Section Four

POWER LINE STUDIES II:

Observations Concerning Power Transmission Lines, Geomagnetic Fields, Atmospheric Potential, and Nuclear Background Radiation.

Introduction

Work in this 4th section concerns the effects of 60 hertz as well as constant manmade or natural electric, magnetic or geomagnetic fields on radioactive sources. In this section the energy of the beta particle emitted from rubidium eighty seven as well as the activity changes after exposure to various electric and magnetic field conditions is presented.The long term monitoring of soil activity under and removed from under a newly energized power line emphazises that repeated and/or prolonged 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 new field studies involving high voltage transmission lines. Constant fields (positive charge) induced by corona apparently is largely resposible for the activity minima at 29.7 feet out from the 161 kV lines and at 45.5 feet out from the 345 kV lines. The DC maximum under the 161 kV lines of horizontal (flat) configuration occurs at 27 feet from the center while for the 345 kV lines of horizontal configuration the maximum is at 38.4 feet from center. The distinct reduction of soil radioactivity occuring in the soil under the power lines which reaches a minimum where the first (princpal) 60 hz electric field maximum occurs apparently is largely due to the corona induced positive charge that is generated by the high voltage 60 hz field.The changes in soil radioactivity will appear to track the magnetic field (which is roughly the inverse of the 60 hz electric field) generated by these lines when the soil has been exposed for long periods of time (years). Laboratory work simulating the effects of the power lines confirms this relationship.

A long term study (1.5 years) was undertaken in which the atmospheric electrical potential along with radioactivity levels was measured. Continuous recording of the local geomagnetic field was done for several months. Daily and monthly geomagnetic values were also obtained from the literature. The effects of these factors account for over ninety percent of the varibility of the background activity.

I. Field Measurements under existing operational power lines and laboratory similations.

   A. Field studies of electric fields and radioactivity levels of the soil.

   B. Laboratory simulations.

II. Measurements of atmospheric potential, geomagnetic fields, and background readings.

III. Measurements of electric and magnetic fields and radioactivity changes in the soil under a newly constructed power transmission line.

IV. Measurements of changes in activity of rubidium eighty seven and calculation of the energy maximum of the beta particle emitted upon exposure to various electric and magnetic field conditions.

V. Summary and Conclusion

VI. Appendix

   A. Tables

   B. Figures

   C. Selected references

I. FIELD MEASUREMENTS UNDER EXISTING OPERATIONAL POWER LINES AND LABORATORY SIMULATIONS.

(A) FIELD STUDIES OF ELECTRIC FIELDS AND RADIOACTIVITY LEVELS OF THE SOIL.

Earlier work indicates that constant electric fields (DC fields) have a strong effect on radioactivity levels with a positive field tending to reduce soil and phosphatic shale radioactivity levels and negative increasing the activity. (See section 2 "Effects of Constant Electric and/or Magnetic Fields on Radioisotope Decay Rate and/or Energy of Emission)

It was felt by this researcher that corona induced space charge build-up around the power lines was causing at least some of this reduced activity near the lines. To investigate this a second field study was done under additional lines of flat (horizontal) configuration at new sites. The DC charge was measured using a Fluke 73 multimeter. The meter was grounded to earth with a metal rod and a small plate of bare metal was used as an antenna. The antenna was connected to the meter with high voltage shielded cable. Measurements were taken at 4-6 feet, 8-10 feet, and 14-16 feet above ground.

Since the amount of space charge (discrete charged particles in the atmosphere) was proportional to the high voltage 60 hertz field the measured DC charge was adjusted using a factor to match the AC field. The fields were measured on the upwind side as well as the downwind side and under the center. With the horizontal 3 line systems investigated, the outer 2 lines rarely had the same AC reading. The 161 kV lines are single cable lines but the 345 kV lines actually are 2 cable lines.

The DC charge is carried by charged particles and hence are free to move in air. The upwind side of the line should have a lesser charge than the downwind side. In the second study readings were taken on three days, two days in which the wind had a south towards north orientation and one the reversed direction. The two days in which the wind blew from the south the sky was clear to partly cloudy and one day the temperature reached ninety degrees Fahrenheit during measurements. The one day the wind was northerly the sky was partly cloudly and cool being after nightly rain. Readings were taken under the center cables, the north and south side cables, and additional locations 10, 25, 50, and 100 feet out from the center. One transmission line was 161 kV and another was 345 kV. Both lines run in a general east-west direction and the sites investigated within twenty miles of the laboratory. Readings were taken at 4-5 feet above ground on two days and 4-5 and 8-10 feet above on the other. The readings at 4-5 and 8-10 feet were averaged as single data points. The DC voltage was measured at heights other than those just mentioned. It was noted that when the probe was raised to 14 feet or more above ground (under the 345 kV line at distances out of 10 to 50 feet) a momentary shock was felt when the probe was grounded. The shock tended to coincide with negative DC readings on the meter. It appears as if there is a layer or sheath of negative DC charge closer to the power line wire with the positive DC field (charge) extending further out. Laboratory simulation also confirms this inside negative sheath, outside positive sheath. See page 9 of this section.

Graphs were prepared from the data taken under the center, outer lines, and at points 10, 25, 50, and 100 feet out from the outer lines. These are presented in figure 41 for 161 kV line and figure 42 for the 345 kV line. Note that the DC (positive field) maximum occurs at 27.0 feet from the center for the 161 kV line and 38.4 feet for the 345 kV line. One can see that these are close to the radioactive minimums at 29.7 and 45.5 feet.

Under the 161 kV line the average DC positive field for the upwind side was +.00366 volts (average of 11 points) and downwind was +.00532 volts. The ratio downwind over upwind (d/u) is 1.4536. The downwind side charge is 145.36% of the upwind side charge.

Under the 345 kV line the DC field was +.0317 volts (average of 14 points) for the upwind side and +.0367 volts for the downwind side. The ratio of d/u is 1.1584 ; The downwind side charge is 115.77% of the upwind side.

On the days this data was taken the wind, measured during daylight hours, averaged 14.5 miles/ hour. The long term average, day and night, for the Kansas - Missouri line, computed from data supplied by the National Climatic Data Center (see 2nd following paragraph) is 10.6 miles/hour.

It can be seen then that indeed the movable positive space charges are being carried by the wind and tend to be more concentrated on the downwind side of the power lines with the average maxima occuring about 27 feet and 38 feet out from the center of the 161 kV and 345 kV lines respectively.

Additional data confirm this. Some of this data was obtained by going back to the initial study in which soil and mineral radioactivity under the power lines was measured or changes in placed radioactive phosphate nodules was measured. In the study involving placement of nodules the percent increase or decrease of radioactivity was noted. When this study was done samples were taken from or placed on both sides of the lines. The geographical orientiations of the lines noted during the initial study could be designated as upwind or downwind. Although the wind direction on the particular day that the samples were taken or placed was noted, this was not used to designate the up or downwind side of the power line. Instead an average "wind rose" for the Kansas City to Pittsburg, Kansas line was computed. The wind direction and velocity for a several year period was obtained for four weather stations; Kansas City International Airport, Richards- Gebauer (near Grandview, Missouri), Springfield, Missouri, and Wichita, Kansas. This data was provided by Mary Knapp at the Weather Data Library, 211 Umberger Hall, Kansas State University, Manhattan, Kansas, 66506. It was taken from the "International Station Meteorological Climate Summary" supplied by the National Climatic Data Center, Federal Building, Asheville N. C. 28801. Basically the wind rose gives the percent of the time that the wind blow from the 8 cardinal points of the compass. Frequently, and in this case, the average wind speed (in knots) is also noted. What follows are the north,south, east,west wind direction-wind speed averaged values multiplied as products. The wind blows from the north 37.39% of the time at 9.445 knots making a product of 3.5314. The wind blows from the south 62.61% of the time at 9.581 knots making a product of 5.9986. Comparing the north-south product it is seen that 62.94% is contributed from the south. The wind blows from the east 50.49% of the time at 8.301 knots making a product of 4.1911. The wind blows from the west 49.51% of the time at 8.950 knots making a product of 4.4311. Comparing the east-west product it is seen that 51.34% is contributed from the west.

In essence the product of wind direction times speed is greatest for the wind from the south and from the west. We thus could expect the positive space charge build up to be on the north side and east side of the power lines. An increased positive charge causes a reduction in radioactivity thus there should be a larger reduction of soil activity on the downwind (north and east) side of the lines.

Out of the initial power line study six sites under the 161 kV lines were investigated or used and seven under the 345 kV lines. Under the lower voltage line (one site was under a 34 kV line) three involved soil activity analysis and three involved radioactive phosphate nodule placement with analysis of increased or decreased activity after a fixed time period. Under the 345 kV lines four involved soil analysis and three phosphate nodule placement and subsequent analysis. A comparison of the soil activity up and downwind was made and expressed as a percentage (d/u x 100). The soil samples taken under the power lines had been exposed to the EM fields for long periods, often exceeding 20 years. As an example say the upwind side activity was 35 cpm and the downwind side 30 cpm. The ratio of downwind over upwind would be 30/35. This ratio times 100 gives 85.71%. The downwind side is 85.71% of the upwind side. With the nodule placement the % changes (comparison of before and after , a/b x 100) on both sides (up and downwind) was noted and the %'s compared. Initial exposure of "virgin" radioactive sources to EM fields frequently causes an increase- see results of initial exposure of soil under the newly energized 161 kV line discussed later in this paper. To use as an example say the upwind side increased in activity by 150% and the downwind side increased by 115%. The ratio of downwind to upwind is 115/150. As a percent this is 76.67%.

The actual changes were noted in the north-south direction and the east-west direction seperately. The changes involving the soils were lumped together for the 161 kV lines seperately and for the 345 kV lines seperately. Likewise the changes involving the nodules were lumped together for the 161 kV lines separately and for the 345 kV lines separately. There was a total of eight data points (4 for north-south, 4 for east-west). Three fourths (75%) showed a decrease in activity on the downwind sides (north and east). The average of the downwind north side activity was 96.52% of the upwind south side. The downwind east side activity was 91.46% of the upwind west side.

The information on the last few pages certainly indicates that the positive DC field is responsible in a large part for the reduced activity in the soil near the power lines. The primary and first activity minimum shown in figure 16 and 18 is largely due to this increased positive DC field.

(B) LABORATORY SIMULATIONS

Laboratory work was done to further confirm this relationship. A minature "power line" was made using a 60 hertz 15 kV neon transformer as the power source. Initially a 50 centimeter segment of bare 1/16 inch diameter aluminum wire was connected to the power supply. The wire was raised 37 to 50 centimeters above the “ground” which was a zinc plate connected to earth ground via an electrical outlet ground. The atmospheric DC field was measured at several heights upwind and downwind from the wire using a Fluke 73 multimeter. A portable fan was used to provide the wind. Wind speed measurements were taken and the speed set at 2.8 knots (3.22 mph) for most work but also at 3.4 knots (3.92 mph) ocassionally. Typically the heights above ground where measurements were taken were 1-1.5 cm, 5-6 cm, 9-10 cm, 15-18 cm, and 30-36 centimeters. These readings were taken at 5 cm up and downwind from the center, 10 cm up and downwind, 15 cm up and downwind and directly under the center wire.

In four trials the measurements were taken over a soil filled grounded tray. The soil covered an aluminum foil sheet that was grounded. In two of these trials the soil was dry and two others the soil was wet (moist). In each trial the soil activity is counted five times for five minutes before exposure and after each of five exposures.

Soil and mineral samples in aluminum weigh boats were placed under the center at various heights above ground as well as being placed within the soil of the grounded soil filled tray at various distances up and downwind.

The “power line” height was adjusted or a rheostat (Variac) was used with the input to the neon transformer to adjust the voltage. These adjustments were made so as the potential at 5-6 centimeters above ground matched that under an actual 345 or 161 kV line at a height of 4-5 feet above ground. The charge at 5 heights above ground was measured at 3 locations upwind and downwind for two 161 kV simulations and two 345 kV simulations. These four trials were done using bare wire and a sheet of grounded zinc as ground. The average height of the wire above ground was 41 centimeters. The average height at which measurements were taken was 2.9 centimeters. The average upwind (2.8 knots) charge was +.0000434 volts (56 data points) at an average distance, at ground level, of 10 cm from under the center wire, The values under the center (20 data points) was +.0037697 volts. The average downwind charge was +.0038829 volt (56 data points) at an average distance downwind of 10 cm from the center wire. One can see that positive charge increases going from the upwind side to the downwind side. Note that this matches the actual field conditions under the 161 and 345 kV lines discussed earlier in this paper.

An attempt to better match the simulation to actual field conditions was done. Here the bare wire was covered with 1/4 inch of fine steel wool to increase corona discharge and the ground indeed was actual soil. The bottom of a shallow plastic tray was covered with aluminum foil and in turn covered with soil to a depth of @ one half inch. The foil was connected to the earth ground via an electrical outlet. The wire height was set at 37 cm and the voltage adjusted using the Variac to match the corresponding voltage of either the 161 or 345 kV 60 hz power lines. Measurements were taken at the same wind speed, same heights, and same distances out from the center as were used in the bare wire trials. One trial each was done simulating dry and wet soil at 161 kV and 345 kV conditions.The averages of the four trials are as follows.

The average upwind charge (20 measurements) was +.002236 volts. The value under the center was -.005375 volts. The average downwind value was +.0028732 volts (d/u x 100 = 128.50%). A considerable number of the values measured under the center or at 5 cm upwind were negative. Also it was noted that when the soil was dry the charges were generally of larger magnitude and positive.

Soil and shale samples were placed in aluminum weigh boats and placed at the center under the steel wool covered wire either at various heights above the soil covered tray or embedded in the soil at various distances up and downwind from the center.

The radioactivity of each of the samples while in the weigh boats was measured with a GM counter five to ten times before exposure and after each of five to ten exposures. The samples were exposed to the EM field 2-12 hours for each of the five or ten exposures.

Seven exposures of soil samples embedded in the grounded soil exposed under the center wire reduced the activity to 96.20% of pre exposure levels. Ten exposures of a soil sample 12 cm above ground reduced the activity to 90.73% of pre exposure value. Five exposures of a soil sample at 20 cm reduced the activity to 72.92% of pre exposure levels. Ten exposures each to two samples reduced the activity to 82.80% when the samples were at 34 cm above ground.

Ground up samples of Hickory Creek shale matrix were placed at 12 and 34 cm above ground during another run. The four exposures of the sample at 12 cm reduced the activity to 44.33% of pre exposure value while the four exposures to another sample at 34 cm reduced the activity to 65.26% of pre exposure value. It was noted that during some runs at 34 cm the surface charge on the sample became negative while the surface charge on the sample at 12 cm remained positive. An additional trial (new series of exposures)was done on the same samples. Here the atmospheric potential was noted to be +.001 volt at 12 cm and -.004 volts at 34 centimeters. After this run the activity of the sample at 12 cm was 94.44% of pre exposure level while the sample at 34 cm increased to 169.56% of the pre exposure value. Again the soil surface showed a negative value at 34 cm while only positive surface charge was noted at 12 centimeters.

In order to measure the effect of wind, samples were placed upwind (2.8 knots), under the center, and downwind. These samples were 10.00 grams of soil in aluminum weigh boats, 10.00 grams ground Pilot or Hickory Creek shale matrix, and discrete phosphatic nodules from the Mineral shale. The samples, within the weigh boats, were embedded within the soil in the tray at 5 cm and 10 cm up and downwind as well as under the center. The activities of the 5 soil samples (2 up, 2 down, 1 center) as well as the 15 shale samples were determined before and after exposure. Each samples' activity was measured 5 times before and after exposure, using 5 minutes counts, with the sample being returned to exposure conditions between readings while other samples were read. The samples were exposed for two periods during which 5 readings were taken before and after exposure.

After the initial period the four samples ten centimeters upwind increased in activity 108.74 % (87.97 to 135.58%) of pre exposure levels. Those four samples at five centimeters upwind increased 130.18% (101.19 to 148.48%) of pre exposure levels. The four samples under the center averaged 99.05% (96.52 to 102.61%). The four samples five centimeters downwind decreased to 92.41% (73.41 to 109.05%) of pre exposure levels. The four samples ten centimeters downwind increased slightly to 100.17% (95.17 to 109.31%).

The average change of all eight samples upwind was 119.46% compared to 96.29% for all eight downwind. The downwind to upwind ratio expressed as a percentage (d/u x 100) was 80.60%. Looking at this as a test of independent samples $t = 2.678$, $df = 14$, $p = .017$ two tailed test; as a matched pairs or repeated measures test $t = 2.294$, $df = 7$, $p = .054$ two tailed. The average of the two dry soil samples was 117.10% upwind, 102.65% center, and 84.29% downwind. The six shale samples averaged 120.25% upwind, 97.85% center (three sample average), and 100.29% downwind.

After these samples were exposed the second time , the activity generally lowered. The samples ten centimeters upwind averaged 91.61%. Those at five centimeters upwind averaged 125.06%. Those under the center averaged 87.67%. At five and ten centimeters downwind the values are 86.97% and 94.48% respectively.

The average of all 8 samples upwind was 108.34% compared to 90.72% downwind. The d/u x 100 value was 83.74%.

The average of the two dry soil samples upwind was 108.34%. The one center soil sample was 57.52% and the average of the two downwind samples was 81.21%. The six shale samples averaged 107.06% upwind, the three center samples 97.72%, while the six downwind averaged 93.90%.

II. MEASUREMENTS OF ATMOSPHERIC POTENTIAL, GEOMAGNETIC FIELDS , AND RADIOACTIVITY LEVELS.

If indeed a constant positive field above a radioactive source reduces activity then the background radiation coming from the surface of the earth and possibily from radionuclides in the air should correlate with changes in the atmospheric electrical potential. The atmospheric potential is roughly 100-150 volts per meter. The earths' surface generally is negative compared to the atmosphere, changing polarity ocassionaly when storm clouds, particularly those associated with thunderstorms, pass over. At each locality there is a daily and yearly rhythm. See Chalmers pages 161-169, Rieter pages 101-138, Hoppel, Anderson, and Willett page 156, and Gringel, Rosen, and Hofmann pages 177,179, and 180.

This author prepared a system for measuring the atmospheric potential using modifications shown on page 28 of R. Reiters' Phenomena in Atmospheric and Environmental Electricity.

The radioactive sources were connected to earth ground by placing them on a sheet of aluminum connected to an electrical outlet earth ground lead. The atmospheric potential dectector was setup in stairway entrance to a 3 story rooftop, 30 - 40 feet above ground. The probe itself, mounted on a stand outside on the rooftop, was connected via high voltage shielded cable to the amplifier in the stairwell entrance. The radioactive sources were Pilot shale, Mineral shale nodules, uraninite ore, and the radiation coming from the environment itself (known sources removed).

The background radiation can be thought of as being produced by two systems. One would include nuclear radiation (primarily gamma and x-rays) coming from the sun, stars, near earth radiation belts such as the van Allen belts. These sources produce "non local" radiation and would not be strongly correlated to changes in the atmospheric potential or the geomagnetic fields. The other system would include nuclear radiation (some beta and alpha as well as gamma and x-rays) from surfaces , or just under, of the physical surroundings; the earth (soil, shale,rocks, bricks), wood, plants, animals, or from even the air. These sources are “local” and would be very strongly correlated to the atmospheric potential and the geomagnetic fields. The radioactive sources from deeper in the earth and in plants and animals would fall somewhere in between local and non local.in that these deeper sources probably would be influnced primarily by geomagnetic fields.

A background reading obtained by placing a GM tube over a lab counter top of course would recieve contributions from both systems but if a radioactive source such as phosphatic shale is placed nearby the "background" reading is more local.

The output from a nuclear radiation survey meter and the atmospheric potential amplifier was modified (damped with low pass filters) and recorded on strip chart recorders. During several periods radioactivity from uraninite and the general (local) background was monitored and recorded in a 2nd floor room in the same building. The uraninite sample was placed on a grounded aluminum sheet. A general background reading was obtained in the 3rd floor stairwell as well as the readings from the mildly radioactive black shales. The atmospheric potential, measured only on the 3rd floor rooftop and radioactivity levels were recorded for 1.5 years. During this period there were occasional breaks such as those caused by overturning of the atmospheric probe by wind and switching of sources.

During this one and one - half year period 4 seasons of useful data was recorded - spring, summer, fall, and winter. The atmospheric potential verus time on a daily basis for a years worth of data is shown in figure 43. The plots were generated using a polynominal regression , 6th order, from a software program called Prostat (IBM). Note the 1st minimum at 2.05 hours, 1st maximum at 10.64 hours (midnight = 0 hour, 24 hour). A plot of radioactivity verus time (24 hours) is shown in figure 44. Note that the 1st maximum occurs at 1.43 hours close to the 1st atmospheric potential minimum. Note too that the 1st minimum at 9.82 hours occurs close to the 1st atmospheric potential maximum. Secondary maxima and minima also have a close inverse relationship.

A plot of daily atmospheric potential verus radioactivity is shown in figure 45. One can see the inverse relationship quite clearly. When the atmospheric potential is high (more positive) , the radioactivity is lowered. A regression plot of atmospheric potential verus radioactivity was done. A correlation (r) of -.907 was obtained. With the sample coefficient of determination , r^2, being .823 one could say that 82.3% of the change in the radioactivity can be explained by the change in the atmospheric electric field.

After this above information was gathered it was decided that the effect of geomagnetic fields on the background activity would be investigated. The Z (vertical) component of the field was recorded on a strip chart recorder for August through October 1995 using a Thornton gaussmeter with a Hall effect probe. The raw data was processed by averaging the magnetic readings recorded at each two hour period for the entire day starting at midnight. A plot of these averaged readings verus time for the 24 hour period is shown in figure 46. These August - October readings were compared to the radioactivity levels recorded during same time period the previous year. The plot of radioactivity, using the authors' sources, for the August - October, 1994 period is shown in figure 47. A plot of the atmospheric potential was made from the authors' data covering this time frame and is shown in figure 48. A plot of daily atmospheric potential versus radioactivity presented as figure 49 which shows again the inverse relationship. The single , r , for atmospheric potential and radioactivity was -.906, r^2 was .821; for the 13 data points the two tailed probability was .000. The plot of daily geomagnetic Z field versus radioactivity is shown in figure 50. The single correlation for Z magnetic field and radioactivity was .746; r^2 was .557; for the 13 data points the two tailed probability was .004. The combined correlation, r , of atmospheric potential , Z geomagnetic field, and radioactivity is .913, r^2 is .834, F value is 25.16, and probability is .000. A coefficient of determination of .834 indicates that 83.4% of the daily varibilty of local background radioactivity could be accounted for by the atmospheric potential and the Z geomagnetic field.

Searching the literature a source , Carnegie Institution Publication 580, was found that presented the 24 hour plots for the X (north - south), Y (east - west), and Z (vertical) components of the geomagnetic field on page 157. The data from the Tucson, Arizona, U.S.A. observatory for the years 1922 - 1933 was used. The Tucson observatory which is at latitude 40.4 degrees and longitude 312.2 degrees was chosen for it is closest, of those listed, to the present research location within the Kanas City metro area in N. E. Kansas.

Multiple regression was done on the plots of the daily atmospheric potential versus radioactivity, Z field versus radioactivity, X field versus radioactivity, and Y field versus radioactivity. A plot of combined daily magnetic fields versus radioactivity (as measured by the author for four seasons) is shown in figure 51. The combined correlation , r , was .961 while r^2 was .924. The F value was 24.397 with a probability of .000. Here the sample coefficient of determination of .924 could be interpreted as saying that the magnetic fields and the atmospheric potential accounts for 92.4% of the daily variation in the local background reading with the major factor being the atmospheric potential.

Yearly plots of the magnetic field components month by month for the years 1911 - 1940 were obtained on page 109 from the same source that the daily plots were in. As with the data on daily plots the values for the individial fields were taken and reentered into the Prostat program after averaging. Plots were made of individual geomagnetic fields versus radioactivity on a month by month basis so as changes throughout the year could be seen. The plot of combined X,Y, and Z geomagnetic components on a yearly basis is shown as figure 52. The data for the yearly radioactivity changes comes from an article," Anomalous Radioactive Variations " by Joe Parr published August 16,1993 in Issue 9 (Jan/Feb/Mar) page 29 of "The Electric Spacecraft Journal" put out by Charles A.Yost, 73 Sunlight Drive, Leicester, NC 28748 USA. The present author (Hammack) used a number of radioactive sources throughout the one and a half years of this study on atmospheric potential changing one for another at times so as no one source was monitored continously during this period.

Parr had recorded continuosly at least a years data on three isotopes Co^{60} , Cs^{137}, and Ba^{133}. The data was presented as line graphs showing radioactivity levels above and below an average value. This author converted from graph to tablular values, smoothed and reformated the data. The reformated data was regraphed using 6th order polynominal regression via Prostat.This plot of yearly change in radioactivity versus time is shown in figure 53. A plot of yearly atmospheric potential versus time is shown in figure 54. The data for this yearly plot of atmospheric potential versus time , month by month, was taken from a literature source, Hoppel, Anderson, and Willett. Monthly averages of the potential at Potsdam, Germany are given in figure 11.6 on page 156. These values are ploted versus time for the yearly changes month by month.

The plot of yearly atmospheric potential versus yearly changes in radioactivity is shown as figure 55. Regression analysis of this plot produces a correlation , r , of -.591. The coefficient of determination , r^2, was .349 with a probability of .032.

Plots of individual yearly geomagnetic fields versus time are shown in figures 56 (Z), 57 (X), and 58 (Y). Multiple regression was done on the plot of atmospheric potential versus radioactivity, Z magnetic field versus radioactivity, X magnetic field versus radioactivity, and Y magnetic field versus radioactivity. A plot of combined yearly magnetic fields versus yearly changes in radioactivity is shown in figure 59. The combined correlation was .798. The sample coefficient of determination was .637 with an F value of 3.513 and probability of .061. Again the atmospheric potential is the dominent factor. Here on a yearly basis only 63.7% of radioactive varibility can be accounted for by the atmospheric potential and the geomagnetic fields.

III. MEASUREMENT OF ELECTRIC AND MAGNETIC FIELDS AND RADIOACTIVITY CHANGES IN THE SOIL UNDER A NEWLY CONSTRUCTED POWER TRANSMISSION LINE.

Newly constructed power lines offer opportunities to confirm the effect of EM fields on soil radioactivity. A 161 kV "double circuit" transmission line was installed nearby and energized in early May 1995. Soil samples were taken at 3 sites at 3 locations under the 2 cable vertically arranged 3 line system. One location was directly under the three vertically stacked pairs of cable where the electric field was the greatest while another was 38 feet out perpendicularly from below the center where the magnetic field maximum occurs. The third location was 100 feet out from below the center . The location of the magnetic maximum and the electric field maximum was determined for the new line prior to energization from measurment of another already energized 161 kV line of similar construction.The 60 hertz magnetic and electric fields were measured at each location at each site and a soil sample taken before energization as well as eight times (as of May 10, 1996) after energization. Samples and measurments are scheduled to be taken November 11, 1996. A few other measurments and samples may be taken the next several years.The average of the electric and magnetic field value as of the 8th reading on May 10,1996 are: center 19.00 mG and 16.36 v ; 38 feet 93.17 mG and 6.58 v ; and 36.92 mG and .654 v at 100 feet. The activity of each sample at each site was read 5 times for five minutes. Approximately 75 grams is taken at each site at each location (9 samples total). The soil is air dried for two days, pulverized, and 50 grams placed in disposable plastic beakers. The soil taken prior to energization was only enough for one set of samples. These samples were reread as many times as new samples have been taken up until a total of eight. Samples were taken aproximately one month prior to energization, one, two, four, eight, sixteen, thirty two and fifty two weeks after energization. Additional readings and samples will be taken at six months intervals or until the radioactivity levels stabilize.

The overall average of 360 five minute readings was 27 counts per 5 minutes (26.54 with a range of -4.8 to +52.2 with the background subtracted out).This was obtained by taking five minute readings five times of the soil taken from eight sets at three sites at three locations prior to energization. Under the center the average of 120 readings was 25 counts per five minute (24.72 with a range of -4.8 to +46.2). This average of 120 readings was obtained from 8 sets of 5 readings at each of 3 sites). At the magnetic maximum 38 feet out from the center the average of the 120 readings was 29 (28.51 with a range of -2.2 to +49.4). At 100 feet out the average of the 120 readings was 26 (26.38 with a range of 0.8 to 52.2).

After energization the activity generally increased. This is seen in Table 30 in which the activity immediately after drying and processing " A " is recorded and the percent change is also shown. The activity prior to energization " B " is an average of eight readings taken on the soil collected before energization. The changes that occur in activity after energization are different at each site.The greastest increase occurs at 100 feet, the least increase at 38 feet where the magnetic maximum occurs, and intermediate under the center. On May 13, after one week of exposure, the 1st set of samples was collected and analyzed. The average activity of the samples from the three sites was found to be 154.33% of the pre-energization activity. On May 29, after 2nd collection and analysis, the average activity was found to be 151.56% of pre-energization values. On the 3rd set, June 2, the activity was 136.80% of pre exposure values. On July 6, the 4th set, the activity was 128.01% of pre exposure activity. By August 29, the 5th set, the average activity was 125.48%. The average activity of the 6th set, December 15, was 122.51% of pre-energization values while by the 7th set at 9 months the activity was 111.98%. At one year after energization (May 10, 1996) the average was only 104.48%. Note that activity was at a maximum very soon after energization. Four regression plots were done on time versus activity. This indicates that sometime between 9 and 15 months the activity of the soil under the power lines, particularly at 38 feet, will drop below the average activity prior to energization. Since the activity near the power lines that have been energized for long periods is reduced this is expected to occur. The regression plots were based on power, exponential, logarithmic and linear functions. The sample coefficient of determination, r^2, which is the correlation coefficient, r, squared is for these .930,.861, .943, and .829 respectivily. The extrapolated (predicted) activity percentages at 1.5 and 2.0 years are 106.07, 103.35; 86.90,73.18; 104.60, 101.22; and 80.00,58.23 respectivily. The average of the 4 functions at 1.5 years is 94.39% and 84.00% at 2.00 years. The log fit plot and equation is shown in figure 60.

In addition to obtaining radioactivity levels immediately (2 days needed for drying and processing) after recovery, the radioactivity levels of these same samples that had been exposed to the effects of the power lines are reread one, two, four, eight, sixteen, thirty two, and fifty two weeks after removal. Table 31 is a record of the changes in the activity of the soils after they have been removed from under the power lines. The percentage at each time after removal is determined by taking the average activity of the sample sets reread at that elapsed time after removal and dividing this value by the average activity of the sample set taken prior to energization (this set was reread eight times). The average activity of the eight sets collected at the three sites immediately after collection and processing is 126.51% of the pre-energization values. The average activity of seven sets was 156.18% one week after collection. Note the increase in activity even though no additional exposure occured. Two weeks after collection the average activity of seven sets was 125.43% of the pre exposure levels. Four weeks after collection the average activity of six sets was 105.48%. The reading at 8 weeks for six sets was 115.48% and 81.83% at 16 weeks for four sets average. The activity at 32 weeks (one set) was 72.87%. One year (52 weeks) after removal the average activity of four sets was 84.73%. Additional post collection readings of these samples will be made up until two years after collection or until the readings stabilize.

Regression plots using the same functions as for Table 30 data also were done on the Table 31 data. The regression plots were based on power, exponential, logarithmic and linear functions. The sample coefficient of determination, r^2, is for these .477, .577, .450, and .540 respectivily.

The extrapolated (predicted) activity percentages at 1.5 and 2.0 years are 85.42, 83.81; 52.55, 440.65; 86.53, 84.54; 37.96, 9.26 respectivily. The average of the 4 functions at 1.5 years is 65.62% and 54.57% at 2.00 years. The power fit plot and equation is shown in figure 61.

IV. MEASUREMENT OF CHANGES IN ACTIVITY OF RUBIDIUM EIGHTY SEVEN AND CALCULATIONS OF THE ENERGY OF THE BETA PARTICLE EMITTED UPON EXPOSURE TO VARIOUS ELECTRIC AND MAGNETIC FIELD CONDITIONS.

While potassium is acknowledged as a contributor to soil radiation rubidium often is not. Although not commonly considered rudidium eighty seven contributes significantly to soil radiation. In this area the Rb^{87} level in the shales, particularly the black ones that weather out to become part of the soil, ranges from @100ppm to 420 ppm (@.042% w/w). In the soil the average elemental potassium as K_2O is 2.38% w/w and elemental rudidium is .0096%. The Rb^{87} radioisotope is 27.83% of the naturally occuring rubidium. This high percentage relative to potassium forty's low value of .0117% of naturally occuring potassium is mainly why rubidium contributes strongly to soil activity. The average soil concentration of potassium is 2.38% but since the percentage of the radioisotope, is so low the radioactivity contribution is approximately 1/10 of that from the Rb^{87}. Even though the amount of radioactive potassium is only 1/10 of the radioactive rubidium the shorter half life ,1.25 x 10^9 yr, of K^{40} compared to 4.89 x 10^{10} yr for Rb^{87} compensates so as the observed activity from both is about equal. Other differences are in the modes of decay. The K^{40} isotope undergoes several modes producing mainly beta with associated gamma. The Rb^{87} isotope is a weak beta emitter with no associated gamma.

Since earlier studies, reported in papers 1-3, showed that Rb^{87} is quite sensitive to electric fields the below subsequent study was started.

One gram samples of RbCl in metal plancets were exposed to various arrangements of electric and magnetic fields. These arrangements all (with one exception) had been used and reported in the earlier papers along with other radioactive sources.Most often the metal plancet was placed on an aluminum sheet that was either grounded to earth or connected to an electric field source. Frequently, particularly if the sheet was grounded, an electrode was placed 5 (2.5) centimeters above the plancet and was energized in various ways. In some cases both the upper electrode and the aluminum sheet, hence the metal plancet too, were energized. A description of the electric field sources and the apparatus is shown in Table 32. The activity of rubidium was determined before and after exposure the percent change noted and recorded. The charge on the surface of the powdered RbCl within the metal plancet was measured whenever feasible. Feather analysis to determine the maximum energy of the emitted beta was done. Changes in the E_{Bmax} are recorded also as a percentage of the experimentally determined value of unexposed RbCl. The experimentally determined value of E_{Bmax} prior to exposure (average of two trials) was .247 MeV which compares favorably to .251 MeV average determined for the five pre exposure trials reported in sections 1-3.

Table 33 shows the results of exposure based on whether it was only above the sample (A), on the aluminum sheet below the sample (B), both below and above (AB), and a couple when two types of simultaneous exposure was from above (AA).

In all four conditions the average E_{Bmax} of those samples exposed to systems that used positive charge was higher than those exposed to systems that used negative charge. Based on 10 measurements, the average surface charge for those systems exposed to positive charges was +.9419v and the average for those exposed to negative charges was -1.0457v. With all four conditions using negative charge the average activity increased and 3 of 4 of those using positive charge the activity dropped. Again this change in activity after exposure to DC fields is in agreement with the general observation of the changes in soil and mineral activities reported in this section as well as earlier ones.

The average of 14 trials from the 4 sets (systems) of exposure is as follows. The beta energy maximum for the positively exposed cases was .259 MeV (104.86% of the experimentally determined pre exposure sample). The corresponding activity was 98.25% of the pre exposure sample. The beta energy maximum for samples exposed to negative fields was .251 MeV (101.62% of pre exposure samples) while the activity was 103.16% of the pre exposure sample.

A comparison between the E_{Bmax} of the positively charged systems and the negatively exposed systems gives a "t" test of 2.34498, df 13, dependent or paired samples, with the probability being .034. The t value is -3.0946, df 13, with the probability being .008 for the comparison of the change in activity of the two systems.

Note that exposure from above (A) produces larger changes than when the samples are exposed from below (B) but exposure from above and below (AB) result in still larger changes in activity but intermediate changes in $E_{Bmax.}$ From the two trials ran it appears that when DC and pulsed AC signals are both from above (AA) the change in activity is the greatest of all cases but the change in E_{Bmax} is the smallest.

Samples of RbCl were also exposed to 60 hz 15 kV AC signal from above only, below only, and above and below together. The average activity was 100.87% of the pre exposure sample and the E_{Bmax} average was .246 MeV or 99.60% of the pre exposure value of .247 MeV.

Exposure of RbCl to the inhomogenous magnetic fields above the north or south poles of a 3.6 kG permanent magnet decreased the activity and increased the $E_{Bmax.}$ Note that the activity (98.77%) was lower and the E_{Bmax} (119.43%) higher for north pole exposure than for the activity (99.82%) and E_{Bmax} (102.02%) of south pole exposure. Earlier work with RbCl as well as PO_4 and soil reported in sections 2 and 3 also shows that north pole exposure results in change in activity that is less than the change in activity when the sample is exposed to the south pole.

The very large change in $E_{Bmax,}$ reported in section 3, where RbCl was exposed from below to pulsed AC with a DC compnent (NN and PP) was confirmed to some extent when a one gram sample of RbCl in a metal plancet was exposed to positive 450v DC with 50v positive pulsed AC (PP) and negative 450v DC with 50v negative pulsed AC (NN). In this last run the E_{Bmax} of NN was .280 MeV, 113% of the experimental pre exposure value of .247 MeV, while PP was .243 MeV or 98.38%.

Earlier studies show roughly that if activity went up the E_{Bmax} went down. Regression plots were done on the data from the 4 systems. Seperate plots were obtained for the negative and positive systems. For the RbCl exposed to positive fields it was found that when the activity went up the associated E_{Bmax} dropped. For the 14 data points the correlation (r) was -.301 and the coefficient of determination (r^2) was .090 with the probability of r being .296. Unexpectedly though the E_{Bmax} of the RbCl that was exposed to negative fields increased with increasing activity. Here for the 14 data points the correlation , r , was .546 and r^2 was .298. The probability was .042. Not surprizingly then when the 14 data points from the sample exposed to negative fields are summed with the 14 points from the sample exposed to positive fields the correlation drops off sharply. For the 28 data points r is -.003, r^2 is .000, and the probability of r is less than .500.

V. SUMMARY AND CONCLUSIONS

The effects are complex and a great deal of more study on any one radionuclide is in order. However it does appear that the electromagnetic fields have an effect on nuclear decay rates and/or energies.The field studies in which the AC magnetic, AC and DC electric fields, and soil radioactivity under a newly constructed high voltage transmission power line were measured show this clearly.

Recent measurement of the DC field under older operating 161 and 345 kV lines of horizontal configuration show that the DC field is positive at or near ground level and is caused by “space charges” that are carried by wind. The downwind side has a higher DC potential than the upwind side. The downwind to upwind positive charge ratio (d/u) for the 161 kV lines was 1.4536 and 1.1584 for the 345 kV lines. The average wind speed measured on the days the data was taken was 14.5 miles per hour. Note that the 161 kV lines sag closer to the ground than the 345 kV lines.The average locations of the positive DC maxima are 27 feet from center at @ three feet above ground level for the 161 kV lines and 38 feet for the 345 kV lines. The actual location being somewhat nearer the center for the upwind side and somewhat further out for the downwind side.

Data recorded but not reported during an earlier field study (section 1; Power Line Study I) was used along with a constructed “wind rose” to show that the soil radioactivity decreased on the downwind side as compared to the upwind side.

Earlier, in lab studies, had shown that a positive DC field tends to reduce soil activity and a negative DC field will increase activity. The field studies dealing with power lines confirms this. The various soil radioactivity maxima and minima under the power lines are not due entirely to the positive DC field distribution . The in lab studies show that AC electric and AC and DC magnetic fields have effects on the soil activity. However it appears that the 1st and primary minimum in soil radioactivity of the soil under the power lines is due largely to the positive DC field induced by corona discharge from the lines.

Further confirmation that high voltage lines produce DC fields that alter activity was obtained from laboratory simulations. Model minature high voltage lines were made in the lab with a portable fan simulating the wind. Soil samples were exposed at “ground level” and somewhat above. The DC field was measured up and downwind and found to be generally more positive downwind. Measurement nearer the wire ocassionally became negative. During the field studies particularly on one warm day under a 345 kV line some negative DC values were recorded. From the lab studies and the field studies it would appear that near a high voltage line there is a sheath of negative charge (negative DC field) and further out a positive charge sheath reaching much further out wraps around the negative one.

During one run a comparison of the charge above wetted and dry soil was made and it was found that charges above dry soil was larger and more consistently positive. The charge on the surface of the samples was measured and generally the larger the positive surface charge the more reduced the activity. In fact in some cases it was noted that when the surface charge was negative the activity increased to above pre exposure levels.

Soil samples placed downwind were reduced in activity and those upwind increased in activity. The fact that the sample upwind increased probably is due to the AC electric and/or magnetic field.

Summarizing the last few pages it can be seen that: 1, there is a positive DC charge near the actual power line that can be duplicated in the lab: 2, this positive DC charge is a “space charge” in that it is carried by wind so that the upwind side of the line is less positive (sometimes even becomes negative) than the downwind side , and: 3, the positive DC charge tends to decrease the measured radioactivity of the soil and minerals under these power lines with a greater reduction down wind from the line. Negative DC charge tends to increase the radioactivity levels.

The atmosphere relative to the earths’ surface has a potential difference of 100 - 150 volts per meter with the earths’ surface being negative. As the atmospheric potential becomes more postive the soil radionuclides and air borne radionuclides activity should decrease and when the potential drops (becomes less positive) the activity should rise. It would appear then that the locally produced nuclear background will track inversely with changes in the atmospheric potential.

This was confirmed with the studies presented in part II of this section. The daily (diurnal) variation of atmospheric potential has a high (inverse) correlation with the daily changes in radioactivity. One study using data collected by the author showed a correlation (r) of -.907.

Since the activity of some of the radioisotopes investigated respond to changes in magnetic fields studies were done to see how the geomagnetic fields affected the background radiation. This author did one study in which the daily vertical (Z) geomagnetic field was measured for several months . The daily atmospheric potential for the same time period was also plotted versus radioactivity. The single correlation for the atmospheric potential versus radioactivity was - .906. The single correlation for the geomagnetic (Z) field versus radioactivity was .746. The combined correlation (r) of atmospheric potential and geomagnetic (Z) field versus radioactivity was .913. With the sample coefficient of determination (r^2) being .834, a high F value and low probability it could be said that 83.4% of local background radioactivity varibility on a daily basis could be accounted for by atmospheric potential and geomagnetic (Z) field changes.

In another study a literature source listing changes in atmospheric potential month by month along with another source listing changes in radioactivity month by month was used to plot atmospheric potential versus radioactivity over a one year period. On a yearly basis the single correlation was -.591.Yearly changes in the combined X,Y, and Z geomagnetic fields versus radioactivity was plotted. When the yearly changes in combined X,Y, and Z geomagnetic fields and changes in atmospheric potential are plotted versus radioactivity the combined correlation is .798 and r^2 is .637. Here on a yearly basis only 63.7% of radioactive varibility can be accounted for by changes in the atmospheric potential and the combined geomagnetic fields.

Before the study measuring the Z geomagnetic field was completed a literature search was done and a source was located listing the X,Y, and Z geomagnetic field changes measured on a daily and monthly basis for a number of years. The monthly data was used in the study discussed in the above paragraph. The diurnal (daily) values of the X, Y, and Z values were combined and plotted versus radioactivity. This plot was combined with the diurnal atmospheric potential plot (using this authors' measured data). The combined correlation (r) for daily atmospheric potential and combined X, Y, and Z geomagnetic fields versus radioactivity is .961. The coefficient of determination, (r^2), is .924 with high F value and low probability. With this and the corroborating data from studies in the lab one could say that 92.4% of the daily variation in local background readings is caused by changes in the combined geomagnetic fields and the atmospheric potential.

Soil radioactivity under the high voltage power transmission lines changes upon energization of the line. Very shortly after energization ,within a week, but possibilty within a day or even within an hour, the activity increases by an additional 50% or more then drops with additional time of exposure. The activity increase seems to be greatest further out (at 100 feet) from the power line (3 vertically stacked double cable 161 kV line) and least near the magnetic maximum at 38 feet. The primary or 1st DC maximum occurs at 4.25 feet, a shoulder at @ 13 feet, and the secondary maximum at 27.5 feet. Note that the pattern of the DC field under this vertical line system is different than that found under the horizontal line system. The location of the magnetic maximum is near the secondary maximum in the measured positive DC field. Since it is known that positive DC fields reduce activity this may more than compensate for the increase caused by the AC magnetic field. If the lowering of the activities of the soils under the lines after the initial rise continues as they already have the activities will drop below pre exposure level particularly at the magnetic (positive DC) maximum some time between 9 and 15 months after the initial energization.The average activity of the three sites after one year is 104.48% of the pre exposure values.

Long term changes in activity of soil samples that have been removed from under the energized lines confirms earlier studies presented by this author in the 3 previous papers. Data presented in Table 31 shows that the activity of the removed soil initially increases then drops off with time. One week after removal the activity rose to 156.18% of pre exposure values (average of 7 sets of samples) but by week 16 the activity dropped to 81.83% of pre exposure values (average of 4 sets of samples). It appears that somewhere between 8 weeks and 32 weeks (@ 7 months) the activity drops to pre exposue levels or even below. One year (52 weeks) after removal the activity was 84.73% (average of 4 samples). The rate at which the activity drops may depend on the length of time that the samples were exposed. The first set of samples that were analyzed had been under the power lines only 0-1 week before it was removed on May 13, 1995 while the sixth set removed December 15, 1995 had been under the lines nearly seven months.The changes in activity reported in Table 31 are the averages of all sets that were analyzed after a designated time (eg. 2 weeks after removal) and thus do not show the effect of duration of exposure.

Samples of Rb^{87} in metal planchettes were exposed to a number of different conditions. Most involved some exposure to positive or negative DC fields or pulses. The activity changes and E_{Bmax} were calculated for these conditions. Of the 14 involving the above conditions (see Table 33) where positive charge was involved the average activity was 98.25% of pre exposure value and the E_{Bmax} was 104.86% of pre exposure value. Those exposed to negative conditions increased to 103.16% of pre exposure values while the E_{Bmax} was 101.62% of pre exposure value. The student t test was given to the two sets. The t value for the E_{Bmax} comparison was 2.34498, df 13 paired samples with the probability being .034. For the changes in activity the t value was -3.0946, df 13 paired samples with the probabilty being .008. It was also noted that overhead exposure caused greater change than when exposure was from beneath and that positive fields tend to reduce activity while negative ones raise activity.

Overall Summary

The reader is now referred to Table 29 which sums up the presentation from the 1st three sections and the results of experiments reported in Tables 25, 32 and 33 in this section.

In summing up the overall obsevations it is noted that short term exposure to electric field alone or magnetic field alone, alternating or constant, single or combined generally results in an increase in radioactivity. The average activity being 109.19% of pre exposure value for the 569 sets of samples (experiments) run during the preceeding twelve years.

Looking at the experiments where “pure” DC voltage was applied or pulsed DC or combinations where some DC component was present it is obvious that the positive DC field will reduce activity more than the negative DC field. Positive pure DC field (Edc+) will reduce activity below pre exposure levels (97.63%) while pure negative DC field (Edc-) will increase activity above pre exposure levels (108.77%).

When samples were exposed to conditions where the magnetic south pole was directed up (generally the samples were placed on top of south pole of the magnet) the activity was higher than pre exposure levels. If the sample sat on the north pole the activity was lower than exposure to the south pole and frequently the activity was reduced to below pre exposure values. The one general exception seems to be where the sample is exposed to positive DC plus DC magnetic north and south pole. However this exception seems to caused by one very high and very low reading for the one soil sample exposed to these conditions.

The average activity of all of the 96 exposed to 60 hz electric field (Eac) alone was 108.27% of pre exposure levels while the average activity of all 39 exposed to 60 hz magnetic fields (Mac) alone was 102.22%. It is observed then that exposure to AC magnetic fields alone will result in a lesser % increase in activity than when exposed to AC electric fields alone. This difference between electric and magnetic field exposure is even more evident when looking at the results of exposure to two fields combined.

When samples are exposed to the combination of Eac and Mac (Eac plus Mac) the activity increases (104.12%) but is intermediate between Eac alone and Mac alone.

Exposure to combined AC and DC magnetic fields (Table 10) more frequently results in a decrease in activity as compared to seperate Mac (102.22), MdcN (104.74), or MdcS (105.44) exposures. The average activity of Mac plus MdcN is 97.49% of pre exposure levels and 99.53% for Mac plus MdcS. Exposure to combined Eac and Edc+ electric fields (Table 9A) results in an intermediate increase in activity (101.40%) while a higher average activity (139.83%) results for the combined Eac plus Edc-. Again we see here that exposure to DC negative bias and to the south pole from below results in higher activity.

The results of exposure to electric fields combined with magnetic fields at least in two systems (Eac plus MdcN,S and Edc+,- plus MdcN,S) are not as expected intermediate between the separate exposures to electric or magnetic fields. However the average (weighed) activity of the 136 samples exposed to combined electric and magnetic fields was 105.71% and is intermediate of seperate exposures. The change in activity of E alone (Eac, Edc+, and Edc-) for 175 samples was 105.95%. The change in activity of M alone (Mac, MdcN, and MdcS) for 63 samples was 103.30%..

Those combined systems where constant magnetic field is used with the south pole below the sample (south up) results in increased activity . Some major exceptions are listed in Table 14. Note that exposure of soil and phosphate to positive DC electric field combined with north pole below the sample (north up) results in a higher activity than when exposed to positive DC electric field combined with south up magnetic field. The soil exposed to the positive DC electric field with south up has reduced activity. Exposure of phosphate to negative DC field with south up results in a decrease.

When taking in situ measurements of radioactivity one needs to be aware of the above observations for the natural soil surface is electically charged (usually a negative DC charge) and exposed to the earth's DC magnetic field. The earth's DC magnetic field is a vector sum of three coodinate values at any given location but neglecting the two horizontial components and using the dip angle, the vertical component, one can get an estimate of the field strength and as to whether the north pole is directed up or down. The vertical DC component (Z) in Kansas ranges from 0.497G to 0.541G. There is an average daily variation of 0.046% to 0 .060% of Z with most of the variation being lower than the average. That is the variation can reduce the vertical field 0.00032G (0.32mG). The DC vertical field is oriented as if the south pole is aimed up out of the ground surface. In the northern hemisphere here at latitude of Kansas the soil surface has generally a negative charge with effectively a south pole underneath aimed up (vertically). As noted previously the vertical atmospheric electric field averages around 130 v/m over land but has a large daily variation of -25% to +30% of this field depending on location, season, and weather. Referring to Table 29 and looking at the line "Edc - plus MdcS" we see that the one phosphate has reduced activity (96.00%) and the one soil sample increased activity of 130.77%. The overall change for all samples was 101.46%. The reader needs to keep in mind that "Edc-" indicates that the soil surface will be negative and "MdcS" should be interpreted as meaning a south pole is below the sample. When viewing the tabulated data in Table 29 one should keep in mind that the laboratory generated fields are much stronger than the natural ones or even the fields under power lines.

Soil under power transmission lines are exposed to 60 hertz electric and magnetic fields as well as to the corona induced DC fields. Table 15 summarizes a few experiments done using 3 fields, 60 hertz magnetic and electric combined with constant DC electric fields. Note in particular that short time exposure to these high laboratory generated fields (15 kV AC , 416 G AC, 5 kV

DC) caused the soil and phosphate activity to increase with the samples exposed to the negative DC fields showing the higher values. Refering to Tables 9A and 12 noting especially the soil and comparing samples exposed to Eac plus constant DC electric versus those exposed to Mac plus constant DC electric it is seen again that the magnetic field exposure results in lower readings than exposure to electric field.

The reader has probably noted the soil shows the greatest range in change in activity expressed as a percentage. This is somewhat misleading for the actual range in terms of real numbers is quite small. The soil activity itself was the lowest of all the sources investigated. A change of activity of 10 cpm out of 20 cpm will result in a much higher or lower % change than 10 cpm out of 200 cpm.

Looking at the results of exposure of samples to all fields it is noted that of the individual radioisotopes reported on here that C^{14} and Th^{232} show a decrease in activity (95.36% C^{14} and 99.40% Th^{232}). Rubidium 87, K^{40} and U^{238} show an increase exposed to these fields with 101.78% for Rb^{87}, 102.61% for K^{40} and 100.54% for U^{238}. The phosphate (shale) and soil show generally a much larger % increase than the individual isotopes with the phosphate being 115.51% and the soil 139.15%. Since a significant part of the soil comes from phosphatic shales that have weathered out it is not surprizing that the soil also responds similarly. The reader may confirm this by looking at the phosphate and soil column in Table 29. Note that generally the soils and the phosphatic shales that contribute to local soil formation increase in activity when exposed to EM fields.

Soil activity changes when the soil is exposed to AC electric or magnetic fields as well as DC fields. Data presented in section one and particulary in parts I and III of section four indicates that the following sequence occurs under a newly energized high voltage transmission line.

Once energized the activity of the soil quickly rises within a week. The increase is caused by the AC electric field and to a lesser extent by the magnetic field. Variation in line height , current flow and voltage affects the rate and extent of increase. Once energized the corona induced DC fields come into play and are effective on the soil surface and somewhat below. Gradually the outer positive DC field (carried by space charges) begins to counteract the effects of the AC electric and magnetic fields and the soil activity begins to drop.Episodes occur where the inner negative DC field pushes through to the soil surface. This will reverse the trend and slow down the decrease of the soil activity. As time passes however the activity drops to below pre energization levels. The amount of time varies depending on line configuration but for the vertical configuration covered in part III in this section it appears to be about 9-15 months after energization. It is uncertain how long it takes to reach an equilibrium state but for the above mentioned vertical configuration with the power rate used from May 1995 to May 1996 it appears longer than one year for the activity of the soil was still falling as of May 10, 1996.

The comments in the above paragraph are based on a summed average of changes occuring near the power line (from under the center to @ 1/4 mile out). The soil directly under the center experiences large AC electric and magnetic fields but the maxima for both fields occur generally at different locations other than under the center. The location depends, among other things, on the line configuration. The DC (positive) field maximum occurs close to the AC electric field maximum. The interplay between these three fields is complex and therefore locating where the soil activity minimum is at is difficult. The position (absolute and relative to one another) of the three field maxima changes as the height of the cables above ground changes. The height of the cable changes between the cable supports; the cable sags. Thus the location of the soil activity minimum changes between poles. Because the DC field is due to suspended space charges the prevailing wind will cause the greatest reduction of soil activity on the downwind side where the positive charge is greatest. Summarizing in one sentence what occurs under the newly energized line. Upon energization the AC electric and magnetic fields initialy cause the soil activity to increase but the corona induced positive DC field begins to reduce the activity and will do so untill the two factors reach equilirium within a year or so.

Further evidence that there is a real change ocurring when radioisotopes are exposed to combined EM fields can be seen by looking at the hugh changes in the energy maximum of emitted beta particles (E_{Bmax}) and the changes in half life. The E_{Bmax} of K^{40} exposed to NN (see Table 9A and 2 in paper 3) was 110.34% higher than the unexposed and the E_{Bmax} for PP exposure was 107.84% of the unexposed. The calculated half life (using procedure shown on pages 108 - 110 in Chase and Rabinowitz) for K^{40} exposed to NN was 88.44% of the unexposed. Exposure of Rb^{87} to PP and NN caused the greatest change in E_{Bmax} and half life that this author has seen in any isotope analyzed in ten years of research in this field. The E_{Bmax} of Rb^{87} exposed to NN, reported in section 3, was 549.00% higher than the unexposed with the calculated half life being 87.88% of the unexposed. The E_{Bmax} of Rb^{87} exposed to PP, reported in section 3, was 66.27% of the unexposed with the calculated half life being 110.49% of the unexposed. Large changes in the energy and half life of $*Ba^{137}$ are also reported in Table 2 in section three. Reported in section 4 are a number of experiments done using Rb^{87}. The individual cases with the arrangement used is given in Table 32. A summation of the results of the various types of exposure of Rb^{87} to some form of DC electric field is presented in Table 33. In the 14 trials involving a positive DC field the measured surface charge averaged +.9419 volts, the activity 98.25% of pre exposure values and the E_{Bmax} was 104.86% of pre exposure value. For the 14 trials involving a negative DC field the surface charge averaged -1.0957 volts, the activity 103.16% of pre exposure values, and the E_{Bmax} was 101.62% of pre exposure value. The differences between the activities and E_{Bmax} were statistically significant at the .008 and .034 probability levels respectively. For additional information the reader is refered back to pages 6 and 9 of section 3. Smaller changes in E_{Bmax} of C^{14} (102.55% - 101.25% of unexposed sample) exposed to AC magnetic fields plus constant electric fields (Table 12) are reported on pages 13 of section three.

The author feels that additional work needs to be done investigating depth of penetration of these effects into (soil) surfaces. It is felt that any magnetic effect would be more penetrating while electrical effects would be limited to near the top of the (soil) surface. Under the power lines does the inner negative DC field “ bloom “ out on ocassion and reverse the effect of the outer positive DC field? Studies need to be done investigating differences between single exposure and repeated exposure as well as differences between short term (seconds to hours) and long term (days to years) exposure. Wide ranging and long term field studies relating soil activity and natural environmental factors (atmospheric potential and geomagnetic fields) should be undertaken. Investigations should be done on the effects that polarization of particularly the magnetic field (along power lines) has on the effects. What effect does phase of the electric and magnetic field have on activity changes? Additional work needs to be done in determining how polarized the emitted radiation is coming from the affected radioactive source. Along with the above work one could more accurately measure the half life of the effects and the energies of emission. Of particular interest would be changes in properties of individual soil radioisotopes occuring under newly energized power lines.

VI. APPENDICES.

A. Tables

B. Figures

C. Selected references