, and changes in EKG tracings resulting from the electrical exposure [63,64]. Changes in heart rate, blood pressure and EKG tracings were positive proof that 60 Hz and 0.72 Hz EMF magnetic fields caused cardiovascular changes in the subject. Some 25 references to cardiovascular changes in occupational exposure to EMF are in the medical-bioelectric literature [64].

Human Hormone Responses to EMF – cell-phone GSM-900 signals reflected on circadian patterns of gonadal, adrenal, and pituitary hormones in men [32] were similar to responses of cattle [83], e.g., "a significant difference under the curve" 10.1% for ACTH for men exposed to cell phone signals vs. nonexposure. The pattern of cortisol paralleled that of ACTH. A significant difference in the maximum secretion of cortisol was found with the Friedman test ($P = 0.025$); the largest change was a 12% decrease for the 2-wk period compared to pre-treatment cortisol levels. The circadian rhythm of growth hormone (GH) was

evident. The largest difference in the area under the curve was a 17.3% decrease of GH reported for healthy men using cellular telephones two hours/day, 5 days/week for 2 and 4 weeks under controlled (hospital) conditions in France. Testosterone, Prolactin, and TSH followed similar patterns [32]. Apparently, blood sampling at a uniform time of day is necessary to minimize natural circadian effects when assessing environmental effects on these hormones. These responses are activated by epinephrine – acute-temporary, and longer-term by cortisol-chronic stimulation of the autonomic nervous system [12,20].

In addition to cortisol's effect on glucose and fat metabolism, Berne et al. [12] highlighted the following specific effects of cortisol:

Cortisol Effects on Connective Tissue – Inhibition of collagen synthesis by cortisol produces thinning of the skin and the walls of capillaries. The resultant fragility of the capillaries leads to intracutaneous hemorrhage [12]. In this regard, a medical officer for an aircraft manufacturer reported finding between 75 and 100 cases of unexplained bleeding tendency, as well as a significant excess of leukemia, brain tumors, and cardiovascular disease, among workers exposed to low-strength microwaves [10,28,86,94,95]. Collagen in smooth muscle is an important component of blood vessels, the intestinal tract, bone-joint cushions, cartilage and skeletal muscle connectors to bone and cell walls. Collagen integrity is impaired by excessive cortisol and cortisol is increased by EMF exposure. A small step of logic allows the conclusion that EMF affects integrity and elasticity of the aorta and other vessels permitting aneurysm, development of weak smooth muscle, gastrointestinal diverticulosis, ulcers, and gastro-esophageal acid-reflex syndrome. Joint-muscle pain is a common complaint associated with EMF exposure and diabetes [9,33,64,110]. Type I personalities are often associated with a stress syndrome and cardiovascular disease, etc. EMF exposure is clearly another source of neuro-endocrine stress [8, 20,43,57,84,87,127,132].

Chronic excessive stimulation of either sympathetic or parasympathetic control mechanism causes a stress reaction involving the central nervous system, through stimulation of peripheral nerves and activation of the autonomic nervous system response in the brain and the hypothalamus which contain the pituitary and pineal glands. The pituitary issues hormonal responses in the blood, neurotransmitters, which influence the adrenal glands and the function of virtually all organs in the body [12,20].

- **Effects on muscle.** Cortisol maintains the contractility and work performance of skeletal and cardiac muscle. [Remember that short-term stress increases cortisol and long-term EMF stress results in adrenocortical fatigue].
- **Effects on bone**. Cortisol inhibits bone formation by several mechanisms: reduces Type I collagen formation; decreases the rate of differentiation of osteoprogenitor cells to active osteoblasts; decreases the absorption of calcium from the intestinal tract by antagonizing vitamin D_3. The result of these actions is a reduction in the availability of calcium for bone mineralization. Thus, one major consequence of excess cortisol production is an overall reduction in bone mass (osteoporosis).
- **Effects on the vascular system.** *Cortisol is required for the maintenance of normal blood pressure.* [However direct exposure to electrical stress increased cortisol, blood pressure, and heart rate of cows and humans as noted above].
- **Effects on the kidney.** *Cortisol influences the rate of glomerular filtration. The hormone is also essential for rapid excretion of a water load.* In the absence of cortisol, the synthesis and secretion of antidiuretic hormone (ADH) are increased and its action on renal tubules is enhanced; free-water clearance is diminished, and dilution of the urine is limited. Diabetes insipidus, the inability to produce concentrated urine, and frequent urination is the hallmark of ADH deficiency.
- **Effects on the central nervous system**. Cortisol modulates excitability, behavior, and mood of individuals; the electrical activity of neurons is influenced. Both Type I and Type II glucocorticoid receptors (GRs) are present in various areas of the brain, particularly in the limbic system and the

hippocampus. Cortisol decreases rapid eye movement (REM) sleep but increases both slow-wave sleep and time spent awake. In excess, cortisol can cause insomnia, strikingly elevate or depress moods, decrease memory and hippocampal volume and memory function.

- **EMF affected sleep** in experimental trials [59,72,73] and student behavior in the classroom [57,58] and electro-hypersensitive persons had higher heart rate and heart rate variability [87]. Cortisol also specifically decreases the ability to detect a salty taste and dampens acuity to gustatory, olfactory, auditory, and visual stimuli. On the other hand, cortisol improves the ability to integrate those sensations that are perceived and to organize appropriate responses.
- **Effects on the fetus.** *Cortisol facilitates in utero maturation of the central nervous system, retina, skin, gastrointestinal tract, and lungs* at physiological levels in blood [12].
- **Reproduction** – In a study of 1583 pregnant women, those using computers more than 20 hours per week had 40% more miscarriages compared with female workers who did not use computers [10]. Dr. Richard Neutra, Director of California Department of Health Services, reported a significant probability that the theoretical added risk of miscarriage for an EMF-exposed pregnant woman may be an additional 10 out of 100 pregnancies (10% increased miscarriages above the 10% of common miscarriages) in his 1991 report, *"An Evaluation of the Possible Risks From Electric and Magnetic Fields (EMFs) From Power Lines, Internal Wiring, Electrical Occupations, and Appliances"* to the California PUC.
- **Effects on inflammatory and immune response.** *Cortisol has a profound influence on the complex set of reactions evoked by tissue trauma, chemical irritants, infection, or foreign proteins.*

The EMF Cancer Link – Cortisol inhibits recruitment of circulating leukocytes to trauma or infection sites, decreases phagocytic and antibacterial activity of circulating neutrophils, i.e., increases neutrophils release from bone marrow but decreases their effectiveness for controlling disease, and EMF decreases AMP to ATP energy transfer in neutrophils. A_{2A} adenosine receptors in human neutrophils were also affected by pulsed transcranial magnetic stimulation, PTMS [118]. Cortisol decreases number of circulating eosinophils, decreases number of thymus derived T-lymphocytes, and depresses the immune system response to invading organisms or substances such as viruses [12, 20].

Hypersensitivity To Electromagnetic Waves – Some persons exhibit reactions when exposed to particular EMF frequencies [75,84,110] that are comparable to the allergic responses that may occur after exposure to chemical allergens [110]. Persons with perceived electrical hypersensitivity (EHS) had higher heart rate, heart rate spectrum ratio, and electrodermal activity than controls in tests with and without exposure to 60 Hz 10 μT magnetic fields [87], whereas EEG characteristics did not differ between groups. The Condition factor (mathematical test vs. relaxed) showed main effects for heart rate, heart rate spectrum ratio, electrodermal activity, and alpha and theta spectral bands of EEG. The authors cited other studies (0-300 Hz) which have shown related changes in integrative characteristics of physiological regulation such as transient deviations in EEG spectrum, brain evoked potentials, heart rate, and heart rate variability [71,72,87]; while others found no effects due to EMF. Behavior of children was impaired by EMF in schools but pupil performance and teacher welfare improved when RF filters installed in electrical outlets removed the high frequency voltage from outlets as measured with Graham/Stetzer microsurge meters [53,56,58,59]. Milham and Morgan found voltage microsurge meter [46] readings corresponded to a clutch of cancer among teachers in a California school [94].

Blood Metabolic Profiles of humans with self-perceived electromagnetic hypersensitivity were found to have clinical signs of dysfunction of the thyroid (more patients had low TSH levels), increases of liver enzyme AST, and chronic inflammatory process (CRP) in small but remarkable numbers of EHS persons [31]. Blood sugar levels among diabetics increased in proportion to the mA exposure to EMF and may explain Brittle diabetes [56,59]. Installing EMF filters in the home reduced blood sugar and the amount of insulin required by

diabetics [56-59]. A pseudo iron deficiency occurs in blood of a population living near high voltage transmission lines [52] .

Cell Phones – Brain and Protein Stress – AUVA Report, July 2009 (diagnose-funk.org). The Austrian Social Insurance for Occupational Risks commissioned the Vienna Medical University to conduct research focusing on effects of GSM 900 and UMTS fields of cell phone radiation on the brain, immune system, and synthesis of cellular proteins. The AUVA studies have verified that electromagnetic fields from cell phones have an impact on the brain: at nonthermal levels of EMF: (1) During and after exposure, the so-called EEG alpha band (8-13 Hz) changed. (2) Some CNS responses to acoustical and optical stimuli (evoked potentials) mediated by brain waves remained changed for some 30 minutes after the exposure. (3) Synthesis of cytoskeleton proteins that form the supporting tissue of a cell were increased notably indicating that RF-EMF caused stress proteins to be synthesized. (4) The observed pattern of a generally increased protein synthesis forming of stress proteins helps explain why in metabolically active cells DNA breaks – caused by the free radicals – are not sufficiently repaired anymore, resulting in increased DNA breaks in cells that are exposed, and the formation of the free radical nitric oxide resulting in an increased rate of DNA damage. These findings concur with EMF cause of stress proteins in cells [14]. Also see www.bioinitiative.org .

Signs and Symptoms of Sensitivity to EMF exposure in patients were established by medical doctors and electrical engineers during blind studies of more than 100 electrosensitive people exposed to 2900 nT of EMF at floor level and 350 nT at the height of a chair seat. The series of tests were replicated three times in 1991 by Rea et al. [110] and summarized below:

Signs and Symptoms of People Sensitive to EMF

Dr. William Rea, M.D., 1991, published Signs and Symptoms of People Sensitive to Electromagnetic Fields. Level of exposure was 2900 nT at floor level, 350 nT (0.35 µTesla) at level of chair seat.

Symptoms were categorized as follows:

- **Neurological– tingling, sleeplessness, headache, dizziness, unconsciousness**
- **Musculoskeletal -- pain, tightness, spasm, fibrillation**
- **Cardiovascular – palpitation, flushing, tachycardia, increased heart rate & BP**
- **Oral/Respiratory – pressure in ears, tooth pain, tightness in chest, dyspnea (difficult breathing); some had 20% reduced pulmonary function**
- **Gastrointestinal – nausea, belching, perhaps ulcers.**
- **Ocular – burning and tearing of the eyes, rate of pupil dilation changes frequencies.**
- **Dermal – red rash, itching, burning, prickling pain.**

The Public Health Boards of the United Kingdom and the Swedish Medical Society have recognized similar signs as impairments to human health.

These factors help explain how EMF was related to increased blood glucose of diabetics during environmental exposure in the home and decreased blood glucose and insulin requirements of diabetics when frequency filters were installed in wall outlets to reduce EMF exposure [48,56]. Similarly, the incidence of Type II diabetes was higher among persons living near high power transmission lines and was positively related to an index (mG x time) daily exposure in Australia [9].

Diabetes mellitus is believed to be genetically imbedded in chromosomes and must be triggered by some environmental stimulant resulting in insulin deficiency through destruction of islet cells of the pancreas and Type I diabetes mellitus. Increasing evidences indicate that exposure to EMF may be one of the stress factors that trigger diabetes [20, Chapter 24,56].

Cortisol inhibits recruitment of circulating leukocytes to trauma or infection sites, decreases phagocytic and antibacterial activity of circulating neutrophils, i.e., increases neutrophil release from bone marrow but decreases their effectiveness for controlling disease, decreases number of circulating eosinophils, decreases number of thymus derived T-lymphocytes, and depresses the immune system response to invading organisms or substances such as viruses. [12]

From personal experience, my heart rate and blood pressure increased linearly as induced EMF (10-50 mG), current (amperes), and voltage (V-AC) increased in the living room as radiated from the ground wire and water pipes beneath the living room floor while I was seated on the sofa [60].

Similarly, a farmer developed arrhythmia, hypertension, and neuromuscular tremor while working near 46-kV transmission lines inducing 4.87-5.2 milliGauss EMF measured at head height, and calculated at 30 inches above ground by utility engineers. The cardiovascular response "signs" were repeated during exposure to 2-4 mG in a doctor's laboratory in Dallas, Texas. References to cardiovascular effects of exposure to EMF are abundant in the bioelectric and medical scientific literature [64].

EMF Proliferated Leukemia in Cows, as in Children, and MSU Mice –

A group of medical doctors, Gang Chen, Brad Upham, Wei Sun, and Chia Ching Chang in the Pediatrics Department of the College of Human Medicine working with Electrical Engineers, Kun Mu Chen, E. J. Rothwell, and Bio-physicist James Trosko, Michigan State University had published an undisputable report in *Environmental Health Perspectives* [24], stating that induced 60-Hz electromagnetic fields inhibited maturation of erythroleukemia cells of mice *in vitro*. Exposure of the cell line resulted in dose-related inhibition of differentiation with maximal inhibition peaking at 40% and 40 milliGauss (4 μT, microTesla). ELF-EMF at 10 mG (1 μT) and 25 mG (2.5 μT) inhibited differentiation at 0 and 20%, respectively. EMF at 1.0 and 10.0 Gauss (1000 μT) stimulated cell proliferation 50% above the sham-treated controls. The authors noted that "ELF-EMF can partially block the differentiation of Friend erythroleukemia cells, and this results in a larger population of cells remaining in the undifferentiated, proliferative state which is similar to the published results of Friend erythroleukemia cells treated with chemical-tumor promoters." This was convincing evidence that EMF exposure of this cell line proliferated erythrocytic leukemia in mice. The finding was consistent with reports of increased leukemia in children living near power lines as reported by Nancy Worthheimer and E. D. Leeper in Colorado in 1979. Engineers and epidemiologist confirmed the earlier finding when they found childhood leukemia was related to current from the 3^{rd}, 5^{th} and 7^{th} harmonics in the victims homes radiated from ground wires from power lines coming into the homes (77).

DNA Breaks Induced and Repairs to DNA Damage Inhibited by ELF-EMF exposure have been reported in a review of DNA research [161]by: Induction of DNA strand breaks by intermittent exposure to ELF-EMF fields in human diploid fibroblasts [151], ELF-EMF fields cause DNA damage in a dose-dependent way [152], ELF-EMF DNA damage induction is Age-related [153], Genotoxic effects of ELF-EMF exposure on human cells, *in vitro* [154], microelectrophoretic study of radiation-induced DNA damages in individual mammalian cells [155], A simple technique for quantitation of low levels of DNA damage in individual cells [156], Oxidative damage to DNA: Do we have a reliable marker? [157], Measurement of DNA oxidation in human cells by chromatographic and enzymatic methods [158], UK childhood cancer study investigators,

exposure to power frequency magnetic fields and the risk of childhood cancer [159], magnetic-field induced DNA strand breaks in brain cells of the rat [160] and, Damage to Molt4T-lymphoblastoid cells exposed to cellular telephone radiofrequency fields *in vitro* [107].

Dr. Martin blank, professor in the school of medicine , Columbia University, NY, has conducted numerous laboratory studies concerning the stress effect on DNA proteins and has listed about 150 research articles pertaining to the topics of ELF-EMF stress and effects on cells. Dr. Blank noted that: (1)"The stress response has been demonstrated in many cells and linked to changes in the DNA and chromosomes, (2) There are similarities in stress protein synthesis stimulated in the non-thermal ELF and thermal RF frequency ranges, (3) the biochemical mechanism that is activated is the same non-thermal pathway in both ELF [powerline frequency 50-60 Hz] and RF, and is not associated with the thermal response. [see www.Bioinitiative.org

In summary Dr. Blank wrote: "It is generally agreed that EMF safety standards should be based on science, yet recent EMF research has shown that a basic assumption used to determine EMF safety is not valid. The safety standard assumes that EMF causes biological damage only by heating, but cell damage occurs in the absence of heating and well below the safety limits. This has been shown in the many studies, including the cellular stress response where cells synthesize stress proteins in reaction to potentially harmful stimuli in the environment, including EMF. The stress response to both the power (ELF) and radio (RF) frequency ranges shows the inadequacy of the thermal (SAR) standard. The same mechanism is stimulated in both ranges, but in the ELF where no heating occurs, the energy input rate is over a billion times lower than in the RF range. He quoted the following: *Scientific research is designed to answer questions, and answers do not come from deciding a priori that certain types of studies are not relevant or can be ignored because they have not been adequately proven in the eyes of the organizers. Scientific method is not democratic. The word 'proof' in 'scientific proof' is best understood in terms of its older meaning of 'test'. It does not rely on an adversarial 'weight of the evidence', where opposing results and arguments are presented and compared. Answers do not come from keeping a scoreboard of positive versus negative results and merely tallying the numbers to get a score. In scientific proof, number and weight do not count.* It is hard to see how the review in Bioelectromagnetics Supplement 6 could reconcile its advocacy of science as a guiding principle with its subsequent endorsement of "the weight of the evidence" to be used in their assessment. *We should be reminded that 'scientific proof' is not symmetric (Popper, 1959). One cannot prove that EMF is harmless no matter how many negative results one presents. One single reproducible (significant) harmful effect would outweigh all the negative results."*

Similarly, in a dairy herd where milk production decreased linearly as the sum of cow-contact harmonic impulses (0 to 25 kHz) increased daily, MSU Veterinarians found a ~30% incidence of bovine leukemia in calves in the herd, near Prescott, MI. The high incidence of leukemia in a herd that had been closed for 30 years (no purchased cattle) was unexplainable by the veterinarians who conducted an extensive investigation of the herd. The linear trend of increased leukemia in children exposed to power line EMF and leukemia in calves immersed in a power line electromagnetic field is not coincidental.

Sources of EMF

Electric Contact Current, and Induced Current from Electric and Magnetic Fields (EMF) occur in all circuits that carry electricity including: Electric power distribution lines, Electric Transmission Lines, the Neutral-to-Ground wire that is connected to water pipes in municipalities, and all electrical installations using a grounded-Y distribution system; Delta distribution systems may have the power quality problem on the phase wires, since the 3-phase wires serve as neutral wires for each other. Telephone and cellular telephone systems that use switch-mode AC/DC converter power supply, and radio stations deposit large amounts of EMF onto the neutral wire.

All household and office circuits that carry electrical current radiate EMF. All electrical appliances and electronic devices, i.e., radio, television, cellular phones and automatically controlled appliances, office and medical equipment (MRI) radiate EMF into the environment. Some people are more sensitive and less tolerant of EMF than others, and children are generally more susceptible than mature adults.

Protection from unnecessary exposure to electric and magnetic fields can be achieved by (1) Creating awareness of the dangers and health risks of overexposure to EMF. (2) Identifying likely sources of EMF in homes, schools, and workplaces and teaching hygienic EMF practices. (3) Working with the electric power and electronics industries to eliminate unnecessary exposure to EMF. (4) Providing effective mitigation devices to reduce EMF and keeping a safe distance from appliances and equipment that radiate excessive EMF. (5) Reduction of health effects can reduce medical and hospital costs in the range of 15 to 20 percent while making the environment healthier, and providing employment to make the necessary changes. The cost of such program could be absorbed in electrical and electronic industry rates per KWH of energy distributed in the environment.

Michigan Public Service Commission Administrative Rules, adopted in 2006 governing animal contact current mitigation, [93] are inadequate for protection of livestock and people working in the vicinity of electrical and electromagnetic radiofrequency interference as noted above.

Members of the Legislature and public agencies will want to re-examine MPSC Rules, and administration of electrical and health issues. At least three statutes adopted by the Michigan Legislature apparently are unattended since no agency accepts responsibility for enforcement of the following:

1. **Electrical Administration Act 217 of 1956** -- An ACT to safeguard persons and property, etc. Any willful violation of a code is punishable in Sec. 8e by
    - (1a) Revocation or Suspension of the electrician's license
    - (d) Restitution
    - Sec. 10 (1) Fines $1000 to $2000 per day for each day of violation

2. **Michigan Occupational Safety and Health Act 154 of 1974** -- An ACT to prescribe and regulate working conditions, to describe the duties of employers and employees as to places and conditions of employment, etc. Refers to OSHA, US Department of Labor, "Hazardous Energy."
    - **The Easement granted to utilities on farms is under the jurisdiction of OSHA.**
    - **Current 400 ft from the lines, induced on a grain bin and a farmer's body violated MIOSHA and OSHA standards for Hazardous Energy.**

3. **Michigan Public Health Code, Act 368 of 1978** -- An ACT to protect and promote the public health, etc., Sect. 333.2221
    - (1) Provides for diligent endeavor to prevent disease, etc.
    - (2) (b) Implement and enforce laws pertaining to health
    - (c) Collect and utilize vital and health statistics [How about effects of EMF in homes, schools, and workplaces ... including cow milkers exposed to EMF?]
    - (d) Make investigations and inquiries etc.
        (i) The causes of disease and especially epidemics
        (ii) The causes of morbidity and mortality
        (iii) The causes, prevention and control of environmental health hazards, nuisances, and sources of illness and
    - (e**)** Plan, implement, and evaluate health education by the provision of expert technical assistance and financial support.

We must remember: **"An ounce of prevention is worth a pound of cure!"**

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