5079

R-2000

SUPER ENERGY EFFICIENT HOME PROGRAM

TECHNICAL REPORT

Canada

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THE R-2000 HOME PROGRAM TECHNICAL REPORT SERIES

The R-2000 Home Program assists in the ongoing development of the various technologies required to build and operate R-2000 homes. This includes support for standards development and the provision of technical information and resources to the building industry. In addition, R-2000 homes and a control group of conventional homes are being monitored over a two to five year period to gather information on construction techniques, the performance of heating and ventilating systems, indoor air quality and energy consumption. The demographic profile and attitudes of R-2000 homeowners are also being surveyed.

This publication is one of a series of reports documenting technical developments and monitoring activities supported by the R-2000 Home Program and the Canadian housing industry. The program's objective is to assist the housing industry to develop the capability to construct and market quality housing that is both efficient and cost-effective.

For further information on the R-2000 Home Program in general, the series of technical reports, or to obtain additional copies of this document, please contact:

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EXECUTIVE SUMMARY

As part of the R-2000 Home Program, indoor air quality monitoring is conducted Canada-wide for a number of indoor air pollutants. The objective of this report was to review the R-2000 Home Program radon monitoring activities to date, to document activities undertaken in the investigation of higher than normal levels, and report the steps taken to reduce these levels. Experiences in selecting, using and evaluating radon monitoring equipment are also documented.

Radon is a colourless and odourless gas which is formed during a process of natural decay of radioactive elements present in soil, rocks, and groundwater in all areas of Canada. Since the amount of radon is related to the surrounding subsoil, rock and groundwater characteristics, indoor radon levels vary widely from region to region.

Radon monitoring was conducted on the initial R-2000 demonstration homes during 1985 and was expanded to include additional R-2000 homes in 1986 and 1987. The geometric mean levels of radon in both R-2000 and conventional homes were well below the Federal-Provincial Subcommittee on Radiation Surveillance interim action guideline of 0.10 WL (working levels) for non-uranium mining

communities. Mean national R-2000 home radon levels for 1985 and 1987 monitoring were 0.006 and 0.004 WL, respectively. In 1986, monitoring was conducted only on R-2000 homes in Ontario. The mean level in Ontario R-2000 homes in 1986 was 0.003 WL.

In 1985, fifteen percent of R-2000 home results were above 0.02 WL and four percent were above 0.10 W.L. In 1987, four percent of homes were above 0.02 WL and less than one percent of R-2000 homes were above 0.10 WL. The mean level for conventional homes was 0.004 WL and the distribution was similar to that found for R-2000 homes with 13 % greater than 0.02 WL.

Based on the 1985 radon monitoring, six homes were identified as having levels greater than or approaching the interim guideline of 0.10 WL. These homes were in New Brunswick and Quebec. The first step in addressing the concern over high radon levels in these homes was to perform repeat measurements. These repeat measurements were carried out after adjustments were made to the mechanical ventilation/heating systems to ensure that they were operating properly. The repeat measurements indicated that levels generally decreased to well below the 0.10 WL guideline, except in one instance. Further investigation of this house revealed that leakage was occurring at a basement telepost. Sealing the telepost and increasing the minimum continuous ventilation rate lowered levels to below 0.05 WL.

ABREGE

Dans le cadre du Programme de la maison R-2000, un projet de contrôle de la qualité de l'air intérieur a été réalisé dans tout le Canada et a porté sur un certains nombre de substances polluantes. Le présent rapport fait état des activités de mesure du radon réalisées jusqu'à présent dans le cadre du Programme de la maison R-2000. En outre, le rapport traite des études approfondies réalisées dans le cas des concentrations de radon anormalement élevées, et des correctifs pris afin de réduire ces concentrations. Le rapport présente également les expériences ayant servi au choix, à l'utilisation et à l'évaluation du matériel de mesure du radon.

Le radon est un gaz incolore et inodore qui est produit par la désintégration radioactive naturelle de certains éléments présents dans le sol, les roches et l'eau souterraine. On retrouve ce phénomène dans toutes les régions du Canada. Comme la quantité de radon dégagée depend des caractéristiques du sous-sol, de la roche et des eaux souterraines, les niveaux de radon que l'on retrouve à l'intérieur des maisons varie considérablement d'une région à l'autre.

Les activites de mesure du radon ont été réalisées dans les premieres maisons de démonstation R-2000 en 1985; ce programme a été élargi en 1986 et 1987. La moyenne géométrique des concentrations de radon dans les maisons R-2000 et les maisons de construction classique visitées dans le cadre du programme se situe bien en deçà des directives provisoires de 0,10 unité opérationnelle (aussi désignée par le sigle anglais WL) dans les collectivités où il n'y a pas d'exploitation d'uranium, directives éstablies par le Sous-comité fédéral-provincial de la surveillance radiologique. La concentration moyenne nationale de radon dans les maisons R-2000 a

été de 0,006 et 0,004 WL en 1985 et 1987, respectivement. En 1986, le programme de mesure a porté uniquement sur des maisons R-2000 en Ontario. On a alors enrigestré une concentration moyenne de radon de 0,003 WL. En 1985, 15% de maisons R-2000 présentaient une concentration de radon supérieure à 0,02 WL, et 4% présentaient une concentration supérieure à 0,10 WL. En 1987, 4% de maisons R-2000 présentaient une concentration de radon supérieure à 0,02 WL, et moins de 1% présentaient une concentration supérieure à 0,10 WL.

D'après les résultats de 1985, on a identifié 6 maisons qui présentaient une concentration supérieures à 0,10 WL ou près de ce seuil. Ces maisons se trouvent au Nouveau-Brunswick et au Québec. Alfin de déterminer les raisons de ces concentrations élevées, on a répété les mesures dans ces maisons. Ces mesures ont été réalisées après que des correctifs furent apportés aux systèmes de chauffage et de ventilation, afin de s'assurer de leur bon fonctionnement. Le second groupe de mesures a indiqué qu'en règle générale les concentrations de radon avaient diminué bient en deçà de la directive de 0,10 WL, sauf dans un seul cas. Une étude plus poussée réalisée dans cette maison a permis de constater que le radon s'infiltrait par un poteau de soutènement dans le sous-sol. Le poteau a été scellé et le débit minimal de ventilation a été augmenté, ce qui s'est traduit par une baisse de la concentration de radon en decà 0,05 WL.

1.0 INTRODUCTION

As part of the R-2000 Home Program, indoor air quality monitoring is conducted Canada-wide for a number of pollutants including radon in R-2000 and conventional homes. Conventional homes are also monitored (as controls) for comparative purposes.

Radon is a colourless and odourless gas which is normally present in air in very low concentrations. It is formed during a process of natural decay of radioactive elements present in soil, rocks, and groundwater in all areas of Canada. Since the amount of radon is related to the surrounding subsoil, and rock and groundwater characteristics, indoor radon levels vary widely from region to region.

Radon gas can enter buildings by way of foundation cracks and other openings, from the soils on which they are constructed. In some instances, radon can also be introduced by the water supply, particularly when the source is a well. Small quantities can also be released from building materials such as stone, brick, concrete and plaster. Because radon normally enters buildings from the surrounding soil, the concentration of the gas is normally highest in the basement.

Indoor concentrations of radon are primarily dependent on the geological location. If a home is located in a region which has underlying geological formations which have higher than normal concentrations of uranium, the potential for the occurrence of elevated indoor radon is higher. In addition to uranium in the underlying formations, the permeability of the surficial geology will also influence radon gas transport to the surface and into homes.

Basement foundations which have soil gas entry points such as dry floor drains, cracks, and poor seals around utility entry points can contribute to higher radon levels. The movement of radon into basements is pressure induced; therefore, homes with basements under negative pressure could also experience higher radon levels. These secondary factors (entry points and negative pressure) will only have an effect if the level of radon is high in the surrounding soil.

2.0 R-2000 RADON MONITORING ACTIVITIES

2.1 General Field Monitoring

During 1985, radon monitoring was conducted in 150 of the initial R-2000 demonstration homes constructed in 1983 and 1984 and, in six new R-2000 homes. General monitoring of radon in 1986 was conducted only in Ontario. In 1986, forty-nine of the fifty-five homes were initial demonstration homes and six were new R-2000 homes. Radon results for 1987 were for 131 of the initial demonstration homes and 164 recently constructed R-2000 homes. A summary of the 1985, 1986 and 1987 radon results is presented in Table 1.

The mean 1985 and 1987 results for all R-2000 homes are similar, geometric means of 0.006 and 0.004 WL, respectively. These are well below the interim action guideline of 0.10 WL. This guideline was derived from the Federal-Provincial Subcommittee on Radiation Surveillance interim guideline for radon gas in residences in non-uranium mining communities of 800 Bq/m^3 (Bequerels/per cubic meter). To convert from radon to radon progeny an equilibrium factor of 50% was assumed.

The frequency distributions for the 1985 and 1987 data are presented in Figure 1. Log-normal function lines of best fit are also presented in the frequency histograms. In 1985, six homes, or four percent, were above the 0.10 WL guideline and nine or six percent of the homes, were above 0.05 WL, or one-half of the guideline. In

TABLE 1

R-2000 INDOOR AIR QUALITY-RADON

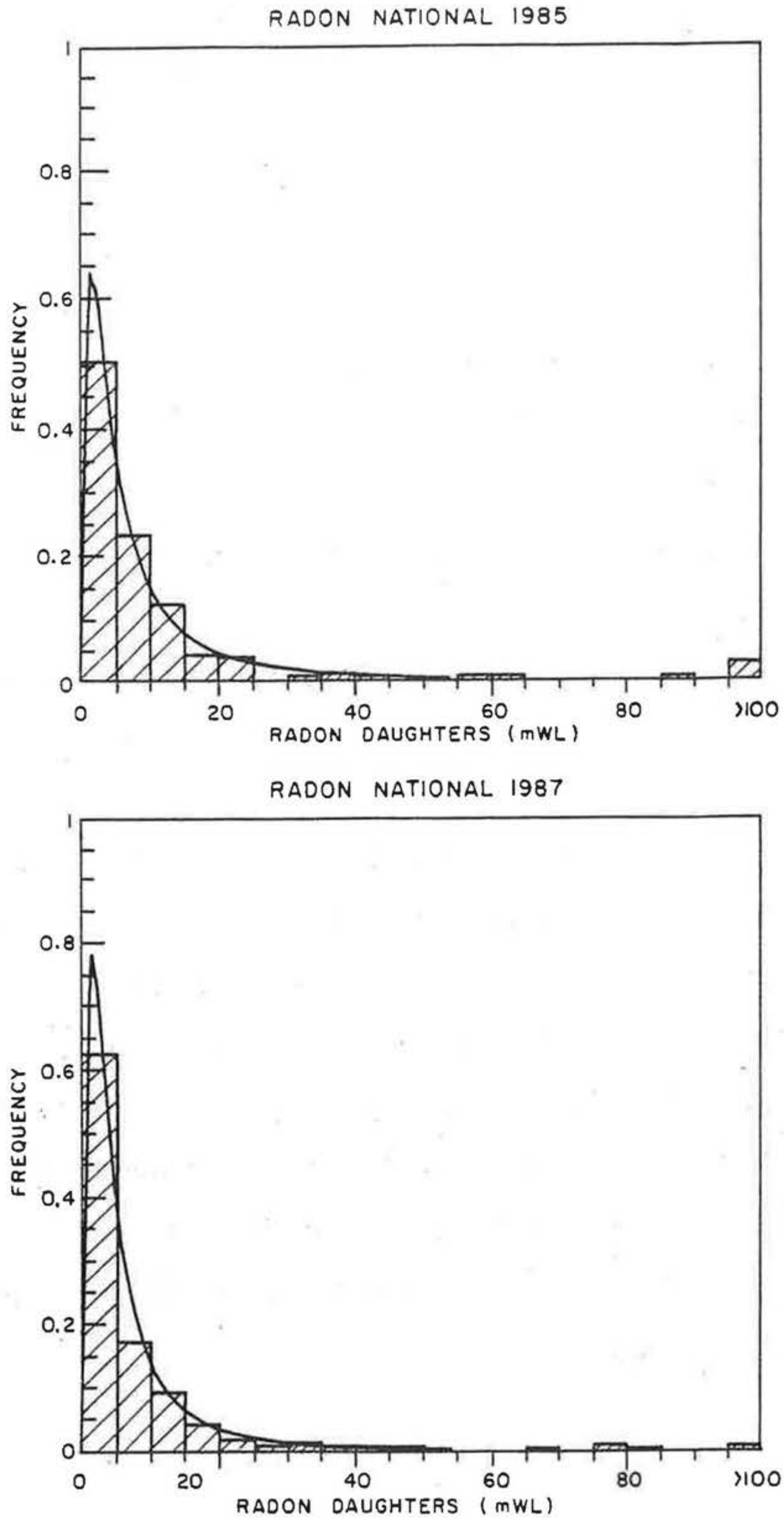
Homes	Year	Number of Homes	Geometric Mean (WL)	Median (WL)
R-2000 HOMES				
All regions	1985	156	0.006	0.006
	1987**	295	0.003	0.004
Maritimes	1985	24	0.012	0.011
Quebec	1985	30	0.005	0.004
Ontario	1985	47	0.005	0.005
Prairies/NWT	1985	47	0.006	0.006
B.C./Yukon	1985	8	0.002	0.001
Ontario	1986*	55	0.003	0.003
Maritimes	1987**	58	0.009	0.009
Quebec	1987**	37	0.004	0.003
Ontario	1987**	88	0.003	0.003
Prairies	1987**	44	0.006	0.006
B.C	1987**	53	0.002	0.001
NWT/Yukon	1987**	15	0.003	0.003
CONTROL HOMES				
All Regions	1985	43	0.005	0.006
Maritimes	1985	5	0.011	0.008
Quebec	1985	7	0.003	0.002
Ontario	1985	10	0.007	0.008
Prairies/NWT	1985	16	0.005	0.005
BC/Yukon	1985	5	0.004	0.002

Notes:

* General monitoring of radon in 1986 was conducted only in Ontario.

** 1987 results are for monitoring conducted in December 1986 and January, February and March, 1987. April 1987 results were not available for inclusion into this report.

FIGURE 1
NATIONAL FREQUENCY HISTOGRAMS 1985 AND 1987
R-2000 HOMES



the 1987 results, five or two percent of the homes were above 0.05 WL.

The majority of the R-2000 homes in 1985, approximately 85%, had levels of less than 0.02 WL. Figures 2, 3 and 4 present the regional frequency histograms of the radon data. The 1985 histograms indicate that the Maritime region had a higher frequency of homes with levels greater than 0.02 WL (32%), followed by Quebec (12%). Ontario and British Columbia had the lowest frequency of levels greater than 0.02 WL, 2% and 0% respectively.

In 1986 only R-2000 homes in Ontario were monitored. The frequency histogram (Figure 3) is similar to the 1985 histogram. Ontario 1986 radon levels were low, with only two percent of the measurements greater than 0.02 WL, and none greater than 0.05 WL.

The 1987 data (Figure 4) indicates lower levels of radon than in 1985. The decrease may be attributable to ventilation systems which must now meet revised technical ventilation guidelines and installation requirements established in 1986. The Maritime region, as in 1985, had a higher frequency of homes (26%), with levels greater than 0.02 WL. The majority of these homes were in New Brunswick, which had two homes with levels greater than 0.10 WL. The other regions had nine percent or less of the homes with levels greater than 0.02 WL.

FIGURE 2

REGIONAL FREQUENCY HISTOGRAMS - 1985

R-2000 HOMES

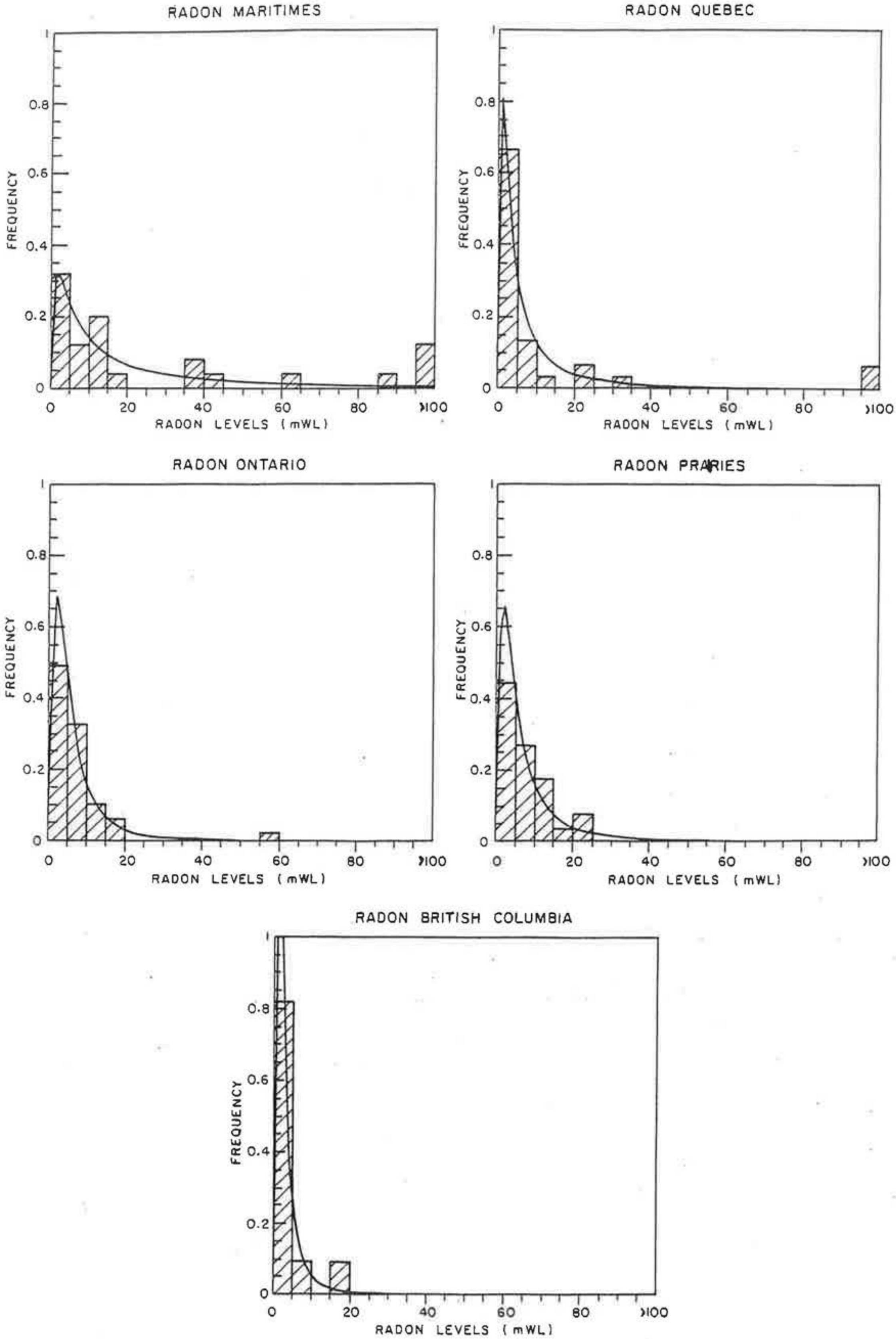


FIGURE 3

REGIONAL FREQUENCY HISTOGRAM - 1986

R-2000 HOMES

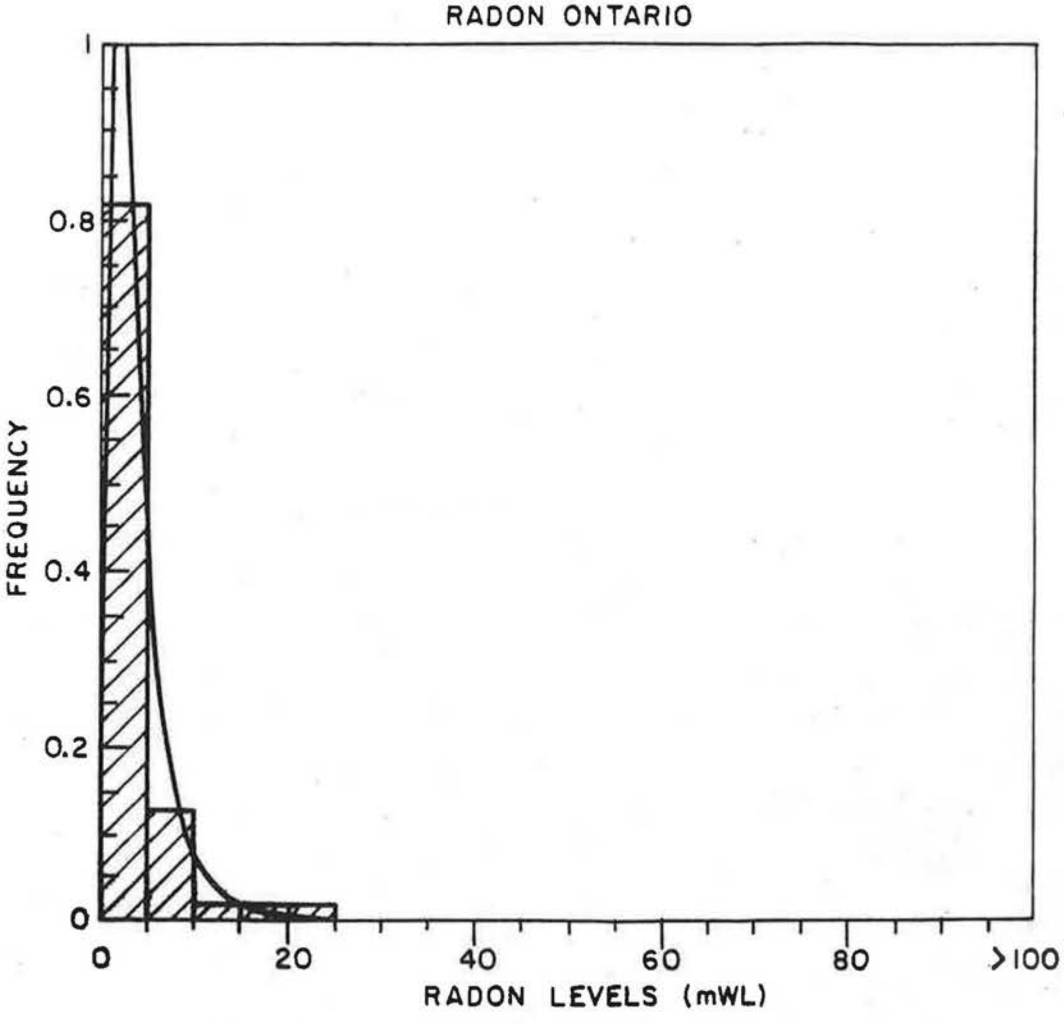
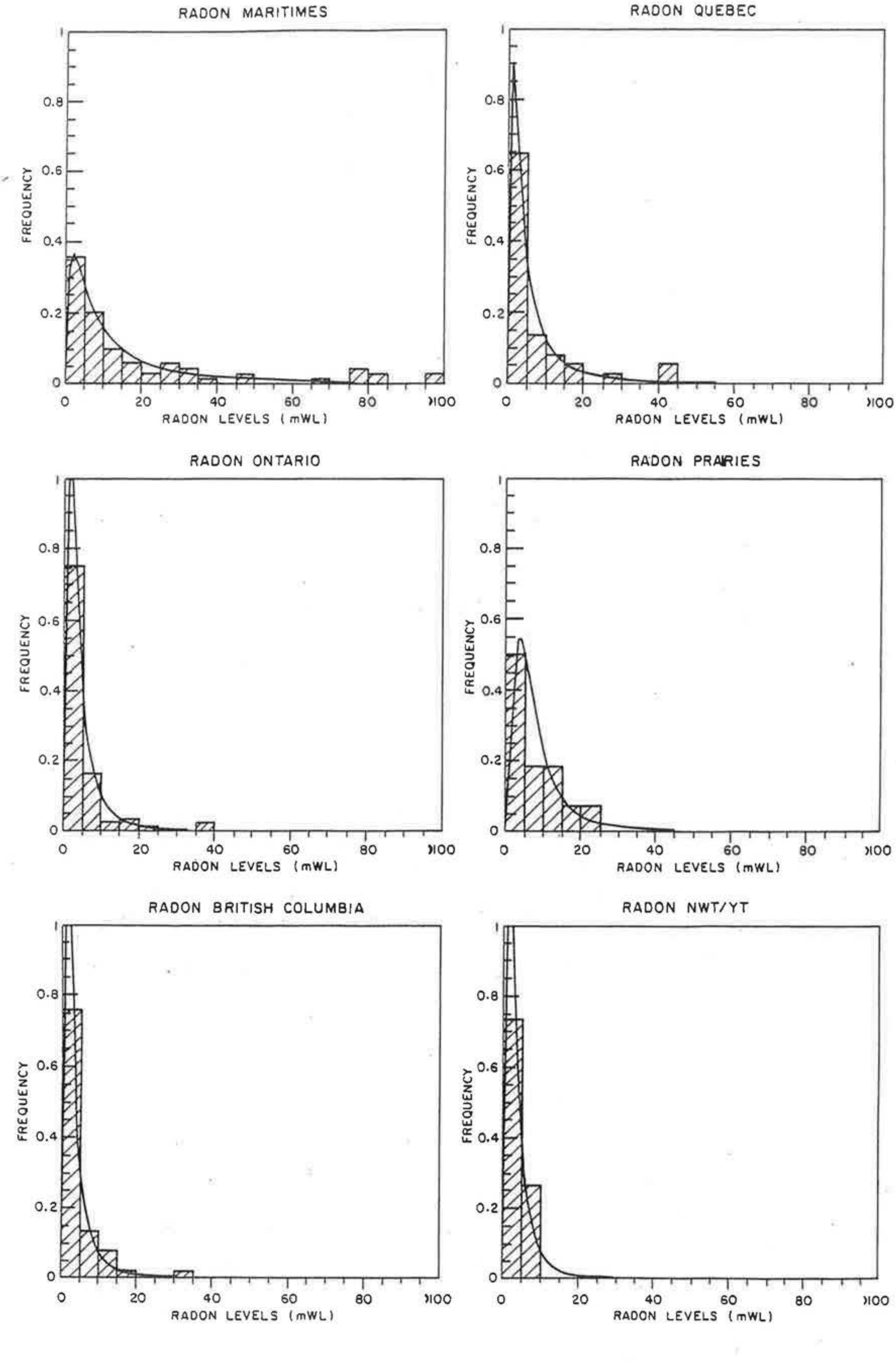


FIGURE 4
REGIONAL HISTOGRAMS - 1987
R-2000 HOMES



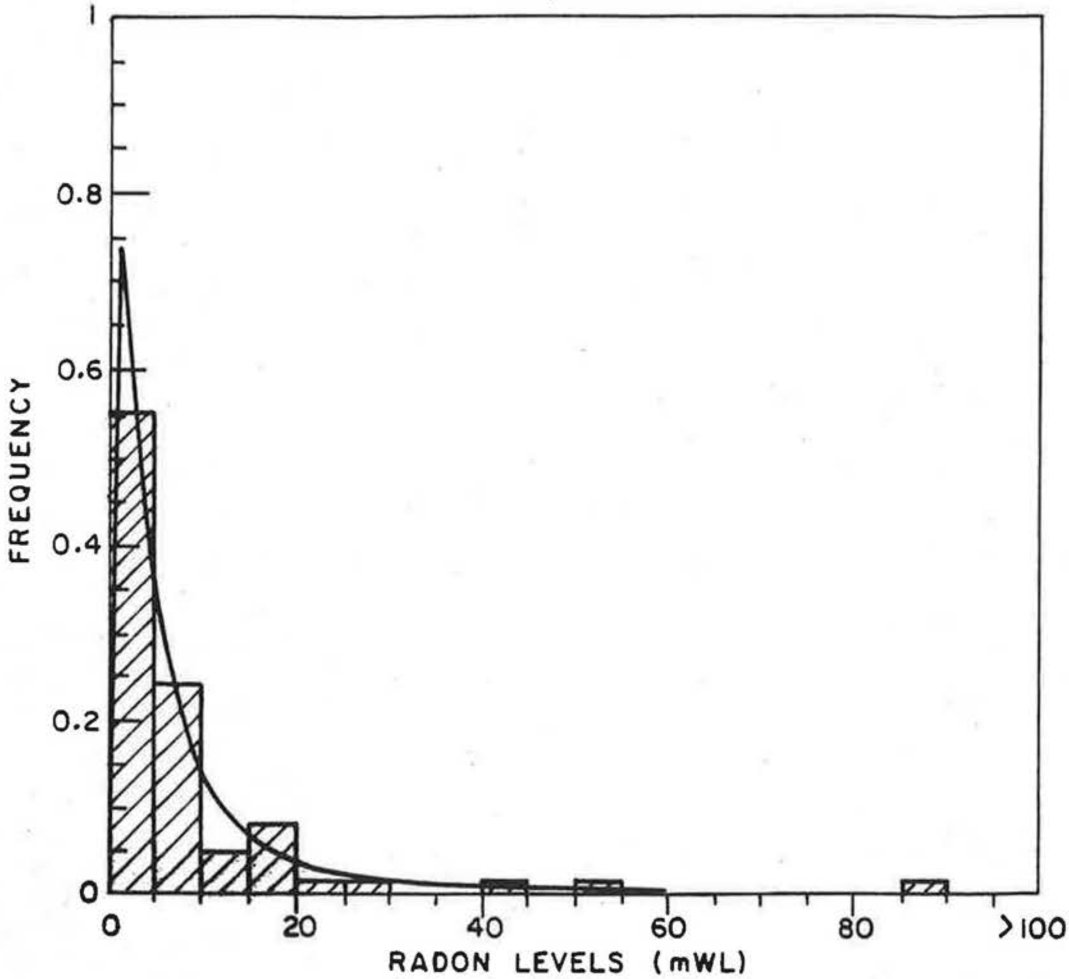
During the monitoring program, 68 conventional homes were also monitored for radon. The majority of these were measured during the 1985 monitoring period. The geometric mean, 0.004 WL, is similar to R-2000 home results as is the distribution, with none greater than 0.10 WL and 13% greater than 0.02 WL. The frequency histogram for these control-home radon results are presented in Figure 5.

2.2 Follow-up Monitoring of Homes with Higher Radon Levels

Based on the 1985 radon monitoring, six homes were identified as having levels greater than, or approaching, the interim action guideline of 0.10 WL. These homes were in New Brunswick and Quebec.

The first step in addressing the concern over high radon levels in these six R-2000 homes was to perform repeat measurements. The repeat measurements were made only after the EMR technicians were satisfied that the ventilation/heating systems were operating properly. With the systems balanced and providing correct continuous airflow, repeat measurements were made. In addition, observations were made and noted regarding possible soil gas entry points. These repeat measurements indicated that levels dropped to well below the 0.10 WL guideline.

FIGURE 5
RADON LEVELS - CONTROL HOMES, 1985 TO 1987



In one instance the level was decreased to just less than 0.10 WL. The basement of this house did not have a floor drain or a sump, utility entry points were well sealed and the poly vapour barrier extended beneath the concrete basement floor. Further investigation with a smoke pencil revealed that a leakage was occurring at the basement telepost. Sealing the telepost and increasing the minimum continuous HRV flow rate lowered levels to below 0.05 WL.

In all other instances, levels decreased to 0.02 WL or less with just HRV balancing and airflow adjustment. These repeat measurements were made during the late spring and summer of 1986. Further repeat measurements were made during the winter of 1987 to ensure that levels in these houses of concern were remaining below 0.05 WL. Preliminary results indicate that levels in these homes are remaining low.

3.0 SELECTION OF RADON MONITORING EQUIPMENT

Since 1985, the R.A.D. Service and Instruments Ltd. M-1 radon daughter monitor has been used to monitor radon in basements. The M-1 monitor is an active, time-integrating, track registering monitor, which has been developed for measuring average concentrations of radon daughters primarily in the indoor environment (Pai and Schell, 1986).

Monitoring with the M-1 was conducted over a seven-day period. Seven days was chosen as the sampling period to be used in the R-2000 Home Monitoring Program, because it coincided with the passive formaldehyde samplers which were deployed at the same time. The M-1 units were installed by EMR regional technicians and removed and forwarded to EMR via courier or mail by the homeowner.

During the initial phase of monitoring in 1984, the Track Etch cups manufactured by Terradex Corp. were used to measure radon in the basements. The Track Etch cups were selected because of the low cost; wide use for large scale surveys; and acceptance by building and indoor air quality researchers throughout North America. Measurement periods ranged from 30 to 60 days, with the majority installed for approximately 40 days. Longer sampling durations would have been desirable, but the winter heating season was ending which necessitated removing the monitors.

During the initial R-2000 monitoring in 1984, it became apparent that there were unexplained inconsistencies in the radon results. The frequency distribution of the Terradex radon results did not exhibit a log-normal distribution (Riley, M., 1986) consistent with indoor radon measurements obtained by Health and Welfare Canada (McGregor et al, 1980).

Further evaluation of the Terradex track etch monitor radon results, revealed that a combination of factors resulted in the inconsistent results. The short sampling duration of less than two months for the Terradex monitors, combined with the high potential for post-monitoring exposure of the monitor detectors, were most likely the factors which adversely affected the results. In future programs, it may be possible to install the track etch monitors for sampling periods of three months or greater. However, a large scale national program, such as the R-2000 program, which requires homeowner co-operation and assistance, cannot adopt strict handling procedures needed to avoid post-monitoring exposure.

The M-1 monitor was also evaluated, and this included: studies in radon test chambers, comparisons with other radon daughter measurement techniques, and replicate measurements. Chamber tests were conducted at three facilities: the CANMET Research Laboratory in Elliot Lake, the Environmental Measurement Laboratory in New York and the Bendix Field

Engineering Corp. facility in Grand Junction. These radon chamber tests are considered preliminary since the number of tests and M-1 monitors evaluated is small. From these preliminary tests, the M-1 monitor measures levels slightly higher than actual for low aerosol conditions (ranging from approximately 0.5 to 2.0 X 10^3 particles per cubic centimeter). At high aerosol conditions (approximately 60 X 10^3 particles per cubic centimeter), the agreement was good. Twenty-one replicate tests were also conducted and the results are presented in Figure 6. A line of best fit had a slope of 1.0 and a correlation coefficient of 0.91. Parallel test data of the M-1 monitor with grab sampling and continuous radon daughter techniques were gathered and are presented in Figure 7.

During 1986, the U.S. Environmental Protection Agency developed the Radon/Radon Progeny Measurement Proficiency Program (U.S. EPA, 1986). Under the program, laboratories are invited to voluntarily demonstrate their proficiency in measuring radon and radon progeny levels. The Terradex alpha track detector and the R.A.D. Service and Instruments M-1 radon progeny integrated sampling unit both received Level 1 qualification. The Level 1 qualifications state that the detectors met all the program requirements, including minimum screening measurement requirements (analysis within 25% of actual detector exposure levels). This proficiency program assesses a method's ability to repeatedly measure levels that are comparable to a primary standard. This program does not address the suitability of a method to actual field use.

FIGURE 6
M-1 SURVEYMETER
REPLICATE TESTS

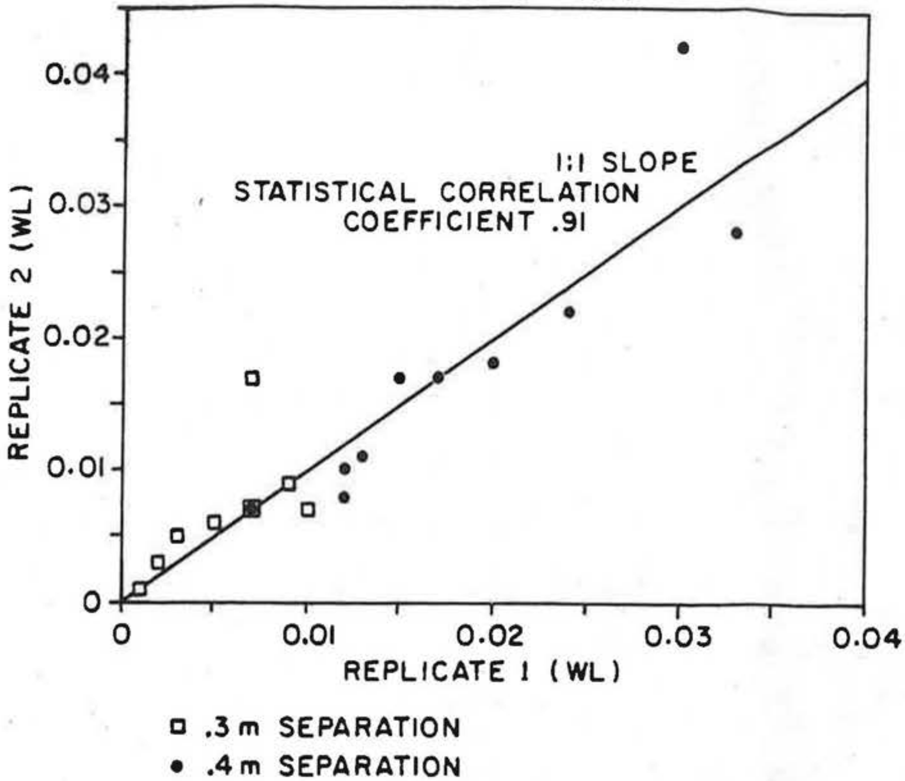
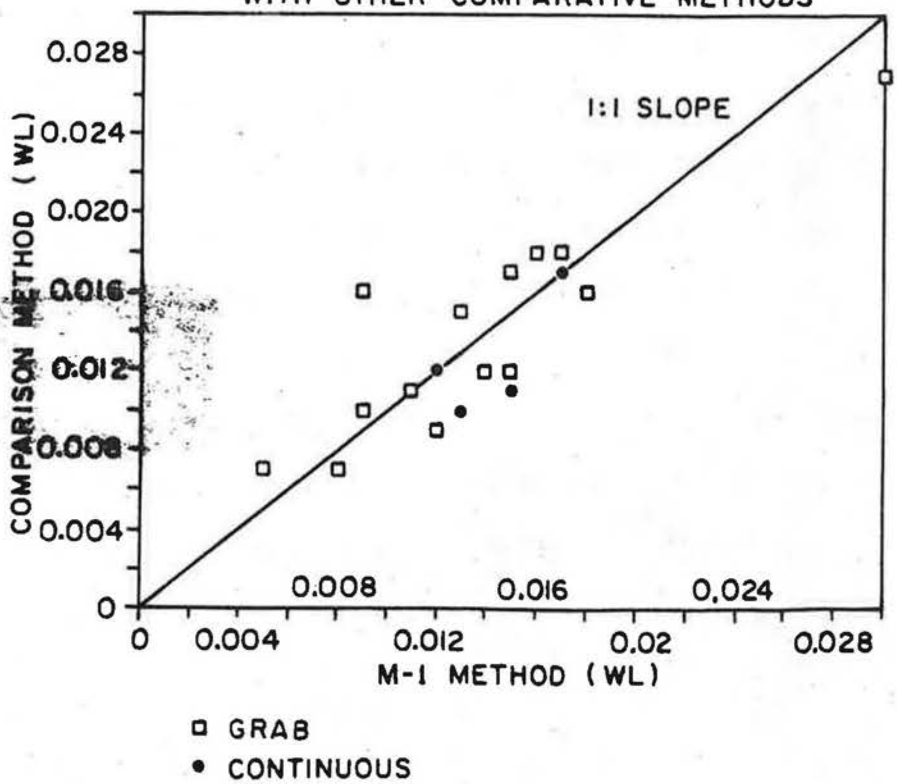


FIGURE 7
PARALLEL TESTS
WITH OTHER COMPARATIVE METHODS



Prior to the selection of the M-1 monitors in 1985, the charcoal technique of indoor radon sampling was also evaluated. The charcoal technique has the advantages of low cost and ease of use, but at the time was not commercially available. American companies now offer charcoal radon sampling services which meet the EPA Level 1 qualification. This technique has a few disadvantages: the exposure time of two to three days is short, and analysis is required within three days of completion of sampling. Even if a charcoal radon sampling service was available in Canada, the analysis timing constraint is too restrictive for general R-2000 monitoring use.

A portable monitor that provides on-site results within one to two hours, the Radon Sniffer, manufactured by Thomson & Nielsen Electronics Limited has also been used in follow-up monitoring in New Brunswick R-2000 homes. The Radon Sniffer has been used successfully as a complementary device to the M-1 seven-day monitor in New Brunswick, where the potential for higher than normal levels of radon exists. It has enabled field technicians to determine potential problem radon levels during the home visits, not a few weeks later as with the M-1 monitors. If a radon level was measured which caused concern, simple remedial measures such as HRV balancing, or increasing ventilation air flow rates, could be instituted and the effects noted.

In one instance the Radon Sniffer was left with the homeowner for a week. The homeowner was encouraged to take various readings throughout the basement and on the other floors of the home. This exercise proved to be successful in educating the owner on indoor radon. At the end of the week the home owner, based on this personal experience, understood more about the behaviour of radon and the levels in his home.

4.0 CONCLUSIONS

Mean material radon levels in the R-2000 homes for three years of monitoring were below 0.01 WL. This is well below the interim action guideline of 0.10 WL. Similar levels were measured in control homes monitored nationally.

In the homes with higher than average radon levels, and those with levels greater than 0.10 WL, minor adjustments to the mechanical ventilation system and simple basement crack sealing were all that was required to lower the levels.

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