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RADON COMPENSATION FOR ALPHA AIR MONITORING SYSTEMS

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Continuous alpha air monitors, employing solid state detectors and single channel analyzers, for the detection of alpha particles of a specific energy have been available commercially for several years. The single channel pulse height analyzers provide good sensitivity to the isotope of interest and reject much of the unwanted activity from other isotopes such as naturally occurring radon and daughters. A small percentage of the radon daughters are degraded in energy by the air between the collecting filter and the diode to the extent that they coincide with energy of the isotope being measured and are counted as unwanted background. When ^{239}Pu is the isotope being measured the activity in the Pu channel resulting from radon is typically 2% of the total radon background. The majority of this unwanted background results from the degradation of the 6.0 MeV ^{218}Po (RaA) peak. This background is sufficient to cause instrument alarms during periods of radon activity. In attempts to reduce the frequency of false alarms, background subtraction circuits have been added as standard equipment to most of the alpha air monitors available on the market for the past several years. These background subtraction circuits generally have provided some help in reducing the frequency of false alarms, but are incapable of dealing adequately with the changing radon background levels that are typically encountered during an overnight temperature inversion. With this standard background subtraction circuit, a temperature inversion and the resulting radon background activity generally result in inadequate subtraction and false alarms early in the cycle and over subtraction and inadequate protection toward the end of the cycle. Calibration of these background subtraction circuits must be a compromise between the false alarm condition and the condition that requires considerable amounts of the isotope being monitored to make up for the negative counts being supplied by the compensation circuit.

In the past we have attempted to adjust these compensation circuits by running an overnight air sample in anticipation of radon activity. If an inversion did occur (sometimes there are days or weeks between good inversions) the subtraction percentage adjustment would be based on the activity on the filter which resulted from the overnight air sample. In addition to being faced with vastly differing levels of activity, this method resulted in the adjustment being made with differing ratios of ^{218}Po and ^{214}Po, depending on the profile of the inversion and the time since the peak occurred.

To provide a more consistent source of radon, a radon generator was constructed. A block diagram of the radon generator and associated plumbing is shown in the first slide.

SLIDE 1

The generator consists very simply of a small radium source sealed in a metal bucket and plumbed as shown. A peristaltic pump provides continuous circulation of the air and radon through the system. The vacuum side of the pump is connected to the outlet side of the air monitor and the pressure side of the pump leads to the radon filled bucket. The pressure side of the bucket is then connected to the air inlet on the air monitor. The radium source used to produce the radon is actually an old aircraft altimeter face. The dose rate at the surface of the bucket is approximately .2 mR/hr. The pump is normally operated at an air flow of about .1-.2 lpm. When the generator is not being used with an air monitor the ends of the tubing normally attached to the analyzer are sealed together to prevent leakage of radon into the room.

If the generator is operated as shown the activity accumulating on the filter is very low and consists primarily of the radon daughters being produced in the chamber in front of the detector. This is because the radon daughters in the bucket are largely unattached and are readily attracted to the walls of the tubing. A transport mechanism is necessary to bring the daughters into the analyzer. A technique that we have found to be very successful is the injection of cigar or cigarette smoke into the system. This is accomplished by filling a 60 cc syringe with smoke and injecting it into the port indicated on the slide. The port is simply a small hole in the tubing that is sealed with a piece of tape. Sixty cc of smoke injected into the port will produce about 1000-1500 counts per minute of ^{218}Po on the analyzer filter in 20-30 minutes.

To obtain a better picture of what takes place during a radon buildup and decay, a multichannel analyzer was utilized. A tee was installed at the output of the air monitor preamplifier and a signal directed to the multichannel analyzer. The additional load imposed by the multichannel analyzer is sufficient to slightly reduce the pulse height into the single channel analyzer located in the air monitor. The air monitor gain was readjusted by positioning an electroplated ^{239}Pu source in the position normally occupied by the air filter and adjusting for maximum response. The source was then removed and replaced by a clean filter paper. The air monitor is then connected to the radon generator and the pump started and an injection of smoke made.

The next series of slides shows the buildup and decay of the radon daughters that takes place under these conditions. Data was accumulated for five minutes and a new count was started every ten minutes. The scale on each slide is the same so that the peak heights may be compared directly to see the buildup and decay of the radon daughters. The analyzer was set up to use 1024 channels, with a sensitivity of 10 keV per channel. This puts the 5.15 MeV ^{239}Pu peak in channel 515, the 6.0 MeV ^{218}Po peak in channel 600 and the 7.7 Mev ^{214}Po peak at about channel 770. Full scale on the ordinate is 1024 counts. A ^{239}Pu peak is shown on each slide in a dashed line to indicate how the ^{218}Po is degraded across the Pu window.

In the first slide the 3.05 minute ^{218}Po peak is just SLIDE 2
beginning to show and the 30 + minute ^{214}Po peak is not visable. In
the second slide, started ten minutes later the ^{218}Po continues to SLIDE 3
grow and the ^{214}Po is just beginning to appear. The next slide SLIDE 4
shows the first daughter approaching equilibrium and the longer lived
daughter continuing to accumulate. The effects of the 6 MeV peak
being degraded across the Pu window are very evident. In the SLIDE 5
fourth slide of the series the relative activities of the two
peaks is seen to change. The next slide shows this trend to SLIDE 6
continue. I've skipped a couple of data sets because the picture
is not changing very rapidly so the time between the last slide SLIDE 7
and the next one is 30 minutes. Here you can see the ^{218}Po activity
is getting to be quite low compared to the ^{214}Po, and the final
slide taken 30 minutes later shows very little ^{218}Po present. SLIDE 8
From this time on the ^{214}Po continues to decay with an apparent half
life of 30-40 minutes.

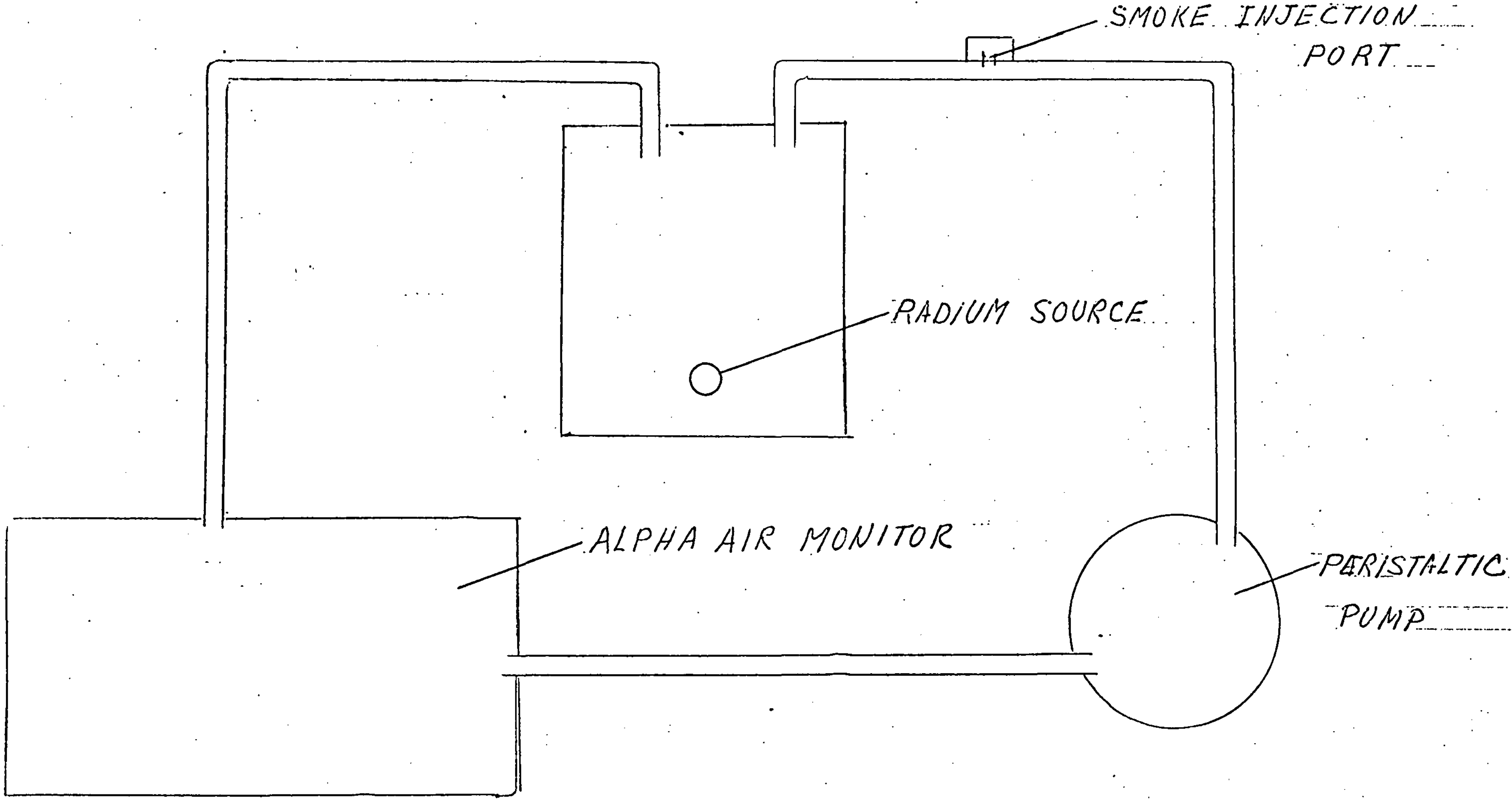
For several years compensators have been offered both as retrofit for older air monitors and as standard equipment on later models. The usual compensator circuit operates by assuming that all counts resulting from alpha energies above the ^{239}Pu window are due to radon and the circuit subtracts a fixed percentage (adjustable by a potentiometer) of these counts from the counts accumulated in the Pu channel. This system would work well if the ratio of activities of the two prominent radon daughters remained constant. The slides that we have just seen indicate that this may be far from the actual situation. During the sequence just shown, the ratio of the number of counts occurring in the Pu window to the number occurring above the window varied by a factor of 50 to 1. As a result of this large variation in the activities of the two daughters the compensator circuit must be adjusted to some compromise subtraction percentage. The results of this setting of the compensation circuit a typically under-compensation during the early part of the inversion and over-compensation during the latter part of the inversion.

The next slide is a strip chart taken from an instrument using this type compensation circuit. The ordinate is in counts per minute and the abaissa is in hours. The chart was made by turning the compensator circuit on and off at 15 minute intervals during the simulated inversion. The slide shows the expected buildup of ^{218}Po in the Pu window. Early in the sequence when the activity was predominately ^{218}Po, the circuit was able to reduce the radon background counts by slightly over half. Later in the sequence as the ^{214}Po begins to predominate the circuit begins to over-compensate. This is because there is very little activity actually being scattered into the window but the circuit is still subtracting a percentage of the ^{214}Po counts that appears, for the most part, well above the Pu window. A meter recording the negative count rate indicated that it was equivalent to 30-40 counts per minute. With typical efficiencies of 8-10% for these instruments, this over-compensation was effectively canceling out 300-500 dpm of ^{239}Pu. The compensation circuit for this sequence had been adjusted, using the radon generator and the multichannel analyzer, so that the background counts were being cancelled when the ^{218}Po and ^{214}Po activities were equal. If the adjustment is being made using radon collected on a filter during an overnight run, it normally is made using the long lived ^{214}Po since the ^{218}Po will have decayed off. This type of adjustment typically improves the over-compensation situation, but causes more false alarms during the early part of the inversion. SLIDE 9

Since nearly all of the interference by radon daughters is caused by the 6.0 MeV ^{218}Po, obviously this peak, if used alone, could provide much more reliable information for use as a radon compensation circuit. In the sequence of slides shown earlier the counts in the Pu window as a percentage of counts in the region just above the window, normally occupied by the ^{218}Po peak, is about 28% during most of the sequence and drops to about 21% near the end. An air monitor was equipped with a second single channel analyzer turned to the ^{218}Po peak to provide the information for background subtraction. The next slide shows a chart of the counts occurring in the Pu channel SLIDE 10 during a radon injection. The instrument was set with a 1 MeV window peaked on ^{239}Pu and a second 1 MeV window immediately above the first. The cordinates for this chart are the same as for the last slide. As in the last slide the subraction circuit was turned off and on at 15 minute intervals. During the early and middle parts of the run the circuit very nicely subtracts out the counts caused by radon. Toward the end of the run as the ^{218}Po has decayed away the number of counts in the Pu channel resulting from ^{214}Po becomes significant. Since this peak has been degraded considerably farther in energy than the ^{218}Po, its slope as it crosses the ^{218}Po and Pu windows, is considerably flatter than the slope caused by the degraded ^{218}Po, and the subtraction percent is incorrect. The result of this effect is insufficient subtraction. However, by the time these conditions exist the total background is low and the error is very few counts per minute. In the sequence just shown where the peak uncompensated background counts due to radon reached 75-80 cpm, the number of counts resulting from insufficient subtraction was approximately 5 cpm.

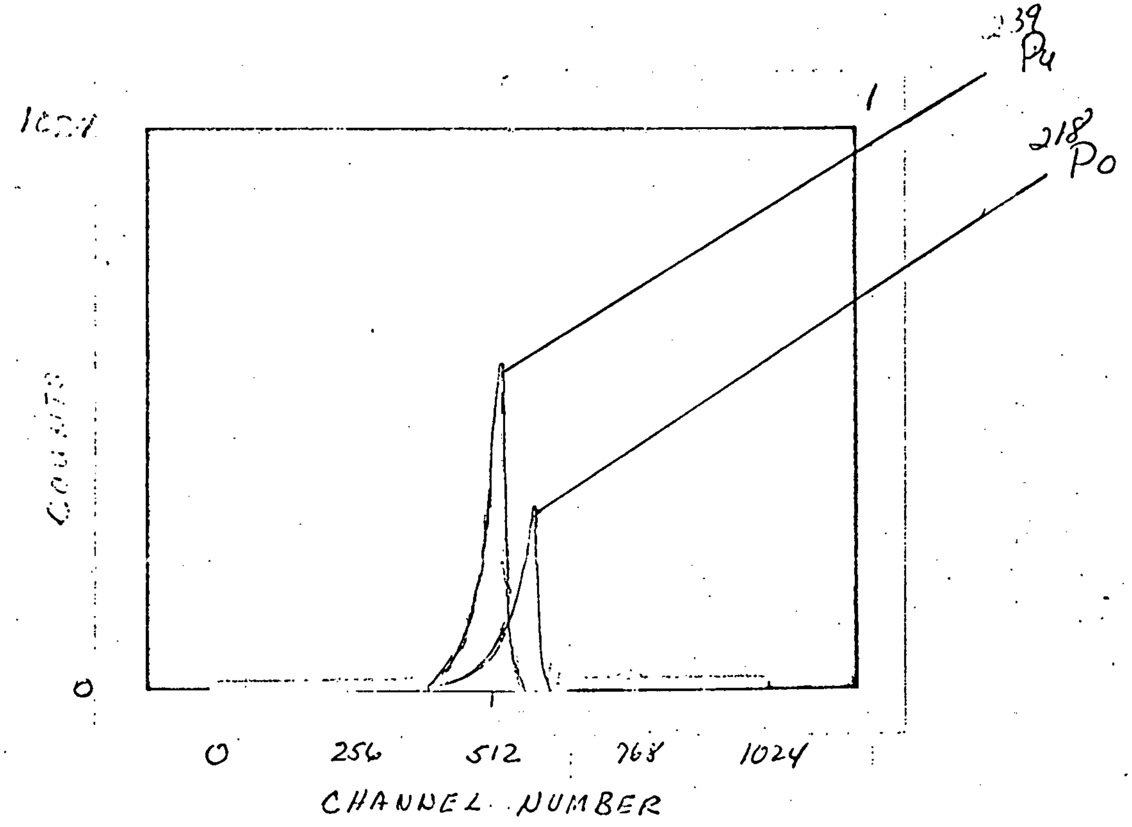
The conditions which produce radon daughters vary considerably depending on, among other things, the age of the air sample, type and length of sampling lines, if any, and number of dust or smoke particles in the air. The example just given probably has as large a variation in the ratios of ^{218}Po and ^{214}Po as may be expected under actual operating conditions. Under some conditions the activity of ^{218}Po and ^{214}Po may start at nearly the same level on the filter paper. This situation is a little easier to handle with the conventional subtraction circuit than the situation just described, but it is impossible to predict in advance just what the conditions will be and the circuit still has problems toward the end of the inversion.

The system using a second single channel analyzer as a source of compensation information is much more versatile and does a good job under almost all conditions. We have had only a limited amount of field experience with this circuit, but have had considerable experience in the laboratory and all indications are that performance is far superior to the other method of background subtraction. In addition the use of the radon generator with this instrument provides a system that can be calibrated conveniently in the laboratory. The adjustment is reproducible, doesn't depend on atmospheric conditions and can be performed in 20-30 minutes because the adjustment is not dependent on any particular equilibrium condition.

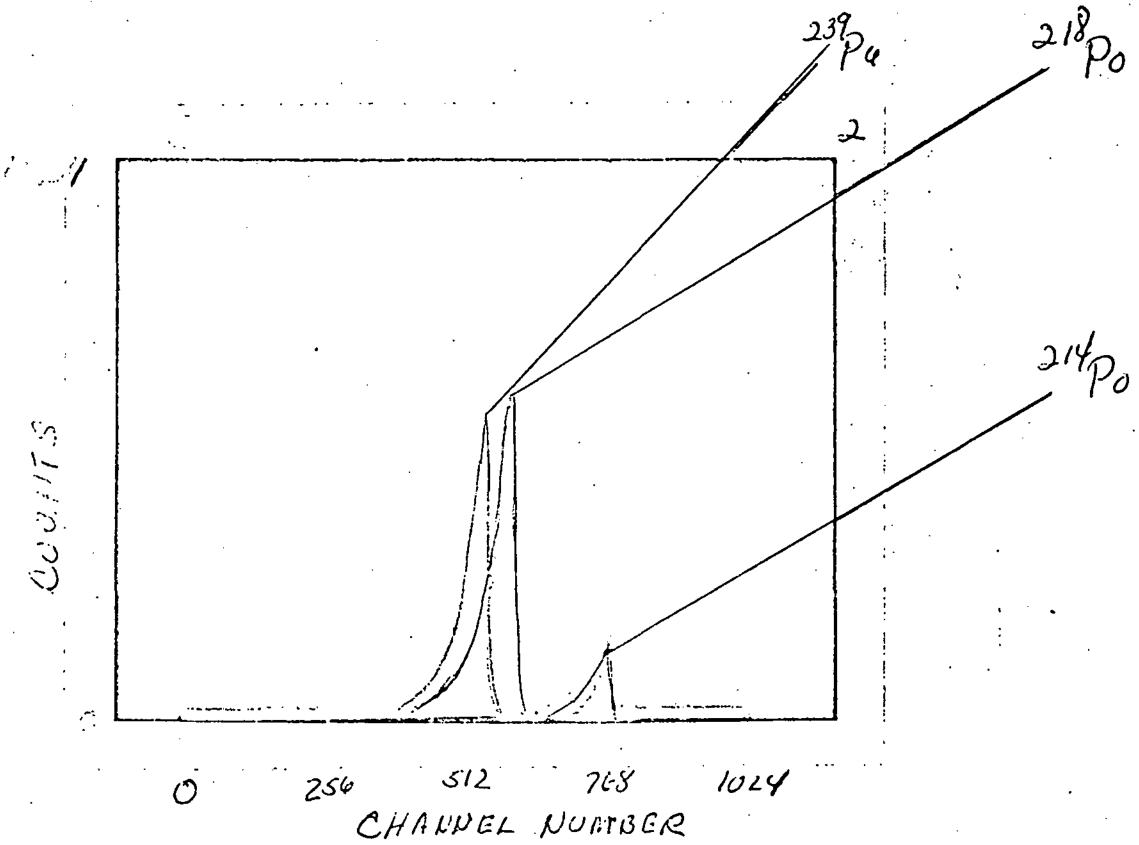


RADON GENERATOR

~~FIG 1~~ Slide 1

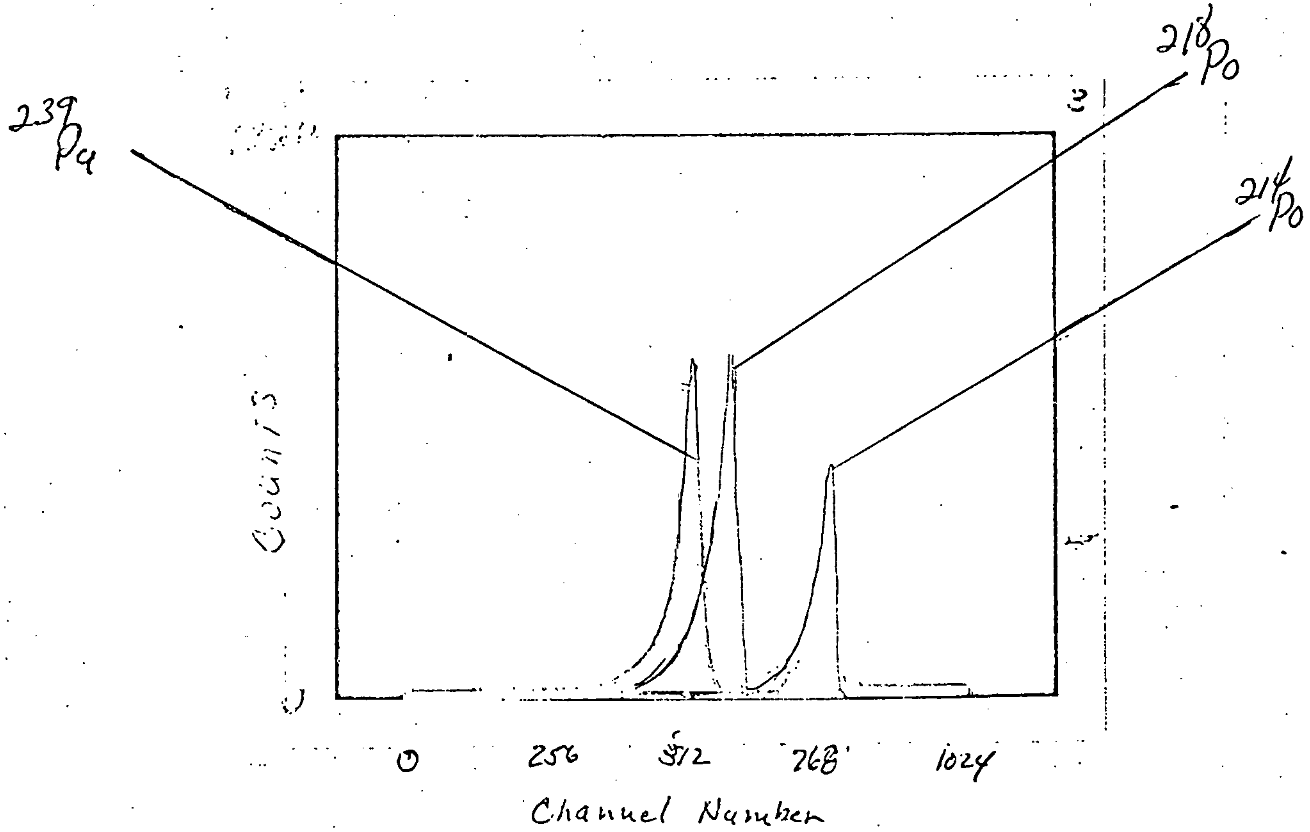


Radon daughter distribution
TIME = 10 minutes



RADON DAUGHTER DISTRIBUTION

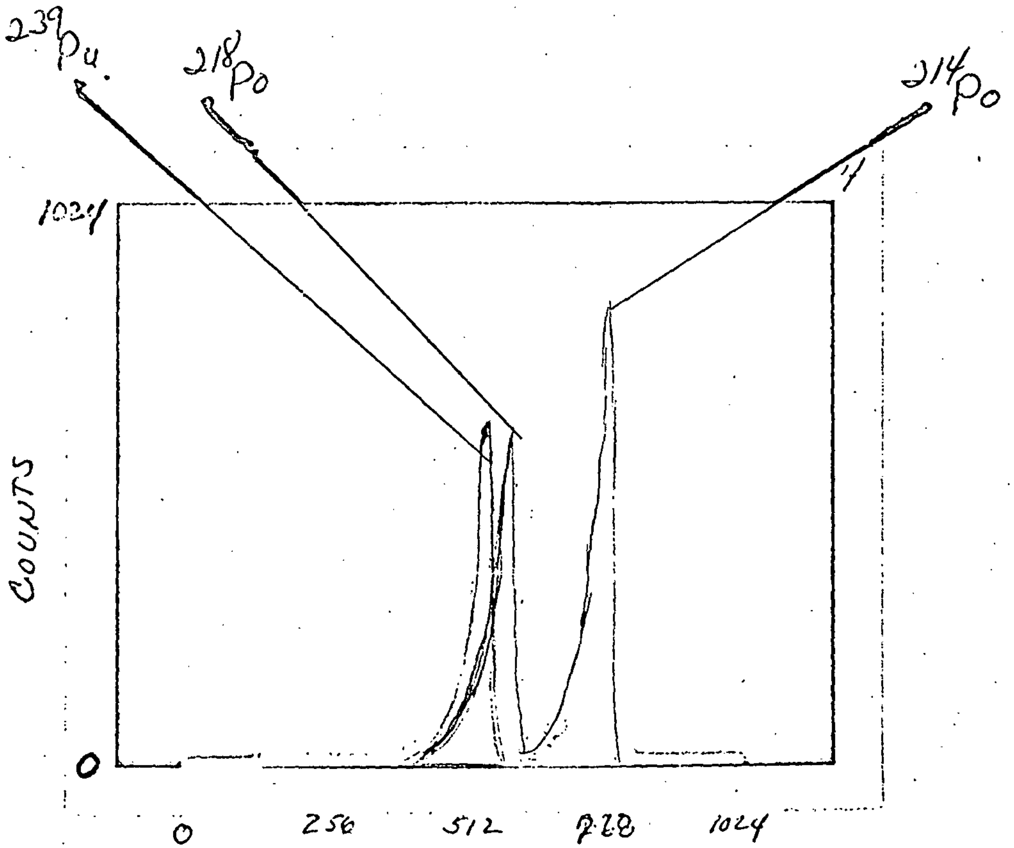
TIME = 20 MINUTES



RADON DAUGHTER DISTRIBUTION

TIME = 30 MINUTES

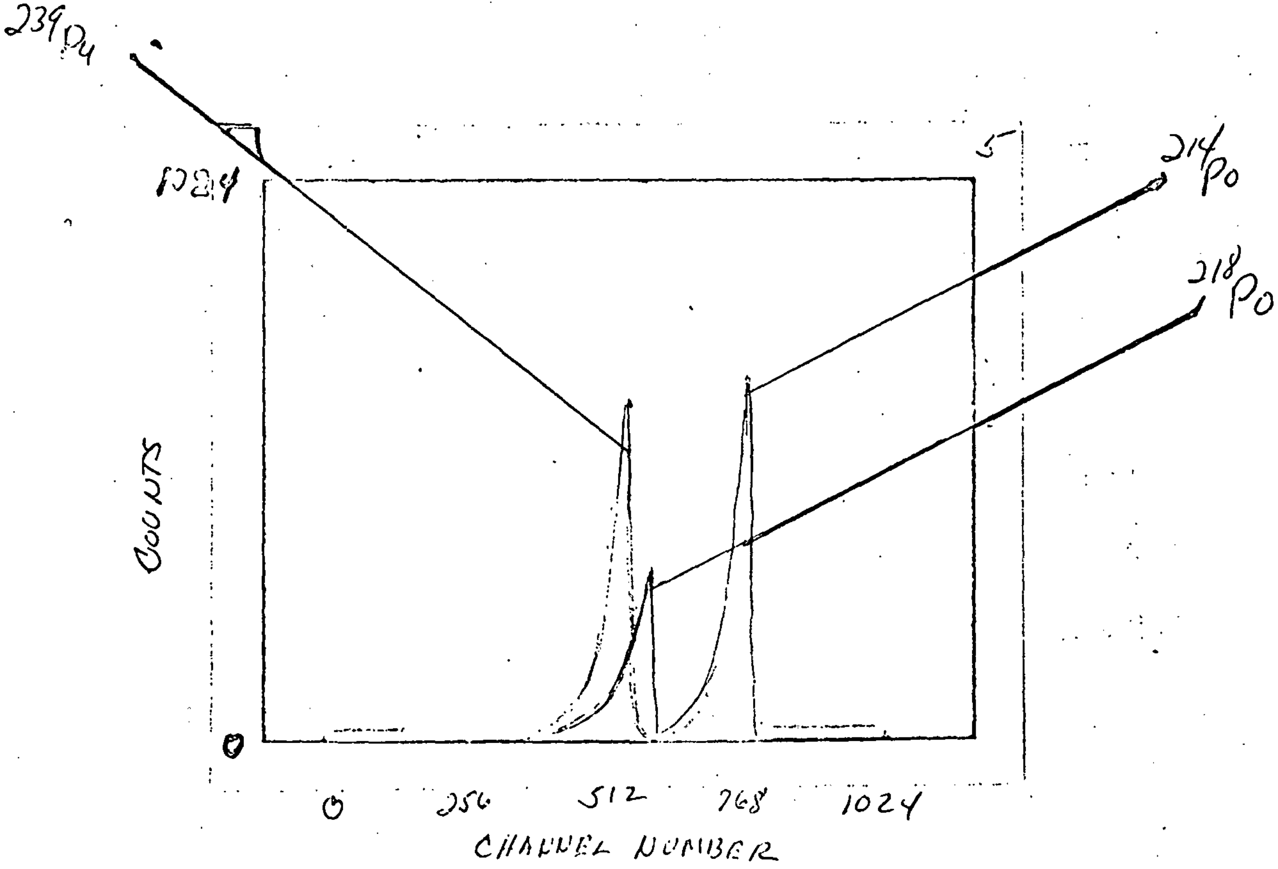
Slide #4



RADON DAUGHTER DISTRIBUTION

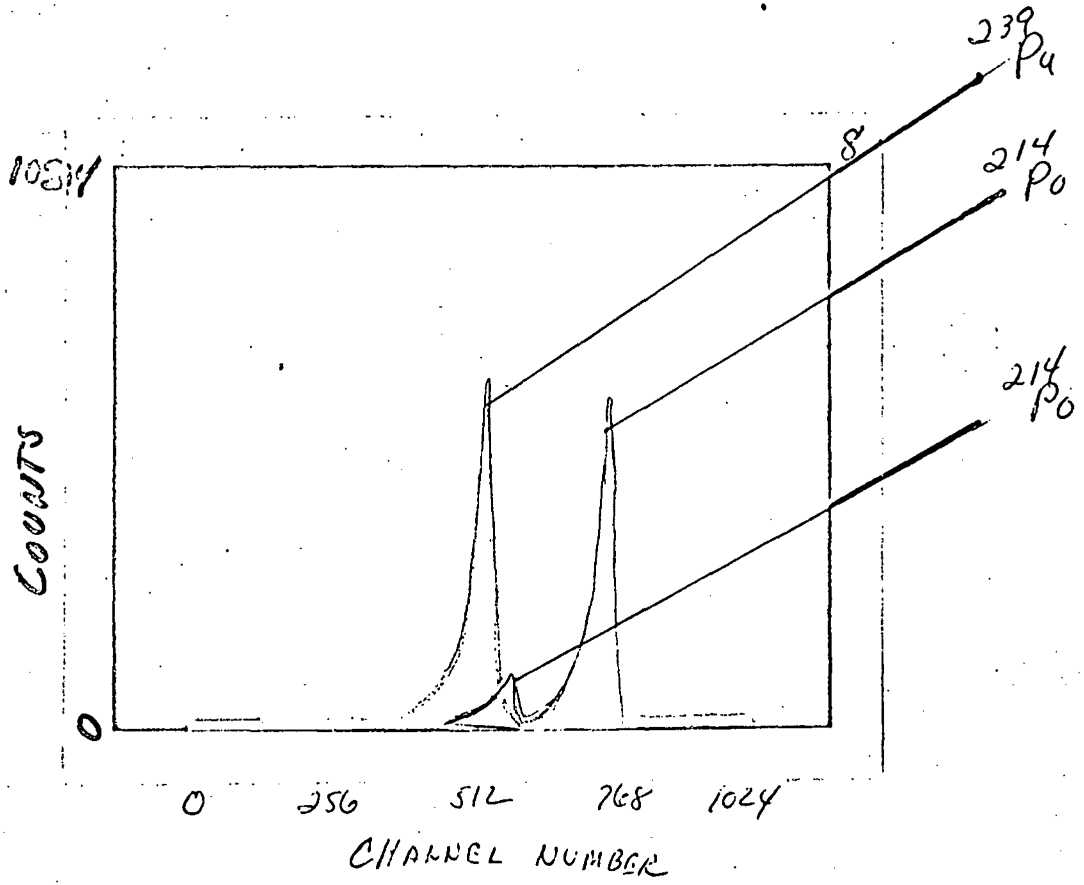
TIME = 40 MINUTES

Slide #5



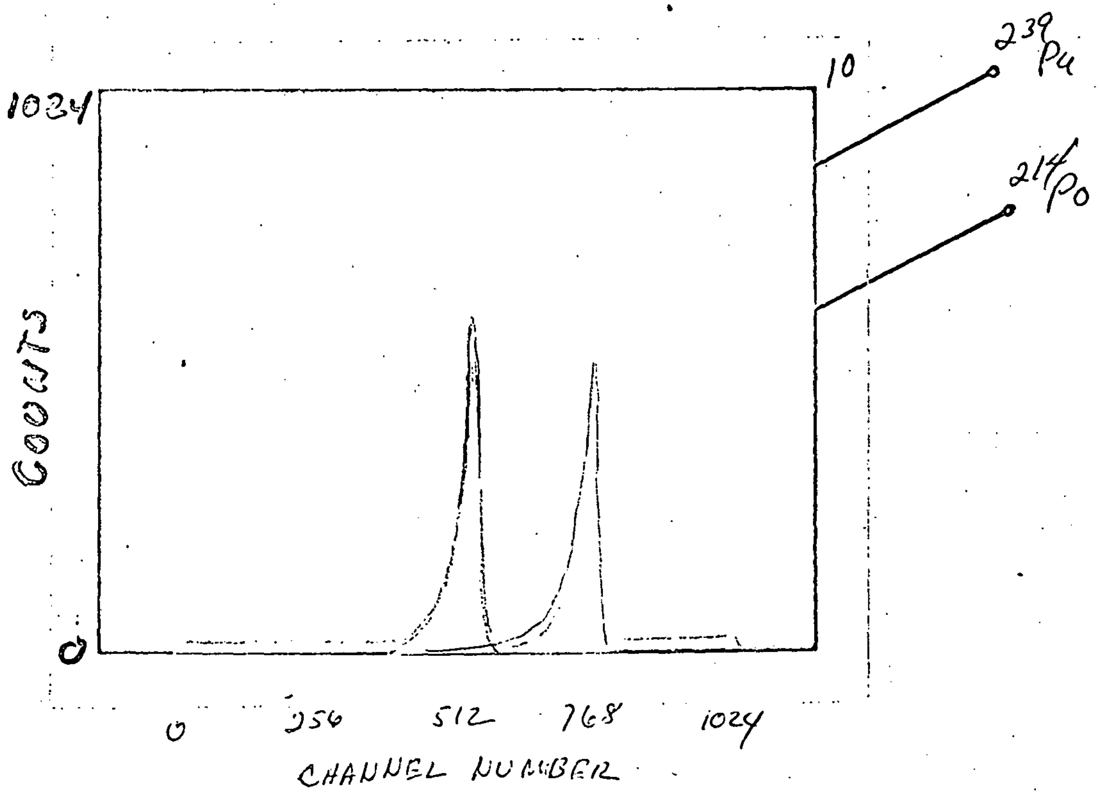
RADON DAUGHTER DISTRIBUTION
TIME = 50 MINUTES

Slide #6



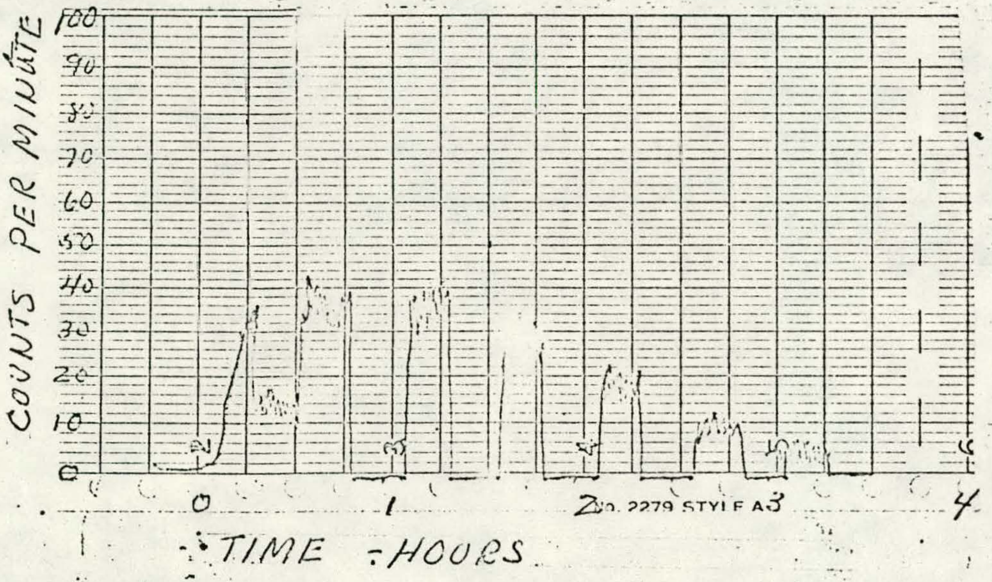
RADON DAUGHTER DISTRIBUTION
TIME = 80 MINUTES

Slide #7



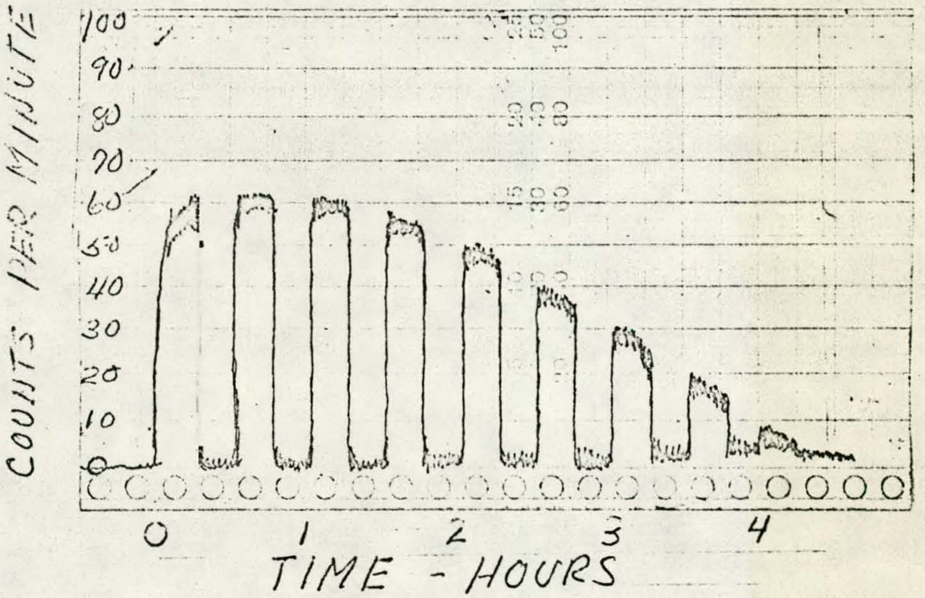
RADON DAUGHTER DISTRIBUTION
TIME = 120 MINUTES

Slide # 8



^{218}Po (RaA) + ^{214}Po (RaC') BACKGROUND UIT
SUBTRACTION

Slide #9



^{218}Po (RaA) RADON BACKGROUND SUBTRACTION

Slide # 10