INVESTIGATIONS OF THE EFFECTS OF NATURAL AND ARTIFICAL ELECTRIC AND MAGNETIC FIELDS ON RADIOACTIVE DECAY

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Section One

POWER LINE STUDIES I:
LABORATORY AND FIELD OBSERVATIONS AND EXPERIMENTS RELATING RADIOACTIVITY AND ALTERNATING ELECTRIC AND/OR MAGNETIC FIELDS

Introduction

Work in the first section concerns the effects of 60 hertz electric, magnetic or electromagnetic (EM) fields on radioactive sources. Briefly, it is felt by the author that these fields as well as the others reported in the following sections can affect the rate of decay and/or energy of emissions. Energy of β particles and γ ray emissions and spectra have been determined for several radioisotopes and often found to be changed after exposure. In many cases the activity was changed. Some half-life values have been calculated for exposed materials and compared to unexposed materials. Some experiments of short duration of exposure of the mildly radioactive phosphate nodules, soils and other sources indicate that the effect can be observed for days, weeks, months and more after exposure. It also was found that repeated exposures to EM fields have an effect different than a single exposure.

Additional evidence that EM fields affect energy and decay rate of radioisotopes was obtained from field studies involving high voltage transmission lines. It appears that soil radioactivity will track the magnetic field generated by these lines when the soil has been exposed for long periods of time (years). A distinct reduction of soil radioactivity occurs in the soil under the power lines where the first (princpal) 60 hz electric field maximum occurs. Later studies, presented in section 4, seem to indicate that to a large degree, the reduction is caused by a positive DC field that is produced by coronal discharge from the high voltage 60 hz lines.

The statistics for the tests (mainly Student "t" tests) run throughout all four sections show a high degree of significance in numerous cases, although in most cases small sample sizes were run.

I. LABORATORY AND FIELD OBSERVATIONS AND EXPERIMENTS

(A) MAGNETIC MEASUREMENTS

In order to measure AC fields a simple gaussmeter was made using a 10” diameter coil with approximately 200 turns of about 0.5 mm diameter enamel or varnish coated magnet wire. This coil was covered with an aluminum foil and plastic sheets (for electrical shielding) and connected to a multimeter. Two models were used: Fluke 93 [1 millivolt limit] and a Beckman model 3060 [fast response, 0.001 millivolt limit]. This system was calibrated using current, volts, radius of coil, and number of turns of wire and was compared against previously reported AC magnetic sources reported in the literature (Becker, Brodeur, and newspaper and magazine sources). The calculated and measured values correspond quite well with the literature values using this instrument (with the Beckman meter). The above mentioned coil was used for work reported in section 1-3. Magnetic fields reported in section four were measured with a 3400 turn coil of copper wire of @ .75 mm thickness. The coil diameter was 5 inches. The measurments were made with the coil laying flat on a portable carrier. The hollow center core was oriented vertically. Use of this larger coil allowed measurement of weaker fields using the Fluke 93 meter. This system was cross calibrated using the original coil.

(B) FACTORS INFLUENCING RADIOACTIVE DECAY

i. GENERAL COMMENTS

After reading several articles on the (im)possibilty of altering radioactive decay rates this author gradually came to believe it was indeed possible. One of the early pieces of evidence comes from a study of C^{14} decay in which L. Anderson at Chattanooga, TN exposed C^{14} deposited on metal and nonmetal plates to a weak DC electric fields and found this altered the distribution of energy and/or decay rate of the C^{14} isotope. Rightly or wrongly, it was interpreted that he had altered either the average energy of the beta particle (affected their energy distribution) or had altered the rate of decay. Some years later the author read that Dr. Radha R. Roy, a physicist at Arizona State University, in 1979 had a method of rendering radioactive waste non-radioactive.

For the above and other reasons it was felt that high electric and/or magnetic fields could change the energy distribution and/or 1/2 life period of the naturally occurring radioisotopes. At this point around twelve years ago in 1984 this author began to test this hypothesis. About 8 years ago (1988) the author ran across some published theoretical work by Howard A. Reiss of Arizona Research Laboratories University of Arizona, Tuscon. He had gone so far as to file patent applications with the U.S. Patent Office, one of which dates back to 1977 which is about two years before the article appeared in a local paper, the Kansas City Star, concerning Dr. Roy's work at Arizona State University.

Reiss has developed a mathematical theory based on quantum atomic and nuclear physics. Since 1977 he elaborated on this and apparently felt up until around 1987 that the application to shorten half lives of forbidden and long lived beta emitting radionuclides was feasible. He has presented along with his many publications in such journals as Physics Review, an article in Proceedings of a Symposium on Waste Management in 1984. In this he suggests using low frequency EM fields to induce enhancement of decay. His theory predicts a shortened half life associated with greater activity will occur for beta emitters (particularly those with forbidden transitions) and metastable isotopes having isomeric transitions involving internal conversion when exposed to high intensity EM fields (particularly low frequency). This author has found, employing a number of different types of 60 hertz EM fields, that 61.5% of exposed samples increased in activity while 77.8% had an increase in the half life and 64.3% had the energy of emission (E_{BMax} or λ_{max}) increase. In a few cases with combined systems did the half life decrease with increasing activity (K^{40} and Rb^{87}) while the the E_{Bmax} of both increased. In a study (details in a later section) using constant electric fields to expose C^{14} it was found that as the activity increased the E_{Bmax} decreased and when the activity decreased the E_{Bmax} increased. In this section the results of 15 kV 60 hertz electric field exposure and 416 G 60 hertz magnetic field exposure to * Ba^{137} is reported. Under both of these systems the activity of C^{14} and Rb^{87} increased upon exposure and C^{14} increased upon exposure to constant negative DC fields while the E_{Bmax} in all three cases decreased. C^{14} held at constant positive DC fields decreased in activity while the

E_{Bmax} increased.

Over the last several years, since 1985, experiments have been performed by this researcher in attempts to alter decay rates and emission energies of a number of radioisotopes using several physical forces. Investigated were the effects of large electric fields; the effects of magnetic fields; effects of field conditions (strength and orientation, oscillations, [AC and DC]); and effects of mixed electric and magnetic fields on decay rates and emission energies. The radioisotopes that were used in this investigation are Cs^{137} (and $*Ba^{137}$), C^{14}, Sr^{90}, Co^{60}, U^{238}, Th^{232}, Tl^{204}, U^{232}, Pb^{210}, Po^{210}, K^{40} (in reagent grade potassium chloride), Rb^{87} (in reagent grade rubidium chloride) and various radioactive minerals such as uraninite (pitchblende), radioactive phosphate nodules and the shale matrix from the black shales in eastern Kansas , allanite, samarskite, corvustie, ellsworthite, carnotite, Wyoming granite, potassium feldspar, wood ashes, and soil.

The radioactive material in most of the minerals and soil was mainly U^{238} and its decay products although some contains a mixture of thorium 232 and its decay products, and frequently K^{40}. The phosphate nodules and in particular the shale matrix itself composing the black Pennsylvanian shale layers also contains fairly large concentrations of Rb^{87}. The soil formed from the breakdown of these shales also contains relatively large amounts of Rb^{87}.

In this local area and wherever the Pennsylvanian outcrops, a major source of soil radioactivity is from weathering of shales, in particular black shales and the radioactive phosphate nodules formed therein. For this reason very extensive work was done using either discrete nodules or the ground up (granular or powdered) nodules or the black shale matrix itself. The shale, the nodules, and many other soil minerals contains K^{40} and Rb^{87} as well as C^{14} (coming from “modern” or recent organic residues in the soil); hence the emphasis on the nodules, shale matrix and in particular the isotopes C^{14}, K^{40}, Rb^{87}, Pb^{210}, Po^{210}, U^{238}, and Th^{232}.

The results of studies on radioisotopes if presented with statistics are usually presented with the two tailed “t” test when enough trials are available. In most cases the number of the trials run is five or ten hence large values of “t” are necessary to show statistical significance, particularly with large variation (large standard deviations). Although “p” value of 0.01 or less are common as criteria of significance 0.05 was chosen as a cutoff point unless extenuating circumstances such as rapidly rising and decreasing tested variable occurred. The choice of 0.05 as a less stringent criteria for significance is justified by the low counts of many of the trials coupled with few trials. Frequently when results of experiments had “p” value close to 0.05 they were repeated. In some cases the two or more individual trials were summed up or another experiment was performed with a greater number of trials. In order to make the length of this book reasonable, where available, the results of the summed experiments or the experiment using larger numbers of trials will be given. In some cases the use of larger samples did give smaller “p” (more significant) values but nearly as frequently the use of larger samples produced larger “p” values (less significant). There are numerous cases where the “p” values were less than 0.001 however. In order to extrapolate existing values, to do curve fitting and statistical calculations two computer programs were used; an Apple program, Stat’s Plus, and an IBM program, ProStat.

Several important points should be noted here.The radioactive sample’s activity was determined first then the sample was moved to the area (often in another room) where the environmental change (a variable) was made. After exposure the sample was taken back to the radiation detector (GM counter or scintillation counter) and the activity after exposure was noted. In most cases one to fifteen seconds occurred between the end of the exposure and the start of radiation counting after exposure. The controls or blanks, if any, were handled in the same manner as the exposed samples.

In some of the early work, attempts were made to expose the sample directly on the planchette holder. This proved difficult particularly when dealing with high electric or magnetic fields. They would influence the counters themselves. Because of these difficulties most of the later work was done by removing the sample from the planchette holder after getting pre exposure readings, exposing the samples in another location and then replacing the sample on this holder.

It was felt this procedure probably is more valid than trying to obtain activity readings while exposure was occurring because after all persistence or residual effects were being sought. This led to two field studies of soil activity under power lines which are presented in the first and fourth sections. As the investigation proceeded, it was found that some effects are indeed persistent.

ii EFFECTS OF ELECTRIC AND/OR MAGNETIC FIELDS ON RADIOISOTOPE DECAY AND/OR ENERGY OF EMISSION

a. Alternating electrical field (E_{AC}) plus (E_{AC}) supplemental

Most experiments using an AC field were conducted with samples being exposed to 15 kV 60 cycle AC electric. In most cases the end of the high voltage lead was a piece of aluminum or stainless steel wire which has a large charge gradient around it. This experimental set up was originally called " high gradient " but later called [AG]. In some cases the high voltage leads were connected to an aluminum foil covered glass plate capacitor so the field was dispersed (low gradient). This set up was called later [G-] or [G]. When using the "neon" transformer to generate this voltage generally no arcing was allowed for the design of the transformer is such that when too much current is drawn it ceases operation. The associated magnetic field when used as "high gradient" is 46 mG when the coil used to measure the magnetic field is held 2-3 cm from the wire or plate. For more details the reader is referred to Table 6 and the supplemental Table 26 in the Appendix.

An extremely general observation of the results of AC electric field exposure was that of the 96 experiments from the selected set, 53 or 55.21% resulted in a decrease in activity but the overall activity was 108.27% of pre exposure levels. The selected set used in all of the papers summarized in Table 29 in section four comes primarily from Table 25 which is listed for studies in each individual paper. The selected set includes C 14, K 40, Rb 87, U 238, Th 232, phosphate (nodules and/or matrix), and soil.

Out of a total of seventeen experiments using C^{14}, fourteen or 82.35% resulted in a reduction of activity. The average activity of the 17 was 97.53% of preexposure level). Most experiments involved three to five readings of a sample prior to exposure and five readings after exposure(s). A few involved ten readings.

In most cases the samples of C^{14} were exposed for 15 minutes although some were exposed for as long as several days before taking a reading. In a very few cases the sample was exposed only a few seconds. The extent to which duration of exposure affected the results or as to what the minimum or maximum voltage was necessary for seeing a measurable change in activity was not determined. Note that Anderson in his research at Chattanooga TN used 45 (90) volts DC and exposure times of hours to obtain the results he observed.

Repeated exposure of the sample caused the activity to drop lower with each period of exposure. To some extent this can also be seen in Anderson 's data. In some cases observed by this author the activity drop seemed to be permanent as if the C^{14} was removed or eliminated or else the energy or half life very extensively reduced. Some early attempts were made to monitor the air above the sample as it was being exposed. The results of those tests were negative but were somewhat inconclusive. Work done in October and November 1993 with C^{14} on or in plastic lids in which arcing was allowed seemed to greatly decrease the activity permanently. It may be that the arcing itself blasted the C^{14} containg salt out of paper that sits in the plastic lids.

The overall results of exposing Rb^{87} to the AC electric field were similar to those obtained with C^{14}. Out of fourteen studies done on rubidium 10 or 71.4% resulted in decreased activity (Average activity of the 14 is 95.50% of preexposure level). Out of eight studies on potassium, five or 62.5% resulted in a increase in activity (Average activity of the 8 is 104.38% of preexposure level). Overall then the activity of the C^{14} and Rb^{87} radioisotopes decrease and K^{40} increases upon short duration exposure. The substrate that the radioactive sample rested on (metal versus non-metallic) seems to have some bearing on the result. For rubidium there seems to be some tendency for decreased activity when the sample is on a non-metallic surface (plastic lid) as compared to metallic surface (aluminum weigh boat). The opposite was true for potassium. A persistent effect (dealt with more extensively in a later section) noted was that if the AC field was above the sample the results were different than when the field was below the sample. See the [AG] vs [G-] comparisons for identical isotopes, particularly the pairs 37&38, 48&49, 56&57 in Supplemental Table 26. In a later section, results of an investgation of these effects are presented.

Studies done on the phosphate nodules and shale matrix revealed that exposure of the nodules either as discrete nodules, or ground up, to AC electric generally decreases the activity. The activity of the matrix however increases upon exposure. These nodules and the matrix contain significant amounts of potassium and to a lesser extent rubidium, uranium and thorium. There were 14 experiments done on the phosphate nodules (discrete or ground); of these 7 or 50% decreased in activity after or during exposure with the average activty being 98.43% of pre exposure values.

The supplemental table for AC electric studies contains some of the results of a long time (several years) study on the effects of EM fields on the phosphatic shales of eastern Kansas and on the phosphatic nodules found within. In this paper the results of exposure to 60 hertz AC electric are shown. A quick look at Table 25 at column "PO_4" one can see that the shale matrix itself when exposed to 60 hertz AC generally increased in activity (9 out of 11 or 81.80% increased) with the average being 112.67% of pre exposure values. Two notable differences between the shale matrix and the nodules found within is that the uranium 238 content is higher in the nodules and the potassium 40 content much lower.

The average nodule from the black shale contains .017% U and .165% K (.0117% of K is

K^{40}) while the shale matrix contains .0057% U and 2.50% K. Considering the uranium all as the radioactive 238 isotope and the potassium as the radioactive 40 isotope there would be .017 grams of U^{238} and .0000193 grams of K^{40} per 100 grams of nodule; .0057 grams of U^{238} and .0002925 grams of K^{40} per 100 grams of shale matrix. The uranium ratio (nodule/shale) is 2.98/1 and the potassium ratio (nodule/shale) is .06598/1. There is about 3 times as much uranium in the nodule as in the shale matrix and about 15 times as much potassium in the shale matrix as in the nodule.

In exploring this relationship further, artifical soils were created using chemically purified compounds. For instance rather than use clays as a silicate source, a mixture of K_2O, CaO, Al_2O_3,and SiO_2 was used. The percentages used were based on "averaged" values obtained from 3 real soils, elemental composition of rocks that weather out to form soils in eastern Kansas, and an average of 4 upper and 2 middle Pennsylvanian black shales found in eastern Kansas. The percentages in the real soil and the artifical soils are shown in Table 27. The percentages of K^{40}, Rb^{87}, U^{238}, Th^{232}, and C^{14} were carefully adjusted. The percentages of the radioisotopes, except carbon 14, were obtained mainly from shale analysis therefore the activity of these artifical soils (AS) was not quite matched to actual soils: AS being somewhat higher.

The results of exposure of these artifical soils to AC field above, [AG] and AC field below, [G-] are shown in Table 26. Looking at set 1 (normal levels 1K, 1U) and comparing to set 2 (.1K,10U) one sees that the % change in activity drops from 109.94 (normal) to 105.25 for [AG] exposure. Notice that although the potassium level is one tenth of normal and the uranium content is ten times normal the change in overall activity activity drops. Then compare set 1 to set 3 (10K,.1U) with [AG] exposure for both. Here one sees that the % change increases to 115.64 with set 3. Here the potassium level is ten times normal and the uranium is one tenth normal. This matches the overall results of exposure of the shale matrix and nodules. The shale matrix has a higher K level, lower U level and has a higher % change (an increase in activity) when exposed. The observation that exposure of the nodules some times results in a decrease in activity could be explained by a higher level of Rb within them: compare set 1 to set 5. Here the activity is much reduced when rubidium is raised by a factor of ten and potassium reduced to one tenth normal. Note that rubidium 87 is one isotope that has reduced activity when exposed to ac electric. A comparison of 42[AG] and 43[G-] in Supplemental Table 26 shows that K activity levels are changed little. The comparison of 48[AG] and 49[G-] shows that Rb activity levels drop considerably when exposure is from below. In set 5 the amount of K is reduced and the amount of Rb is raised. This should cause reduced activity particularly when the sample is exposed from below.

Another piece of evidence supporting this is a comparison of the exposure of granite and the seperate exposure of large crystals of potassium feldspar excised from this granite. A comparison of 30 and 31, potassium feldspar (Average = 123.2%) and 6a and 59, granite (Average = 106.3%) in Table 26 shows that on the average the potssium feldspar increases more upon exposure. The intact granite contains significant amounts of uranium and thorium (resembling the nodules) whereas the potassium feldspar contains much less U and Th and much more K (resembling the shale matrix).

As with the potassium and rubidium, placement of the phosphate sample in a non-metallic plancette versus placement in a metallic plancette was significant. One interesting observation is that when the same sample is repeatedly exposed, the first exposure which may result in lowered or elevated activity levels as compared to pre exposure can upon repeated periods of exposure be greatly elevated or lowered as compared to the first post exposure reading. For example see Table 26, experiments 19a&b, 23a&b, 27a&b, 28a,b&c, 31a,b&c and 33a,b&c. Even long after removal from the excitation source changes occur. In three separate experiments discrete Mineral nodules were placed on the top of a small 60 cycle 6 V step down transformer (184 mG and 4.65 v field at site where sample was placed) for one month (4 samples) or two (1 sample). The initial readings after removal from the transformer averaged about 85.1% of preexposure levels. The sample’s activities were monitored for seven days after the removal. During this time the activities rose to an average of @100% of preexposure level by day 7. A graph of this change in activity versus time is presented (figure 10A). From this data a plot of log of activity versus time was obtained (figure 10B). Assuming a first order process the half life can be calculated from the slope (t 1/2 = .693/-slope). The half life of the effect or the "relaxation time" was 0.4517days (10.84 hours). From a similar plot of log activity vs time for repeated short term exposure of a Mineral nodule to 15 kV AC above, [AG], a half life of 0.10 day was obtained while U^{238} acetate had a half life of 5.21 days when exposed to the same conditions. Later work, presented in section 4, on soil collected at selected sites from under a nearby newly energized power line shows this very clearly. The soil after removal from under the lines and with no additional exposure increases in activity for a week or so and later decreases approaching pre energization levels within several months and falling below within approximately a year.

Four trials using pure uranium salts were exposed to the 15 kV AC electric field : all increased in activity. Uraninite (pitchblende ore) and a uranium glaze on Fiestaware were also exposed. The Fiestaware glaze showed a decrease in activity while the uraninite after a total of three investigations was split: 2 runs increased and 1 run decreased. One experiment using Sr^{90} was done with the result that exposure resulted in a decrease in activity. Two trials on Th^{232} gave split results but each result showed a high degree of significance.

A number of experiments were done on soil most of which came from around the science building at JCCC campus which is located on (in) the Plattsburg limestone, a part of the Lansing formation. The soil type probably is Grundy or Polo silt loam or a mix of these two due to soil mixing ocurring during campus construction. In these experiments the soil was exposed to 15 kV AC from a neon transformer used in the high gradient mode and later was analyzed wet (damp) or dry inside the lab using plastic disposable beakers or aluminum weigh boats as sample containers. In several cases the neon transformer and the GM counter were taken outside and the soil analyzed in situ. In the soils analyzed in the laboratory the samples were placed on one plate of the aluminum foil covered glass capacitor used in DC studies. In most of these cases the aluminum foil that the sample rested on was earth grounded. The "hot" lead was dangled above the soil sample just high enough to prevent arcing. This set up later was called [AG] or [HGA]. In the studies outside only one lead was used and it too was placed just above the site to be exposed, high enough to prevent arcing. Another laboratory set up ,[G-], was prepared by connecting the hot lead directly to the aluminum foil of the capacitor plate that the sample rested on. Here the exposure was from below the sample.

The samples exposed in lab, wet or dry, in aluminum weigh boats or in plastic disposable beakers frequently increased in activity (ocassionally more than 200%) while the samples analyzed outside, in situ, after exposure (the GM counter was taken outside for the analysis also) all decreased in activity. The percent drop in activity was proportional to the distance from the site of exposure. The activity of the soil outside the lab was measured at the site by positioning the GM tube over (near) the exposure site. The GM tube (counter) was the same used inside the laboratory. This decrease in activity when the soil activity was measured outside using the counter outside cannot be attributed to change in the counter's efficiency mentioned earlier for soil activity was measured before and after exposure with the counter outside. The efficiency effect is thus the same at both times.

The wetness of the soil has an effect on the % change in activity. A comparison of all 23 soil samples analyzed show that the 14 wet ones averaged 93.14% and the 9 dry ones averaged 140.33% after exposure. It was noted from in situ studies that as the soil in the ground outside of the laboratory dried out the change in activity increased. Several experiments that were done in situ prior to 1993 and in summer 1993 show that increasing dryness will increase the activity of the after exposure although the % change is less than 100.

In experiments done in fall 1993 (data presented in a later section) it was found that the soil in the aluminum weigh boats and the plastic disposable beakers gain a charge if a DC source is placed on the capacitor plate that the sample rests on or if the DC source is above the sample. This DC bias affects the results even when the 15 kV AC is applied above or below the sample. It was found that the surface of the soil will carry the charge of the applied DC source while turned on but for a very short period (seconds) after turning off the charge on the surface is the opposite. When high voltage ac is applied the charge the soil surface takes on depends on the DC charge formed by the corona discharge and the distance the soil is from the ac source. It appears that for a high voltage AC wire source above ground there is a negative DC charge close to the source with a DC positive charge farther out from the source. More on this in the fourth section.

Researchers into atmospheric electricity (eg. Chalmers and Reiter) have found that in fair weather there is a positive electric field gradient of @ 130v/m above ground. The ground surface itself carries a negative charge. The aforementioned experiments which are presented in sections 2 and 4 on effects of constant fields and AC fields on activity revealed that indeed soil will show decreased activity when the surface of the soil carries a positive charge. When the outside soil (in situ) was being exposed to the 15 kV AC from the transformer it acquired a positive charge during excitation : hence the reduced activity after exposure.

In a series of experiments an aqueous solution of $*Ba^{137}$ was eluted into a plastic planchette from a Cs^{137} minigenerator. The activity was monitored using a scintillation counter with a NaI crystal detector. The integrated output from the counter was fed into a strip chart recorder where the activity was recorded versus time. The exposure was to the electric field generated by an automobile ignition coil triggered by a wetted mercury relay. The output was about 60 cycles at 2400 volts. The slope of natural log of the activity versus time for the unexposed sample was −0.2652107 which corresponds to a half life of 2.613 minutes (literature value 2.552 minutes).

The slope of the exposed sample was −0.2547541 corresponding to a half life of 2.720 minutes.

This corresponds to an increase of 3.71% in the half life after exposure.

Figure vii shows a superimposition of slopes while Figure viii shows initially the slope of the sample while no field is on and the change that occurs when the electrical field is turned on after about seven minutes.

A later experiment was done on $*Ba^{137}$ exposing it, in solution, to 15 kV AC electric field from above. The half life of the unexposed control (2.557 minutes) was very close to the accepted value of 2.552 minutes. The exposed sample value of 2.571 minutes was 0.014 minutes longer than the control. This represents an increase of 0.55% in the half life after exposure. Spectra was taken of the $*Ba^{137}$ also. The exposed samples wavelength maximum of the γ ray was increased to 0.674 MeV: up from the 0.662 MeV of the unexposed. The γ ray wavelength maximum was 101.81% of the unexposed. The height of the γ ray photopeak and x ray peak of the exposed sample was 71.33% and 70.39% respectively of the unexposed sample. Based on the height of the γ ray peak the exposed sample had an average of 71.33% of the activity of the unexposed sample. Student t test was done on the four trials resulting in p=.002. See 66 in Supplemental Table 26 for details.

The reduction in activity as measured at the x ray peak (70.39% of preexposure value) is about 1% lower than the reduction in activity as measured at the γ ray peak (71.33%). Internal conversion of some of the γ rays producing Auger electrons and x rays can occur. The conversion coefficient (N_e/N) appears to be somewhat lower for the readings taken after exposure to the 15 kV AC. This is assuming the % change in activity measured at the γ ray peak matches the change in activity at the x ray peak during the unexposed conditions (undisturbed system).

b. Alternating magnetic fields (M_{AC})

Here samples were exposed to magnetic fields produced by electromagnets, solenoids, or transformers operated with AC current (60 cycle). For details the reader should refer to Table 8.

A general observation concerning exposure of samples from the selected set to these magnetic fields was that of the 39 experiments run 21 or 53.85% resulted in decreased activity.

Short term exposure of carbon 14 may frequently cause an increase in activity. Out of eleven experiments done increased activity was found in nine (81.8%). The average activity of the eleven was 101.82% of pre exposure values. Several experiments using C^{14} shows that exposure to the magnetic field associated with a 6V step transformer (184mG magnetic field and 4.65 v electric field) will increase the activity. Some samples were wrapped with aluminum foil and placed on the small 6 V transformer. Others were placed on top of the black solenoid energized with 60 hertz line current (generates 416 G).

A Feather analysis was done on C^{14} in a plastic lid before and after exposure to the 416 G 60 hertz magnetic field. From this the maximum energy (E_{Bmax}) of the beta emitted was calculated. The E_{Bmax} of the unexposed sample was 0.1575 MeV (literature value is 0.157 MeV) while the E_{Bmax} of the exposed sample was 0.1535 MeV. The exposed C^{14} produced a beta with 97.46% of the energy of the unexposed. The activity of the exposed was 102.29% of the unexposed (see 34 Table 8). Note here the higher activity but lower energy of emission.

When rubidium chloride was exposed to the 416G 60 hertz magnetic field the activity dropped in 3 out of 5 cases (60%). However the overall change in all 5 results in a slight increase in activity (100.50%). In a fashion similar to the Feather analysis done on C^{14} exposed to the magnetic field a rubidium 87 sample was exposed to the same field for Feather analysis. The E_{Bmax} of the unexposed sample was 0.266 MeV (literature value is 0.273 MeV) while that of the exposed sample was 0.230 MeV. The Rb^{87} exposed to the 416G 60 hertz magnetic field produced a beta with 86.47% of the energy of that of the unexposed. Activity of the exposed sample was 103.82% of the unexposed (see 39 in Table 8). Again a higher activity is associated with lower energy of emission.

Five experiments were done on K^{40}. Of these four (80%) resulted in reduced activity; however the overall change was slightly positive.

Short term exposure of the aluminum foil wrapped phosphate nodule to the 200 gauss generated by the solenoid reduced the activity. However exposure of ground up phosphate nodule for 34.5 days on the 6V transformer increased the activity significantly. This ground nodule probably was from the Mineral shale (possibly Mecca Quarry) but the foil wrapped definitely came from the Mineral. In a later experiment involving short term exposure of 10 grams of ground Mecca Quarry nodule the activity increased also. Of ten experiments done eight (80%) resulted in a increase in activity.

Three experiments were done using U^{238} acetate; two of these showed a slight decrease upon exposure. One exposure of Th^{232} and Pb^{210} resulted in decreased activity in both.

Four experiments were done in which 10 grams of dry soil was placed in an alumium weigh boat and exposed to 416G 60 hertz magnetic field. The results were; one`s activity increased to 160%, another to 107%, still another to117% and the fourth decreased to 79.80% of preexposure levels. The sample whose initial activity was 107% immediately after removal from the field continued to rise to a peak of 206.19% on day 4 and fell back to 69.09% by day 11. Note that this increase in activity followed by a decrease was observed for the soil removed from under the newly energized power line as reported in section four.

The $*Ba^{137}$ isotope that was eluted or “milked” in an aqueous solution from a Cs^{137} minigenerator or “cow” was subjected to 416 G 60 hertz magnetic field. Spectra was taken of the four trials and the relative activity obtained from the height of the γ ray photopeak. A plot of activity versus time was obtained for the exposed as well as the control (unexposed). From this data the half life, wavelength maximum, and % change in activity was obtained as was the case in an earlier experiment performed on $*Ba^{137}$ exposing it to 15 kV 60 hertz electric field.

The exposed samples wavelength maximum of the γ ray photopeak was increased to 0.684 MeV; up from the 0.662 MeV of the unexposed. The γ ray wavelength maximum of the exposed was 103.32% of the unexposed (higher in energy). The γ ray photopeak and x ray peak of the exposed sample was 69.97% and 68.99% respectively of the unexposed sample. Based on the γ ray peak the exposed sample had an average of 69.97% of the activity of the unexposed. Student t test was done on the four trials resulting in p=.002. See 49 in Table 8 for details. The half life of the control (unexposed sample) was 2.557 minutes. The exposed sample half life was 2.917 minutes which is 0.360 minute longer than the control. This represents an increase of 14.08% in the half life after exposure. Here we see increased energy of emission after exposure and again we see a reduced activity associated with a longer half life after exposure.

Later experiments in July and August 1994 were done in which the diluted $^*Ba^{137}$ was exposed to a 416 G 60 hertz magnetic field for 6.5 minutes. The γ ray wavelength maxima of the unexposed and exposed samples were determined using the half thickness method as described on page 143 of Chase and Rabinowitz. The unexposed γ ray wavelength maximum was found to be .650 MeV and the exposed .688 MeV; an increase of 105.85% following 6.5 minutes exposure to the 416 G 60 hz magnetic field.

The half lives of the unexposed and exposed (6.5 minutes) samples were determined using in one series the total integrated count measured via a scintillation counter and in another series the counts obtained using a 2% window at the γ ray wavelength maximum. In the series using the integrated counts the average half life of three trials for the unexposed was 2.752 minutes (literature value 2.55 minutes) and 2.623 for the three trials of the exposed. Exposing the sample to 416 G 60 hz reduced the half life to 95.32% of the unexposed. In the series in which the activity was monitored at the γ ray wavelength maximum the average half life value of the three trials unexposed was 2.593 minutes and for the three trials for the exposed was 2.545 minutes. Here exposure to the 416 G 60 hz magnetic field reduced the half life to 98.12% of the unexposed.

When doing the half life studies the conditions were carefully controlled and the average of 48 (30 seconds) counting periods from the three trials of the unexposed was 939.96 and 956.63 for the exposed. The exposed samples had an increased activity; 101.77% of the unexposed. Here we see an increased activity associated with a shorter half life.

c. Alternating magnetic and electric fields $(M + E)_{AC}$

Investigations done on soil samples taken from under power lines and samples taken onto the site under power lines logically should be included in this section. However the results of these studies is presented separately later. Here in Table 13 is presented data on laboratory studies. The most common system involves use of the solenoid to generate an ac magnetic field (line current, 60 hertz) to energize the solenoid. This AC magnetic field (about 416 gauss) was superimposed on the AC electric field generated from a 15 kV neon transformer. The transformer had one output lead connected to a metal plate of the capacitor, the other high tension lead was connected to a short thin section of aluminum wire and it was lowered to above the sample to be exposed just short of the distance that would produce arcing. This produced a high gradient electric field above the sample which was placed on the metal foil on a sheet of plastic (the glass capacitor unit). The plastic sheet was placed on top of the vertical solenoid.

A general observation from experiments using the selected set is that of the 28 experiments using 60 hertz signal on six different types of radioactive samples (five different isotopes) 13 or 46.43% had decreased in activity.

Two of four experiments (50%) involving C^{14} showed a decrease in activity, one dropping to 81% of the preexposure value.

The potassium 40 responded similarly. Three of five experiments (60%) showed a decrease in activity.

Two rubidium 87 experiments gave a slight increase upon exposure.

Phosphate as nodules or ground powder showed a decrease in 5 out of 12 experiments (41.67%). One nodule showed a decrease to 61% of preexposure value.

Included in the section covering exposure to 60 hertz electric field was a relatively long term study in which during three seperate trials five discrete phosphate nodules were placed on a small 6v transformer for an average of 1.33 months. The electric was not shielded at the time by wrapping the nodules in aluminum foil for it was felt it would be negligible. Measurements made after the experiment however showed a larger electric field than anticipated. It is felt therefore the results of this long term exposure experiment should properly be placed under the combined system of electric and magnetic fields rather than under electric or magnetic alone.

The results of this experiment were that initially upon removal from the transformer the activity was reduced to 85.1% of the pre exposure value but rose to @100% by day 7 after removal. Assuming first order decay of the effect the half life of the change was 10.8 hours (0.45 day).

A series of experiments with the phosphate nodules in plastic disposable beakers was done.

In one group the sample was exposed to only the electric field. This was done by turning off the current to the solenoid that generated the AC magnetic field. The results of this group was compared to a group in which the sample was exposed to both the electric and magnetic field. Three periods of exposure was given to each group. The sample's activity was compared by dividing the activity of the sample exposed only to the electric field by the activity of the sample exposed to the electric plus magnetic field. In the first period the ratio was 92.45% (0.9245); in the second period 87.85% (0.8785); and in the third period the ratio was 72.11% (0.7211). This may possibly show that the magnetic field effect increases (causes increased activity) with repeated exposure and/or that the electric field in combination with the magnetic field effects increases (causes increased activity) with repeated exposure. From earlier work reported in this section, one can see that phosphate nodules and more certainly shale matrix will increase in activity when repeatedly exposed to the ac electric field alone. Subsequent data from the power line studies reported in this section would seem to indicate that the changes in the $(M + E)_{AC}$ system is largely due to magnetic field effects. Later work reported in section four indicates that the corona induced positive DC field has a very strong effect on soil activity.

Two experiments using U^{238} showed a slight decrease in activity.

The uraninite sample decreased significantly in activity when exposed to the field.

Four experiments were run on Po^{210} and three of these (75%) revealed a decrease upon exposure

One experiment on Th 232 resulted in a slight decrease in activity.

All five experiments using Pb^{210} (only one listed in Table 25) revealed an increase of activity.

A more elaborate series of experiments was done in which barium 137 was eluded from a Cs^{137} minigenerator and subsequently exposed. In this experiment the gamma ray spectra of $*Ba^{137}$ was obtained for both the pre and the post exposure sample of the eluted $*Ba^{137}$ using the scintillation detector. The reader is referred to the spectra shown on Figure 11 & 12 . As the spectra was taken the total activity of the sample was recorded. A comparison of the 10 “pre” and 10 “post” exposure samples show a 54.95% decrease for the post exposure sample as compared to the preexposure value. That is the exposed sample had an overall activity 54.95% of the unexposed sample . Please note the small shift in the wavelength peak $(gamma_{max})$ as well as the small changes in the overall spectra. The gamma ray photopeak wavelength maximum for the unexposed sample was 0.662 MeV while the exposed sample’s was 0.654 MeV. Thus the exposed sample’s wavelength maximum was 98.79% of the unexposed. Does this imply that during exposure the activity shoots up? Although some attempts were taken with earlier experiments to determine this they were abandoned for it was very difficult to shield the instrumentation from the excitation sources. The results above as was usually the case, were obtained by measuring the samples after they were removed from the excitation sources.

In this section the results of exposure of $*Ba^{137}$ to the electric, magnetic, and combined electic and magnetic 60 hertz fields are presented. For the electric field exposure alone the change in activity was 71.33% of pre exposure; for magnetic alone, 101.77%; and the results of the combined fields was 54.95%.

In the second section of this book, “Effects of Constant Electric and/or Magnetic Fields on Radioisotope Decay Rate and/or Energy of Emission”, data is presented that show the $*Ba^{137}$ isotope in solution during exposure to positive or negative 10 kV DC fields will increase in activity and when removed from the field the activity drops.

II. POWER LINE STUDIES

If indeed electric and magnetic fields have an effect on radioactive decay then one ought to be able to measure differences in the natural radioactivity found in the soil under power lines as compared to similar areas not under the power lines. Furthermore, if the effects are persistent then one ought to be able to remove samples (of soil and minerals) from under the power lines and take them to the laboratory and measure these differences. If the EM fields do alter radioactive decay rates and energies and do so rather persistently then one ought be able to take “previously” unexposed radioisotopes or sources, place them under the power line for extended periods of time, retrieve these, take them back to the lab to measure any differences.

Studies were not done in which the soil radioactivity under the power lines was measured in situ but extensive work was done on retrieved soil (mineral) samples under the power lines as well as placing “virgin” radioactive samples under the power lines and retrieving them later.

Soil samples were taken from several sites under 161 kV and 345 kV transmission lines found in Johnson and Leavenworth counties in northeast Kansas, in Linn county in east central Kansas, and in Crawford county in southeast Kansas. Phosphate nodules (Mecca Quarry) were taken from under a 161 kV line in Crawford county. The power lines have been in operation for decades so the minerals and soil have been exposed for more than 20 years to the EM fields.

Samples of previously unexposed potassium chloride, rubidium chloride salts and discrete phosphate nodules and ground up nodules were taken out to 161 kV and 345 kV transmission lines in Johnson county and placed at selected locations perpendicular to the lines for selected periods (usually one to three and one half months). The phosphate nodules came from a black Pennsylvanian shale found associated with the “Mineral” coal bed mined in southeast Kansas. The samples used in these studies were taken from “spoil” banks in mined areas far removed from large power lines (transmission or distribution).

Field studies were done in which the electric and magnetic fields under the 161 kV and 345 kV lines were measured at various distances out from the lines. A magnetometer and voltmeter was carried to various points under the lines. The measurements themselves were done at three to six feet above the ground. Generally, measurements were first taken under the centermost lines. The 161 kV lines used in the study have three single lines across in a row horizontal to the ground, while the 345 kV lines have three double lines horizontal to the ground. In the power line industry literature this arrangement is called the “flat configuration “. In both cases each line of the set is at the same height. Readings at each site were taken under the center lines, the outermost lines, and then at several fixed distances out from the the electric line up to half a mile on either side of the lines.

In a major field study several (five or six) sites for each power line voltage level were investigated. These largely rural sites were chosen because of the absence of other nearby transmission power lines or distribution lines going to homes or businesses. Soil or mineral samples were removed from the locations under the power lines and transported back to the lab to check overall radiation levels using a GM tube and counter.

The results of the survey of electric fields under the lines that were investigated pretty much matches the data that Kansas City Power and Light (KCPL -a local ultility) provided. That is, the KCPL pattern pretty much matched the authors' although the magnitude did not. The magnetic survey however showed some surprises. There seemed to be a series of maxima and minima in the field perpendicular to the power lines. The KCPL data, which was good to only 70 feet from center, shows a rather simple pattern. The authors' data used for the computer generated graphics is presented in Tables 23 and 24. Figure XI is a plot of electric field versus distance from the center line under the 161 kV line. Note that the first maximum occurs at 36.9 feet and the first minimum is at 94.8 feet. Figure XII is a plot of electric field versus distance from the center line under the 345 kV line. Here the first maximum occurs at 39.8 feet and the first minimum at 175.7 feet.

The 161 kV lines showed the first magnetic minimum (X of 22 readings from four sites) at 35.628 feet from the center line and the first magnetic maximum at 77.75 feet from the center line. These were obtained by walking out from the outermost lines and noting where the first maximum and first minimum occurred beyond the outermost line. The values obtained from a computer generated curve (data obtained from measurements at 0 feet, 18, 28, 37, 58, 68, 118, and 218 feet from the center line) were 48.0 feet (first minimum) and 68.7 feet (second maximum) respectively. The computer generated curve is shown in Figure 13.

The 345 kV line shows the measured first minimum at 47.6 feet from the center line and the measured first maximum at 67.4 feet from the center line. There seems to be a much weaker secondary minimum and maximum still further from the center. The values for the first maximum and minimum beyond the outermost lines that were obtained from the computer generated graph (data taken at 0 feet, 25, 35, 75, 125, 225, 325, 415, 555, 1056, 1584, 2112, and 2690 feet from the center line) were at 49.4 feet (first minimum) and 69.17 feet (second maximum) respectively. The computer generated curve is shown in Figure 14.

Several subsequent studies were done placing samples at these magnetic maxima and minima.

Observe figures 15, 16, 17, and 18; note the maxima and minima that appear in the radioactivity levels in the soils.

To obtain these graphs soil samples were taken at various distances from the center line and analyzed for radioactivity in the lab after drying and weighing (used mainly 40 or 50 gram dry weight per sample analyzed). Each sample was read at least five times using five minute counts and this average value was recorded. The background reading was not subtracted from these readings. Samples were taken under the 345 kV line at "0" feet (from under the center line) and at 25, 35, 75, 125, 225, 325, 415, 555, 1056, 1584, 2112, and 2690 feet from the center line. The samples taken under the 161 kV line were at "0" feet (from under the center line) and at 18, 28, 68, 118, 218, 318, 418, 528, 1056, 1584, 2112, and 2640 feet from the center line.

There were two samples at each distance out from the line. One sample was taken on the left side of the powerline and one sample was taken on the right side of the power line. For the "0" feet value, two samples at the center were taken. Each of these was analyzed five times and the average was recorded. These two averaged values were themselves averaged out and carried as a single data point. For the 345 kV lines there were five sites investigated in this manner. From zero to 2112 feet there were five of these data points taken for each distance out from the 345 kV line. Beyond that distance generally three or four data points were taken. From zero to 218 feet there were six of these data points taken for each distance out from the 161 kV line. Beyond that distance, two data points were taken. See Table 19 and 20 for details.

Figures 17 and 18 is prepared from the data on the 345 kV lines. Those maxima and minima that occur within 1/10 th of a mile (528 feet) of the center line are very pronounced and noted in most sites investigated. Note that the power line effects begin to drop off after about 1/4 mile and by 1/2 mile the radioactivity has risen to presumably the normal values for that area. Figures 15 and 16 show the plot of activity (cpm) versus distance from the center of the 161 kV line. Although there are maxima and minima they are at different distances than these under the 345 kV lines. The 161 kV study does not have as many data points as the 345 kV study, particularly in the 1/10 to 1/2 mile range.

After presentation of data on results of more recent placement of K^{40}, Rb^{87}, and ground phosphate nodule under the power lines, other field studies will be covered. These include retrieval of long exposure phosphate nodules under a 161 kV line over a spoil bank in Crawford county and earlier placement of discrete nodules under 161 and 345 kV lines to determine the effect of magnetic field separated from the combined electric and magnetic fields.

In an attempt to see if the EM fields under the power lines could affect previously unexposed radioactive materials samples of KCl, RbCl, and phosphate nodules (both discrete and ground up) were placed at selected distances out from the power lines for one to two months. A comparison of the results of the “placed” phosphate experiment is later compared to analysis of phosphate nodules collected under a 161 kV line in Crawford county.

Samples (20.0 gram) of KCl were placed in small glass vials with metal tops. Tests ran on this system indicate that both the electric and magnetic field would penetrate to the KCl in the vials. In somewhat similar manner 1.0 gram of RbCl was placed in a plastic container with a metal top. These samples were protected from direct precipitation when placed at two different sites which are separated by two miles. Under this 345 kV power line the samples were being exposed to both the electric and magnetic fields.

The samples were placed under the center lines and near, but not exactly on, the magnetic minima (35 feet from center line of the 161 kV line and 47 feet from the center of the 345 kV line) and the magnetic maxima (77 feet from center of the 161 kV line and 64 feet from center of the 345 kV line). The activity of each sample was measured five or ten times before being taken out to the field and measured five or ten times after retrieving them a month (2 months) later. A summary of results is shown in Table 21 in the appendix.

The overall results were that the K^{40} and Rb^{87} increased in activity.

For the K^{40}, exposure under the center line where the electric field is high caused the activity to increase to 105.13% of the preexposure value. For the Rb^{87}, however, the activity dropped to 98.38% of the preexposure levels. These two results agree quite nicely with the in laboratory study (see page 10 and/or summary table, Table 25).

When the K^{40} was placed at the magnetic minimum the activity rose to 111.28% of preexposure levels while the Rb^{87} remained almost unchanged at 100.32% of preexposure level.

At the magnetic maximum the K^{40} rose to 106.31% of preexposure level and the Rb^{87} also nearly the same at 106.07% of preexposure level. Note from page 16 and17 or Table 25 that overall the magnetic field tends to increase the activity of both isotopes.

Ground up "virgin" phosphate nodules (20.0 gm in aluminum weigh boats) was placed under the center wire of 161 kV and 345 kV lines and at the that time what was felt to be the magnetic maxima (16.7 feet from center for the 161 kV line and 19 feet from center for the 345 kV line), and at the magnetic minimum (100 feet from center for the 161 kV line and 145 feet from center for the 345 kV line). The sample activity was read five or ten times before exposure and five to ten times after exposure. The samples were left under the lines for one to three and one half months. One set designated "m" was wrapped in aluminum foil to eliminate the effects of the electric field. The unwrapped set was designated "e" although it was exposed to both the magnetic and electric field.

The overall results were that the activity read higher after exposure under all locations for both power line values. Samples that were left under the 345 kV line for 3 1/2 months showed a higher activity than when those samples had been under only one month. For the 161 kV line the "m" values averaged 101.80% (1 month exposure) and the "e" averaged 107.97%. For the 345 kV line the "m" values averaged 98.62% and the "e" values averaged 104.41%. Note that for both lines the "e" samples were unshielded from the electric field and the activity was substantially increased as were the samples exposed in the laboratory. The change is greater for 161 kV line and referring to figure 34a and 34b one sees that surprizingly the measured electric field seems to be higher under the 161 kV lines at the sites selected.

A “blank” or control run was also done at the same time in which samples were prepared and read the same as the “test” except these samples were take to a rural area 1 1/4 mile from any 161 kV or 345 kV lines and about 1/2 mile from any small distribution lines. These samples showed an increase also. The ones wrapped in aluminum foil gave an increase of 108.72% (m) and the unwrapped ones (e & m) read 103.29% of initial values. This could possibly mean that the “weathering” of the freshly ground phosphate resulted in an increase in activity. In any case these percentages of the controls were subtracted from the percent change and the “adjusted” values are shown in Table 22.

One reason for the generally increased reading regardless of the site location may be this: the samples were dipped in a styrene-toulene mixture to “glue” the ground nodules to the aluminum weigh boats and to water proof the sample. This could trap the evolved radon gas. The “glued” samples were read within two days after preparation and of course the exposed samples a month (3 1/2 months) later. The additional time may have lead to build up of trapped radon gas up to an “equilibrium” value.

In an early experiment to determine if power lines affect radioactive decay and/or energy, previously unexposed discrete (whole) phosphate nodules were used rather than ground up nodules. The nodules are rich in potassium and rubidium as well as containing uranium and thorium, and their decay products.

These nodules were collected at the surface on the spoil banks in strip mined areas in Crawford county in southeast Kansas. The black shale which contained the nodules used in all these studies is found immediately above the Mineral coal mined in that area. The Mineral coal is the first substantial coal below the Croweburg coal which is associated with the Mecca Quarry shale. The elemental analysis of the shale and nodules should be quite similar to that for most Pennsylvanian black shale such as the black Mecca Quarry shale, black shale found over the

Croweburg coal in southeast Kansas and similar shales shown on pages 31 - 35 of **Geologic Causes of Natural Radionuclide Anomalies** ed. M. A. Marikos and R. A. Hausman, Missouri Department of Natural Resources Special Publication # 4, 1988. The information is provided in a paper by R. A. Coveney, P. L. Hilpman,, A. V. Allen of the University of Missouri at Kansas City and M. D. Glascock at the University of Missouri, Columbia. The percent potassium is reported is to be as high as 3% w/w and the rubidium up to 420 ppm.

These loose, weathered nodules were chosen rather than those found within chunks or boulders of shale because they have weathered at least 20 years. Some of these nodules were wrapped in aluminum foil which screens out the electric field while others were left unwrapped. The activity of each of the nodules was measured three times before placing them in the fields. The backgrounds were subtracted from these readings. The nodules were then taken and placed on the ground surface at previously determined locations under 161 kV and 345 kV transmission lines in Johnson county Kansas. The locations were perpendicular to the lines at increasing distances from the line.

The locations were under the centermost line,under each outside line and at 10, 50, 100, 200, 300, and 400 feet to the left and right of the lines. Some of the samples were lost due to animals, over-growth of vegetation, human activities (plowing or mowing), or poor marking of location in field. If the aluminum foil wrapped sample had the foil greatly broken open, that sample was discarded as an electrically shielded sample. The samples that were wrapped in aluminum foil were designated “m” for they were essentially exposed only to the magnetic field. The unwrapped samples were designated “e” or “e &m”. These unwrapped samples were being exposed to both the electric and the magnetic fields.

After one to three months (all were exposed at least one month) of exposure the nodules were retrieved and the activity read again three times within 48 hours after retrieval. The background also was subtracted from these readings. The average activity after (A) exposure was divided by average activity before (B) exposure and this ratio was multiplied by 100 to express the change as a percentage (A/B X 100 = % change). A percent less than 100 indicates that the sample decreased in activity upon exposure and a percentages greater than 100 indicates that exposure increased activity.

In reviewing Table 22 (Tabulated data from a late experiment using ground nodules), it's pretty obvious that activity dropped only in those samples exposed exclusively to the magnetic field and then only at certain distances out and not at others. All samples exposed to the combined electric and magnetic field increased in activity. It appears that the electric field is more effective in causing an increased change than the magnetic. Generally the drop in activity caused by the magnetic field was more than compensated by the increases caused by the electric field. The results of short duration laboratory exposure of phosphatic black shale and soil presented in Table 25 shows this quite well. Note that in this table when phosphate is exposed only to the high voltage AC electric field we get the greatest increase, the least when exposed exclusively to AC magnetic fields, and an intermediate increase when exposed to combined AC electric and magnetic fields. It is important to note that these exposures were of intermediate duration (1 - 3.5 months) and not the extremely long duration of 20 years exposure of the soil and mineral under the undisturbed lines.

The unwrapped nodules (e + m) under the 161 kV line showed a maximum change in activity at 15.4 and 79.7 feet from the center line and a minimum at 35.9 and 187.5 feet from the center line. The aluminum foil wrapped nodules (m) showed a maximum at 39.9 and 156.5 feet from the center line and a minimum at 11.9 and 84.9 feet from the center line. A look at Figure 19 where the two curves are superimposed one can see that effects that the magnetic field alone has on the nodules is nearly 180 degrees out of phase with the effect that the combined electric and magnetic fields have on the nodules. Since the electric plus magnetic fields are 90 degrees out of phase with each other some difference would be expected.

The unwrapped nodules under the 345 kV line showed a maximum at 19.1 and 106.2 feet from the the center line and a minimum at 51.0 and 308.1 feet from the center line. The wrapped nodules showed a maximum at 17.9 and 129.8 feet from the center line and a minimum at 65.9 and 281.8 feet from the center line. Here the maximum and minimum of each type of sample are more nearly in phase (see figure 20).

It should be noted that the electric field strength and magnetic field strength were different when comparing the electric field of the 161 kV line to the 345 kV line and when comparing the magnetic field of the 161 kV line to the 345 kV line. Likewise the ratio of the electric to the magnetic for each power line was different. These differences could account for the different "phase differences" found under the two types of power line.

Earlier in this section plots of activity in the soil versus distance out from the center line were mentioned. These plots shown earlier are Figures 17 & 18 for the 345 kV line and Figures 15 & 16 for the 161 kV lines.

Using this same data, graphs were generated showing the activity up to 200 feet for the 161 kV line and 400 feet for the 345 kV line. A somewhat more accurate determination of the maxima and minima in this region were obtained. The graphs can be directly compared to the graphs obtained from the placement of the phosphate nodules , the graphs obtained from measurement of the electric and magnetic fields, and the graph of activity of phosphate nodules found under the 161 kV line in Crawford county.

Under the 161 kV lines the soil radioactivity reached a minimum at 29.7 feet from the center line and a maximum at 101.9 feet from the center line. Under the 345 kV line the soil radioactivity reached the first maximum at 17.8 feet, a secondary maximum at 91 feet, and a third maximum at 335 feet from the center line. The first minimum for the 345 kV line was at 45.5 feet and the secondary minimum at 176 feet from the center line.

When the plot of electric field versus distance is superimposed over the plots of activity of soils versus distance (Figures 21 and 22) it is seen that where the electric field is at a maximum

(36.9 feet - 161 kV; 39.8 feet - 345 kV) the activity is at a minimum (29.7 feet - 161 kV; 45.5 feet - 345 kV).

The correlation between the magnetic field and the activity is not as clear as the relationship of the electric field and activity. However, Figures 23 and 24 which is a superimposition of the magnetic field versus distance over activity versus distance under the line shows that when the magnetic field reaches a minimum the activity reaches a minimum (45.5 feet for 345 kV). For the 161 kV line however, when the magnetic field first peaked (20.7 feet) the activity reached the first minimum (29.7 feet).

Phosphate nodules had been taken and placed under power lines and the effects noted. It was assumed that if the fields affect the soil then they should affect the nodules and we see they did. Later the comparison of the exposed placed nodules to soil activity as well to the measured electric and magnetic fields will be made. In the Pittsburg, Kansas area there is the Crawford County land fill that lies below a 161 kV line. This land fill is 2 miles north of Frontenac, Kansas, a small town on the north side of Pittsburg. This landfill uses previously dug dry “pits”that were dug decades earlier and are covered over by the old spoil dumps which contain the Mecca Quarry (Croweburg coal) black shale. The nodules at the surface have been exposed for four to twenty plus years to the power lines that run above it. This offered an excellent check on the effects that power lines had on the “virgin” phosphate nodules that were placed under the power lines in Johnson county. In 1991, some years after samples were taken, the landfill was closed, the pits filled and graded to level ground and seeded to local grasses and forbs. In 1993 the area became a public wildlife area regulated by Kansas Wildlife and Parks.

Several nodules, on each side of the line, were collected at each site. These were taken back to JCCC and ground up. Ten grams of the powdered phosphate nodules taken from each site were analyzed fifteen times. Since samples were taken from both sides of the line this was equivalent to a single sample being analyzed thirty times. The plot of activity (background was not subtracted from the readings) versus distance out from the 161 kV power line is shown in Figure

25. There is a maximum at 13.0 feet and a secondary maximum 86.0 feet from the center line. There is a minimum at 41.0 feet and a secondary minimum at 141 feet from the center line. These nodules had been exposed to the field a very long time and behave much like the soil under the power lines which also has had a very long exposure. When the plot of the electric field versus distance is superimposed over the plots of activity of these phosphate nodules versus distance (Figure 26) it is seen as with the soils that when the electric field reaches a maximum (36.9 feet) that the activity reaches a minimum (41.0 feet). When the magnetic field versus distance is superimposed over the plot of activity versus distance (Figure 27) it is seen that the first activity maximum (13.0 feet) occurs near the first maximum (20.7 feet). The first activity minimum (41.0 feet) occurs near the first magnetic minimum (48.0 feet). The second activity maximum (86.0 feet occurs at the second magnetic minimum (93.7 feet). The second activity minimum (141.0 feet) occurs at the third magnetic maximum (152.6 feet). Overall, it appears that the long exposed phosphate activity closely matches the magnetic field strength. The activity “tracks” with the magnetic field. Again it should be noted that where the AC magnetic field is the lowest the AC electric field is the highest but also the corona induced positive DC field is the highest also.

The interpretation of the results of the “placed” phosphate nodules is difficult. At the front here it should be noted that although the nodules were exposed for one to three months to the fields this was a short time compared to the exposure that the soil and the collected nodules received. Some of the aforementioned laboratory work with repeated exposure indicates that the activity of the phosphate nodules frequently was lowered initially but increased later. This may explain some of the observed results but caution should be used in comparisons for the laboratory generated fields were much higher than the fields near the ground under the power lines.

Superimposition of the electric field (161 kV) versus distance over percent change of activity of the unwrapped nodules versus distance (Figure 28) shows that when the electric field was at a maximum (36.9 feet) the percent change was also at a maximum (39.9 feet). Where the electric field versus distance is superimposed over the percent change of the wrapped (magnetic only) nodules versus distance (Figure 29) it is seen that the first electric maximum (36.9 feet) occurs at the first activity minimum (35.9 feet) and the first electric minimum (94.8 feet) occurs at the second activity maximum (79.2 feet).

When the magnetic field (161 kV) versus distance is superimposed over the percent change of the unwrapped nodules (Figure 30) it is seen that the first magnetic maximum (20.7 feet) occurs near the first activity minimum (11.9 feet). The first magnetic minimum (48.0 feet) occurs at the first activity maximum (39.9 feet). The second magnetic minimum (93.7 feet) occurs near the second activity minimum (84.7 feet). The third magnetic maximum occurs near the second activity maximum (156.5 feet).

If one superimposes the magnetic field versus distance over the percent change of the wrapped (magnetic only) nodule (Figure 31) one finds that the first magnetic maximum (20.7 feet) occurs near the first activity maximum (15.9 feet). The second magnetic maximum (68.7 feet) occurs near the second activity maximum (79.7 feet).

A very interesting observation occurs when the percent change of activity of the wrapped sample (magnetic only) versus distance is superimposed over the unwrapped (electric & magnetic) versus distance. Referring back to page 21 one sees that the curves are almost 180 degrees out of phase with each other (Figure 19). Along these same line if the "placed " phosphate percent change versus distance is superimposed over the collected (old) long term exposure phosphate versus distance one finds the "e & m" (Figure 32) is again almost 180 degrees out of phase and the magnetic only (Figure 33) tracks well for the first two maxima and the first minimum. From this one could say that upon very long term exposure the changes in activity will track the magnetic field closer than the electric field, at least for phosphate under 161 kV lines.

A look at Figure 24 and Figure 23 where the magnetic field under the 161 kV and 345 kV line is superimposed over the activity of the soils under these lines shows that the soil activity "tracks" the magnetic field also. It would appear that when phosphate nodules, K^{40}, Rb^{87}, and soil is exposed to high electromagnetic fields the electric field causes a rapid increase in activity, but under very long term exposures the magnetic and the corona induced positive DC fields presumably “causes” the activity to drop.

When the electric field (161 kV) versus distance is superimposed over the magnetic fields (161 kV) versus distance (Figure 34a) it can be seen the electric maximum (36.9 feet) occurs near the first magnetic minimum (48.0 feet). The first electric minimum (94.8 feet) occurs at the second magnetic minimum (93.7 feet) and the second electric maximum (156.7 feet) occurs at the third magnetic maximum (153.6 feet). Figure 34b shows that for the 345 kV lines the electric field has a maximum at 39.8 feet while the magnetic field shows the first minimum at 49.4 feet.

Superimposition of the percent change of activity of unwrapped nodules under the 345 kV lines versus distance over the electric field of the 345 kV lines versus distance (Figure 35) shows that when either electric field reaches a maximum (39.8 feet) the activity reaches a minimum (51.0 feet). When the electric field versus distance is superimposed over percent change of activity of wrapped sample (magnetic only) versus distance there are no strong correlation (Figure 36).

When the magnetic field versus distance is superimposed over the plot of percent change of activity of unwrapped sample versus distance (Figure 37) it is seen that the magnetic minimum (49.4 feet) occurs at the first percent change minimum (51.0 feet) If the plot of percent change of activity of wrapped (m only) nodules versus distance (Figure 38) it can be seen that the first magnetic maximum (69.1 feet) occurs at the first percent change minimum (65.9 feet).

When the activity in soils versus distance is superimposed over the plot of percent change in unwrapped phosphate nodule samples versus distance(Figure 39) one can see a very close agreement between the first maximum (17.8 feet) of the soil activity and the first minimum of the percent change of the unwrapped (19.1 feet) and the first minimum (45.5 feet) of the soil activity and the first maximum of the percent change (51.0 feet) . There also is close agreement between the first maximum of percent change (17.9 feet) of wrapped (m only) versus distance (Figure 40)and the first maximum of the soil activity versus distance (17.8 feet).

How much error is there in the location and the field strength of the magnetic maxima and minima of the power lines? A field study was carried out in which location of and strength of field at center, maximum and minimum was measured at various distances between the line supports. The location of the maxima and minima depend on the distance from the three line supports: two poles support the three lines and for the 345 kV line the spacing between these locations is 877 feet. Near the poles the magnetic field strength is lower than for the center location, and the location of the magnetic minima and location of the magnetic maxima is further from the lines. Near the poles the milligauss values are 25.00 for center; 0.0 for minimum; 3.8 for maximum. The lines sag down and as they come closer to the ground at mid span the measured magnetic values increase. At the half way distance between the two pole support (438.5 feet from the center of the two pole support) the milligauss value are 54 for center; 2.8 for minimum; 32.0 for maximum. As the line sags the location of minimum and maximum changes. The locations are distances perpendicular from the outmost line. As the line sags down closer to the ground the locations are closer to the outermost line. Near the poles the minimum occurs at 30.5 feet from the outermost line while the maximum occurs at 78 feet. At the half way point between pole supports the minimum occurs at 11 feet while the maximum occurs at 30.1 feet.

From the above data one can see that notation of distance from the pole supports is necessary for precise work. Unfortunately in this work these distances were not measured but only estimated. The best estimate is that measurments of the magnetic and electric fields (for 345 kV lines) were between 0.2 of the distance to 0.5 of the distance between poles with the average value being about 0.35 of the distance. The estimated value for the milligauss values are 51 for center; 2.5 for minimum, 27.2 for maximum. The estimated value for the location of the minimum is 13.5 feet from outermost lines (38.5 feet from center line) and the location of the maximum is 31.5 feet from outermost line (56.5 feet from center line). The values obtained from the graph (Figure 14) were at 49.4 feet from center line and 5.6 milligauss for the minimum and 69.17 feet from the center line and 31.0 milligauss for the maximum and 143 milligauss for center line at 0.0 feet.

No estimate of error in field strength and location of maximum and minimum for the 161 kV line was done.

The results of experiments on Rb^{87} and K^{40} seem to indicate that Rb^{87} is more strongly affected by AC electric fields than K^{40} with the tendency being to reduce Rb^{87} activity and increase K^{40} activity upon exposure. On the other hand the AC magnetic field tends to reduce both Rb^{87} and K^{40} activity.

This taken into consideration with C^{14} activity dropping when exposed to electric ac field would seem to lead to the prediction that humans which contain C^{14} and K^{40} should logically have a reduced level in their radioactivity if exposed chronically and/or periodically to AC electric and magnetic fields.

In an experiment involving people the overall radioactivity in the palm of the hand was measured by placing a GM tube out a fixed distance above the probe. People were selected into two categories based on whether or not they were around high electric and/or magnetic fields for a substantial part of the workday. Some in the high exposure group were media and communications personnel working frequently on instruments that generate high electric fields. Others were people who work at arc welding which requires large current which produce high magnetic fields. Still others worked as electricians and/or electrician helpers which frequently put them near large electric fields and moderate strength magnetic fields, with occasional bursts of large electric and magnetic fields during switching operations.

The low exposure people were difficult to find. Selected out were those people who spent more than one hour a day around computers. The static electric field at some video screens and the magnetic and electric AC fields in back would cause some effect. When people work at computers normally they are much closer to the instrument than those watching television. So primarily people who did not use a computer often and did not have hobbies or activities that put them around machinery or instruments generating large electric or magnetic fields were sought out as the low exposure group.

There were twelve people in each group. The average radioactivity of the palm after subtracting out background was 9.33 counts/10 minutes for the low exposure group and for the high exposure group the reading was 1.5 counts/10 minutes below background. The standard deviation for the low exposure group was 38 and 27 for the high exposure group. the comparison of the two groups gives a “t” value (two tailed) of 1.0612 for a coupled or dependent analysis (df = 11) and the “p” value is 0.312. If each individual in each group is considered as independent (not correlated) to any other in the other group the “t” value = 0.8134 and the “p” value is 0.430.

Even though the “p” value is not even close to being statistically significant the tendency is there. People exposed to high levels of electromagnetic radiation (near line frequency of 60 hertz) have a reduced level of nuclear radiation.

The connection between such illness and cancer and power lines has been hotly debated for well over a decade. At present there seems to be good evidence for saying that certain levels of magnetic fields (usually stated to be AC) are correlated with certain types of cancers. Several people have proposed a mechanism for this. It involves cell membranes (as well as intracellular membranes). The magnetic fields seem to affect melanin levels and membrane organization.

In this diminution of the nuclear radiation in the body a part of this this? Articles in “Physics Today” (Mar. 1992 page 13) , “R&D magizine” (Feb. 1996, page 19) and “Science” (Mar. 29, 1996, page 1821) again point out there may be some positive effects (less risk of cancer) for people exposed to low levels of radiation versus very low (or possibly no external) radiation level.

III. SUMMARY AND CONCLUSIONS

A word of caution here: the effects are complex and a great deal of study on any one of the common natural radionuclides is in order.

Short duration exposure of strong (intense) 60 hertz electric fields to soil and phosphatic shale results in an increase of activity and while short term exposure to strong 60 hertz magnetic fields seems to cause some increase its immediate effect is much weaker. Very long exposure of soil or phosphatic shale to the weaker AC electric and magnetic fields under high voltage transmission lines results in a decrease in activity where the electric field is high and/or the magnetic is low. There is a positive DC field produced by corona discharge that also contributes to reduced activity near the power lines in particular near the AC electric field maximum. This factor is covered extensively in section four. It could be said that the radioactivity levels under the power lines track with (or are directly proportional to) the magnetic fields; higher activity associated with higher magnetic fields, lower activity with lower magnetic fields. The radioactivity levels then are inversely proportional to both the AC and positive DC electric fields. The radioactivity changes, in the soil, perpendicular to the power lines show several maxima and minima and measurable to more than 1/4 mile out from the 161 kV and 345 kV transmission lines.

The distinct primary or first minimum in the radioactivity levels found in the soil under the power lines may primarily be due to the high voltage AC electric and the corona induced positive DC field but an increase in the atmospheric DC potential may also have an effect. Chalmers and others have noted that in fair weather the atmospheric potential downwind (or under) the power lines is increased by several times. During fair weather the soil surface carries a negative charge . The sign of atmospheric potential downwind during fog or mist may be reversed so as the ground surface becomes positive. This effect can be measured 5 to 7 kilometers downwind from the power lines. This author has found that when soil carries a positive DC surface charge the activity is reduced and since the atmosphere itself carries a positive charge it felt that this connection ought to be investigated. Additional information can be found in the next two sections; “Effects of Constant Electric and/or Magnetic fields on Radioisotope Decay Rate and/or Energy of Emission” and “Effects of Combined Electric and/or Magnetic Fields on Radioisotope Decay Rate and/or Energy of Emission", but most significant information is presented in the 4th section "Power Line Studies II: Observations Concerning Power Transmission Lines, Geomagnetic Fields, Atmospheric Potential, and Nuclear Background Radiation".

The additional maxima and minima in radioactivity versus distance plots for the 161 kV and 345 kV may possibly be due to interaction of the phases of the electric and magnetic fields on the radioisotopes.

The energy of the β particle emitted (E_{Bmax}) from β emitters is changed by exposure to 60 hertz electric and/or magnetic fields. Both K^{40} and Rb^{87} show an increase in E_{Bmax} when exposed to short duration high intensity 60 hertz electric fields. The potassium forty E_{Bmax} increases 0.44% when exposed to an overhead AC source and the rubidium eighty seven E_{Bmax} increases 36.33% when exposed from above and 15.97% when exposed from below.

Subsequent work has been done investigating factors that might affect decay rate and/or energies. This is presented in the next three sections. Additional work still needs to be done in finding how strength of field affects the findings and more pecisely what the half life values are of the effects. However it does appear that the electromagnetic fields around the electrical transmission lines have an effect on nuclear decay rates and/or energies. This the author feels is of importance to those involved in the dispute over routing of the the transmission lines.

IV. APPENDIX

A. Tables

B. Figures

C. Selected reference