# A NEW ELECTROSTATIC RADON PROGENY COLLECTION METHOD

John C. Dempsey
SR Environmental Monitors
Frederick, MD

Paul Kotrappa
Rad Elec Inc.
Frederick, MD

Darold M. Wobschall
SR Environmental Monitors
Amhurst, NY

## ABSTRACT

A new method for collecting radon progeny was investigated that reduces particle concentration including radon progeny in indoor air without air movement. The LECA (for Large Electrostatically Charged Area) system uses a high voltage source to charge the collector surfaces (e.g., furniture pieces were used) once they have been electrically isolated from ground by teflon film. When a piece was touched by the high voltage lead its entire surface immediately become charged to about 60% of the line voltage regardless of its material makeup. By limiting the current to 250 ua no sparking or shock sensation was experienced when touching the charged wire or collector surfaces. Progeny collection efficiencies were measured for collector areas from 8.6 to 51.8 $m^2$ and voltages from 2.5 to 9 KV in an 82 $m^3$ test-room. The optimum LECA configuration tested reduced all particulate in the test-room including both the attached and unattached progeny by about 92%.

## BACKGROUND

Lung cancer, the principle radon health effect, is not caused by the radon gas itself but by its progeny, especially by the smaller unattached progeny particles that can penetrate into the deep respiratory tract. Several researchers have investigated methods of reducing progeny in indoor air but most methods tried have been unsuccessful because of their inability to remove enough of those more hazardous unattached progeny.

It is well known that particles, including radon progeny particles, tend to gather on electrically charged surfaces such as TV screens. The concept investigate here flows from that observation; i.e., it is an attempt to charge a large enough surface area to a high voltage so as to remove most of the progeny from an entire room or house. The fact that TV screens, which carry surface charges in the order of 20 KV, do not spark or shock users when touched, indicated that the method could be safe if the current was kept low enough. It also appeared that the method might circumvent the limitations of the "No-Rad" approach described above since it would involve no air movement and its power and space requirements would be minimal.

## PRIOR R & D

Most of the progeny removal methods tried to date have been adaptations of some available type of electronic or mechanical air filtration devices. The use of an ion generator, the only other approach which involves no air movement, was evaluated in a test-room by Maher et al (1975). Positive and negative ions reduced the total PAEC by 67 and 85%, respectivly, in dry air but only 25 and 50%, respectively, above about 60% humidity. The relative removal of attached and unattached progeny was not investigated. Many other systems have been investigated (Rajala, et al. 1946) (Jonassen et al. 1982)(Rudnick et al. 1983) but only one, a combination of an ion generator and a fan, has proven able to reduced the unattached progeny and thereby the brachial dose significantly (Maher et al. 1987) (Hopke et al. 1994) (Jonassen et al. 1985). A commercial ion generator-fan device called the "No-Rad", which was marketed by Ion Systems Inc. in the late 1980s, apparently did not meet with much commercial success. The cost and space requirements for the multiple units required for whole house mitigation with such devices appear to be their principle limitation but they also use considerable power and generate undesirable noise and air currents.

Only one paper was found that investigated the use of charged surfaces to reduce radon progeny via the LECA approach; i.e., without the use of fans or pumps to move the airborne particles to a charged surface. Its authors (Jonassen and McLaughlin 1985) studied the concept only theoretically and concluded that it would "only be able to remove a small fraction of the potential alpha energy concentration (PAEC) from the air." In arriving at this negative conclusion, the authors relied largely on data from an earlier investigation (Jonassen 1982) in which he measured the rate at which progeny collected on a small diameter (74 mm) metal disk while its voltage was increased from -2 to -15 KV. The favorable results of the present investigation (see below) indicate that such small scale disk data may not be applicable to large, room-size systems. Their negative conclusion was also based on another assumption, also derived from the disk study, that the only force which attracts progeny to a charged surface is that between the positively charged progeny (most progeny are formed with a positive charge) and a negatively charged collecting surface; i.e., that a positively charged surface will not attract progeny. In view of the nearly equivalent collection efficiencies obtained with positively and negatively charged collectors in the present study, that assumptions also appears to be invalid. Instead, it appears that the well known reverse polarity effect (sometimes termed the "mirror-charge" effect) is the predominant force which causes the particles to move to the charged surfaces in the LECA system.

Two other investigators (Kahn and Phillips 1984 and 1985) also studied the rate of progeny collection on a small charged disk and they explored the effect of several environmental conditions on that collection process. They were able to measure the effect of variations in progeny concentration, unattached fraction concentration, particle concentration, particle size and relative humidity. Two of their conclusions tend to support the present investigation; viz. (1) the flow of progeny from the air to their disk increased substantially as the percentage of unattached fraction was increase and (2) that the progeny flow rate increased with progeny concentration.

## INSTRUMENTATION AND METHODS

Instruments Two types of Rad Elec Inc (REI) instruments were used to make most of the radon and progeny measurements; viz., H-chamber E-PERMs were used for most of the radon gas measurements and two E-RIPSU instruments were used for most of the total PAEC measurements. Both regular REI short-term and newly developed short-short-term electrets were used interchangeably as the sensors in these instruments. The latter electrets, which are 2.1 times more sensitive than the usual short-term type, were used to reduce the duration of experiments when feasible. A non-contact REI voltmeter was used to measure electret voltages and its accuracy and repeatability were checked frequently with REI calibrated reference electrets.

A new German-made instrument called the SARAD monitor was used for all measurements of unattached progeny. The SARAD also measured radon gas and attached progeny as well as the unattached progeny every two hours automatically. Its automatic data recording and PC printout capabilities also proved to be useful. This monitor samples the unattached progeny via a mesh screen and the attached via a HEPA filter arranged in series. It then counts the screen and the filter separately for a set time while it measures the radon gas concentration. The mesh dimensions (54 by 54 wires to the inch) and air flow rate are designed to give a progeny size cut-point of 4 nm (Dp50); i.e., the unattached progeny particles measured were all less than 4 nm in diameter.

All radon and progeny measuring instruments used were exposed in the EPA radon chamber at the Los Vegas Laboratory and that calibration was used throughout the investigation.

Non-contact voltmeters manufactured by Trek and REI were used to read all charged surface voltages. The Trek voltmeter, which was pre-calibrated by the supplier to read surface voltages at specified distances, was used to calibrate the more sensitive REI voltmeter. Both instruments were fitted with distance positioning rods, which served to hold them at exactly the same distance from the surfaces measured.

A 10KV General Electric high voltage power source with both positive and negative polarity voltage outputs was used early in the project to charge the collector surfaces. A variable 2 to 20 KV source manufactured by Accopian Inc. was also used. This latter source only provided negative polarity voltage, but it had access terminals for measuring its line current and voltage output values with an ordinary voltmeter. The maximum current output of both power sources was limited to 250 micro-amps with an appropriate resistor during all experiments for the reasons described below.

The measurements of total airborne particle concentrations were made with a TSI Model 3025 condensation particle counter. This instrument does not distinguish the size of the particles but it counts even the smallest ones present by first "growing" them through a gas condensation process.

<u>The Test-Room</u> Fig. 1 is a dimensional sketch of the basement room that was used for all of the tests. It is about 4.88 X 8.54 X 2.43 meters and its volume was about 82 $m^3$. The furniture pieces shown in the sketch were charged in various groupings to serve as the collector surfaces. The groupings were always chosen to give approximate symmetry to the overall charged surface pattern in the room..

All experiments were carried out with the test-room in a static condition; i.e., with the forced-air heating system off and with the room carefully closed off from the rest of the house. During experiments, all cracks where air containing progeny might enter or exit (e.g., around the two doors) were sealed. The unusually wide range of radon concentrations that occurred naturally in the room with weather changes (about 3 to 35 pCi/L) enabled testing in a variety of radon and progeny concentrations.

<u>Methodology</u> A four step procedure was used to test and evaluate each set of LECA design or operating parameters as follows: (1) operate the LECA with those parameters for at least two hours to be assure equilibrium, (2) measure the progeny and radon concentration and (3) calculate the f-factor for the condition(s) tested. Tlhen (4) that f-factor was divided by the average undisturbed test-room f-factor of 0.644(see below) and the resulting ratio converted to the desired collection efficiency percentage value. In this way, all progeny collection efficiency values used to evaluate the LECA's performance were all reference to a single average undisturbed test-room f-factor. This procedure eliminated the long waiting periods (a minimum of 6 hours) which would otherwise be required to permit the room to come to equilibrium between each of the many conditions tested. The reference undisturbed f-factor was determined by measuring and averaging ten separate f-factor measurements at times throughout the project when the test-room had been undisturbed for at least 12 hours. As seen in Table 1 they were all very similar even over widely different radon and progeny concentrations and their average was 0.644.

## LECA DESIGN INVESTIGATION

<u>Collector Surfaces</u> Preliminary experiments showed that once any piece of furniture was electrically isolated from ground (see below), touching it firmly anywhere on its surface with the bare high voltage wire caused the entire piece to become charged immediately. This high voltage contact with a very small area on any piece, (e.g., a single wrap of the bared wire taped to the leg of a cloth sofa or a wooden cabinet) charged it all completely regardless of its material of construction. The use of special-made wall and ceiling collector panels for collectors was considered impractical because of the large area needed. The zero cost and immediate availability of the furniture option favored

its adoption, at least for the first phase of the investigation. Items used are shown in Fig. 1. Other household objects such as curtains, venetian blinds, art hangings and plants (real or artificial) may also serve as collector surfaces.

High Voltage Power Supply It was predetermined that a power source current output with a maximum output of no more than 250 ua essential to preclude all possibility of electrical shock to installers and users of the system. The maximum amount of current required during LECA operation in only the amount lost to ground through the wires and collectors; i.e., the amount used in the particle collection process itself is negligable. It was found that by inserting pieces of either PTFE (white) or FEP (clear) Teflon as thin as 0.02 cm. at each collector to ground contact point (e.g., between each leg of a cabinet and the floor) the current loss could easily be contained within the 250 ua limit. Teflon coated wire was also used to minimize loss.

Fig. 2 is a plot of the average voltage of the collector surfaces as the voltage of the power source was increased from 4 to 20 KV. All eight collectors were connected for this experiment and all were isolated with 0.15 cm of PTFE Teflon. The collector surface voltage is seen to climb fairly linearly at about 60% of the source voltage up to about 12 KV where it starts leveling off due to increased current loss to ground. The current flowing in the circuit measured at 10 KV was only six ua.

Once the optimum current and voltage were established for the power source, a unique 9 KV (negative) high voltage power supply was designed, developed and tested for the LECA. It has an average rated current of 10 miro-amps and a maximum output of 250 micro-amps. As discussed above, this low maximum output assures that the system cannot cause sparks or shock users under any circumstance. The unit is quite small; the electronic components are all potted inside a small (4 x 2.5 x 2.5 in.) case that plugs directly into any 110 V wall socket 10 ua (DC). The source includes a flashing LED signal light to indicate when a short-circuit occurs; i.e., when a insulator piece is removed). The estimated production cost of a unit is only about $20. The circuit used for the source was published elsewhere (Dempsey et al 1997 and Wobschall 1987 ).

## LECA OPERATION INVESTIGATION

The progeny collection efficiency of the various LECA configurations was investigated with respect to three operating variables (viz., voltage polarity, charged area and charging voltage) and two environmental parameters (viz., radon and progeny concentrations). When the optimum system design was realized, its ability to collect unattached as well as the attached progeny was also measured. (The effect of humidity, air flow and the simultaneous operation of an ion generator and a fan were also investigated to a limited extent and reported elsewhere (Dempsey et al 1997) but space limitations precluded inclusion of those data here.)

Voltage Polarity Effect Table 2 shows the results of several experiments wherein the LECA progeny collection efficiency was measured with positive and negative polarity at different times but with approximately the same collector voltage about 6 KV). As shown, the individual collection efficiencies measured were all very similar and the average with positive polarity voltage is only slightly less than with negative voltage; i.e., 90.1 and 91.2%, respectively.

Collector Area Effect Table 3 lists the estimated effective areas of the various furniture pieces used as collectors during the investigation. Many factors limit the accuracy of these estimates. Fig. 3 shows how the LECA progeny collection efficiency increased as the charged collector area was increased. The ratios of the various charged areas to the test room volume are also plotted in Fig. 3. All these measurements were made at the same voltage (about 6.7KV) . (It is interesting to note that even the smallest charged area tested (the 8.6 $m^2$ bookcase) collected 75.5% of the progeny in the room. This may indicates that a small charged area LECA systems may suffice for some mitigation situations.) The efficiency is seen to increase rapidly at first as collecting area is added and then to slow as still larger area is added. The figure reveals another interesting characteristic of the LECA; viz., that its collection efficiency is independent of radon concentration. Since the f-factor in the undisturbed test-room air remained essentially constant throughout the project regardless of the radon concentration, it follows that the LECA efficiency is also independent of the progeny concentration.

Collector Voltage Effect. Fig. 4 show the results of a series of SARAD measurements taken as the voltage on the eight LECA collectors was increased in six steps from 2.5 to 9.0 KV. The SARAD measured the radon, attached PAEC and unattached PAEC every two hours as shown. The times when the voltage was increased are shown by the superimposed vertical lines and the collector voltages are written in between those lines. The curves labeled "PAEC at f=0.644" and the "Collection Efficiency %" in the figure were derived as explained above. The largest PAEC reduction is seen to occur at the lowest voltage (2.5 KV) tested. Smaller reductions are seen at each successive voltage increase through 6.3 KV but none from there through 9 KV. The maximum collection efficiency observed is seen to be about 92% which compares favorably with the 91.2% seen in Table 2.

Collection of Unattached PAEC Fig. 4 also shows that the unattached progeny concentrations decrease in about the same proportion as the attached component after each voltage increase. This indicates that the system collects the unattached as efficiently and it does the attached progeny at most operating voltages. Table 4 shows the results of a second SARAD run to verify this conclusion. It shows14 simultaneous measurements of attached and unattached progeny with the voltage-on on the left and 14 of the same measurements taken later with the voltage-off on the right. As seen, the ratios of the averages of the unattached to attached progeny in the voltage-off and voltage on series were 0.147 and 0.094, respectively. Thus, in this experiment, the LECA again reduced the concentration of unattached progeny even more than it did the attached.

## REMOVAL OF TOTAL PARTICULATE

It was suspected at this point in the project that the LECA must be reducing the concentration of all other particulate together with the progeny particles. Mindful that an efficient total particulate removal capability should add to the commercial viability of the method, a few brief experiments were carried out to determine how efficiently the system was removing total particulate from the test room. Table 5 shows the particulate concentration in the test room before and after the LECA was turned on at 6.3 KV. As seen, the total particle concentration fell to about 95% in 3.5 hours. As might be expected, this is about the same as the progeny reduction percentages seen in Table 2 ( 92 to 93%).

## LECA INSTALLATION CONSIDERATIONS AND COMMERCIAL POTENTIAL

(The discussion in this section is tentative and speculative and will remain so until some whole house LECA systems have been installed and evaluated. Such installations have been proposed as part of Phase 2 of the project reported on herein.)

Cost Estimate Component cost for a whole house "furniture collector" LECA system (e.g., a power source, some Teflon coated wire and Teflon insulator pieces) may only be about $50 where in homes where one of the $30 power sources will suffice; however, larger homes may require more than one source. At this preliminary stage, it appears that installation in a small home may take about the same as it takes for an average SSV installation; viz. about three to six hours. Thus the only difference in installed cost of the two systems would result from the lower LECA component cost; i.e., where SSV components may cost $140, those for a LECA might only cost $50 to $80.

Potential For Homeowner Installation As described above, the cost of LECA components should be somewhat less than those for an SSV system. They would also be much smaller so they could easily be combined and sold to homeowners in kit form. The LECA should also be easier homeowners to install because they would require no cement drilling or roof work. Since the system is essentially a "plug-in" device and there are no electrical hazard involved, it appears that wiring codes or electricians need not be involved in its installation. All of these factors appear to make the LECA system suitable for homeowner do-it-yourself installation. If this option proves to be feasible, it should reduce mitigation costs substantially.

Homeowner Acceptance Considerations A perceived electrical hazard from the LECA high voltage may limit homeowner acceptance, at least initially. As mentioned earlier, all real electrical hazard is precluded by the shock proof high voltage power supply. "Touch" demonstrations should eventually eliminate this natural fear. Concern about the electric field may also be a concern for some potential users even though there are known adverse health effects from continuous electrostatic fields. Nevertheless such perceived hazards will probably deter some prospective users.

## CONCLUSIONS

The most significant conclusion of work to date is the finding that the LECA method reduced both the attached and unattached progeny concentration in an 82 $m^3$ test-room by about 92% air. This reduction is especially significant because it includes unattached progeny and thereby would yield in a substantial reduction in bronchial dose to individuals in the room. Other significant conclusions concerning the LECA system as currently developed are as follows:

- Its collection efficiency is independent of the radon or progeny concentrations.
- Negative collector voltage yields a slightly higher collection efficiency than positive.
- Its collection efficiency increases with voltage up to about 6 KV then levels off at higher voltages.
- It collects about the same percentage of unattached as attached progeny.
- It removes about the same percentage of total particulate as it does the progeny; i.e., 90 to 93%.
- It is safe; i.e., it can not cause sparks or shock or harm installers or users in any way.

Potential Advantages Relative to SSV Systems Much more work needs to be done to develop the LECA method and to determine if it can mitigate entire homes as well as it did the test-room. Nevertheless, it is interesting to at this point to speculate on some advantages it may eventually offer over the Sub Slab Ventilation (SSV) method. Some possible advantages might be as follows:

1. The cost of electricity for LECA operation would be in the order of 1% of that of a SSV system.
2. Since no air is exhausted, It eliminates the cost of heating or cooling the SSV exhausted air.
3. Its 100-fold lower energy use means 100-fold less emissions. (Lawrence Berkley Laboratory scientists[1] estimate that SSV systems will eventually result in power plat emissions of 1.2 to 3.5 x$10^9$ Kg/y of $CO_2$. ).
4. Since LECA systems have no moving parts they may reduce system maintenance and replacement costs.
5. Since the small LECA components can be hidden from sight it may enhance resale value of mitigated homes.
6. It may accommodating the congressional "outdoor-air mandate" in more homes; i.e., mitigate more homes to outdoor radon levels ( 0.4 pCi/L or less).
7. It will mitigate the hazard of radon entering homes from any source, not just that from soil; i.e., from water or building materials.

8. The relatively safe and simple installation work involved (e.g., no cement drilling or rooftop work involved ) and low component cost (about$50) may enable homeowner "do-it-yourself " installation.

9. It can be installed in a single apartment, condo or room in cases where selective mitigation is desired; e.g., in a basement bedroom or recreation room.

10. It's efficient total particulate removal capability should add value, especially for folks with breathing difficulties and thereby enhance its sale and use.

11. Installed system cost should be less and it could be much less if a homeowner "do-it-yourself" option proves feasible. This potential cost advantage would be greater where SSV costs are highest; e.g. in homes which have a dirt basement floor.

Potential Disadvantages Relative to SSV

1. An unwarranted fear of the high voltage involved or the electric field may limit public acceptance.

2. Installation may be more intrusive in some homes.

3. A short circuit may cause the entire system to stop functioning.

4. The cause of short circuits may be difficult to locate.

5. Room dust will gather on charged surfaces (e.g., furniture) instead of on usual areas; i.e., floors, etc.

6. The limited number of radon measuring companies Certified or Listed as capable of measuring progeny may temporarily limit its application in some areas.

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Table 1 F-Factor in the Undisturbed Test-Room

| Date Measured (Mo/day) | Radon Concentration (pCi/L) | Equilibrium F-Factor (f) |
|---|---|---|
| 10/5 | 28.7 | 0.545 |
| 10/6 | 33.3 | 0.680 |
| 10/9 | 18.3 | 0.832 |
| 10/13 | 22.0 | 0.567 |
| 11/6 | 16.3 | 0.549 |
| 11/6 | 29.8 | 0.645 |
| 11/7 | 23.5 | 0.632 |
| 1/3 | 18.7 | 0.653 |
| 1/3 | 25.3 | 0.720 |
| 1/6 | 15.2 | 0.595 |
| Averages | 23.1 | 0.644 |

Table 2 Effect of Voltage Polarity on Progeny Removal

| Date (Mo/day) | $V_s$ (KV) | Rn (Bq/m$^3$) | Rn (pCi/L) | PAEC (mWL) | $f_1$ | $f_2$ (Ave) | Effic. (%) |
|---|---|---|---|---|---|---|---|
| 1/30 | -6.5 | 255 | 6.9 | 4.02 | .0582 | 0.644 | 91.0 |
| 10/11 | -5.6 | 317 | 8.6 | 5.45 | .0634 | " | 90.2 |
| 1/7 | -6.1 | 363 | 9.8 | 4.20 | .0429 | " | 93.3 |
| 1/23 | -6.1 | 533 | 14.4 | 7.50 | .0521 | " | 91.9 |
| 1/23 | -6.3 | 570 | 15.4 | 8.99 | .0584 | " | 91.0 |
| 10/27 | -5.6 | 836 | 22.6 | 15.3 | .0678 | " | 89.5 |
| | | | Average negative voltage collection efficiency | | | 91.2% | |
| 10/20 | +5.7 | 215 | 5.8 | 3.20 | .0551 | 0.644 | 91.5 |
| 10/31 | +6.0 | 366 | 9.9 | 6.16 | .0622 | " | 90.4 |
| 10/20 | +6.0 | 370 | 10.0 | 6.12 | .0612 | " | 90.5 |
| 10/26 | +5.8 | 370 | 10.0 | 6.15 | .0615 | " | 90.5 |
| 10/24 | +6.1 | 395 | 10.7 | 5.32 | .0497 | " | 92.3 |
| 10/26 | +6.0 | 463 | 12.5 | 7.06 | .0565 | " | 91.2 |
| 10/27 | +5.9 | 736 | 180 | 14.40 | .0800 | " | 87.6 |
| 10/27 | +5.9 | 944 | 25.5 | 21.73 | .0852 | " | 86.8 |
| | | | Average positive voltage collection efficiency | | | 90.1% | |

Table 3  Estimated Effective Areas Of Collectors

| Collector[a] | Area ($m^2$) | Collector | Area ($m^2$) |
|---|---|---|---|
| #1 Folding screen | 13.43 | #5 Bed | 3.5 |
| #2 Sofa | 5.2 | #6 Table | 1.0 |
| #3 Cabinet | 1.8 | #7 Large Bookcase | 8.6 |
| #4 Small Bookcase | 4.8 | #8 Sofa - 2 | 3.7 |
| | | Total area available | 51.8 $m^2$ |

[a] Collector numbers in this column correspond to numbers on the furniture pieces in Figure 1.

Table 4  Collection of Attached and Unattached Progeny

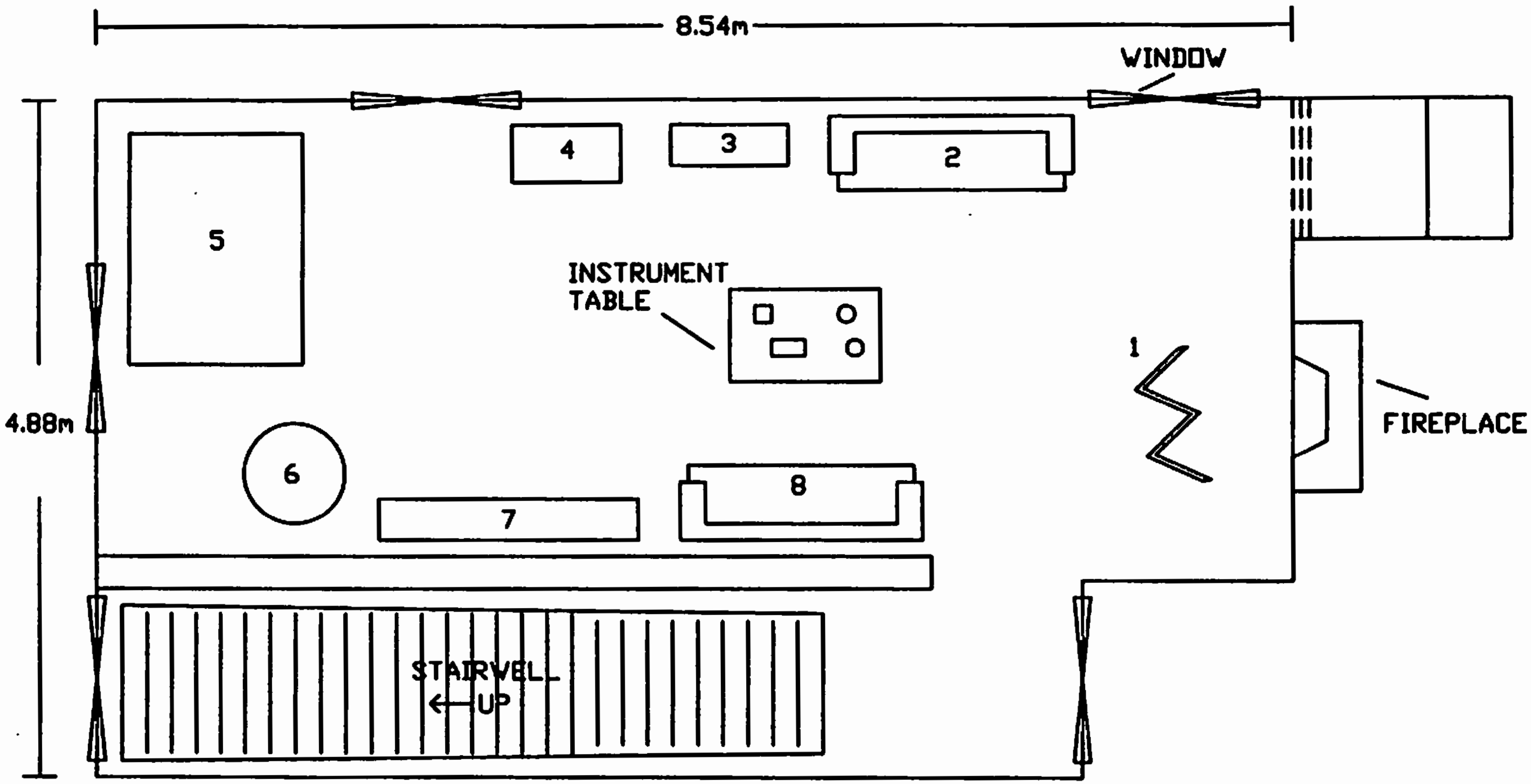
| Voltage Off | | | Voltage On | | |
|---|---|---|---|---|---|
| Time (Hours) | UA-PAEC (mWL) | A-PAEC (mWL) | Time (Hours) | UA-PAEC (mWL) | A-PAEC (mWL) |
| 2 | 7.12 | 90.39 | 2 | 2.63 | 20.68 |
| 4 | 9.12 | 120.9 | 4 | 2.31 | 28.81 |
| 6 | 10.82 | 98.65 | 6 | 3.37 | 30.97 |
| 8 | 8.13 | 59.49 | 8 | 2.17 | 24.66 |
| 10 | 3.28 | 31.06 | 10 | 1.28 | 16.51 |
| 12 | 3.05 | 32.83 | 12 | 0.74 | 11.63 |
| 14 | 4.72 | 45.26 | 14 | 1.25 | 11.03 |
| 16 | 4.25 | 27.18 | 16 | 0.51 | 7.86 |
| 18 | 4.99 | 20.92 | 18 | 0.51 | 5.48 |
| 20 | 4.24 | 19.68 | 20 | 0.32 | 6.82 |
| 22 | 3.75 | 38.26 | 22 | 0.55 | 3.74 |
| 24 | 5.09 | 45.51 | 24 | 0.42 | 5.88 |
| 26 | 3.33 | 38.99 | 26 | 0.74 | 5.32 |
| 28 | 3.14 | 45.16 | 28 | 0.60 | 5.27 |
| Averages | 5.36 | 36.44 | Averages | 1.24 | 13.19 |
| | Ratio (UA/A) 0.147 | | | Ratio (UA/A) 0.094 | |

[a] 3.6 V collector voltage.

Table 5 Collection of Total Room Particulate

| Area Charged ($m^3$) | Time from Start (hr) | Particle Count ($P/cm^3 \times 10^3$) | Collector Voltage (KV) |
|---|---|---|---|
| 0 | 0 | 15.5 | 0 |
| " | 0.5 | 20.0 | " |
| " | 1.0 | 16.9 | " |
| | 1.5 | 12.0 | " |
| | Average | 16.1 | |
| 51.8[a] | 2.5 | 2.0 | 6.0 |
| " | 3.5 | 0.8 | " |
| " | 5.5 | 0.7 | " |
| | Average | 1.2 | |

a All eight collectors charged.




AREAS OF CHARGED FURNITURE PIECES

| | |
|---|---|
| #1 FOLDING SCREE | #5 BED |
| #2 SOFA - 1 | #6 TABLE |
| #3 CABINET | #7 LARGE BOOKCASE |
| #4 SMALL BOOKCASE | #8 SOFA - 2 |

TOTAL CHARGED AREA 51.8m$^2$; ROOM VOLUME 82m$^3$

Figure 1 Sketch of Test-Room and Its Furnishings

Figure 2 Power Source vs Collector Surface Voltage

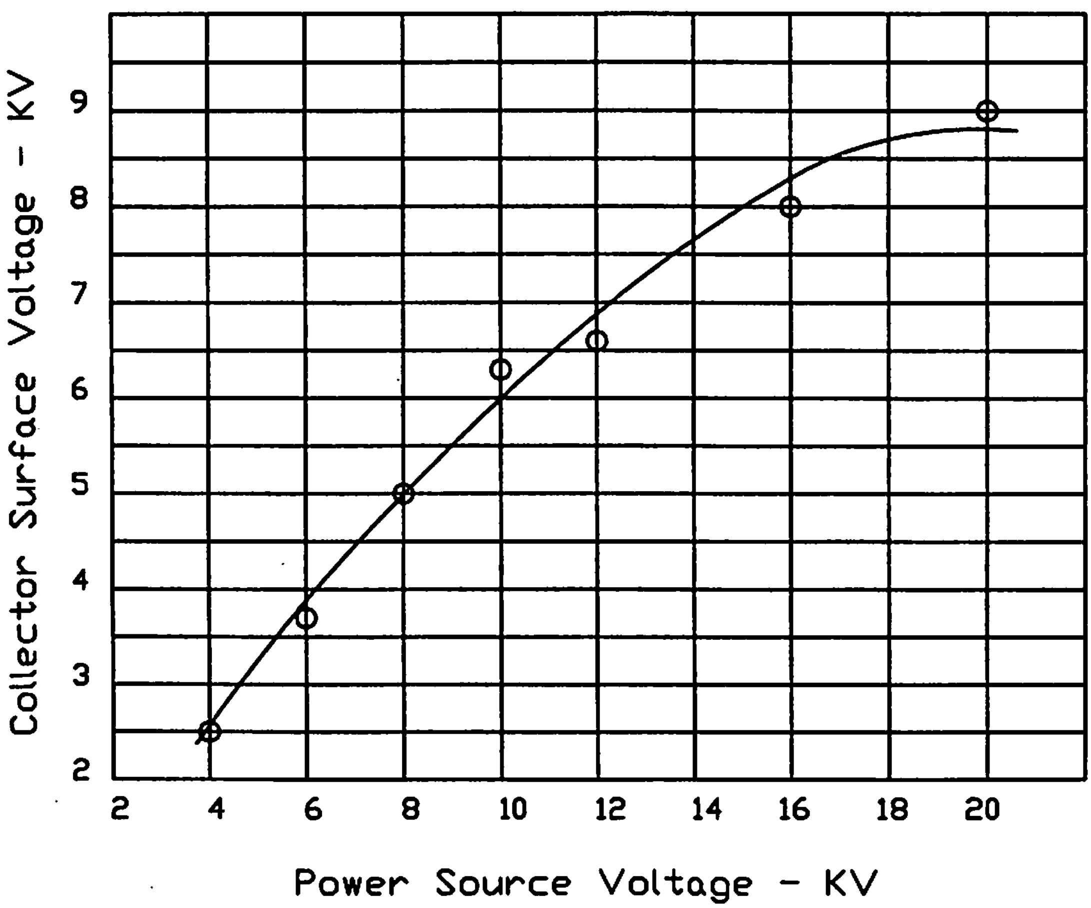
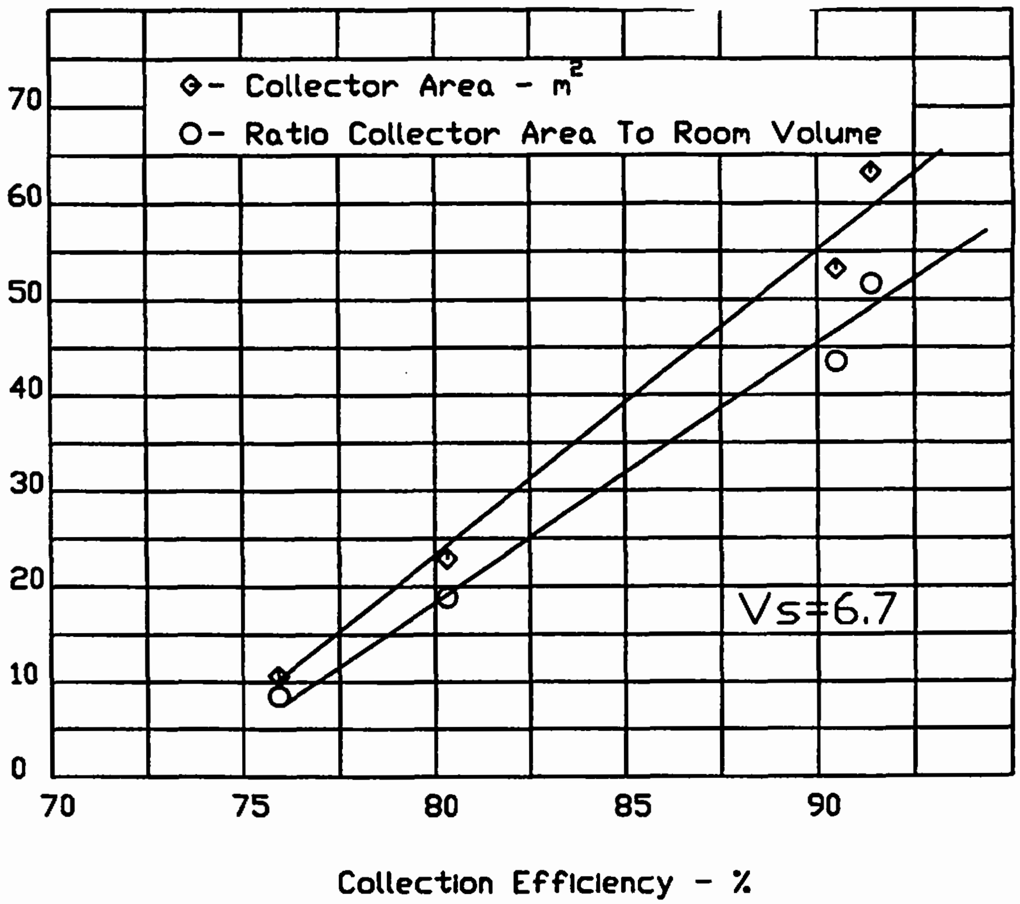


Figure 3 Collector Area vs Collection Efficiency



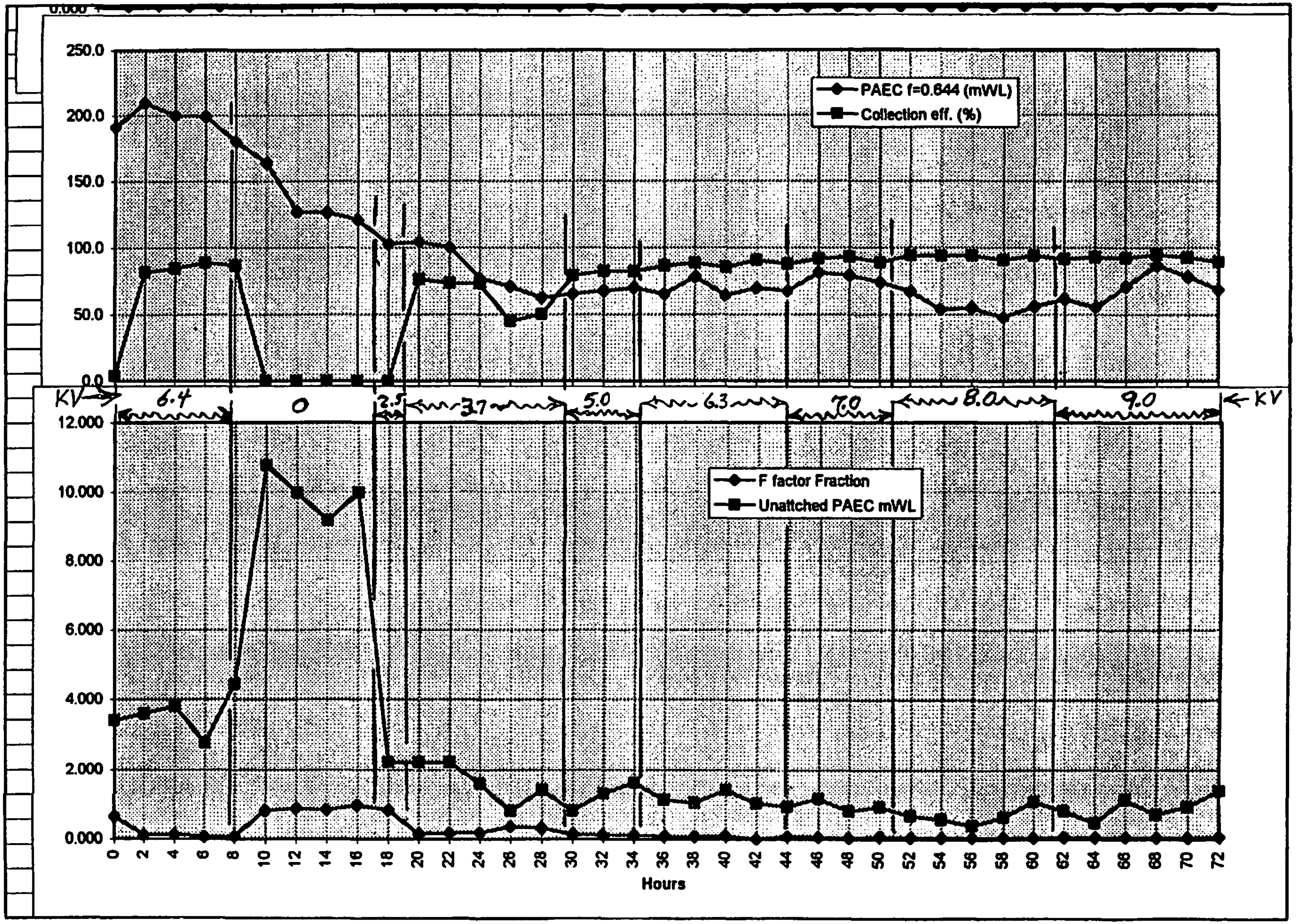



Figure 4 Effect of Voltage Change on Total and Unattached PAEC