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NEW HOUSE EVALUATION PROGRAM (NEWHEP)

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ABSTRACT

The New House Evaluation Program (NEWHEP) is designed to evaluate the effectiveness of radon-resistant construction techniques, obtain data on the relationship between radon/radium in soil at building sites and subsequent indoor radon levels, and to identify any dominant factor(s) that contribute to effective radon-resistant homes. Data was collected from five home builders in Colorado and one in Michigan on a total of 148 new homes. From analysis of this data, it is concluded that use of only the passive building techniques outlined in EPA's "Radon Reduction in New Construction, An Interim Guide" may result in measurably lower indoor radon levels but such techniques do not consistently result in radon levels below EPA's current 4 pCi/L action level. On the basis of very limited data on active (fan-driven) radon control systems, such systems do produce levels below 4 pCi/L. Data from soil testing showed some general correlations with indoor radon levels in 7 out of 11 homes tested. Of the 4 that did not correlate, 2 had higher than expected indoor radon levels and 2 had lower than expected levels. The dominant feature in building successful radon-resistant homes appears to be use of active substructure ventilation.

This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies, and has been approved for presentation and publication.

INTRODUCTION

The New House Evaluation Program (NEWHEP) was established in September 1987 shortly after public release of the EPA pamphlet titled, "Radon Reduction in New Construction, An Interim Guide" (OPA-87-009).

The NEWHEP has two basic objectives. The first is to install, and evaluate the effectiveness of, building techniques outlined in the "Interim Guide" and includes comparison of active versus passive radon reduction techniques. The second is to obtain data that might contribute to development of a correlation between soil radium and/or radon levels and subsequent indoor radon levels in new homes. Underlying both objectives is the search for any dominant factor(s) that can be applied to ensure a truly effective radon-resistant home.

This is an evaluation program and not a detailed research activity. Participating home builders are provided copies of the "Interim Guide" and asked to incorporate any one, some, or all of the building techniques outlined therein. Indoor radon measurements are made when the home is ready for occupancy. Soil Tests for radon and radium are made, when possible, prior to ground breaking, during site preparation and after construction is completed.

Two builders in Denver, three in Colorado Springs and one in a Detroit suburb have provided the data analyzed in this paper. Indoor radon measurements and/or soil test have been made in a total of 148 homes and at 6 future building sites. The NEWHEP is currently being expanded to include additional builders in Virginia and Maryland.

There are inherent limitations in any new house evaluation program. Since there can be no pre-construction indoor radon measurements, the significance of the post-construction radon levels is open to question. Would these levels have been higher if radon-resistant features had not been incorporated? When high levels of radon and/or radium are found in the soil at a building site, and low levels of radon are subsequently measured in the building, a tentative conclusion can be drawn regarding the effectiveness of the radon-resistant construction features. There is, however, no method for precisely determining which single or combination of construction features contributed to the low indoor radon levels. All of the builders participating in the NEWHEP used several of the sealing and barrier techniques and some form of sub-slab ventilation. For obvious reasons, none of the participating builders are willing to build "control" houses, without radon-resistant features, side by side with houses incorporating those features. In the absence of specific control houses, we examined data from the Colorado and Michigan State radon surveys for those Zip codes where NEWHEP houses are under construction. The results are compared later in this paper.

NEWHEP RESULTS

The level of participation in NEWHEP varied from builder to builder. The majority of the data was derived from one builder in Denver, but each of the participants provided an opportunity to examine specific building techniques in different geological environments. While we did not attempt to assess differences in the quality of workmanship between identical houses, it is important to recognize that the manner in which any radon resistant building technique is installed will be a major factor in its success. There is no guarantee that a technique will produce its desired result without extraordinary supervision and quality control. This will continue to be a major weakness in assessing the effectiveness of all radon-resistant building techniques.

The following sections contain the results of the NEWHEP for the period 1987 through July 1988. To preserve confidentiality, NEWHEP participants and the several subdivisions referred to in this paper have been given letter designations.

DENVER BUILDER A

During the 1987-88 heating season, 128 basement and 128 first floor radon measurements were made in 120 newly constructed houses in the Denver area (duplicate measurements were made in 8 houses to verify and/or compare with earlier results). All measurements were made using charcoal canisters deployed for 2 to 3 days. All houses were either full basement or combination basement-crawlspace foundations with adjacent garage slabs on grade. The houses were spread among seven different subdivisions and six different ZIP code areas surrounding the Denver metropolitan area. Twenty-seven different models were built. Fourteen of these were built in two or more subdivisions offering the opportunity to compare the effectiveness of identical design and construction features in different geological settings.

Two different construction methods were used to prevent or reduce radon entry into these homes. Method A involved sealing the floor-wall joint and around all pipe penetrations of the foundation below grade level, venting the crawlspace with two 8x16 inch vents, isolating the crawlspace from the basement, sealing around heat ducts that enter the first floor from the crawlspace, and providing external makeup air to the basement furnace. Method A was used in houses that had already been completed when this builder entered the NEWHEP and was essentially a series of retrofit or mitigation techniques applied to newly constructed homes.

Method B was used beginning in October 1987. It involved the following additional construction features. Plastic sheeting (10 mil thick and 3 feet wide) was installed under all foundation walls (above footers and caissons) and extending under the slab approximately 2 feet.

The slab was under-layed with 6 mil poly sheeting sealed to the perimeter 10 mil sheeting with 3M Spray 90 adhesive. Utility pipes that penetrated the slab were fitted with 18 inch square EPDM rubber gaskets that were sealed to the 6 mil poly sheeting with 3M Spray 90. Below the slab, a perforated drain pipe network was installed at 15 foot intervals and passively vented to a point 12 inches above the surface at 3 places outside the foundation walls. This network was also tied into a street under-drain designed to handle surface water run off. This sub-slab network was also stubbed up and capped at one location in the basement for possible future use as the suction point for a fan-driven vent system. After November 15, 1987, Method B was modified by adding a more extensive sub-slab piping network spaced at four foot intervals. Exterior venting was reduced to one location, the connection to the street under-drain was eliminated and the capped interior vent was retained for future use. A comparison of indoor radon measurements between Method A and B houses and among the seven subdivisions is summarized in Table 1.

There are a number of preliminary conclusions that may be drawn from this data. The average of all basement radon levels in these 120 houses was 5.2 pCi/L. First-floor radon levels averaged 3.0 pCi/L. Although there are differences in the various sub-division averages, the range is relatively narrow and not statistically significant, given the sample size. The slightly higher average in the M/L sub-division (8.7 pCi/L) may be of some significance since 15 of the 19 models built in M/L were also built in the P/H sub-division where the average basement level was only 3.8 pCi/L, and 18 of the 19 models in M/L were also built in the C/C sub-division where the average basement level was 4.2 pCi/L and soil radium content was measured at 1.1 to 1.4 pCi/g.. Since house design and construction were essentially the same in all three sub-divisions, the only factor that could produce the higher radon levels in M/L would appear to be a higher radon source strength. Soil samples taken at one home in the M/L sub-division contained 1.9 pCi/g of radium at a depth of 90 cm and 1.3 pCi/g at the surface. Of the 38 soil samples taken in Colorado under the NEWHEP, 1.9 pCi/g ranked 4th highest behind two samples taken in Colorado Springs and one other sample in the Denver area.

As we compare basement and first floor measurements in Table 1, the data appears to confirm the roughly 2 to 1 relationship found in other surveys. To assess the seasonal variations we grouped the measurements into two periods. The 102 houses measured during the period September 1987 through April 1988 averaged 5.8 pCi/L in basements and 3.4 pCi/L on the first-floor. The 26 houses measured during the period May through July 1988 averaged 3.8 pCi/L in basements and 1.6 pCi/L on the first-floor. Again, the winter to summer relationship of roughly 2 to 1 is consistent with previous survey data.

In analyzing the average radon measurements in construction methods A and B, the data on the P/H sub-division is the only sample large enough to support any conclusions. The difference between 3.4 and 4.2 pCi/L is probably not significant, but the similarity of results is indicative of

DENVER BUILDER A
SUB-DIVISION COMPARISONS

	ALL HOUSES			METHOD A			METHOD B		
SUB-DIV	NO. HOMES	AVG. BASE.	AVG. 1ST.	NO. HOMES	AVG. BASE.	AVG. 1ST.	NO. HOMES	AVG. BASE.	AVG. 1ST.
S/G	24	6.0	4.2	21	5.5	3.9	3	9.9	6.5
P/H	36	3.8	2.1	25	3.4	1.9	11	4.2	2.3
C/C	23	4.2	2.2	22	4.2	2.1	1	5.6	3.3
M/L	19	8.7	4.7	19	8.7	4.7			
D/V	10	6.9	3.1	6	8.1	2.9	4	4.9	3.3
F/H	6	5.2	1.7	6	5.2	1.7			
N/H	2	2.8	1.1	2	2.8	1.1			
TOTALS	120	5.2	3.0	101	5.2	3.0	19	5.2	3.2

WINTER — 102 HOUSES = 5.8 AVG. BASEMENT 3.4 AVG. 1st FLOOR
SUMMER — 26 HOUSES = 3.8 AVG. BASEMENT 1.8 AVG. 1st FLOOR

TABLE 1

the fact that adding additional passive ventilation under the slab does not produce any significant reduction in indoor radon levels.

To summarize, while the passive radon-resistant construction techniques used by this builder were successful in achieving average basement radon levels near 4 pCi/L in the P/H, C/C (and adjacent N/H) subdivisions, these same techniques were not successful in the M/L and other subdivisions where radon source strength was significantly higher.

An additional factor that was considered a possible contribution to different indoor radon levels was the basement size. We calculated the exposed below grade surface area in the basements of each of the different house models and plotted those areas against the radon levels in those models. In the four subdivisions where we had data on 8 or more models, we found no correlation between exposed below grade surface area and indoor radon levels (Figures 1,2,3, and 4). From this limited data, it would appear that homes with large basements are no more vulnerable to radon entry than homes with smaller basements.

An additional comparison of individual house models built in more than one subdivision (Figure 5) provides further evidence that radon source strength is a dominant factor influencing indoor radon levels. Nine models built in the M/L subdivision had high levels of indoor radon in 8 out of 9 comparisons with the same models built in the other three subdivisions. When we compare the geology of the subdivisions in terms of both soil composition and permeability, we find a general correlation between predictably high radon sources and higher indoor radon levels (Table 2). For example, the relatively higher indoor radon levels at the M/L subdivision can be related to the above average radium content of the Pierre Shale on which this subdivision is built. In contrast,

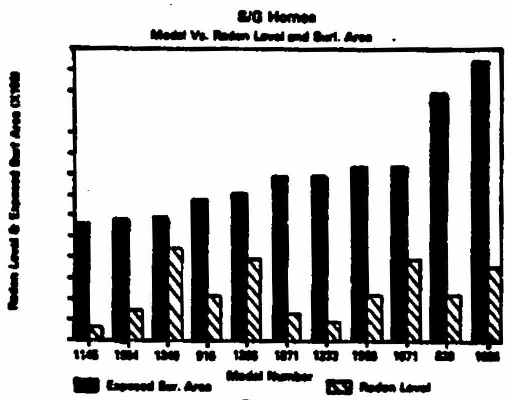

Figure 1

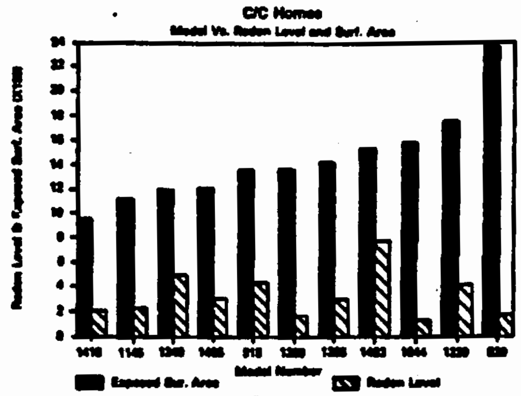

Figure 2

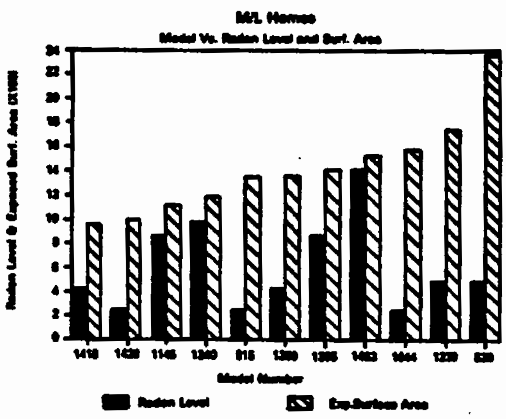

Figure 3

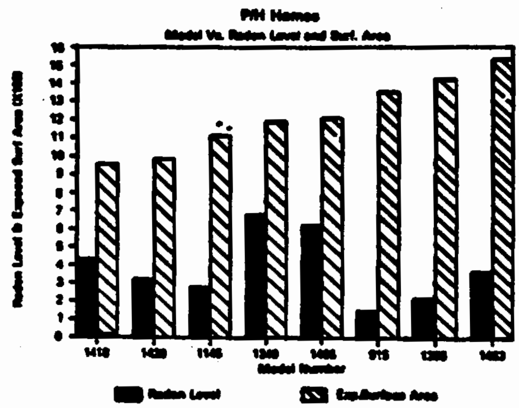

Figure 4

RADON LEVELS IN MODELS BY SUB-DIVISION

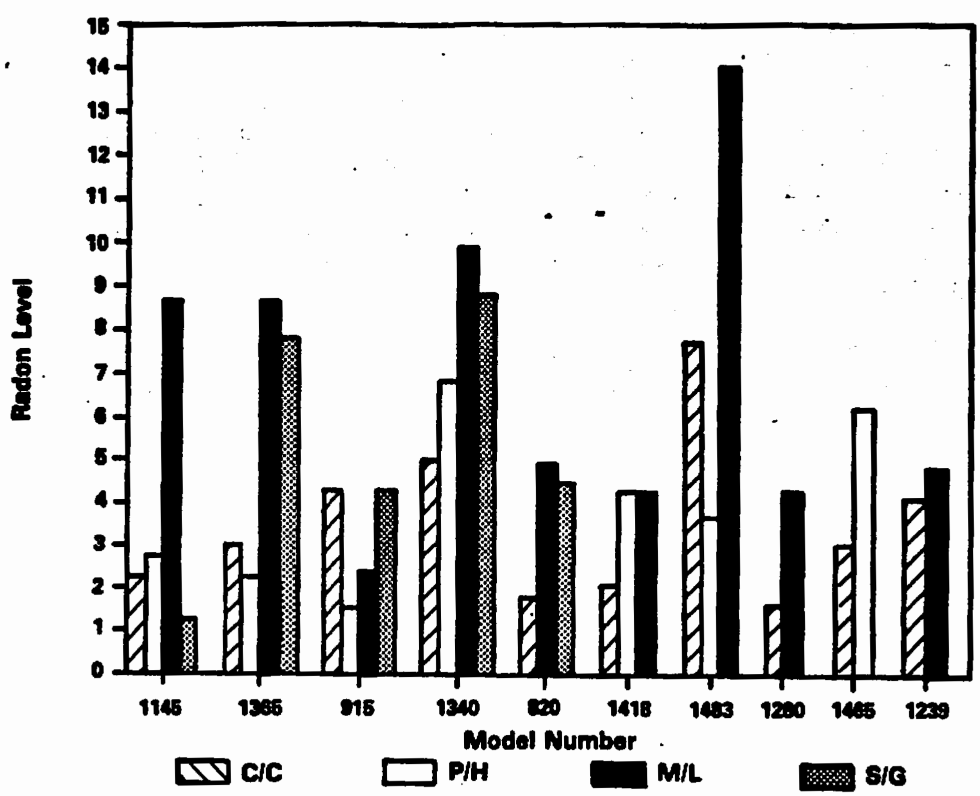

Figure 5

the lower radon levels in P/H, C/C, N/H and S/D Subdivisions is a reflection of the sandy, lower radium content soils in these locations. The high average level of indoor radon in the O/G subdivision can probably be attributed to locally elevated levels of radium rich soil. We found one soil sample in O/G that measured 2.0 pCi/g of radium. We also found soil gas radon levels up to 1650 pCi/L in this area. The low indoor radon level in the O/L subdivision can be attributed to the active sub-floor ventilation system installed in these three homes.

DENVER BUILDER B

A second builder in Denver uses an innovative foundation technique to simultaneously deal with problems of expansive soil and high soil radium content. The foundation excavation is over-dug to a depth of 10 feet. Caisson pilings are driven to support the 10 foot tall reinforced poured concrete walls. Band joists are bolted to the walls two feet above the dirt floor and a carefully sealed wood sub-floor, supported by steel "I" beams and standard size floor joists, is installed. The two foot high "buried crawlspace" is actively ventilated by installing a sheet metal inlet duct in one corner of the basement, drawing in outside air through an above ground vent. A similar duct with an inline fan is located at the opposite corner to exhaust air through an above ground vent. Results of this technique are shown in Table 3. Note that in HECO 7001, turning the crawlspace exhaust fan off for 24 hours prior to testing had no effect on the radon levels in the crawlspace. The basement levels went up but only slightly. Note also that we found high levels of radon in the soil gas (4647 pCi/L) and slightly elevated levels of radium in the soil at this site. In the presence of this radon source strength, the indoor radon level of 0.6 pCi/L would appear to indicate that the active sub-floor ventilation system used in this house was successful in reducing radon infiltration into the living spaces. In HECO 7005, we found comparably high levels of radon and radium in the soil, but with continuous operation of the crawlspace ventilation system, indoor radon levels were very low (0.9 pCi/L). We had no soil data on HECO 7009 but this house was located within 100 yards of the other houses tested and we assume similar geology. Again, the indoor radon level was low, even though elevated levels were measured in the ventilated crawlspace. When we returned to this area in March 1988, an excavation and foundation had been constructed for a house located between HECO 7001 and 7005. The exposed vertical wall of the excavation provided an opportunity to examine the radon source characteristics of several different visible layers of soil surrounding these homes. Note the correlation of radon in soil gas and radium in the soil at depths of 60 and 130 cm. We were unable to obtain a soil gas measurement at 200 cm due to a cracked probe, but the soil sample taken at that depth showed a high level of radium (3.5 pCi/g). This illustrates rather clearly the potential for error when using soil gas probes for building site radon characterization. A single probe to 130 cm in this case could have led a builder to assume a low probability of indoor radon problems at this site.

SOIL TYPE/INDOOR RADON CORRELATION

SUB-DIV	NO. HOUSES	BASEMENT RADON	SOIL TYPE	PERMEABILITY
(DENVER)				
M/L	19	8.7	PIERRE SHALE	MODERATE
D/V	10	6.9	SANDSTONE, SILTSTONE	MODERATE
S/G	24	6.0	SANDSTONE, SILTSTONE	MODERATE
F/H	6	5.2	SANDSTONE, SILTSTONE	MODERATE
C/C	23	4.2	SANDY	MODERATE TO HIGH
P/H	36	3.8	BOULDERY, COBBLE GRAVEL	MODERATE TO HIGH
N/H	2	2.8	WINDBLOWN SAND	MODERATE TO HIGH
O/L	3	1.2	CLAYSTONE, SILTSTONE	MODERATE
(COLORADO SPRINGS)				
W/P	4	4.5	GRANITE ROCKS	MODERATE
N/W	7	5.0	SANDSTONE, SILTSTONE	MODERATE
S/D	3	3.1	WINDBLOWN SAND	MODERATE TO HIGH
O/G	6	15.3	BOULDERY, COBBLE GRAVEL	MODERATE TO HIGH

TABLE 2

DENVER BUILDER B

HOUSE ID NO.	DATE	VENT FAN STATUS	RADON IN CRAWLSPACE (pCi/L)	RADON IN BASEMENT (pCi/L)	RADON IN SOIL GAS			RADIUM IN SOIL		
					pCi/L	LOCATION	DEPTH	pCi/g	LOCATION	DEPTH
HECO 7001	JUL 87	ON – 2 WKS PRIOR	9.9	1.4				1.4	4½ M WEST	60 CM
			8.4	1.4				1.1	4½ M WEST	110 CM
	AUG 87	OFF – 1 DAY PRIOR	8.8	1.9				1.3	4½ M NORTH	60 CM
								1.2	4½ M NORTH	100 CM
								1.6	4½ M EAST	60 CM
								1.3	4½ M EAST	70 CM
	MAR 88	ON–CONTINUOUS		0.8	4647	4½ M NORTH	100 CM	0.7	4½ M EAST	100 CM
HECO 7005	JUL 87	ON – 1 WK PRIOR	18.6	1.2				1.9	4½ M EAST	85 CM
			16.7	0.9				1.4		120 CM
	AUG 87	OFF – 1 DAY PRIOR	27.3	1.8						
	MAR 88	ON – CONTINUOUS			3166	4½ M EAST	100 CM			
HECO 7009	JUL 87	ON – 1 DAY PRIOR	26.4	1.3						
			18.5	0.9						
BUILDING SITE BETWEEN HECO 7001 AND HECO 7005	MAR 88				1540 600	WEST WALL OF EXCAVATION USING LATERAL PROBE	60 CM 120 CM	1.2 0.4 3.5	WEST WALL OF EXCAVATION	60 CM 130 CM 200 CM

TABLE 3

Table 4 contains the results of soil tests made at five other homes in the Denver area and reveals a general correlation between soil test data and indoor radon levels. At the four sites where radium content of the soil was above average (1.3 pCi/g), we found three houses with above average indoor radon levels (6.8 to 15.6 pCi/L) and one house (HECO 7306) with a lower reading (3.0 pCi/L). At the site (HECO 7338) where we measured below average (0.7 pCi/g) soil radium content and soil gas radon (620 pCi/L), indoor radon was comparably low (2.3 pCi/L). Thus, in 4 out of the 5 homes there is a general correlation between soil test data and indoor radon. The lower than average level of indoor radon in HECO 7306 may be attributable to the radon-resistant features installed, although that assumption cannot be supported by the available data.

COLORADO SPRINGS BUILDER A

A total of 37 charcoal canister radon measurements were made in 10 homes built by one contractor in Colorado Springs. All of these homes had two living levels above either basement or combination basement-crawlspace foundations with poured concrete walls. Seven of the homes were in the N/W subdivision and three in the S/D subdivision. Radon reduction techniques used in these homes included: 6 mil polyethylene sheeting under the slab, a caulked expansion joint where the slab joined the footing, a drain tile loop layed in a gravel bed around the exterior of the footing and stubbed up to the surface for passive venting, polyethylene sheeting on the crawlspace floor but not sealed to foundation walls, external air ducts to fireplaces, two standard 8x16 inch crawlspace vents on each of two external walls, and trapped floor drains connected to sewer lines. All radon measurements were made during the period of December 1987 through March 1988 and repeat measurements were made in 6 of the 10 homes. The average of all 16 basement measurements was 4.5 pCi/L. In the N/W subdivision, 12 basement measurements averaged 5.0 pCi/L and in the S/D subdivision, 4 basements averaged 3.1 pCi/L. First floor measurements averaged 3.0 pCi/L in N/W and 1.7 pCi/L in S/D. Second floor measurement were slightly higher averaging 3.2 pCi/L in N/W and 2.0 pCi/L in S/D.

As we examine these results together with the results of soil testing at 5 of these homes (Table 5), we find a variety of relationships. At HECO 7431, in September 1987, the high soil gas radon level (2030 pCi/L) was reflected in an above average indoor radon level (7.6 pCi/L). By comparison, the very low soil gas radon level measured in March 1988 (388 pCi/L), at the rear of the same house, produced an expected lower indoor level of 3.5 pCi/L. The wide variation in soil gas radon is presumably due to differences in the soil moisture content causing changes in permeability. Other soil gas radon measurements in the same subdivision ranged from 710 to 1095 pCi/L and produced indoor radon levels from 1.8 to 9.3 pCi/L. At HECO 7410 and 7413, we found moderate levels of radon in the soil gas (996 to 1240 pCi/L) although radium content of the soil was relatively low (.4 to .6 pCi/g). In both of these homes, indoor radon levels were very low.

DENVER BUILDER A
SOIL TEST/INDOOR RADON CORRELATION

HOUSE ID NO.	SUB-DIV.	BASE. RADON	1st FL. RADON	SOILGAS RADON	LOCATION	DEPTH	RADIUM IN SOIL	LOCATION	DEPTH
HECO 7300	S/G	6.8	3.2				1.3	REAR	90 CM
HECO 7302	S/G	7.1	8.5	1002	FRONT	120 CM	1.3	FRONT	90 CM
				1779	REAR	120 CM	1.4	REAR	90 CM
HECO 7306	C/C	3.0	1.4	1430	FRONT	90 CM	1.1	FRONT	SURF.
				1316	REAR	90 CM	1.4	FRONT	90 CM
NECO 7338	N/H	2.3	1.1	620	FRONT	90 CM	0.7	FRONT	90 CM
							1.3	FRONT	SURF.
NECO 7386	M/L	15.6	8.5				1.3	REAR	SURF.
							1.9	REAR	90 CM

TABLE 4

COLORADO SPRINGS BUILDER A
SOIL TEST/INDOOR RADON CORRELATION

HOUSE ID NO.	SUB-DIV	BASE. RADON	1st FL RADON	2nd FL RADON	SOIL GAS RADON	LOCATION	DEPTH	RADIUM IN SOIL	LOCATION	DEPTH
HECO 7410	S/D		.7	.9	1240	REAR	120 CM	.4	REAR	SURF.
HECO 7413	S/D	2.2	1.8	2.3	886	REAR	120 CM	.6	REAR	90 CM
HECO 7431	N/W	7.6	3.9	4.2	2030	FRONT	120 CM	(SEPT. 87)		
		3.5			386	REAR	120 CM	(MAR. 88)		
HECO 7434	N/W	1.8	1.8	1.6	1085	FRONT	90 CM	1.0	FRONT	SURF.
					1014	REAR	90 CM	1.9	FRONT	30 CM
HECO 7418	N/W	5.8	3.5	3.0	710	(SEPT. 87)				
HECO 7422	N/W	9.3	6.3	7.2	930	(SEPT. 87)				

TABLE 5

While the passive radon-resistant features built in to these homes may be contributing to lower indoor radon levels the available data is sufficient to assess whether these features were having any effect at all. The variability of this data does offer further evidence that passive systems cannot be relied upon to consistently produce low indoor radon levels. We might further conclude that the results of testing for radon in soil gas and/or radium content of soil cannot be used with any confidence to accurately predict indoor radon levels for a specific house.

COLORADO SPRINGS BUILDER B

A second builder in Colorado Springs has also been using only passive radon-resistant building techniques in subdivisions where soil gas radon and radium content are higher than average. Building techniques include use of 6 mil poly sheeting under the slab, caulking the floor-wall joint, and installing a drain tile loop around the exterior footing, stubbed up in a passive vent. External air is provided to fireplaces and other combustion heating systems. Results of testing at these homes and building sites are shown in Table 6. Initial soil samples taken in September 1987 at two building sites in O/G Subdivision contained 1.0 pCi/g of radium. Subsequent indoor radon measurements in 6 houses in this subdivision ranged from 2.7 to 31.4 pCi/L with an average of 15.3 pCi/L. We were unable to obtain soil test data at these six homes but in March 1988 we tested the soil at 3 other building sites in this subdivision and found radon levels ranging from 210 to 1650 pCi/L and radium content from 0.5 to 2.0 pCi/g. These ranges appear to have a positive correlation with indoor radon measurements in homes tested within this subdivision. Homes are currently under construction at the three building sites and indoor radon levels will be obtained when construction is completed. In the B/M subdivision, we obtained soil test data at three building sites that indicates a high potential for elevated indoor radon levels if radon-resistant features are not incorporated. Homes being built at two of these sites are nearing completion and will be tested prior to occupancy. It is considered likely that the passive radon-resistant features currently built in to these houses will not be adequate to achieve radon levels below 4 pCi/L.

COLORADO SPRINGS BUILDER C

The third NEWHEP participant in the Colorado Springs area provided indoor radon measurements in five homes. These were all combination basement-crawlspace homes with poured concrete foundations and were built with the following radon resistant features: a polyethylene barrier was laid under the basement slabs, the floor-wall joint, other slab joints and foundation penetrations were caulked, an exterior drain tile loop was stubbed up outside the walls for passive ventilation, and standard 8 X 16 inch vents were installed in the crawlspace. One of the houses also had an interior (as well as exterior) drain tile loop that was stubbed up and capped inside the basement for use in an active sub-slab ventilation system if warranted by post-construction indoor radon measurements. Radon levels of 2.4, 2.6, 0.8 and 12.3 pCi/L were measured in the living rooms on the first floor of 4 houses in March 1988. The living room in the 5th house was measured in July 1988 at a level of 2.7 pCi/L. The house that measured 12.3 pCi/L was located in a low flood plain area characterized by a heavy black soil. If we assume a twofold increase in radon levels from first floor to basements, 4 out of 5 of these homes would exceed the 4 pCi/L action level. These results are consistant with those of the other NEWHEP builders in Colorado who used only passive building techniques.

DETROIT BUILDER

One builder near Detroit, Michigan provided radon data on 5 houses equipped with radon prevention features that included: sub-slab gravel and a drain tile loop terminating in a covered sump crock, a visqueen barrier under the slab, a water stop seal between the footing and base of the poured concrete foundation walls, a sealed floor-wall joint, make up air to the furnace, and complete external wrapping of the foundation walls with Owens-Corning Tuff and Dry. A 4 inch pvc vent stack was inserted in the sump cover and routed through the upper floors to the roof. This stack was not actively ventilated although a wind driven turbine was mounted at the vent outlet points and electrical provisions were made for future installation of a fan if needed.

In September 1987, soil samples were taken at 3 of the building sites in this development. These samples were taken at depths where basement floors were to be laid. Analysis of the samples showed radium levels of .8, .9, and 1.2 pCi/g -- levels considered medium to below normal. Indoor radon measurements were subsequently made in 5 houses in the same subdivision. None of these houses were built on the 3 lots where soil tests were made, therefore direct correlation was not possible. The average basement radon levels in the 5 homes tested was 2.4 pCi/L. This average level appears to be consistant with the below normal source strength and cannot be directly attributed to the built in radon resistant features installed by this builder.

COMPARISON OF NEWHEP AND STATE SURVEY DATA

As mentioned earlier, the absence of "control" houses in the NEWHEP prevents a before and after or side by side analysis of results. In an attempt to provide some sort of comparative data, we examined the results of the Colorado and Michigan State radon surveys and compared data from the same zip codes where NEWHEP houses were built. The results are summarized in Table 7.

COLORADO SPRINGS BUILDER B

HOUSE/LOT ID NO.	SUB-DIVISION	DATE MEASURED	BASEMENT RADON (pCi/L)	SOIL GAS RADON (pCi/L)	DEPTH	RADIUM IN SOIL (pCi/g)	DEPTH
L1	O/G	9/87				1.0	90 CM
L2	O/G	9/87				1.0	90 CM
H3	O/G	11/87	2.7				
H4	O/G	2/88	31.4				
H5	O/G	2/88	8.8				
H6	O/G	2/88	7.9				
H7	O/G	2/88	28.0				
H8	O/G	7/88	14.9				
L9	O/G	3/88		210	120 CM	0.5	90 CM
L10 Hole 1	O/G	3/88		470	85 CM	0.8	30 CM
L10 Hole 2	O/G	3/88		1650	80 CM	1.1	80 CM
L10 Hole 2	O/G	3/88				1.2	SURFACE
L11 Hole 1	O/G	2/88		1810	90 CM		
L11 Hole 2	O/G	2/88		1840	90 CM	2.0	SURFACE
L12	B/M	2/88				1.1	SURFACE
L13 Hole 1	B/M	2/88		2020	120 CM	.7	SURFACE FILL
L13 Hole 2	B/M	3/88		1340	75 CM		
L14 Hole 1	B/M	3/88		2430	75 CM	1.5	SURFACE
L14 Hole 1	B/M	3/88		3210	120 CM		
L14 Hole 2	B/M	3/88		4020	70 CM	2.0	100 CM

TABLE 6

NEWHEP vs STATE SURVEY RADON LEVELS BY ZIP CODE

COUNTY	ZIP CODE	NEW HEP SUB-DIV	NUMBER OF NEW HEP HOUSES	BASEMENT RADON	NUMBER OF SURVEY HOUSES	BASEMENT RADON
ARAPAHOE	80013	D/V	10	6.9	15	11.7*
ARAPAHOE	80015	F/H	6	5.2	5	5.3
ADAMS	80020	S/G	24	6.0	4	4.2
BOULDER	80020	O/L	3	1.2	4	4.2
JEFFERSON	80123	P/H	36	3.8	12	5.8
ADAMS	80241	C/C-N/H	25	4.2	2	5.0
BOULDER	80601	M/L	19	8.7	22	3.1
TELLER	80863	W/P	4	4.5	7	18.6**
EL PASO	80918	N/W	7	4.5	19	2.9
EL PASO	80918	S/D	3	2.3	19	2.9
EL PASO	80919	O/G	6	15.0	8	5.2
OAKLAND	48322	M/P	5	2.4	4	1.4
TOTAL			148	5.0	93	6.1

*1 HOUSE IN THIS ZIP CODE MEASURED 110.5 pCi/L

**1 HOUSE IN THIS ZIP CODE MEASURED 74.3 pCi/L

TABLE 7

There are a number of factors that weaken the validity of any direct comparison between NEWHEP data and State radon survey data in the same zip code areas. The first is the lack of sufficient data points in some of the areas. There is also a potentially large difference in the size, design and construction of houses in the two samples. The only value in comparing average basement measurements in the two samples is that it provides a general indication of how homes with some radon-resistant features compare with those that do not have these features. The 148 NEWHEP houses averaged 5.0 pCi/L while the 98 State survey houses in the same zip codes averaged 6.1 pCi/L. The significance of the difference is questionable but we may tentatively conclude that building-in radon-resistance contributes to a measurable (although not large) reduction in indoor radon levels. The application of active rather than passive radon reduction techniques should further reduce indoor radon levels. As the New House Evaluation Program continues and expands, increasing focus will be placed on evaluating the effectiveness of active radon reduction building techniques.