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RADON DIAGNOSIS IN A LARGE COMMERCIAL OFFICE BUILDING

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ABSTRACT

Large commercial office buildings present a significant challenge to the commercial radon mitigator. A radon problem in a Washington, DC area was recently analyzed with a number of diagnostic techniques in a attempt to get a quick understanding of the nature of the problem while operating within a limited budget. The building has 7 stories, is 5 years old and it has a VAV type HVAC system with 21 air handler zones. The diagnosis was carried out using and integrated approach combining: 1) multiple short term radon screening to look for hot spots, 2) continuous radon monitoring in a few sites to identify day/night radon variations, 3) pressure tests across doors to identify localized depressurization, and 4) continuous pressure in hot spots monitoring to identify building HVAC cycles. This integrated approach identified different mitigation solutions in each zone. Mitigation options have been presented to the building owners, but a final decision on mitigation has not been made at the time this paper was written.

BACKGROUND

Radon mitigators may need to use a wide variety of diagnostic tools to analyze radon problems in large office buildings. These buildings generally have sophisticated HVAC systems and complex foundation structures that are not generally found in homes or schools. For quick, cost effective radon diagnosis in large office buildings, it may b necessary to use a variety of radon and pressure measurement equipment. This paper describes an attempt to diagnose a building using: 1) multiple short term radon screening to look for hot spots, 2) continuous radon monitoring in a few sites to identify day/night radon variations, 3) pressure tests across doors to identify localized depressurization, and 4) continuous pressure monitoring in hot spots to identify building HVAC cycles.

The ground floor of this Washington, DC Metro area 7 story, 5 year old building is underground except for a loading dock area. The HVAC system is a VAV type with 3 air handlers on each floor, supplies in most rooms, and a return plenum overhead. Figure 1 shows the floor plan of the basement and each of the three HVAC zones is outlined. There are a number of areas in the basement with slab-to-slab walls that may cross the boundaries of the HVAC zones.

Previous radon tests were made with alpha-track monitors deployed for three months during the summer and winter of 1989. Rooms indicated on Figure 1 are locations of radon tests. Table 1 lists all of the radon test results. When some radon levels above 4 p/Ci/L were found, all the building VAV units were adjusted to supply a minimum airflow of 30%, and booster fans were installed in the fresh air supply ducts. All of this work was assumed to guarantee that the building would be under a positive pressure while the HVAC system was on. No further radon tests were performed after these modifications, and one of the goals of the Infiltec work was to determine if the HVAC modifications have made a change in the radon levels. Additional goals include a determination of the pressure balances inside the building and suggestions for mitigation if elevated radon levels are found.

RADON MEASUREMENTS

In order to determine if the radon levels had changed since the HVAC modifications were performed, radon tests were conducted by Infiltec over the period 9/6 to 9/14 with electret passive monitors in 23 rooms and continuous radon monitors (CRMs) in two rooms. The electrets were read out every few days to check the average radon levels and the CRMs recorded hourly data so that the short term fluctuations could be monitored. Table 1 lists the electret results and Figures 2 and 3 show the hourly radon data in 2 zones.

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A quick 24 hour test was performed to get a snapshot of the building and to check out areas such as elevator shafts and HVAC rooms that had not been tested before. This data is shown in the first data column of Table 1. No new sources were found but the shop area which had shown the highest radon levels in previous tests was not as high as the rooms in zones B and C.

PERIOD 9/6-9/10

A longer electret test (second data column in Table 1) over the weekend was performed in more rooms with the hope of finding sources in the building when the HVAC system shut down over the weekend. Unfortunately, it was found that during the weekend the HVAC system operates with the same cycling as a weekday because of partial weekend occupancy. However, the longer tests showed continued elevated levels of radon in most rooms in zones A and B, and the shop showed the highest levels.

PERIOD 9/6-9/14

Adding 4 more days to the electret test (third data column in Table 1) resulted in a surprising lowering of radon levels in zones A and B, but the shop room stayed at about 6 pCi/L. When the electret data is analyzed for the levels between 9/10-9/14 (fourth data column in Table 1) it can be seen that the radon levels have dropped substantially in both of these zones during this period, while the levels in zone A have not changed very much.

Figure 2 shows what happened to the radon levels in one room in zone B which is expected to be representative of most of the rooms in this zone. On the evening of September 10 the radon levels fall from about 4 pCi/L to about 2.5 pCi/L and remain there. The electret data suggest that this is what happened in all the rooms in zones B and C. One possible explanation is that the onset of cooler weather on 9/10 may have changed the VAV settings to bring in more fresh air. At present the reason for this sudden change in radon levels is unknown but it seems to have only affected the radon levels in zones B and C. Since Figure 2 shows that the radon levels in zone B do not show a day/night fluctuation, it seems that radon is being constantly pulled into these zones during the day and that when the HVAC system shuts down at night there is no significant increased or decreased entry.

Figure 3 shows that the radon levels in the shop area exhibit extreme day/night fluctuations with peaks up to 30 pCi/L at night and decreasing to 1 or 2 pCi/L during the day. The shaded area on this graph shows the radon levels during occupied hours (7 am to 5 pm), and the average radon during occupied hours is not very much different from the average levels during occupied hours because the HVAC system comes on a t 7 am and it takes several hours to sweep the radon from this room. Some of this effect may be due to time lag in the CRM response. Note that Table 1 shows that radon levels in the rest of zone A rooms are quite low. There seems to be a strong radon source in the shop that is suppressed during the day by either positive pressure or ventilation, but when the HVAC system shuts down this source raises the levels in the shop very quickly.

PRESSURE MEASUREMENTS

Figure 4 shows a recording of the pressure difference between the shop and the subslab gravel layer. This data was measured through a small hole drilled through the slab in the shop. The graph shows that there is a positive pressure in the shop (relative to the subslab) during the day of 0.01 to 0.02 inches of water column ("wc) and when the HVAC system is shut down at night there is still a positive pressure of about 0.002 "wc. The pressure in the shop relative to the hall was measured at about 0.007 "wc lower than the hall during the day (Table 1) and Figure 4 suggests that zone A is generally well pressurized by the HVAC system. It is generally assumed that if there is any positive pressure in a room relative to the subslab that all radon entry will be suppressed. Therefore it is surprising that the shop appears to be at a slight positive pressure even at night when the radon is entering. This suggests that the radon source is not in the subslab and that it may be somewhere in the walls. We have been unable to locate the entry point and it may be necessary to conduct further investigations when the HVAC system is not pressurizing the room.

Subslab radon measurements were made through three drilled holes in the shop floor and levels of 130 to 280 pCi/L were found (Table 2). These radon levels are very low. From our experience we have generally seen subslab radon levels in problem buildings ranging from 500 to 80,000 pCi/L. It appears that the subslab radon may be diluted by the positive room pressurization induced flow or that there is a hot spot somewhere that we have not located.

Figure 5 shows the pressures measured through a hole drilled through the slab in room H0228A in HVAC zone B. Again we see good HVAC pressurization during the day (0.01 to 0.01 "wc) and nighttime pressure around zero, with the exception of a half hour negative period (about -0.006 "wc) just before the HVAC system comes on in the morning. Note that several days of data were recorded and each daily pressure cycle is almost identical to the one shown. Table 1 pressure measurements made under the doors in zones B and C show that the only rooms that are significantly negative are the HVAC and electrical rooms. When these rooms were investigated for possible radon sources, drains were found that had large gaps around them leading directly to the subslab. When radon measurements were taken in these drains, levels of about 250 pCi/L were found (Table 2) together with significant air flow into the HVAC rooms. It seems reasonable to believe that the negative pressure in the HVAC rooms pulls in radon during the day and distributes it around zones B and C, and that when the HVAC system goes down at night this radon does not decay enough to show any decrease in levels.

Pressure in the HVAC rooms (relative to the halls) in zones B and C were measured on 9/10 at -0.050 and -0.026 "wc

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respectively. The significant decrease in zone C negative pressure may be the reason that this zone had lowest radon levels during the 9/10-9/14 electret monitoring. It is assumed that this lower pressure was present during that previous time period. The lower pressure would have reduced the flow of soil gas from the drain hole in the zone C HVAC room. Zone B radon entry may not have changed but there may be some communication between the air in the two zones and the zone B radon reduction may be caused by zone C.

CONCLUSIONS AND RECOMMENDATIONS

Based on the diagnostic measurements, the following conclusions and recommendations were made:

1. The radon levels appear to be generally lower now than they were during the 1989 summer and winter alpha-track measurements. Of course, these radon measurements may not be representative of the longer term, since they only covered one week and we already have seen significant variations that appear to be due to HVAC changes resulting from weather changes. Long term (3 month) winter radon measurements are definitely recommend for confirmation.

2. The building appears to be generally under positive pressure (relative to the subslab) in most rooms while the HVAC system is on. Only a few rooms were found to be significantly negative relative to the hallway and subslab. No continuous pressure measurements were made in HVAC zone C but all other measurements suggest that it is just as positive as zones A and B.

3. At night during HVAC shutdown there appears to be very little negative pressure, but this may change as the weather gets colder and the "stack effect" becomes stronger. In order to investigate this possible effect it would be necessary to do continuous radon and pressure measurements during cold weather. If this stack effect causes significant radon entry during the night, the HVAC system might be turned on earlier in the morning (e.g. 6 am) to flush out the building. Another option is to run the basement air handlers continuously during the night to guarantee a continuous positive pressure over the slab.

3. The negative pressure in the pump room and the HVAC equipment rooms should be eliminated if possible. Since a very wide range of depressurization was measured in these rooms (from 0.8 to 0.008" wc), it is assumed that there is a balancing problem that could be corrected.

4. The radon source in the shop was not found and it might be easier to locate when the HVAC system was shut down. It is difficult to locate it during the day because the positive pressure in the shop appears to suppress the radon entry.

5. The drain openings in the HVAC equipment rooms should be sealed to prevent radon and soil gas entry. Sealing could probably be done with a non-shrink grout or with a pourable

polyurethane caulk. This may be the primary solution to the radon problem in zones B and C, but it cannot be guaranteed because radon tends to build up behind sealing and emerge at other entry points. A combination of reducing depressurization and sealing is likely to be most effective. It is not clear whether the porous block walls in the HVAC rooms are also a source and it may be necessary to seal them too.

6. The standard radon reduction technique of subslab depressurization (SSD) may not be necessary in this building if all rooms can be pressurized, the major soil gas leaks can be closed, and any radon that enters when the HVAC system is shut down can be countered by bringing up the HVAC system early enough to flush it out. The shop area might be treated with SSD if the source is located, and a small exterior exhaust fan could probably be located in the bermed area next to the shop.

DISCLAIMER

The work described in this paper was not funded by the U.S. Environmental Protection Agency and therefore the contents do not necessarily reflect the views of the Agency and no official endorsement should be inferred.

Table 1 Radon and Pressure Test Results by Room

Room or zone Tested	Electret 9/6-9/7 (pCi/L)	Electret 9/6-9/10 (pCi/L)	Electret 9/6-9/14 (pcCi/L)	Electret 9/10-9/14 (pCi/L)	Alpha-Trk Summer89 (pCi/L)	Alpha-Trk Winter 89 (pCi/L)	9/10 Door Pressure (" wc)
	Test Type and Date						
HVAC ZONE A							
Shop (Pylon)	3.3	6.0	5.9	6.4	12.8	16.1	-0.007
H0001 pump	3.2	2.6	2.5	2.4		2.8	-0.098
Custodial	1.1	1.5	1.3	1.1			-0.022
H0138 Locksmith	1.7	1.6	1.3	1.0	2.0	4.0	0.002
Elect	0.7	0.5	0.5	0.5			-0.120
Kitchen elevator	0.2	0.2	0.3	0.4			-0.010
Kitchen storage	0.7	0.8	0.8	0.8		2.3	-0.003
Freight elevator	1.2	0.6	0.5	0.4			-0.010
cable chase	0.6	0.5	0.4	0.2			-0.009
H0001 storage	na	1.3	1.3	1.3			0.000
H,168 HVAC							-0.800
H0168 electrical							-0.120
HVAC ZONE B							
H0226 electrical	3.6	3.6	2.7	1.8			-0.008
H0226 HVAC	4.5	3.6	3.3	2.4			-0.050
H0256	na	4.4	3.4	2.6			0.000
H0266 (Pylon)	na	4.1	3.4	2.9	5.0	4.5	0.000
H0244	na	4.2		2.4			0.000
H0229B	n	4.0	2.2	1.5		3.7	0.000
HVAC ZONE C							
H0407 electrical	4.9	4.2	2.5	1.1			-0.005
H0407 HVAC	5.0	4.6	2.7	1.1	3.8		-0.026
H0470	5.4	4.2	2.5	0.9	2.9	6.2	0.000
H0440					3.0		na
H0450	na	4.2	2.2	0.9			0.000
H0495	na	3.9	2.0	0.7			0.000
H0308	na	3.9	2.0	0.8			0.000
H0310					2.9	6.3	na
H0318	na	4.2	2.1	0.8			0.000
H0324	na	4.3	2.7	1.6			0.000

Pylon indicates continuous monitoring available for that room

Negative pressure indicates that pressure across door is ower inside room

Table 2 Subslab Radon Test Results By Room

Room Tested	Test Date	Radon (pCi/L)	HVAC Zone
Shop hole A	9/14	200	A
Shop hole B	9/14	130	A
Shop Hole C	9/14	280	A
H0226 HVAC drain	9/18	240	B
H0407 HVAC drain	9/18	270	C

Grab sample test using Pylon AB-5 with Lucas cell

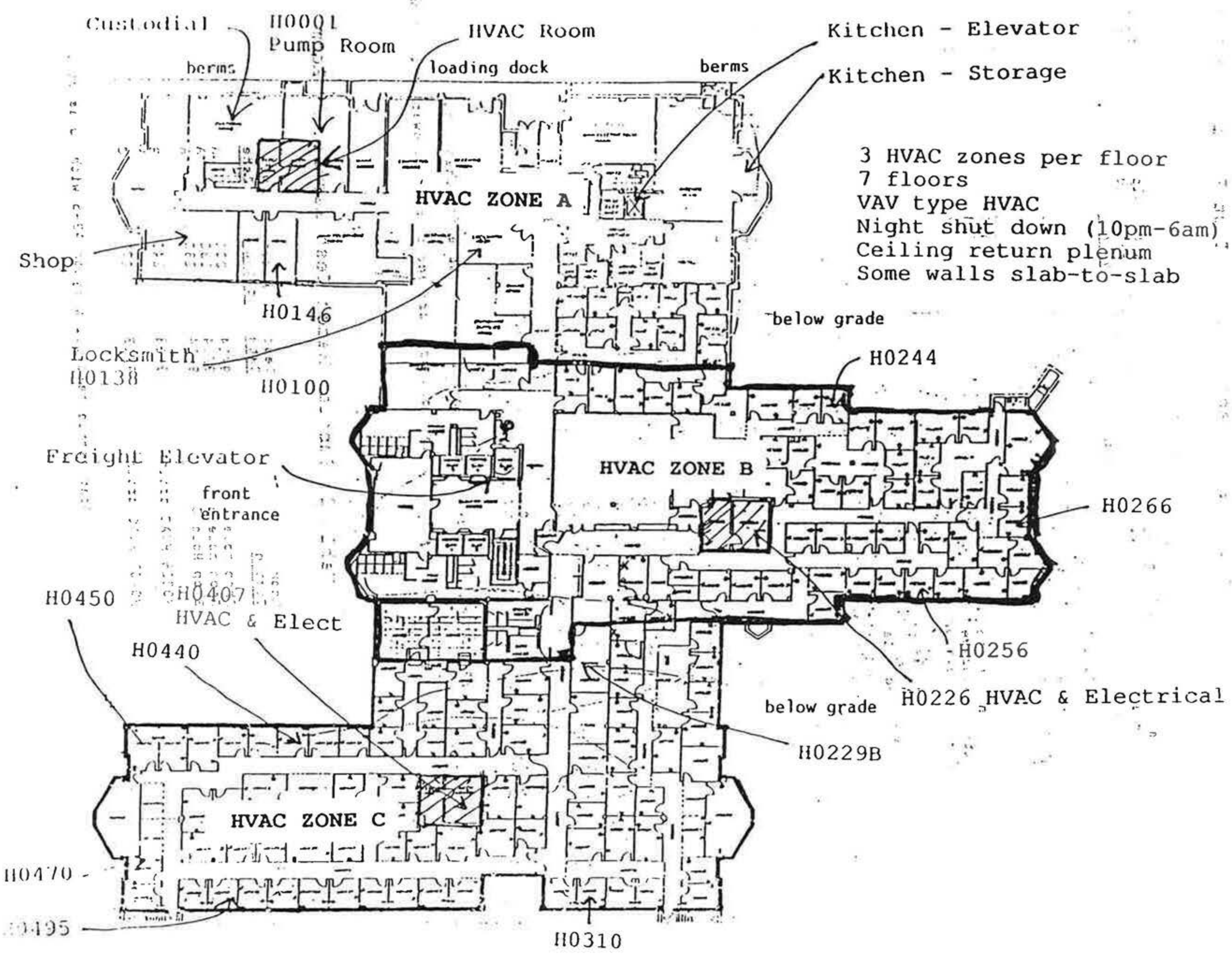

Figure 1 Basement Plan of Building

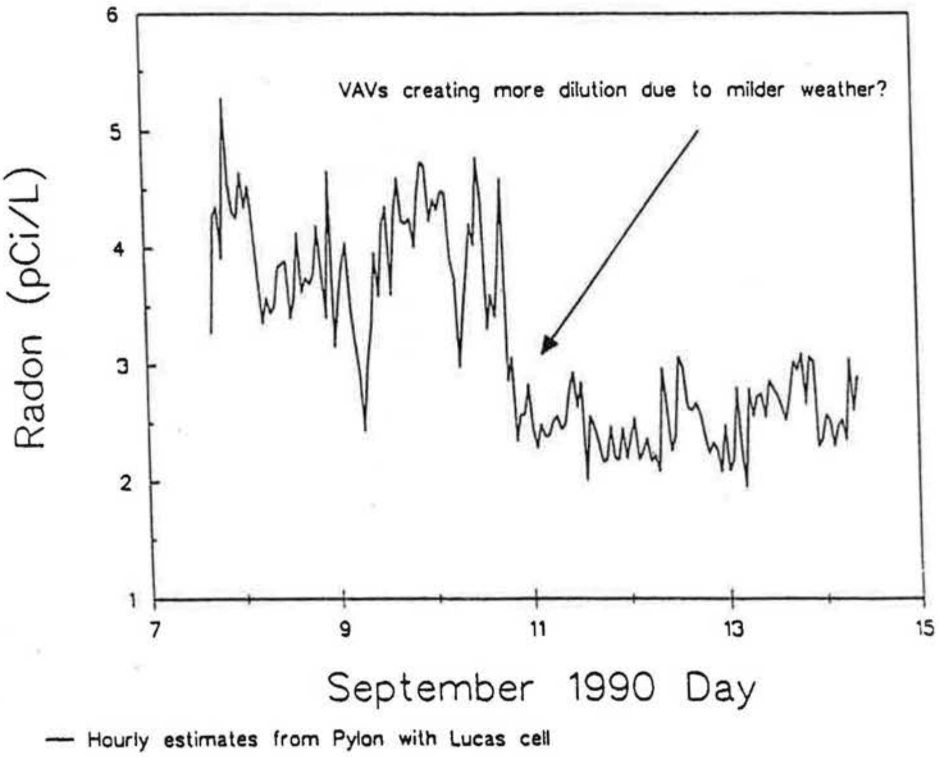

Figure 2 Continuous Radon in Zone B, Room H0226

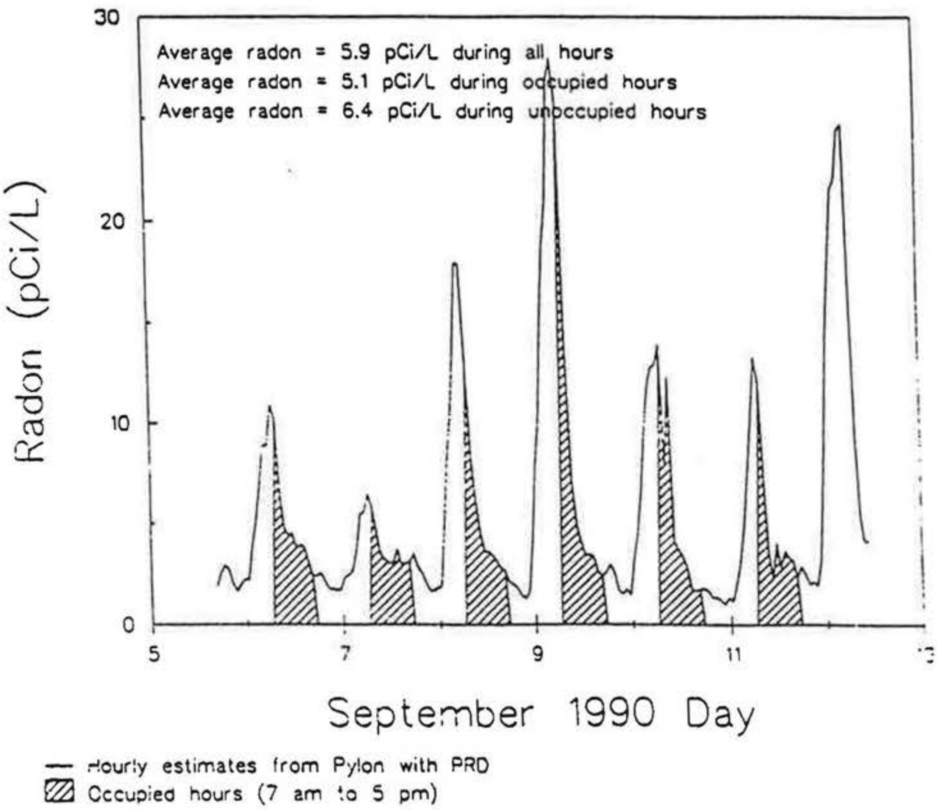

Figure 3 Continuous Radon in Zone A, Shop Room

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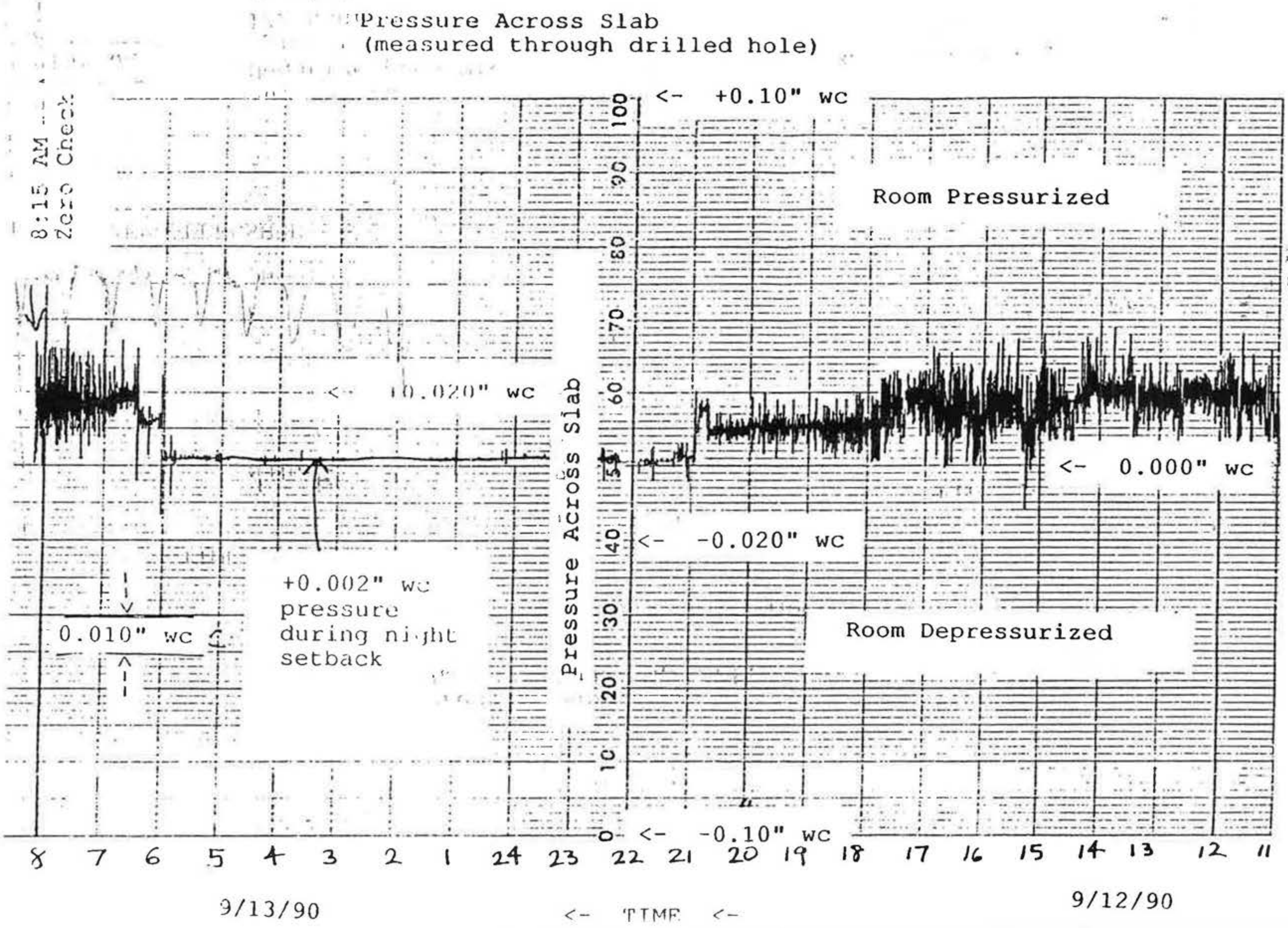

Figure 4. Continuous Pressure in Zone A, Shop Room

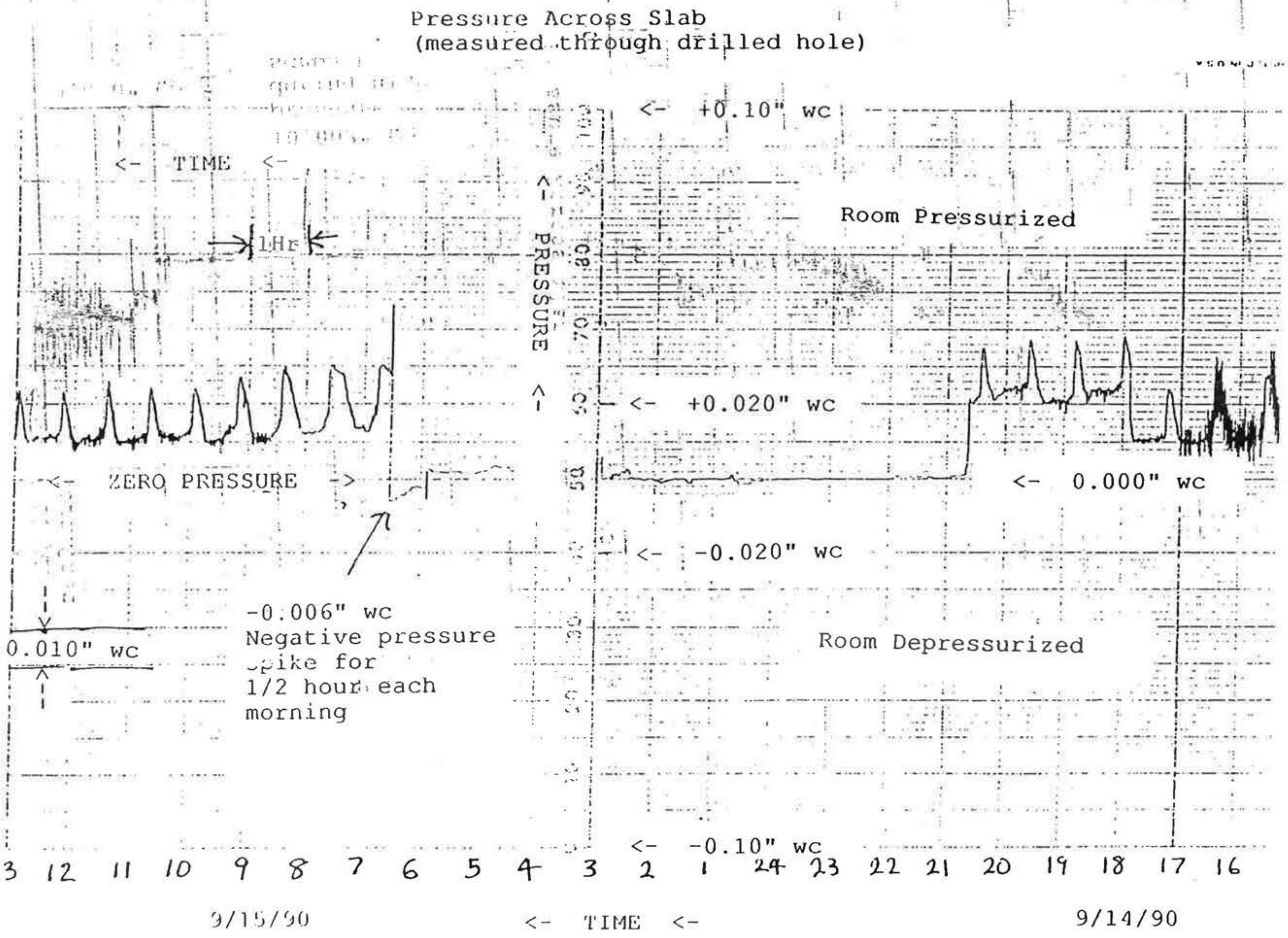

Figure 5. Continuous Pressure in Zone B, Room H0226