Exh. J. 2

Effects of Electrical Shock on Cattle

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Conclusions from Careful Examination of Published Research

[An article, *Review of Stray Voltage Research, Effects on Livestock*, by Robert L Fick, Director of the Michigan Agricultural Electric Council (an employee of the electric power industry) and Visiting Assistant Professor, Agricultural Engineering Department, Michigan State University, and Truman C. Surbrook, Professor, Agricultural Engineering Department, is on the MSU information network and in other Michigan State University publications. Conclusions of that article are challenged for understating effects of low voltage on health and performance of dairy cattle on farms. Conclusions are too dependent on limited research of doubtful merit while ignoring findings and implications of other valid, conflicting research. Such representations jeopardize administration of justice to owners of herds so afflicted and risk the establishment by the Michigan Public Service Commission or others of nonactionable voltages which are biased in favor of electric power suppliers. Such actions threaten access of plaintiffs to due process and are financially detrimental to dairy farm users and their families affected by such extraneous voltage. D.H. 1/30/99]

Research workers have documented effects of electrical shock on cattle and reported in scientific journals. They have called the electrical shock of concern here stray voltage. More precise and inclusive it is termed "extraneous voltage" defined as any outofplace voltage within environment of the animal regardless of cause, source, or magnitude (recommended by Bodman, Ref. 5). As cattle vary widely in response to voltage and to the same voltage on different days, opinions vary by research workers on effects of electrical shock on cattle. Our analyses indicate that major experiments had few enough cows that important differences in milk production, reproduction, and herd health may not have been detectable. Other conclusions are not excluded. The following is a summary of those findings:

Commonly Cited Cow Responses to Electrical Shock were summarized by Appleman and Gustafson (3): 1) Intermittent periods of reduced production; 2) reasons unexplained; 3) increased incidences of mastitis; 4) elevated somatic cell count [in milk samples]; 5) lengthened milking times; 6) incomplete milk letdown; 7) extreme nervousness in milking parlor [stepping, or raising of feet, switching of tail, kicking off milkers]; 8) reluctance to enter the milking parlor; 9) rapid exit from the parlor; 10) reluctance to use water bowls or metallic feeders; and 11) altered consummatory behavior [such as lapping water or splashing rather than normal drinking behavior]. Authors observed effects of stray voltage on four general areas: milking performanceand behavior, herd health, nutritional intake, and yield of product. Reproduction should be added to the list.

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Cows exhibit clear responses to applications between 2 and 4 mA of current according to Scott, Gorewit, and Drenkard (21). Variation between responses of cows to 4 and 8 mA shocks was large. Same cow response differed markedly to the same current on different days for Drenkard et al. (7).

Lefcourt (12) reported that as little as 0.199 volts and 0.693 mA electrical current was mildly shocking and 0.272 volts (.964 mA) resulted in distinct shock reactions in one cow in five tests for behavioral response to electrical shock. He found resistance from 250 to 405 Ohms and concluded that a cow with little electrical resistance is twice as susceptible to stray voltage as is a cow with high electrical resistance. He further concluded: "Therefore, because stray voltages on a farm do not exceed .5 V does not mean that the farmer will be free of stray voltage problems. In addition, because sensitivity to electrical current varies with parts of the body through which it passes, it is possible that cows might be even more sensitive to stray voltage if the current passes through the teat or tongue."

Electricians commonly include a 500 Ohm resistor in the circuit when measuring voltage in areas of cow contact as if the resistor represents resistance of the cow. Ohms should be at least 250-500, although resistances presumably change regularly as a cow picks up one or more feet either in walking or attempting to escape electrical current. Further, if the filament of a light bulb represents resistance on the circuit, then the heat and light produced by the resistor hardly can be considered no consequence in the circuit. A possible relationship between regular low amperages, e.g. 1 or 2 mA, causing pain (hot-foot ?), separation of hoof laminae, abnormal hoof growth, and other anomalies associated with stray voltage on farms cannot be ruled out by published research. Use of resistors in voltage meters would underestimate likely effects of low voltage on cattle. Also, transient voltages measured during low peak usage often increase significantly in late afternoon when heavier loads are consumed from same lines in the neighborhood.

In the latter experiments of Lefcourt et al., (14) 28% of the cows (2 of 7 cows) became so distressed by 10 mA electrical current that they could not be handled safely and had to be removed from the experiment. And Gorewit et al. (8) reported that 2 of 30 cows in one test and 4 of 44 first parity cows in another test refused to drink at 4, 5, or 6 V for 36 h and were given an alternative water source; that cows might have died should be part of the outcome. Such difference may not be statistically significant but may be economically significant (loss of $7,200 in cows plus $18,000 of milk) with no other water source available as under farm conditions.

Effects on Milk Yield and Milk Fat: In New Zealand (25, 26) as the number of electrical shocks 1 min before milking increased, workers found milk ejection increasingly was suppressed. Milk yields were 10% less when Phillips (19) applied three volts between milking claw and the rear feet of the cow during milking. Lefcourt and Akers (13) reported that 5 mA current resultedin 11% to 17% decrease of milk yield: "Milk yield and milking time were decreased in cows subjected to stimulation by intermittent voltage."

Similarly, Aneshansley et al. (1) reported to the American Society of Agricultural Engineers, (ASAE #87-3034, page 6, Milk Production)--"week 5 was significantly lower than week 2 for all cows that received voltages greater than 0." The authors' graphic presentation of "Milk Production Decline," Figure 11, is in the Appendices. Milk production changed (up to 3.5 kg/day) and at all voltages: 0.5, 1, 2, and 4 volts compared to the controls. Weeks 1 and 2 were pre-trial adjustment, weeks 3, 4, & 5 were voltage treatments, and weeks 6 & 7 were posttreatment.

Trends were apparent for "Water Consumption," Figures 2A vs 2B (Appendices), "Feed Consumption" Figures 12A vs 12B (Appendices), and possibly "Milk Fat" Figure 14A vs 14B (Appendices). Gorewit et al. (8) on the same experiments in the Journal of Dairy Science did not mention the significant differences at week 5 and did not present the graphic figures from the ASAE report. However, they did report that two animals receiving 4 volts did not drink for 36 h, at which time their voltages were disconnected. [And] "All other animals drank within 36 h and showed no significant long-term difference in the monitored parameters." This is not consistent with the Aneshansley report (1) where milk production was affected by a wide range of low voltages. Addition of 44 more cows to their numbers for a 2 d water and feed consumption and milk production "experiment" where they found four more cows that did not drink for 36 hours drew their conclusion: "... no significant long-term difference in monitored parameters." Variances, small numbers, and limited time exposure render contribution doubtful for describing on-farm expectations from stray voltage.

Behr (4), a forensic economist, studied research notes and data provided by Cornell workers under Court subpoenas and concluded that "The turnover of cows in the samples is too high to support a claim of controlled full-lactation experimentation." He determined that the number of cows per slot (40 slots) averaged 3.6 for the 394 days and 141 cows which passed through the experiment from 9/2/88 to 9/30/89. This computes to a 365 d "cull" rate of 3.3 cows per slot, or 230% compared to the more usual 30%, or at about 8 times the normal farm cull rate. And Behr concluded that the turnover rate "is so far in excess of feasible farm conditions it renders the Cornell Research results irrelevant even if they were valid."

A list of the "Final 40" cows in means was not provided in either published article nor request for such data. However, lactation records were provided for 40 cows identified as □93"The Final 40."

For these, differences between groups for published 305-d lactations were surprisingly small as if means were restricted from varying as they would with normal residual variation among cows. Authors' conclusion that none of voltages 0, 1, 2, and 4 V affected milk production 7312, 8527, 6938, and 7725 kg probably should elaborate that design did not enable such evaluation through this trial. Conclusion that voltage did not affect milk yield may have misled where it was testimony by expert witnesses in court.

Milk fat was depressed from voltages (Aneshansley et al. (2)) during measurement of cow sensitivity to electricity during milking. "Milk fat was lower when currents were applied to first lactation cows [-.2%] and significantly lower [-.5% (p<.05)] for multiple lactation cows." Decreases of fat test reduced the market value of milk at least $.20 to $1.60 per 45.5 kg of milk sold; $40 to $320 per cow for a typical herd averaging 9,091 kg milk/cow/year. Similarly, milk fat was less for all voltages (1, 2, and 4 V) vs 0 controls in the full lactation trial by Gorewit et al. (9, Table 2). The average percent for the three periods given for 2 volts is miscalculated and should be 3.7% rather than 4.0%. Average for controls was 3.8% fat in milk.

Milk fat depression is a common response to heat stress (24), and apparently it occurs in cows subjected to electrical stress as well. Depressed milk fat is common in farm herds subjected to stray voltage, but it has been attributable to variations of dietary fiber and electrolyte imbalances, not mentioned in the Cornell reports but assumed to be equally distributed among treatments. Because cows were fed supplemental grain individually from an automatic transponder feeder, differences in amount of grain fed could have affected fat test. Depression of milk fat by electrical stress, if real, may be further supporting evidence of the adrenocortical stress syndrome as increased blood cortisol is produced by electrical stress.

Effects on Health and StressRelated Disorders: Persistent, intermittent electrical shock produces typical stress syndrome characterized by increase of blood adrenal hormones: cortisol (hydrocortisone) (7) and epinephrine (adrenalin) (7,14). Henke Drenkard and Gorewit, et al. (7) found blood cortisol increased by 4 and 8 milliamps (mA) electrical current applied for 5 of every 30 sec during milking. While increased mean cortisol of 4 mA treatment during milking (6.44, 8.78, and 10.86 ng/ml) was not different from controls, with 6 cows and treatments switched every 8th day for 3 wk, (p>.05) a trend is apparent, and the 8 mA group mean was significantly different. Cortisol continued to rise for 16 to 20 h posttreatment when means were 13.25, 14.31, and 18.38 ng/ml for the 0, 4, and 8 mA shock. More somatic cells in milk of cows from the control group suggest that mastitis might have played a role in the controls as evident by the larger SCC standard deviation and its possible effects on blood cortisol and statistical analysis. The authors noted that: In work prior to this trial, most cows exhibited behavioral responses to electrical current at 4 mA.

In the full lactation report on Cow Health and Reproduction (9) Cornell authors noted, "When an experimental cow got mastitis, she was removed from the experimental pen and placed with other mastitic herd cows." "Also, the waterer for any mastitic cows was not connected to any voltage." Apparently, effects of exposure to voltage on the severity or recovery of sick animals was not considered important nor was the effect of replacing mastitic experimental cows with other cows in the analysis of data. Gorewit's statement, "All indications of cow health that were measured (somatic cell counts, cases of mastitis, repeat mastitis, hoof problems, and body weight) showed no detrimental effect that was due to voltage," needs to be qualified to advise readers "given the large variations and few cows on our experiment."

Calculation (22) of "sample size" necessary to show significant differences between controls and treatment means for the measured "Services per Conception" where treatment means and SEM(standard error of the means) are in Table 2, p. 2729, revealed that 48 cows per treatment would be required to show significant differences ($p<.05$) to be sure that means will be significantly different 90% of the time.

In the USDA (14) experiment, blood glucocorticoids of 0 mA controls were abnormally elevated, nearly twice baseline of treatment groups (controls=13.9 baseline) compared to treatment baselines of 9.9, 6.0, 6.0, 6.9, and 8.3 ng/ml for 2.5, 5.0, 7.5, 10.0, and 12.5 mA treatments for 10 seconds, 1 hour prior to milking. These high cortisol controls made significant differences between treatment baseline-minus-peak versus controls impossible for any voltage treatments with "standard error of the mean (range) 4.5-5.5 ng/ml." Results were based on seven cows divided into two groups shocked bi-weekly. Calculation of the sample size required to show statistical significance indicates that 25 cows per treatment would have been required to be sure that means are different 90% of the time (22). Otherwise, the experiment provides no scientific basis for claiming that any voltage had "no significant effect" on the hormones measured. The inadequate controls and small number of cows would not allow any other conclusion, except that two cows became so unmanageable as to endanger workers at 10 mA that they were not subjected to 12.5 mA currents, and the experiment was terminated without completing its objective. Unmanageable cows were labeled "exceptional" as in the Cornell reports, although they represented 28% of the cows on experiment.

Reproductive Efficiency may be inhibited by electrical stress because repeated acute stress, with a brief significant rise of blood cortisol, can disrupt the preovulatory luteinizing hormone (LH) surge and ovulation in heifers (23) such as caused by transportation or severe climatic conditions. These authors noted that previous investigators have found that ACTH, cortisol, and progesterone, also released by the adrenal cortex, can inhibit LH surge in the cow. Wilson et al. (27, 28) confirmed that controlled heat stress inhibited ovarian function and reproductive efficiency in cows and heifers by inhibiting follicle growth and development and increasing incidence of delayed regression of corpus lutea. Reproductive failure is a common complaint in herds affected by stray voltage and can have severe economic consequences by reducing the number of off-spring born, culling opportunity, and eventual number of cows in the herd. Increasing adjusted calving interval resulted in net revenue losses of $7.33 (US) per cow/day in a study of the economic effects of reproductive efficiency (20). Data in the Cornell (10) study were too limited for valid conclusions regarding effects of electrical stress on health and reproduction. Also, cows that were not seen in estrus within 50 d after calving were given prostaglandins F2-alpha to destroy the corpus luteum, stimulate estrus, and were inseminated in 5 to 7 d. This procedure corrects the delayed (retained) corpus luteum problem caused by stress as described by Wilson et al. and, therefore, corrects the problem supposedly being measured by the experiment, rendering it invalid and unrelated to objectives of the experiment. From the means and variances for services per conception, 48 cows per treatment would have been necessary to obtain statistical significance and be sure that means would be different 90% of the time. Again, the few cows and large variation limit data and concluding "no significant difference" can be misleading.

Effects on Resistance to Disease: Increased blood cortisol caused by persistent stress, such as prolonged intermittent electrical shock, results in an immediate leukocyte shift, longer adrenocortical fatigue, and eventual reduction of peripheral white blood cells. Serial injections with 100 and 200 IU of ACTH to stimulate adrenocortical hormones reduced phagocytosis (engulfing) of bacteria (staphylococcus aureus) by white blood cells 43% and 56% after the sixth injection through a combination of decreased lymphocytes and decreased phagocytosis, as demonstrated by Paape (17) and (18, Tables 3, 6, & 7) and Gwazdauskas et al. (11). ACTH is the hormone produced by the pituitary gland, at the base of the brain, in response to stressful stimuli. It stimulates the increase of cortisol and other hormones produced by the adrenal glands. ACTH injection and heat stress of cattle produced similar moderate leukocytosis and increases in somatic cell counts of milk in Arizona studies (24).

Electrical stress from stray voltage may be similar to heat stress in which both feed and water consumption dramatically were reduced, and milk energy output declined nearly twice as much as digestible energy intake, resulting in marked decrease of efficiency of utilization of energy, and in considerably higher maintenance energy requirements (15). Corresponding protein catabolism via gluconeogenesis, electrolyte imbalances, atrophy of the thymicolymphatic system and gastrointestinal ulcers are all known consequences of adrenocortical stimulation caused by such noxious stressors as exposure to extreme cold, heat, xrays, burns, intense sound or light, pain, forced muscular exercise, starvation, hemorrhage, and anxiety. Electrical shock now can be added to the list of common stressors. Eventually, we may learn that electrical shock may be a contributor to abnormal incidences of metabolic disorders, lameness or bone disorders, and an immune deficiency syndrome similar to AIDS in humans.

Water and Feed Consumption: Craine (6) reported that water consumption from a watering trough charged with 6.0 volts was 68% less than from the zero volt trough, and 48% less for the 6.0 volts than from a 3.0 volt trough. Three volts reduced water consumption about 20%. Norell et al. (16) taught cows to escape from 5.0 mA treatments over a front to rear hooves pathway. During the test, cows were exposed from 1.0 to 5.0 mA. Cows expressed the learned escape behavior in 23% of 2.0 mA current treatments and 97% of 5.0 mA treatments. When the same series of current treatments was applied over a mouth-to-all hooves pathway, cows responded to 15% of 1.0 mA treatments and to 90% of 5.0 mA treatments.

In contrast, Cornell workers claimed no significant differences in milk yield or composition, health and reproduction, or water consumption (1, 9) of cows exposed to 0, 1, 2, or 4 volts at their waterers. In the Journal of Dairy Science articles, authors claim that results were based on 40 cows (10 cows per treatment group) for complete lactations. However, five months were required to complete filling the treatment groups with 10 fresh cows as designed, and apparently, according to research notes of the trial furnished by the authors under Court Subpoena, 141 cows were actually in the pens during the trial, and cows were put in the wrong pens 16 times during the trial. Water consumption was measured for the whole pen, not for individual cows; and cows were observed drinking from the waterers over the fence from outside the electrocution stall. Therefore, water consumption reported has no direct relationship to milk production of experimental cows because nonexperimental cows occupied spaces to keep the pens full.Gorewit et al. (9) stated that average current (and ranges) for 2 d (randomly selected) were 3.1 mA (4.5 to 1.5), 6.5 mA (8.6 to 4.6), and 11.2 mA (14.1 to 7.5) for the 1, 2, and 4 V pens, respectively in the Cornell experiment. Evidently current was not monitored regularly.

In view of results by others, design of the Cornell trials must have permitted meager exposure of cattle to electricity for outcomes to have differed so from reports of decreased water, feed consumption, and milk yield.

Researchers claim that amperage (flow of electrical current) rather than voltage per se is the culprit affecting cattle. The relationship between voltage and current is expressed by Ohm's Law:

E=IR, where E is volts, I is current flow (amperes), and R is resistance of the circuit (Ohms). Then, volts divided by resistance equals amperage.

A table of resistances to current flow through various pathways of the body is in the publication by Appleman and Gustafson (3). Resistances ranged from 244 to 1960 Ohms depending on the animal contact point and the pathway through the animal. For example: if the particular animal's path resistance is 250 Ohms, then .5 volts yield 2 milliamps as:

.5 volts/250 Ohms = .002 amps x 1000 = 2 milliamps current.

Because individual animals respond differently, arbitrarily selecting a predetermined voltage or amperage as safe for all animals seems foolish and irresponsible. Economic consequences occur when as little as 2 of 37 or 2 of 7 of the cows in a herd are afflicted by stray voltage.

The Attorney General of Michigan concluded (Re: Michigan Electric and Gas Association, Case No. U11368, October 15, 1997) that the Michigan Public Service Commission does not have the statutory authority to approve rules to regulate the levels of extraneous electrical current, which attempt to authorize utilities to spread unwanted and detrimental electrical power (voltage and/or current) outside of contractual easements onto private property to the detriment of the health, safety and welfare of both people and animals, and to the detriment of the use and enjoyment of property. The Attorney General's opinion was in response to a request by Consumers Energy Company for the PSC to rule that 2 mA electrical current or less was not harmful to livestock, and, therefore, plaintiffs claims could not be brought to litigation.

Conclusions

Scrutiny of the published articles cited in *A Review of Stray Voltage Research, Effects on Livestock*, by Robert J. Fick and Truman C. Surbrook, does not support their conclusion that 2.0 or less milliamps current from extraneous voltage is harmless to dairy cows and of no economic consequence to dairy farmers. Much of the data are unreliable and irrelevant to voltages found on farms and are misleading to an unsuspecting public.

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Appendices

Figures from: D. J. Aneshansley, R. C. Gorewit, D. C. Ludington et al. Paper #87-3034. 1987. Am. Soc. Agr. Engineers (Baltimore, Md.).

Figure 11: Milk Production Decline.

Figures 2A and 2B: Water Consumption.

Figures 12A and 12 B: Feed Consumption.

Figures 14A and 14B: Milk Fat

FROM: Aneshansley, D. J., R. C. Gorewit, D. C. Ludington, and Z. Xin. 1987. Effects of Neutral-To-Earth Voltage on Behavior, Production and Water Intake in Dairy Cattle. Paper No. 87-3034. Am. Soc. Agricultural Engineers. Baltimore, MD.

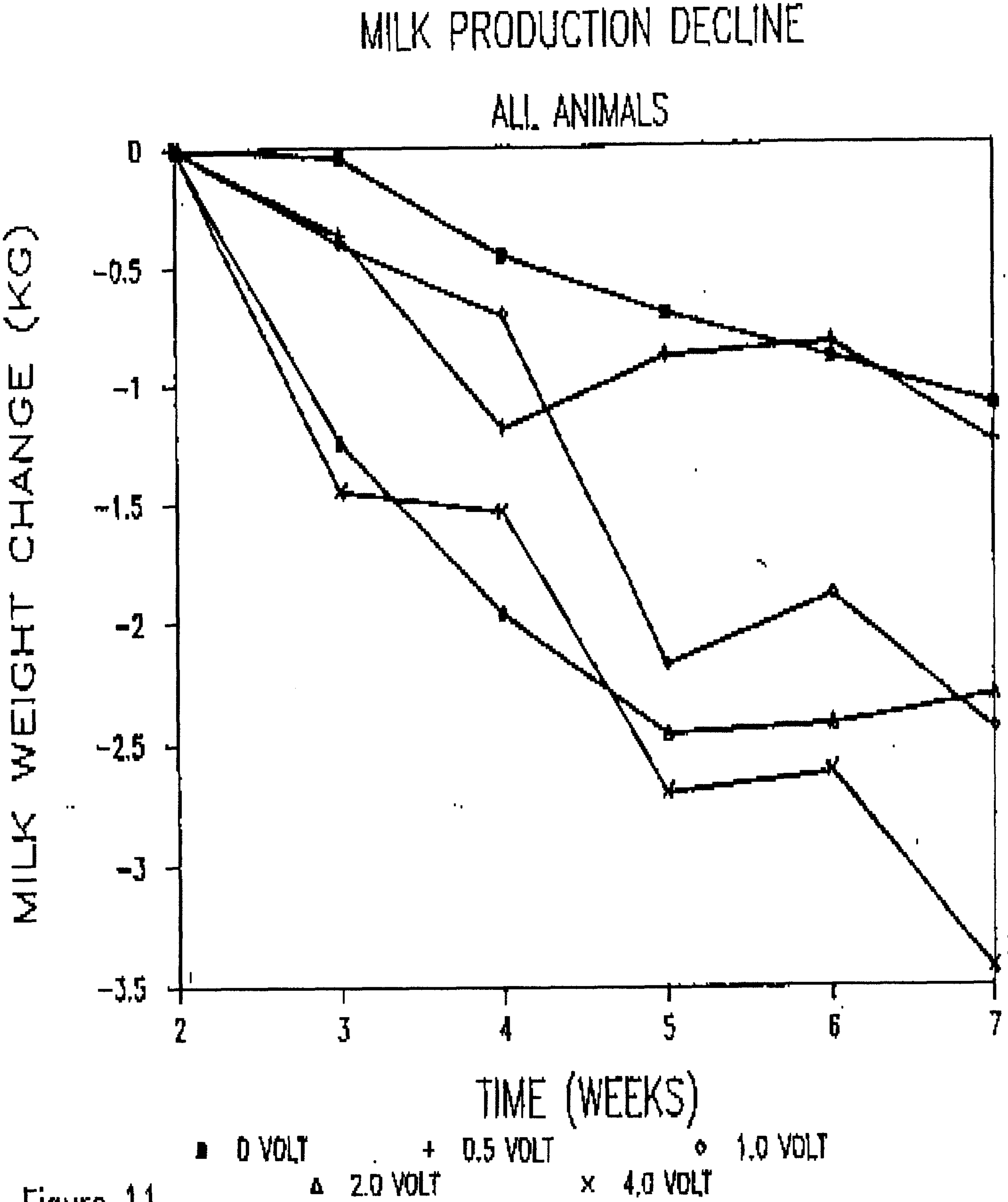

Figure 11

From: Aneshansley, et al. Paper 87-3034, ASAE, Baltimore, 1987.

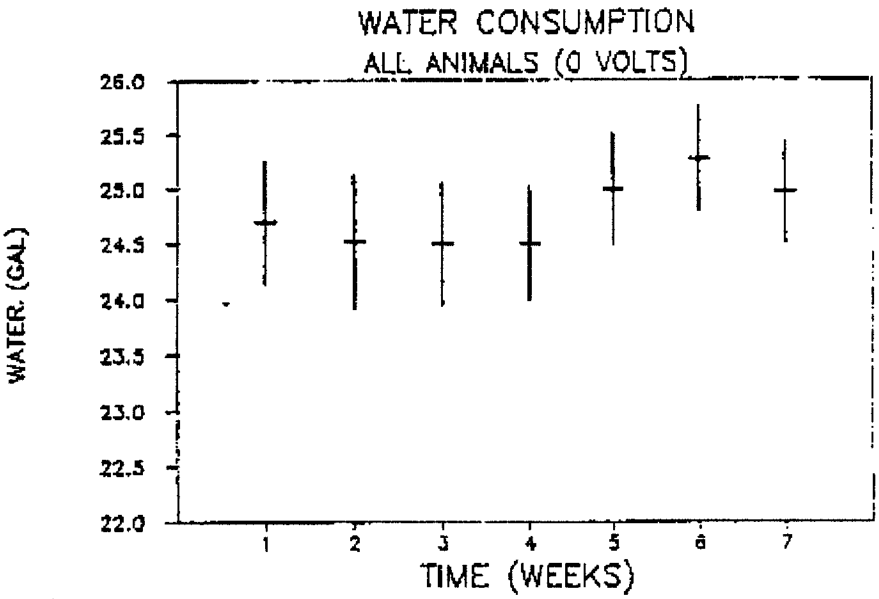

Figure 2A

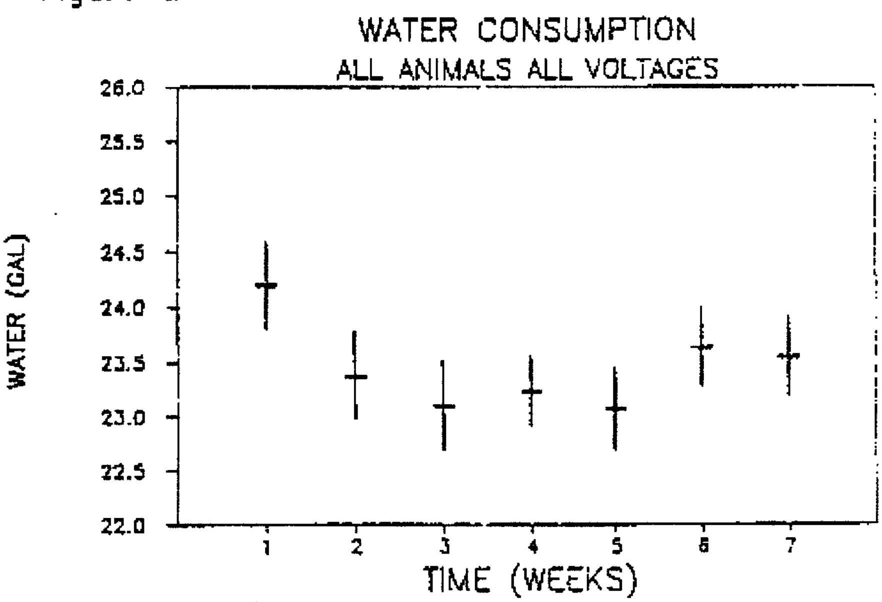

Figure 2B

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From: Aneshansley, et al. Paper No. 87-3034, ASAE, Baltimore, 1987.

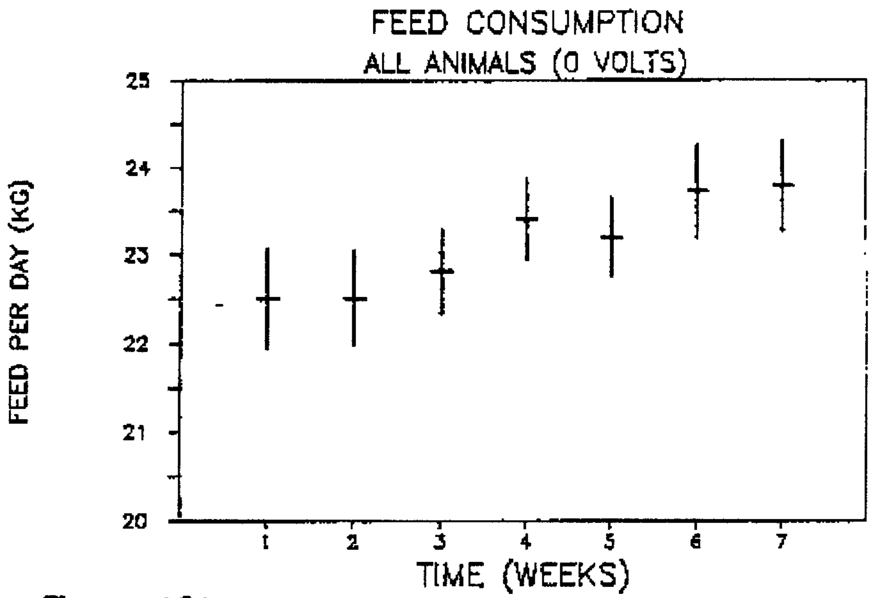

Figure 12A

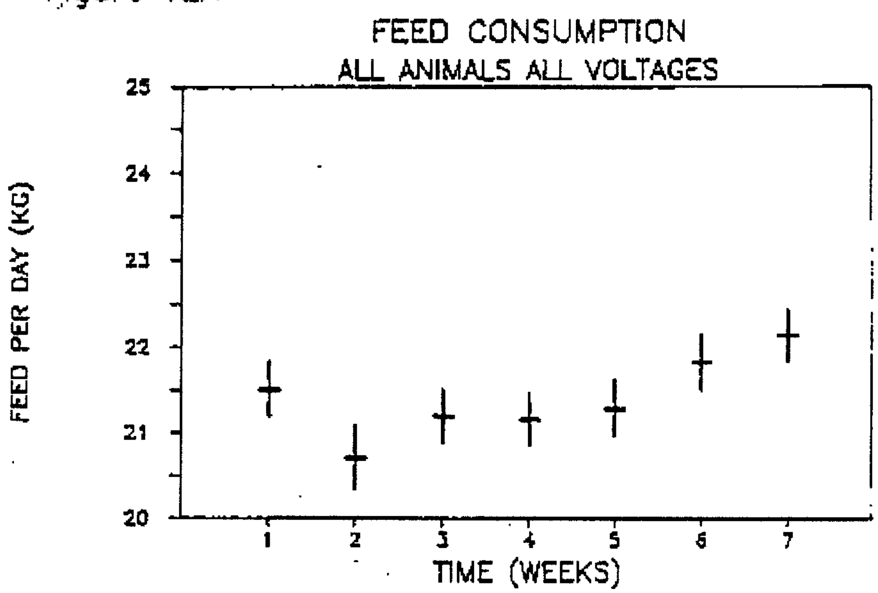

Figure 12B

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From: Aneshansley, et al. Paper No. 87-3034. ASAE, Baltimore, 1987

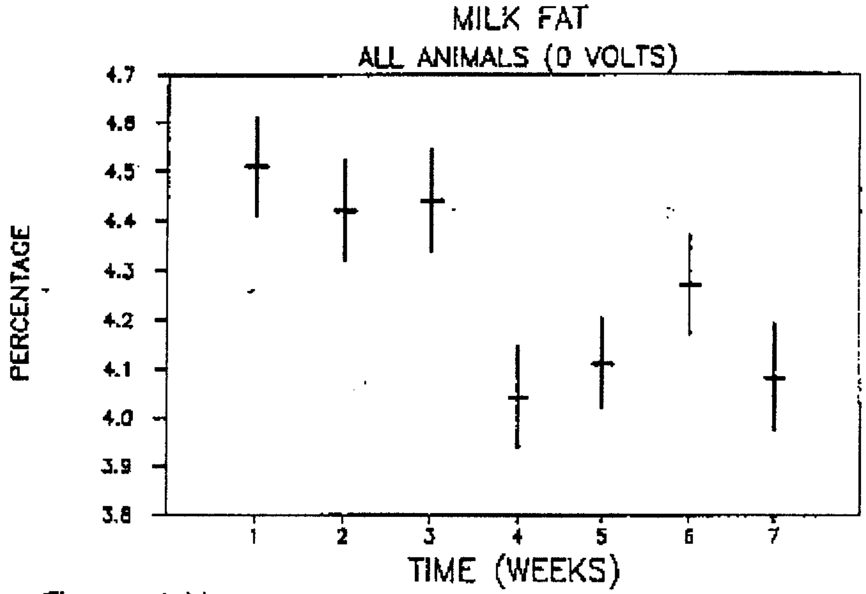

Figure 14A

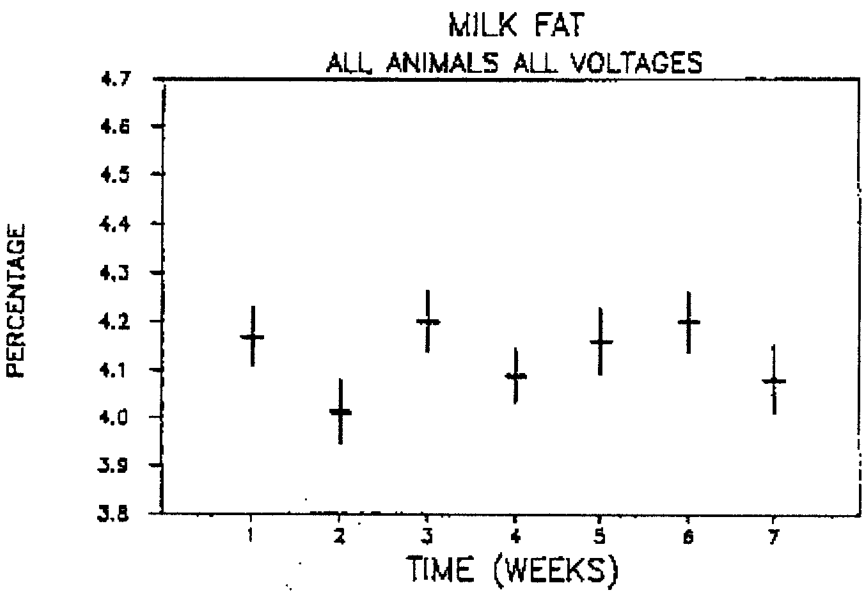

Figure 14B