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Letters

Radon levels

Robert Fleischer, in August (page 9), called your readers' attention to the need for a sustained national effort to understand radon levels in buildings. Indeed, what we and others are exploring, as a component of the country's currently beleaguered buildings-science research program, is the potential for reduction of radon levels in houses. A better understanding of buildings as physical systems should permit houses to become both more energy-efficient and less radioactive.

In the few regions of the country which have been studied thus far, the distribution of seasonally averaged radon concentrations across houses shows considerably greater spread than the distribution of seasonally averaged air infiltration rates. Radon levels vary as much as 100-fold, manifesting what may be a log-normal distribution, with a small percentage of the houses at very high radon levels (including, apparently, some of the few houses with rock-bed thermal storage). Air infiltration rates, by contrast, rarely fall outside the range of 0.3 to 1.5 air exchanges per hour; most ordinary houses conform well with long-standing rules of thumb for the sizing of home furnaces—values of 0.75 or 1.0 air exchanges per hour.

The national interests in energy conservation and in reducing the exposure to radiation will not be in conflict, but rather in harmony, if it can become common practice for buildings to receive the periodic attention of technically trained professionals equipped with instruments and sanctioned to intervene to improve the building's quality. ("Your home deserves a house call.") The buildings research community is well along in inventing diagnostics to establish air-infiltration rates and leakage paths as well as finding quick low-cost ways to block these paths. Currently, however, even conscientious house-tightening with best available instrumental support can rarely succeed in reducing the air-exchange rate by more than a factor of two. Nonetheless, along with these techniques, and with a view to their role in super-tight new construction as

well, air-to-air heat exchangers are being investigated, with the presumption that they represent the low-energy solution that avoids the overtight house. It is already evident that an important criterion for determining over-tightness will be the radon concentration, and that the ability to mitigate radon levels by source control (sealing off an unused sump pump, for instance) will compete with the ability to mitigate radon levels by air-to-air heat exchangers or by simple local ventilation.

Among the pertinent buildings-science research areas deserving the attention of physicists are

- ▶ the pathways by which radon enters building materials,
- ▶ the fate of Radon-222 and its daughters in indoor spaces,
- ▶ diagnostics to establish radon levels and to identify radon sources cheaply and quickly, and
- ▶ inexpensive measures to reduce radon sources in houses.

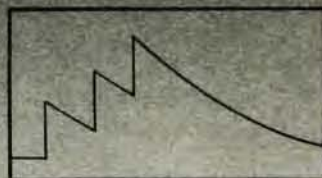
In short order, progress in these areas will translate into improved housing quality, through the efforts of homeowners, builders, land-use planners, building inspectors, house doctors, and others.

ROBERT H. SOCOLOW
HARVEY M. SACHS
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10/81

I share Robert Fleischer's regret that—due to federal budget cuts—much of the Environmental Protection Agency's effort to investigate indoor radon exposures is being discontinued. More recent cuts may result in curtailment of Department of Energy programs aimed at understanding the effect of "tightening" houses to reduce air leakage and save energy.

However, Fleischer's note is unfortunate in that it may mislead in regard to the effect of tightening. The New York homes monitored by Fleischer and collaborators included two groups of about ten houses each that were nominally "energy-efficient" and "non energy-efficient," with Rn^{222} levels in the first group found to average three times



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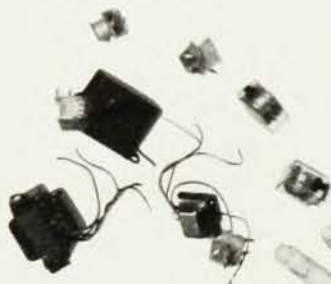
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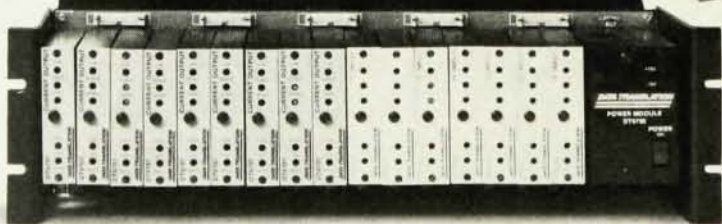


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those in the second. (The August comment cited a factor-of-five difference, but a ratio of three is given by Fleischer in a paper based on more complete results and submitted to *Health Physics*.)

After citing this work, Fleischer remarks on the risk associated with homes that are "similarly tightened," without defining this expression. From Fleischer's comment, the unwary reader could mistakenly associate a several-fold increase in Rn^{222} concentration with ordinary "measures taken by home owners to conserve energy . . . by tightening homes," an error of more than an order of magnitude; typical measures to tighten existing homes—weather-stripping, caulking, inspection for air leaks—ordinarily reduce air leakage about 20 or 30 percent, even with careful work. Such a reduction results in infiltration rates comparable to those in new houses employing ordinary tightening measures, and this is far less than the factor of three reduction that would be required to account for the elevation observed by Fleischer *et al.*, if this were due to tightening. Such radical tightening has only been achieved in a small portion of new housing employing special construction techniques to yield a "super-tight" shell.

In any case, much of the difference in the two groups observed by Fleischer and his coworkers is probably due to differences in source strength, not ventilation rate (which was not, however, measured). This large source variability has been observed explicitly in about 100 homes in which both Rn^{222} concentration and ventilation rate were measured¹ by the Lawrence Berkeley Laboratory: The primary cause of differences in indoor concentration was not the ventilation rate, but rather the rate at which radon entered the house from soil, building materials, or other sources. Since Ra^{226} in the soil is often the dominant source of indoor Rn^{222} , indoor source strengths and hence concentrations can vary strongly by location, because of variability in natural radium concentrations.

The large variation observed in the relatively small number of houses monitored in the US leads to a suspicion among workers in this field that a few percent of the general population, that is, millions of people, may be receiving doses approaching occupational limits for radiation exposure, not because they live in "tight" houses but simply because of where they live. Extreme tightening measures in new houses, reducing ventilation rates by factors of 5 or so, could move many more into this range, assuming no control measures

are employed. But the modest measures more ordinarily employed cause changes that are one to two orders of magnitude smaller than the variability attributable to source strength alone. Many of us hope, in fact, that indoor air quality monitoring in connection with large-scale energy-conservation programs that employ ordinary tightening measures will help to identify homes with unacceptably large sources of Rn^{222} (or other pollutants), so that remedial measures can be taken to help members of the population at significant individual risk. Incorrectly attributing factor-of-three changes to these ordinary energy-saving measures will make it difficult to focus an effective attack on this problem.

Reference

1. A. V. Nero and W. W. Nazaroff, "Distribution of Indoor Radon Concentrations and Source Magnitudes," Lawrence Berkeley Laboratory Report LBL-12565, presented at the International Symposium on Indoor Air Pollution, Health, and Energy Conservation, Amherst, Mass., 13-16 October 1981.

ANTHONY V. NERO JR

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10/81

Fleischer's piece was especially interesting in that the next issue of *PHYSICS TODAY* had an article (September, page 17), "Studies revise dose estimates of A-bomb survivors." This article notes that there is "hot contention" over the risk of low-dose gamma radiation sufficient to split the BEIR-3 Committee into three factions. Fleischer is anything but hesitant in assessing the risks of low-dose radiation by estimating that 10 000 people will die each year from lung cancer caused by indoor radon.

Of all of the numerous causes of lung cancer listed in Ackerman and del Regato¹, radon is not included as an etiologic agent. Further, radon levels in someone's basement have to be measured in the millirem- to microrem-per-hour category; Fleischer's conclusion is thus contradicted by the article in the September issue.

The author also stresses that radon exposures are known to produce increased lung cancer in mine workers. Since the source of the radon-222, according to the author, is trace amounts of uranium in rock and soil everywhere, then all deep miners should be exposed to radon-222. This, however, is not the case: In 1912 Adler had difficulty in collecting 374 cases of cancer of the lung.²

Cancer of the lung is certainly increased in uranium miners³ but the increased incidence of cancer is not due to radon-222 but to the inhalation of pitchblende dust. The data are sof-

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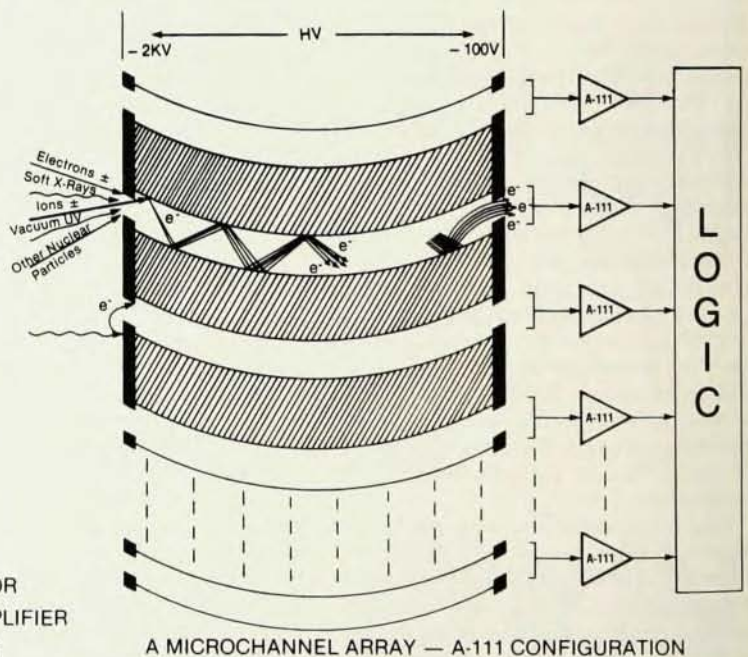
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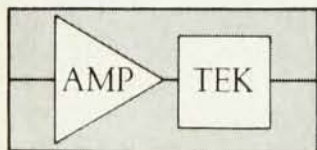
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tened by the fact that almost all miners concerned were also heavy smokers.

The number of new lung cancer patients expected per year is⁴ on the order of 110 000 and there is simply no evidence to support the contention that radon is a causative agent in any of these cases, let alone nearly 10% of them.

In summary, it appears to me that the OMB's elimination of the EPA radon program was richly deserved. I will, however, forward a copy of this article on to Senator Proxmire for consideration of the appropriate award. I believe as well that PHYSICS TODAY should also receive something similar, say, the "Janet Cooke Award" for the physics media.

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4. American Cancer Society, *1980 Cancer Facts and Figures*.

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10/81

I found Robert Fleischer's article on the radon hazard in houses most informative.

The EPA estimate of 10 000 deaths yearly caused by indoor radon indicates that this is a serious public-health problem that deserves attention.

I, and probably others, would like to measure the concentration of radon, or its radiation, in our living rooms. Would someone please tell us how to do this?

RICHARD V. WATERHOUSE
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9/81

THE AUTHOR COMMENTS: Robert Socolow and Harvey Sachs point out lucidly and quite properly that there are measures that can be taken to improve homes that are too tight, and that there exists need for widespread radon monitoring so that individuals can be advised as to hazards, where they exist.

Anthony Nero worries that our data in Northeast New York State,¹ where the "energy-efficient" 14 out of 27 homes that we surveyed have three times the radon levels as the conventional ones, will lead home owners to expect that tightening a house will increase radon levels by a factor of 3. It is correct that most of the energy-efficient homes in our survey were constructed as tight homes, rather than

altered from conventional structures to increase tightness. At the time I wrote about "tightening" homes, I was concerned primarily with altering construction practices rather than with attempts to alter existing structures.

Nevertheless, effects of tightening existing houses can be significant on a national scale. If, for example, all existing structures were tightened by 33% (so that the mean air residence time was increased by 50%) and if the EPA's estimates are correct, 5000 more people per year will die of lung cancer once the incubation time has passed. Published data on retrofitting is meager, but data on the two conventional homes reported by other Lawrence Berkeley Laboratory workers² showed 65% and 43% increases in the measured mean residence time. And the new energy-efficient homes in the survey had residence times that were indistinguishable from those of these retrofitted houses.

Nero, Socolow and Sachs all noted that nationwide variability in source terms (the radon emanated from the ground) is greater than is usual for the escape rates of radon from structures. That is certainly true, but there is no evidence for Nero's suggestion that in our particular studies indoor values are controlled by variable geological sources. Although we have not measured these contributions at all of the sites studied, we have in the worst cases. As reported recently,³ perfectly normal soil or sand, used improperly, was responsible for high levels. No unusually high or low natural sources were found in an area where radon values in indoor living areas ranged from 0.16 to 25 pCi/l. Construction practices appear to be critical.

In asserting that there is "no evidence" that radon has a connection with lung cancer in the US, Kenneth Lucas overlooks a vast literature on radon and lung cancer and hence comes to invalid conclusions. Bronchial cancer is in fact the first cancer⁴ for which exposure to ionizing radiation was implicated (in 1879). Lucas also writes from a false premise as to how radon is involved in lung cancer.

His premise is that the radon problem is attributable to gamma radiation, as evidenced by his reference to the BEIR-3 Committee argument on low-level gamma radiation and to the units millirem per hour, which are unusual in considering the effects of alpha particles in the lung. As I noted in my Guest Comment, alpha particles produce effects that are qualitatively different from those of gamma rays. This is because they ionize so densely that one calculates a dose to a cell nucleus that is directly hit by an alpha particle to be hundreds of Rads or thousands of

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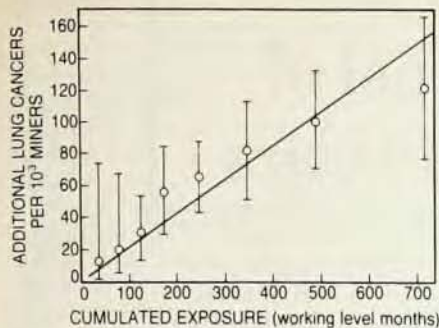
Rem. Such high localized values are thought to be capable of producing cell mutations through a single-hit process and hence are more likely to produce linear effects than is lightly ionizing radiation (as noted by the BEIR-3 Committee). The actual dose to the lungs is primarily delivered not by radon directly but by its prompt daughters, which attach to aerosols, are inhaled, and can then deposit on bronchial surfaces. From there, the subsequent alpha decays of Po^{218} and Po^{214} can reach sensitive epithelial cells.

This scenario has been described extensively in the literature; recent issues of *Health Physics* typically contain several articles on radon, radon daughters, and health. Equally current, "Radiation Hazards in Mining" was the title of a recent five-day international conference at Golden, Colorado, attended by scientists, physicians, epidemiologists, and public health and safety personnel. There was universal agreement that radon—through its alpha-active daughters—is the primary cause of increased lung cancer mortality among underground miners.

An example of the type of evidence used is given in the figure on the next page, which shows increase lung cancer mortality as a function of exposure to radon daughters in Czechoslovakian uranium mines.⁵ Similar data giving substantially the same rate of cancer incidence has been derived for fluorospar and uranium mines in Canada and for iron and zinc mines in Sweden.⁶

The estimate to which Lucas referred of 10 000 lung cancer deaths per year currently from indoor radon is not my imagination but rather the US Environmental Protection Agency's calculation from the data collected from mines—non-uranium as well as uranium. The role of dust from uranium ore (not necessarily pitchblende) has been considered carefully and is believed to be a 5% to 30% factor in uranium mines.⁷ The near equality of the cancer rates in uranium and non-uranium mines suggests that the lower estimates are more realistic.

In some homes that we and others have measured,⁸ over the lifetimes of the residents, doses of radon daughters will be acquired that equal those of the first few data in the figure. Thus the radon hazard is qualitatively different from that of environmental gamma radiation where lengthy extrapolation to untested lower doses is required. We have direct measures for the results of existing radiation hazards from radon daughters in some homes, and the extrapolation required for numerous other homes with elevated radon levels is slight.



Increase in lung cancer for Czechoslovakian uranium miners as a function of dose from radon daughters. Redrawn from reference 5 with permission of the Health Physics Society.

As noted in my Guest Comment, it is regrettable that no public agency has accepted the mission of testing the indoor environment for Rn²²², even in cases where undesirable levels are suspected to be present.

To my knowledge there is only one commercial service that will give the type of measurement that is appropriate, a year-long integrated measurement. This is the type of reading that we have made ourselves in our limited survey of upper New York State and is done by means of a solid-state nuclear track detector in a housing that allows only radon gas to be admitted. The result is an unambiguous reading, free from effects of ambient aerosols and soil particles. Although readings over more limited times are of interest in understanding elevated radon levels, it is the long-term average that is most pertinent to inferring radiation doses of consequence. Because we have found that summer and winter radon concentrations can differ markedly in an as yet unpredictable manner,¹ a full-year integration is my recommendation. In addition to covering a more meaningful period of time, the long integrating time will allow good statistical significance of the measurements at a reasonable cost.

The radon-monitoring service is supplied by Terradex Corporation (460 N. Wiget Land, Walnut Creek, California 94598), with which we at General Electric have interacted strongly over the years. Terradex has done several tens of thousands of measurements in homes in the US and Europe. The current price for radon is \$16.50 per reading, if done in lots of fifty. Of several configurations that Terradex offers, the "filtered cup" is the most appropriate for home monitoring, since it gives the maximum sensitivity for a radon-only reading.

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11/81

Quality in science education

I was pleased to note the importance that PHYSICS TODAY places on leadership in science education (editorial by Harold Davis, September, page 152). Unfortunately I do not feel Davis makes a thoroughly convincing case nor does he describe a program that is likely to achieve its objectives. First of all, he understates the military threat posed by the Soviet Union's increasing emphasis on science education. It is not enough for us to maintain, as I am sure we will, our leadership in the productivity of first-rate scientists. If the soldier in the field has a fifteenth-century understanding of twenty-first-century equipment, that equipment cannot last long. A comparison of the performance of our aircraft carrier maintenance crews during WWII in the Pacific with that of the same crews two years ago off Iran illustrates the problem. The contrast between Israeli and Egyptian maintenance personnel in 1967 again demonstrates that this is a critical issue even during brief modern engagements.

The economic threat from Germany and Japan is at least as serious as the military problem and for the same reasons. Technological advances may only compound these difficulties. Twenty years ago a large part of one's technical training could be obtained out of school by fiddling with the family car. Today air-pollution accessories

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