The Department of Energy's Radon Testing Program*

H. L. Scott
U. S. Department of Energy
Washington, D.C. 20585 USA

C. S. Dudney, D. L. Wilson, and R. B. Gammage
Oak Ridge National Laboratory
P. O. Box 2008
Oak Ridge, Tennessee 37831-6113 USA

First International Workshop on
INDOOR RADON REMEDIAL ACTION

Rimini, Italy

June 27 - July 2, 1993

*Research sponsored by U.S. Department of Energy under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

THE DEPARTMENT OF ENERGY'S RADON TESTING PROGRAM*

H. L. Scott
U. S. Department of Energy
Washington, D.C., 20585 USA

C. S. Dudney, D. L. Wilson, and R. B. Gammage
Oak Ridge National Laboratory
P. O. Box 2008
Oak Ridge, Tennessee 37831-6113 USA

ABSTRACT

The U.S. Department of Energy recently completed an initial survey of indoor radon in its buildings in response to Public Law 100-551, the Indoor Radon Abatement Act of 1988. Other federal agencies have also conducted radon surveys. This paper presents an overview of the results from radon testing of several thousand buildings ranging from 100 m^2 to over 10,000 m^2 in size. In addition, we have examined results from groups of buildings, classified according to ventilation and usage characteristics. So far, there is no apparent difference among building classes. The paper also discusses our proposal for phased radon surveys. We suggest that first-phase results can be used to identify facilities with radon problems. In the second phase, we suggest measurements be made at a much higher sampling density at facilities with radon problems. The results of the second phase are expected to identify all buildings in need of mitigation.

*Research sponsored by the U. S. Department of Energy under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

THE DEPARTMENT OF ENERGY'S RADON TESTING PROGRAM*

H. L. Scott
U. S. Department of Energy
Washington, D.C. 20585 USA

C. S. Dudney, D. L. Wilson, and R. B. Gammage
Oak Ridge National Laboratory
P. O. Box 2008
Oak Ridge, Tennessee 37831-6113 USA

BACKGROUND

Radon is a naturally occurring, odorless, colorless, radioactive gas arising from the decay of uranium in soil. For many years, radon was not considered to be a health problem in buildings but that changed in 1984, when private homes in the Reading Prong area of Pennsylvania were discovered to have levels of radon in excess of federally mandated exposure limits for radiation workers.[1] It is still not completely understood how to apply radon risk estimates derived from underground mining populations to populations exposed in homes and workplaces[2] but in recognition of the potential health hazard presented by indoor radon, the U.S. Congress passed and the President signed into law the Indoor Radon Abatement Act of 1988 (IRAA). IRAA declares the national goal to be "that the air within buildings in the United States should be as free of radon as the ambient air outside the buildings." In addition, the law stipulates that the head of each federal agency will design a study to assess the extent of radon contamination in buildings within its jurisdiction. In response to IRAA, the U. S. Department of Energy (DOE) began a multiyear, multiphase program for the identification of buildings with unacceptable radon concentrations.

Our goal is to review the available data from Federal radon surveys so we may begin to address these questions: (1) how many measurements are needed to establish absence of unacceptable radon concentrations in a group of large buildings; and (2) is there evidence of identifiable statistical distribution(s) so that fewer measurements may be needed?

OVERVIEW OF DOE STUDY RESULTS

During November, 1989, personnel from DOE and its contractors placed alpha track detectors[3] in many of the buildings under DOE control. About three months later, the detectors were returned to the vendor for etching and track counting. In this way, buildings at 60 facilities were surveyed for indoor radon. Three facilities were near Oak Ridge, Tennessee and two facilities were near Richland, Washington. Otherwise, all facilities were widely separated groups of buildings. A total of 2,916 buildings were surveyed. In 1,448 buildings the area of the building was reported and only one measurement was made. The mean area of these buildings was 1,200 m^2 (13,000 ft^2) and the mean radon concentration was 32 Bq m^{-3} (0.86 pCi L^{-1}). In 644 buildings the area was reported and more than one measurement was made. The mean area was 7,300 m^2 (79,000 ft^2) and the mean radon concentration was 36 Bq m^{-3} (0.97 pCi L^{-1}). On average there were 3.52 measurements per building and 2,000 m^2 (21,000 ft^2) per measurement. In the remaining 824 buildings where area was not reported the mean radon concentration was 37 Bq m^{-3} (1.0 pCi L^{-1}) in buildings with one measurement and 28 Bq m^{-3} (0.77 pCi L^{-1}) in other buildings.

For each facility, the distribution of results for all radon measurement sites were examined graphically. The logarithms of the results were plotted on normal probability paper. For all facilities, the data lay on a straight line except for the very high and very low values. The deviation from the line for low values is attributed to the measurements being below the limit of detection (about 20 Bq m^{-3}). The deviation of the values at the high end of the distribution is consistent with what has been seen in the statistical distribution of radon levels in homes in northeastern Pennsylvania.[4] This suggests the need for additional work on the distribution of radon concentrations in workplace facilities. At this time there is a limited understanding of radon processes and distributions in large buildings. We believe the high valued observations will fall within the range of uncertainty when regression analysis is done on the data in the linear range. We are currently testing that assumption and our results will be reported elsewhere.

Figure 1 provides an example of results from a typical DOE facility (#24999). A linear regression analysis was done using the results above the limit of detection except for the two highest values (i.e., excluding data below 22 Bq m^{-3} and above 450 Bq m^{-3}). From the regression results, we computed the upper and lower 95% confidence limits for the distribution. For example, we computed from the regression results that about 10% (with 95% confidence limits of 6.7% to 15.6%) of the measurement sites at the facility have radon concentrations above 150 Bq m^{-3} (4 pCi L^{-1}). Of 74 measurements made at the site, seven were above 150 Bq m^{-3}. A similar analysis was conducted on 188 radon results from facility #10001-ER. The highest result at the facility was below 115 Bq m^{-3}. The regression results indicate that about 0.01% (with 95% confidence limits 0% to 0.02%) of the measurement sites might be expected to have radon levels above 150 Bq m^{-3}.

Preliminary application of this type of analysis suggests that more than half of the DOE facilities have been adequately screened. The table summarizes the results from the DOE facilities.

Is more testing needed to locate radon problems?	Yes	No	Uncertain
Facilities for which building size data are not available	3	8	1
Number of data	196	170	26
Facilities for which building size data are not available	2	34	12
Number of data	153	3775	740
Total floor space (m^2)	0.09×10^6	4.5×10^6	1.9×10^6

In comparison with a sampling plan calling for one measurement per 186 m^2 of floor space, a substantial number of detectors can be saved by implementing a radon survey in two phases. Considering only those facilities which have reported building sizes in the table above, DOE needs to make about 37,000 radon measurements under 1-per-186-m^2 sampling. If DOE were to sample once in every ground contact room in every facility that is in the "Yes" or "Uncertain" column, there would be 23,000 (assuming an average room is about 83 m^2) measurements in the second phase in addition to the 4,668 measurements already made (i.e., in the first phase). Savings would be even greater if less dense sampling were found to be acceptable.

OVERVIEW OF RESULTS FROM COMPLETELY SAMPLED FEDERAL BUILDINGS

To examine critically the consequences of sampling densities less than one measurement per 186 m^2, we will study results from buildings that have been sampled very densely. There are some data available from buildings under control of either the U.S. Navy or the U.S. Postal Service in which all rooms in ground contact have been sampled for radon. These buildings were surveyed for three months or longer using either alpha track detectors or electret ion chambers. There are 10,422 data collected from 908 buildings. In 365 buildings, more than 9 measurements were taken in each building (7,882 measurements in all). In 123 buildings, more than 19 measurements were taken in each building (4,937 measurements in all). In 126 buildings the area of the building was reported and only one measurement was made. The mean area of these buildings was 210 m^2 (2,300 ft^2) and the mean radon concentration was 35 Bq m^{-3} (0.95 pCi L^{-1}). In 654 buildings the area was reported and more than one measurement was made. The mean area was 3,300 m^2 (36,000 ft^2) and the mean radon concentration was 56 Bq m^{-3} (1.51 pCi L^{-1}). On average there were 14.2 measurements per building and 240 m^2 (2,600 ft^2) per measurement. In the remaining 128 buildings where area was not reported the mean radon concentration was 23 Bq m^{-3} (0.61 pCi L^{-1}) in buildings with one measurement and 51 Bq m^{-3} (1.4 pCi L^{-1}) in other buildings.

The data from 365 buildings were examined on an individual building basis with no attempt to correct for data below the limit of detection. For each building, a statistical test of the lognormal distribution was computed. In 152 buildings, the lognormal distribution provided an acceptable fit to the data distribution. A P-value of 5% was used for the statistical tests. We have begun to look at the effect of building size. The distributions of radon data are similar in buildings divided into four size groups: large (more than 19 ground-contact rooms), medium (10 to 19), small (6 to 9), and very small (1 to 5). We have found there is no consistent difference among buildings based on presence or absence of forced-air distribution systems. We are also looking at differences among buildings based on building use (e.g., administration, warehouse, medical, training, etc.).

DISCUSSION AND RECOMMENDATIONS

In this paper, we are recommending that radon screening of large facilities be conducted in two phases. The first phase serves to identify facilities with potential radon problems while the second phase identifies buildings in need of mitigation. The principal benefit of a phased approach, contrasted with a single phase with a constant sampling density, is that a higher sampling density will be achieved at facilities with a demonstrable radon problem. The data collected so far indicate that identifiable statistical distribution(s) describe the radon data in buildings or groups of buildings. If adequate sampling designs can be developed, large populations of buildings can be screened, using a two-phase strategy, for unacceptable levels of radon with far fewer measurements, saving the public considerable funds without undue increases to public health risk. We are proposing that the available data from 908 completely sampled buildings be examined to test possible screening strategies (i.e., first-phase sampling). Using standard numerical sampling techniques, we will evaluate suggested sampling densities ranging from 1 measurement per 93 m^2 of floor space to 1 measurement per 1,900 m^2. No assumptions will be made about predicting where radon entry will occur in a large building. It is our experience that only very experienced radon mitigation professionals are likely to identify entry pathways or effectors. The technicians most likely to implement a radon survey in large buildings are unlikely to have the needed expertise.

REFERENCES

1. NRC (National Research Council), Committee on Biological Effects of Ionizing Radiation. *Health Risks of Radon and Other Internally Deposited Alpha-Emitters.* National Academy Press, Washington D.C., 1988.

2. NRC (National Research Council), Panel on Dosimetric Assumptions Affecting the Application of Radon Risk Estimates. *Comparative Dosimetry of Radon in Mines and Homes.* National Academy Press, Washington D.C., 1991.

3. Alter, H. W., and Fleischer, R. L. *Passive Integrating Radon Monitor for Environmental Monitoring.* Health Phys. **40**:693-702, 1981.

4. Janssen, I., and Stebbings, J. H. *Gamma Distribution and House ^{222}Rn Measurements.* Health Phys. **63**(2):205-208, 1992.

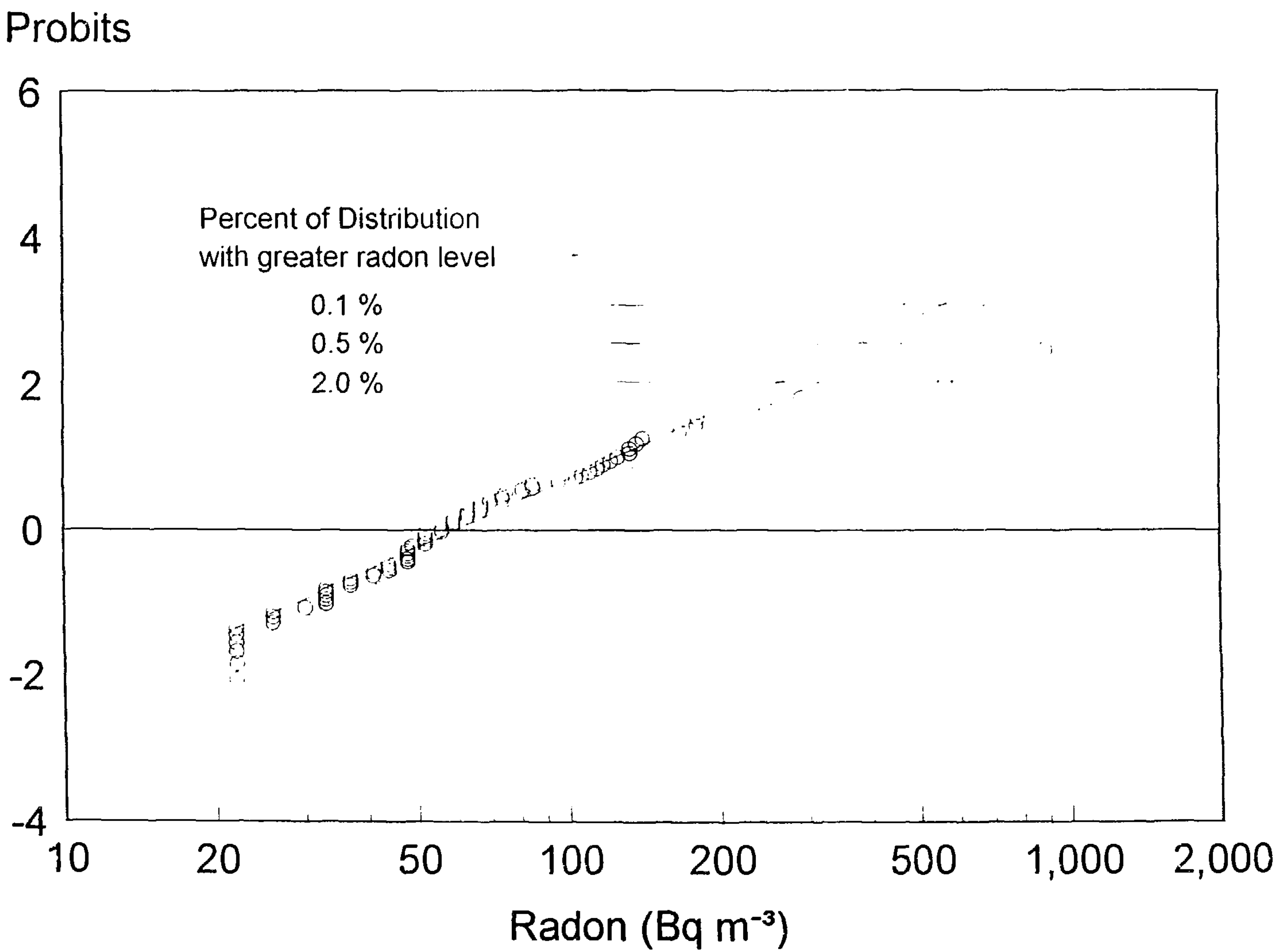
Probits
6
4
2
0
-2
-4
Percent of Distribution
with greater radon level
0.1 %
0.5 %
2.0 %
10
20
50
100
200
500
1,000
2,000
Radon (Bq m⁻³)

Figure 1. The distribution of radon results from facility #24999 is plotted on a probability (or probit) scale. The horizontal solid lines indicate the probit levels corresponding to points on the distribution where 0.1%, 0.5%, or 2.0% of the data are expected to be larger. The data values are indicated by open circles. The distribution predicted by the regression is indicated by the solid line and the upper and lower 95% confidence limits are indicated by dotted lines.