Radon Reduction Using a Stirling Technology SD-200 RecoupAerator

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ABSTRACT

The United States EPA warns of the risks of elevated levels of Radon gas in living space. In their publication, "A Citizen's Guide To Radon"[1], the EPA states that Radon levels above 4 pCi/l are "considered above average for residential structures," and they recommend abatement action. In this series of measurements, a reduction in Radon concentrations was achieved using an SD-200 RecoupAerator in a residential structure having nominal pre-existing Radon levels in the range of 10 - 20 pCi/l. The results of these measurements indicate that factors of at least 2 may be obtained.

INTRODUCTION

Radon, ^{222}Rn, is a naturally occurring radioactive gas which results from the radioactive decay of Uranium, ^{238}U, through its daughter radionuclide, radium, ^{226}Ra. Radon also decays by releasing an alpha particle continuing a chain of decays eventually ending with the stable isotope of Lead, ^{206}Pb. Since Radon is the only member of the decay sequence that is a gas and is therefore highly mobile, it has the potential to increase exposure of human lung tissue to radiation. The health significance of the Radon decay sequence to Lead is that it occurs in a very short period of time and can deposit potentially ionizing radiation in lung tissue. The effects of exposure of underground Uranium miners to high levels of Radon are documented in a 1981 National Academy of Science report[2]. The levels experienced by the miners studied were 100 to 1000 times "normal" indoor levels. (Levels in mines studied ranged from 200 pCi/l to 4000 pCi/l. Average outdoor concentration are estimated at 0.25 pCi/l and acceptable indoor levels are taken to be at or below 4 pCi/l.)[1] Based on the so-called linear-dose response function relating cancer incidence to radiation exposure, researchers have extrapolated to acceptable safe levels. The recent BEIR V report on the "Health Effects of Low-Level Ionizing Radiation" suggests that "the population's risk of injury to be somewhat larger than estimated previously."[3] It should be pointed out that new evidence challenges the linear-dose response function at low radiation levels.[4] Several independent studies indicate beneficial effects on human health of low level radiation.[4,5] At issue is the existance of a threshold for radiation damage.[3,4,5,6] The linear-dose response function is based on the assumption that a threshold for radiation damage to cells does not exist and thus any level of ionizing radiation including background radiation may contribute to the damage.

Radon is found in high concentrations in soils and rocks which contain Uranium bearing minerals. Radon is often found in high concentrations in granites and shales. Normally, this natural radioactive gas is harmlessly dissipated into the atmosphere. However, the construction of buildings over geological formations containing high concentrations of Radon may permit the gas to be trapped and concentrated within the structure. The levels are usually highest in the lower levels of the building since the gas can enter the building through cracks in concrete basement floors and walls, drains, sumps, private water wells etc. The EPA basically recommends reduction of levels in buildings to 4 pCi/l or below even though they believe that there is still some risk of lung cancer even in this range. They state for levels at 4 pCi/l or below that "Exposures in this range are considered average or slightly above average for residential structures. Although exposures in this range do present some risk of lung caner, reductions of levels this low may be difficult, and sometimes impossible to achieve."[1]

Mitigation of Radon in building can be achieved by 1) preventing or reducing its entry or 2) removing it after it has entered. The EPA technical manual, "Radon Reduction Techniques for Detached Houses"[7] provides detailed guidance for the reduction of Radon in dwellings. In many instances both approaches must be used. This brief study addresses one approach to removal of Radon. Maher et al.[8] describe several other methods. Here we will discuss the results obtained employing the Stirling Technology SD-200 RecoupAerator. The SD-200 is an air exchange device which incorporates a heat exchanger having specifications of 90% efficiency. The free flow air exchange rate is rated at 200 cfm.

EXPERIMENTAL SET UP

The purpose of these measurements was to determine the extent to which the Stirling Technology SD-200 RecoupAerator could be used to mitigate Radon build up in an existing building. Figures 1 and 2 show the basement and first floor plan of the structure investigated. The basement level represented about 988 ft^2 of ground plan and a volume of approximately 7900 ft^3. The upper level contained a volume of 12,500 ft^3 for a ground plan of 1560 ft^2. The SD-200 was installed in the basement area near the furnace, but not connected to the duct work. 6" flexible ducting connected the outside intake and exhaust ports through a basement window. The fresh air and building exhaust lines were arranged as show in Fig. 1. The fresh air was allowed to "dump" into room B in the figure and the air exhausted from the building was drawn from room A. The exhaust line was arranged over head between basement ceiling/first floor joists. Room A is a finished room with dry wall on interior walls and ceiling. The outside walls are painted concrete block construction. A hole in the ceiling of room A permitted air from that space to be exhausted. In all measurements, the door to the Room A was left open so that air from other areas of the basement (especially Room B) and the rest of the house could be exchanged. The plan area and the volume of room A are 276 ft^2, and 2,200 ft^3 respectively. No means other than air exchange were employed to reduce Radon levels.

Radon detectors were located at various times in rooms A, B, C, and D. The experiments began in January of 1992 and continued until July of 1992. Previous measurements had indicated levels of Radon in the 10 to 20 pCi/l range in tests using an "At Ease" Radon Monitor Model 1020 manufactured by Sun Nuclear Corporation, Melbourne, Florida. A set of 49 measurements obtained prior to January 1988 in the Newark, Thornville, and Granville areas yielded 94% at a level greater than 4 pCi/l. Average values for Licking County Ohio have been found to be 21.5 pCi/l. These data are attributed to the charcoal canisters distributed and analyzed by Ryan Nuclear Laboratories in Columbus Ohio. No specific information is available concerning placement or other details of the data gathering process since the tests were preformed by individual homeowners. Thus the preliminary data for this building seems to be consistent with levels experienced in the area. It should be noted that time dependent variations in Radon levels have been experienced which seem to correlate with weather conditions; wind velocity and barometric pressure. Concurrent weather data were not taken with these measurements.

INSTRUMENTATION

Two Radon rate counters were used for this series of measurements. The primary instrument was a femto-TECH Model R210F Radon Monitor manufactured by femto-TECH, Inc., Carlisle, Ohio. The R210F is a precision airborne alpha radiation detection instrument based on pulsed ion chamber technology. It is a continuous Radon monitor employing passive diffusion sampling of the ambient air environment in which it located. The unit was used in combination with the DL40A data logger/printer and was ideal for long term monitoring. It displayed time, "Total Count" from initialization, "Present Concentration", and "Average Concentration" at one hour intervals. The last two quantities are computed by the data logger making use of the current calibration constant for the instrument. The second instrument used was an At Ease Radon Monitor Model 1020 manufactured by Sun Nuclear Corporation, Melbourne, Florida. This device employs a silicon solid state alpha detector. Data are continuously accumulated and are read out in binary format. The 1020 was used as a back up instrument and for comparison purposes. Agreement between the two instruments was within the statistical error of measurements. An estimate of the statistical error for the two instruments is +/- 1 pCi/l.

RESULTS

The details of the measurement conditions and the measurement results will be discussed in chronological order. The data are displayed as plots of "Current Concentration" and "Average Concentration" in pCi/l versus "Elapsed Time" in hours. In most cases, information on the plots will include the location of the monitor (usually the R210F), significant times (turn-on or turn-off), beginning and ending dates for that series of measurements. During a given measurement interval, the monitor was allowed to accumulate data continuously. An obvious feature of these plots is the rather large excursions of the Present Concentration from the Average Concentration. An examination of the data over the course of the project indicates fluctuations as much as +/- 15% over a period of a day are not uncommon. Although no attempt was made to determine the origins of these variations, it is suspected that they may be correlated with meteorological phenomena and represent fertile ground for more study.

The following is a presentation of the data collected along with pertinent information on the existing conditions.

Figure 3 Start: 1304 01-14 / End: 1201 02-01-92

These data were recorded to determine the typical background Radon levels in Room A. Installation of the SD-200 had not been completed at this time. The run was approximately 21 days long. The plot shows the hourly variation in the Radon level as well as the cumulative average value on the same time scale. Large excursions, as great as 60%, from the long term average are quite apparent at the start. The average is comparable with the average of 21.5 pCi/l quoted earlier for the county. The origin of these large swings are unknown.

Figure 4 Start: 1205 02-01 / End: 1105 02-16-92

The R210F was moved to Room B where a series of measurements determined the background for that room. Here, the background is of the same order of magnitude, averaging 21 to 22 pCi/l. Near the end of this data set, at 1515 on 02-16-1992 the SD-

200 is turned on for the first time. In a period of 7 hours the "Present Concentration" has dramatically dropped from nearly 25 pCi/l to around 6 or 7 pCi/l.

Figure 5 Start: 1145 02-16 / End: 0840 02-21-92

Both monitors are reset at the start of this run. The Average Concentration is consistently less than 10 ranging between about 7 and 9 pCi/l until the SD-200 is turned off at 2215 on 02-18-1993. (Also note that at 1005 on 02-18-1992 the R210F and the 1020 monitors read 8.6 and 9.2 pCi/l respectively in very good agreement. Both were in the same location.) After the SD-200 is turned off, the Present Concentration abruptly rises to around 20 pCi/l comparable to the Average Concentration observed in figure 5 for this room, Room B. The R210F and the 1020 read 20 and 18 pCi/l at 0842 on 02-21-1992. Both monitors are again reset.

Figure 6 Start: 0846 02-21 / End: 2220 02-23-92

At 0846 on 02-21-1992, the SD-200 is again turned on and the Radon concentration is seen to drop to between 8 and 9 pCi/l in about 5 hours. The hourly concentration is seen to fluctuate, dropping to below 2 pCi/l and averaging around 8 to 9 pCi/l. The 1020 accumulated average value is 11 pCi/l at 2200 on 02-23-92.

Figure 7 Start: 2220 02-23 / End: 0820 02-26-92

The R210F monitor is moved to Room A at 2020 on 02-23-92 and reset. The 1020 monitor is left in Room B continuing to accumulate counts. Average Concentration is level at about 9.7 pCi/l with fluctuations up to 13 and down to 6.7. Clearly the SD-200 has lowered both the Average Concentration and the peak fluctuations.

Figure 8 Start: 0820 02-26 / End: 2345 02-27-92

The SD-200 is turned off at the beginning of this figure. The Radon concentration rises to a steady Average Concentration of around 17-18 pCi/l.

Figure 9 Start: 0000 02-28 / End: 1400 03-03-92

The next series of measurements relocated the R210F to the 1st floor level of the building in Room C. This space is immediately over Room A in the basement. At the beginning of this figure, the SD-200 is not running. It is turned on at 1945 02-28-92. Concurrently, the Radon concentration recorded on the 1020 monitor read 26 pCi/l in Room B. The figure shows a steady drop from around 18 to around 6-9 pCi/l. Again, fluctuation are evident in the Present Concentration.

Figure 10 Start: 03-04 / End: 03-10-92

This figure is a continuation of the previous one. The SD-200 has been running continuously since 02-28-92. The Average Concentration in the previous figure reached a steady value less than 10 pCi/l. This plot continues and the Average Concentration drops to around 7.5 pCi/l. The Present Concentration seems more variable here. The scale of this graph is expanded compared to the earlier one so in fact the variability is not different. The fact that some first floor windows have been open at various times adds additional uncertainty. Unfortunately, not enough detailed information about the condition of the windows was recorded to make this figure very useful. The Radon monitor in Room B reported a concentration of 8.6 pCi/l during this time. Clearly the RecoupAerator continues to have a lowering effect on the basement area.

Figure 11 Start: 0816 03-10-1992 / End: 1506 03-14-92

At the beginning of the figure, the SD-200 is turned off, both counters are reset and a steady increase is observed in the Average Concentration during the first day, then a slight decrease, and then a steady level of a little less than 12 pCi/l there on until 03-14-1993. This steady concentration is typical of the average values observed for this area of the building in the past.

Figure 12 Start: 1511 03-14-1992 / End: 0853 03-14-92

The R210F was moved to Room D. This space is located over a crawl space which is surfaced with 4" of concrete. The vertical distance between the floor of Room D and the crawl space is about 2 feet. The crawl space is well ventilated and it is suspected that most of the Radon concentration measured in this area may originate in other areas of the building. This has not been verified, nor has the concentration been measured in the crawl space. Without the SD-200 running, the level averages about 11 pCi/l.

Figure 13 Start: 0853 03-17-1992 / End: 1900 03-18-92

At the beginning of this figure, the SD-200 is turned on. A clear and steady drop is observed in the Average Concentration to around 8 pCi/l an indication that the assertions of the previous paragraph may be valid. That is, the Radon in this area originates in the basement area. This run was terminated due to a power outage caused by a severe storm.

Figure 14 Start: 0915 03-19-1992 / End: 1536 03-22-92

Both monitors were reset and the SD-200 was restarted when power was restored. The Average Concentration leveled out around 7 pCi/l, not too different from the previous measurement.

Figure 15 Start: 1543 03-22-1992 / End: 1743 03-27-92

This and the following figures present additional data reported for Room A. The SD-200 is on throughout this run. The 1020 monitor reported 6.2 pCi/l at 1522 on 03-22-92.

Figures 16-17 Period: 04-16-1992 through 04-21-1992

Figures 16 and 17 are self evident.

Figure 18 Start: 1506 04-25-1992 / End: 2208 05-07-92

Figure 18 covers a 12.5 day period during which the effects of open first floor window are observed. The SD-200 is turned on near the start of the figure, then turned off at 1800 on 05-02-92. Windows were opened at about the 135 hour mark and then closed at about 230 hours into the run. The SD-200 is turned on at 1734 on 04-25, turned off at 1800 on 05-02, turned on at 2014 on 05-03, and off again at 2000 on 05-04. The windows were also closed at 2000 on 05-04. The open windows appear to drive the concentration down dramatically to about 1 pCi/l while the RecoupAerator is running. The spike at about 171 hours corresponds to turning the SD-200 off from 1800 05-02 then turning it back on at 2014 on 05-03. With windows open and SD-200 off, the level is approximately the same as the condition with the windows closed and the SD-200 operating. With both windows open and SD-200 running, the concentration is in some instances reduced to around 1 pCi/l. With windows closed and SD-200 off, the level quickly returns to ambient concentrations on between 20 and 30 pCi/l. Note that the Average Concentration does not respond very rapidly to changes in this figure because of being weighted by more than 200 hours of data for concentrations at or below 10 pCi/l.

Figure 19 Start: 1117 07-04-1992 / End: 2100 07-14-92

The R210F was reset and restarted. Weather was cool and clear due to passage of a cold front. The windows were open. The concentrations vary greatly from 2 or 3 pCi/l to greater than 25 over a 100 hour interval. Although no weather information has been recorded, it is suspected that the large swings are due to passages of frontal systems and their associated changes in barometric pressure. It is suspected that Radon escapes from the ground more readily during periods of low barometric pressure. At 1122 the SD-200 was turned on and the resulting concentrations tended to be lower at the 2-3 pCi/l level. The SD-200 was turned off at 0200 on 07-13 due to thunder storms and intermittent power outages which account for the rise at about 230 hours into the run. The run was finally terminated due to a power outage caused by another thunder storm at 2100 on 07-14-92. It would be interesting to check the degree of correlation between the Radon concentrations and meteorological data, especially barometric pressure, wind velocity and temperature.

CONCLUSIONS

The concentrations of Radon in a building is obviously a complicated matter depending on many factors. Among these are geological factors such as concentrations of certain radioactive minerals and soil types. Additionally, aspects of the construction of the building such the integrity of floor and wall membranes determine to what extent Radon will enter the structure. In concert with the forgoing, weather factors such a wind velocity and the degree to which it causes the pressure within the structure to be lowered as well as other conditions of changing weather possibly including barometric pressure influence the permeation of Radon into structures. This study attempted to evaluate the degree to which the Stirling Technology Model SD-200 RecoupAerator could mitigate Radon concentrations in an existing structure. The evidence indicates that the SD-200 is effective in reducing Radon concentrations by factors of 2 to 3. The extent to which the sizing and installation of the air exchange could be optimized was not investigated. In all likelihood, some additional improvement can be realized. It seems clear that Radon mitigation to the level recommended by the United States Environmental Protection Agency, below 4 pCi/l, is probably best accomplished by employing a variety of proven techniques of which air exchange is but one.

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8. Maher, E.F., Rudnick, S.N., and Moeller, D.W., "Effective Removal of Airborne ^{222}Rn Decay Products inside Buildings," Health Physics, 53, 351-356, (1986).

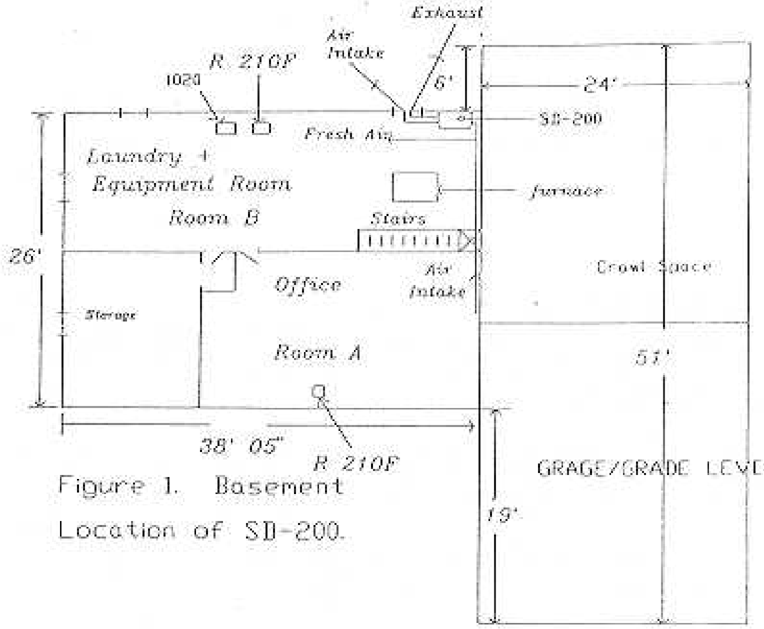

Figure 1. Basement
Location of SD-200.

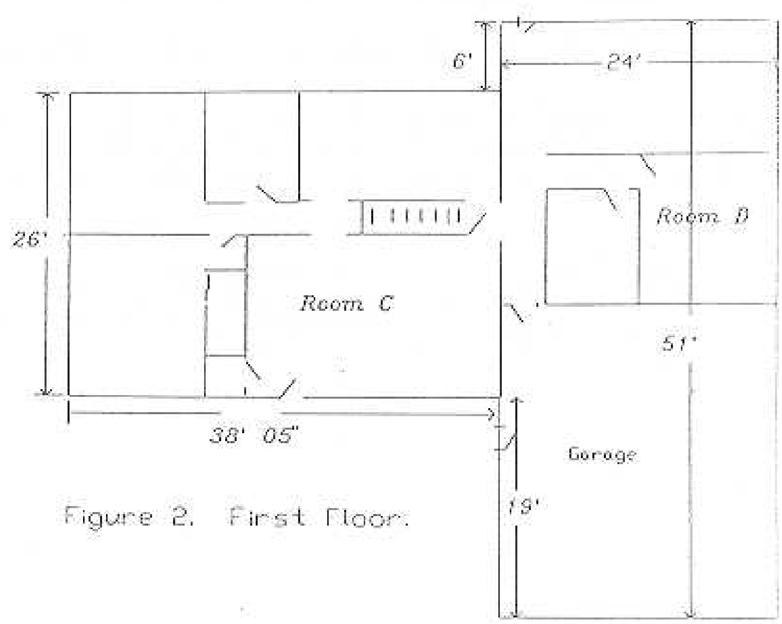

Figure 2. First Floor.

Figure 3. Start Jan 11 & End Feb 1
Room A

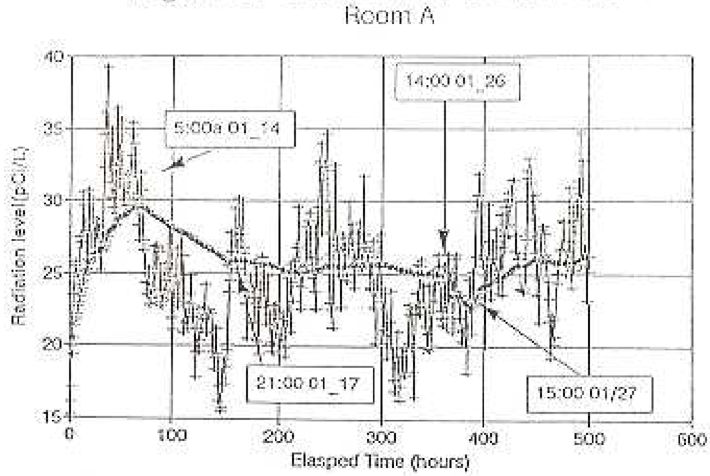

Figure 4. Start Feb.1 & End Feb. 16
Room B

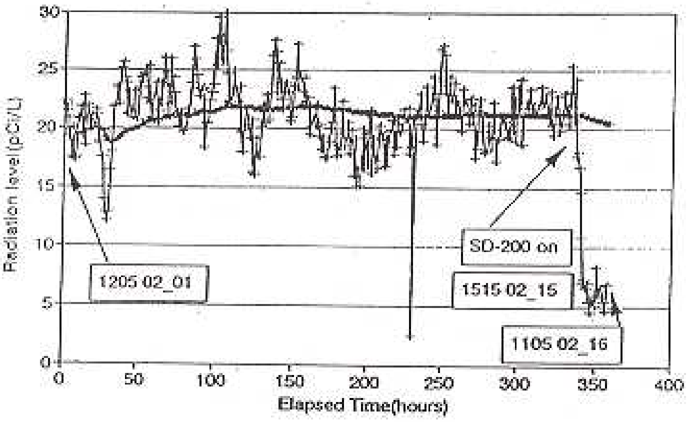

Figure 5. Start Feb.16 & End Feb.21
Room B

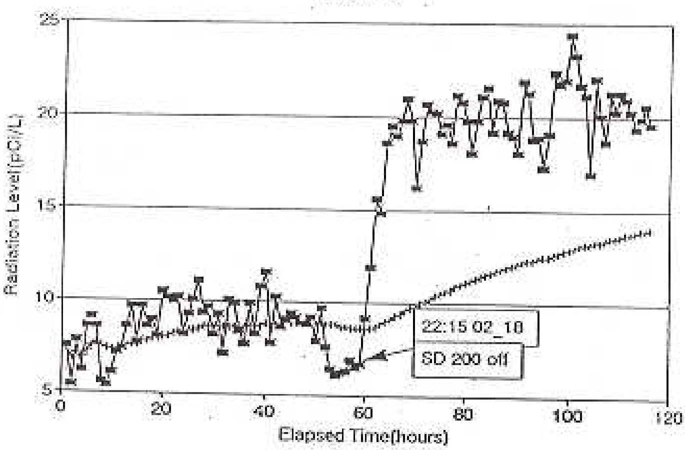

Figure 6. Start Feb. 21 & End Feb. 23
Room B

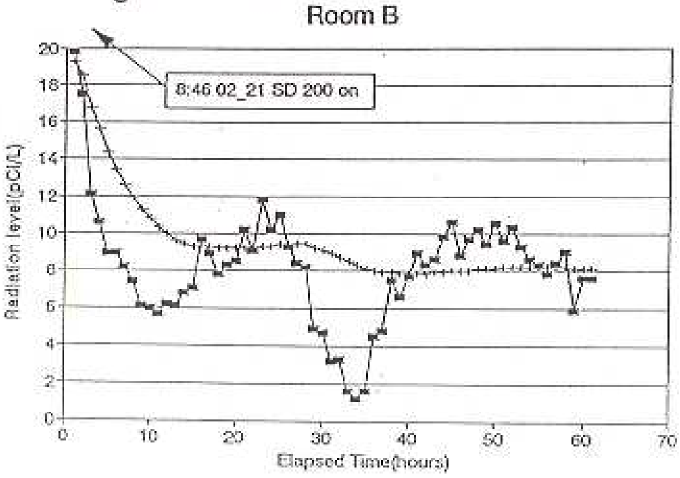

Figure 7. Start Feb.23 & End Feb.26
Room A

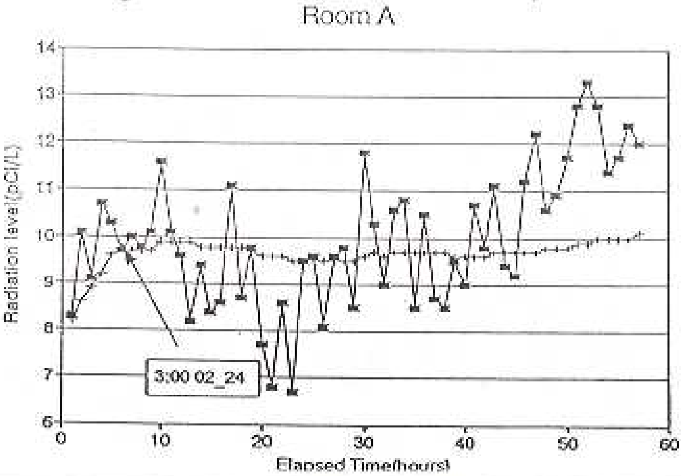

Figure 8. Start Feb.26 & End Feb. 27
Room A

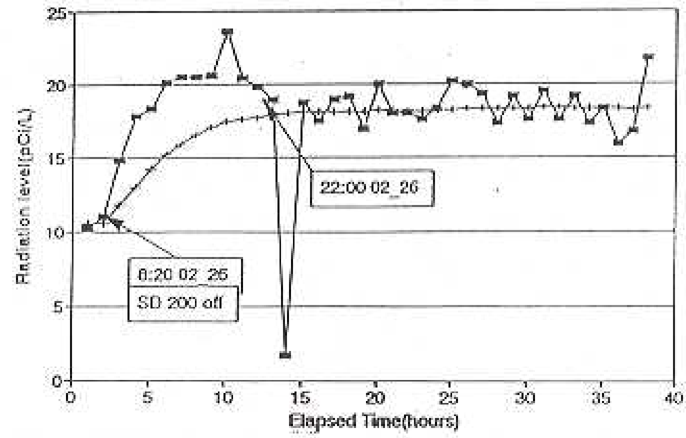

Figure 9. Start Feb.28 & End March 3
Room C

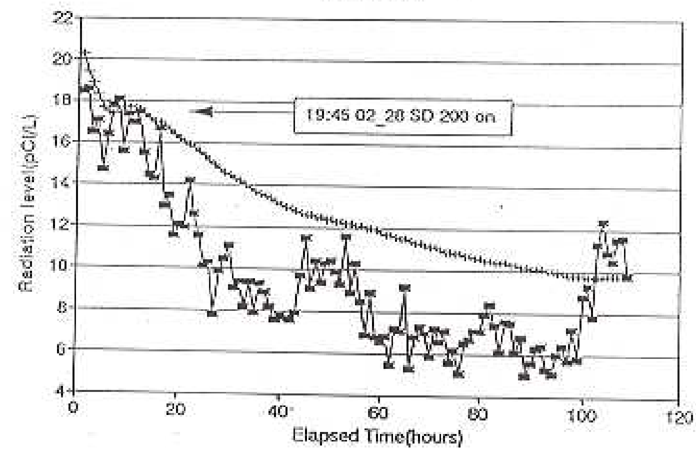

Figure 10. Start March 4 & End March 10
Room C

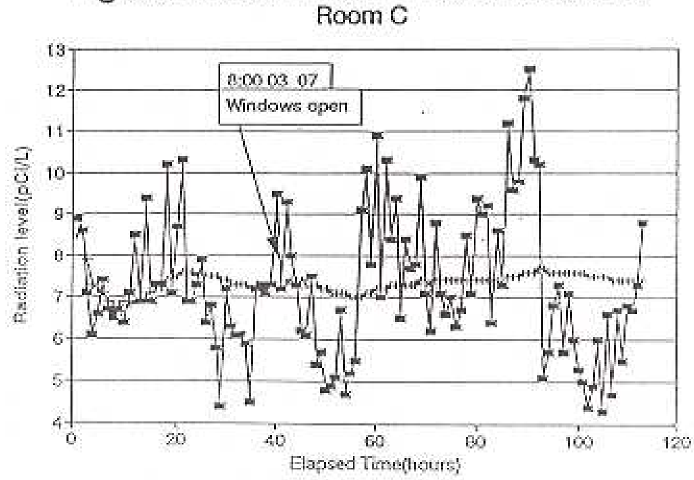

Figure 11. Start March 10 & End March 14
Room C

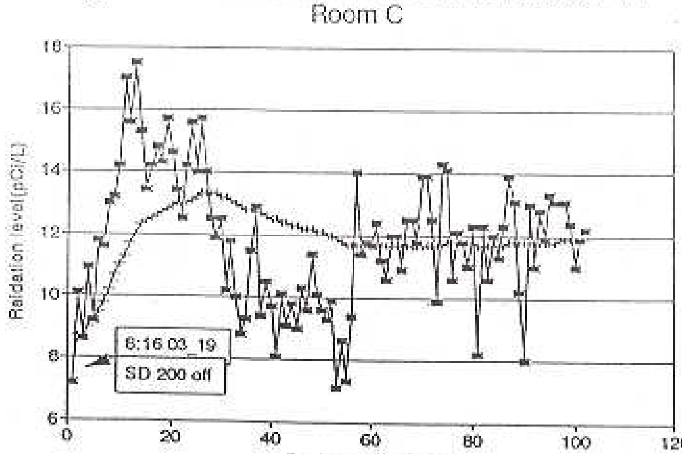

Figure 12.Start March 14 & End March 17
Room D

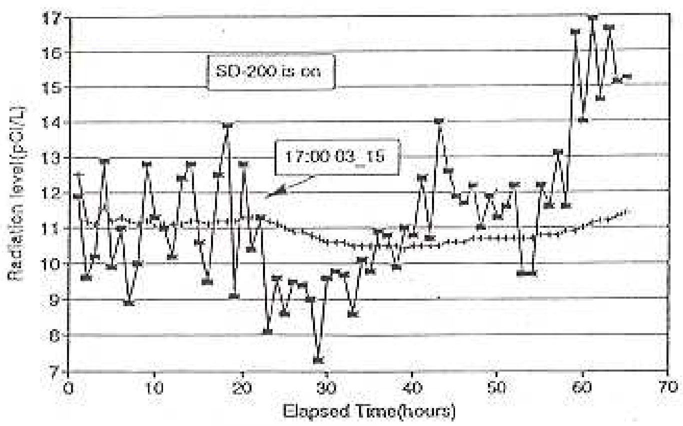

Figure 13.Start March 17 & End March 18
Room D

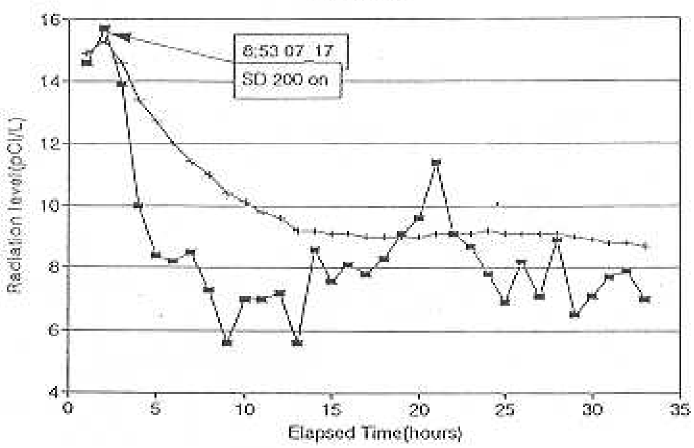

Figure 14.Start March 19 & End March 22
Room D

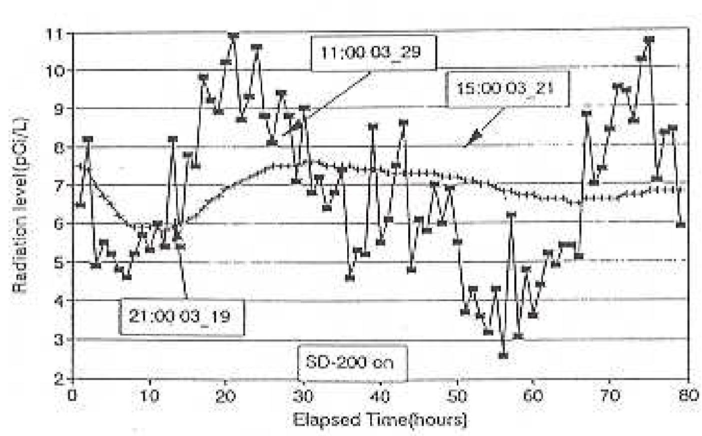

Figure 15.Start March 22 & End March 27
Room A

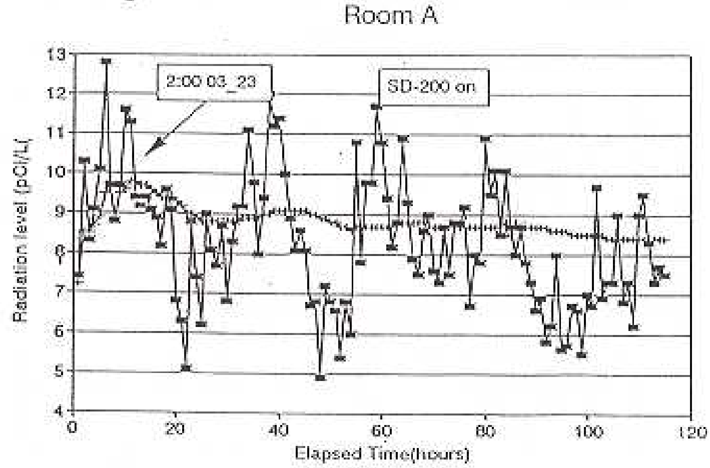

Figure 16.Start April 16 & End April 18
Room A

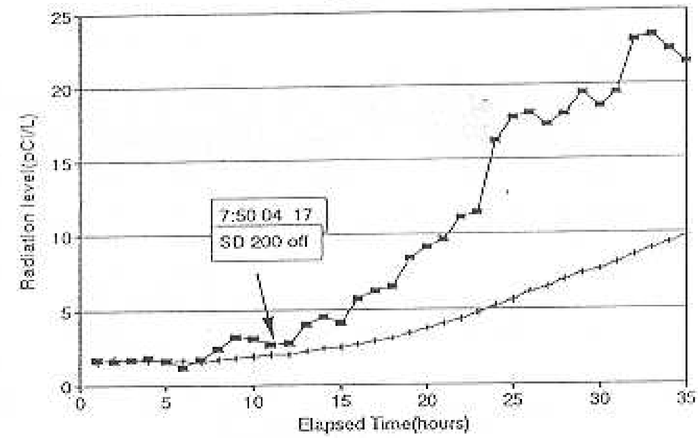

Figure 17.Start April 18 & End April 21
Room A

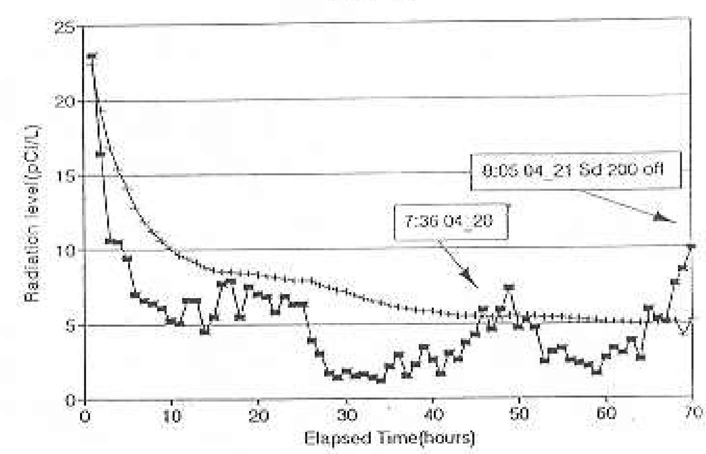

Figure 18. Start April 25 & End May 7
Room A

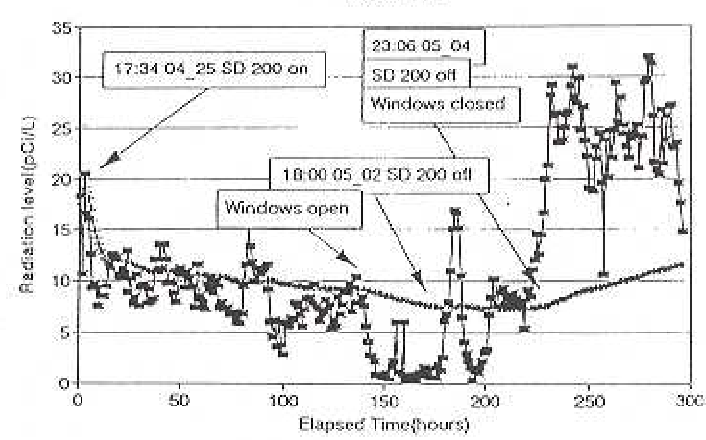

Figure 19. Start July 4 & End July 14
Room A