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WELL VENTS, A SIGNIFICANT SOURCE OF INDOOR RADON: A CASE STUDY

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ABSTRACT

Intentional and unintentional air vents in private wells have been found to be a significant source of indoor radon in several residential structures. This case study follows the investigation of failed mitigation attempts in one Connecticut home, which led to the discovery of well gasses containing substantial concentrations (58,000 pCi/l) of radon entering the home. Methods of investigation utilized and both original and final corrective mitigation are reviewed. This case study illustrates the importance of pre-mitigation diagnostics and post-mitigation evaluation in the management of "difficult to mitigate" buildings.

Following installation of sub-slab depressurization (SSD), block wall depressurization (BWD), and radon in water reduction utilizing shallow tray aeration (STA) technology, radon in air levels remained elevated in a residential basement. Although examination of the mitigation systems revealed various potential sources for catastrophic leakage of radon in air, none of which significantly contributed to the elevated levels. Real time and point source measurements attributed the unabated radon in air as originating from pressurized air leaking into the basement from the well pressure tank and the well circuit supply lines.

INTRODUCTION

Repeated unsuccessful attempts at radon mitigation were conducted in a single family Connecticut home during 1989 by a mitigation contractor who was accredited under the U.S. EPA Radon Contractor Proficiency Program (RCPP). Basement radon levels following mitigation as measured by an At-Ease® radon monitor were observed to fluctuate between 7.2 and 36.5 $pCiL^{-1}$. Technical assistance in investigating the basis for this failed mitigation was initially requested of the second author by the contractor and homeowner, and subsequently requested of the first author by the Connecticut Department of Health Services Radon Program and the U.S. EPA. Working together, the coauthors discovered a series of inadequacies with the mitigation systems that had been installed during the course of this investigation in 1990. However, the sum of these deficiencies which could have permitted radon re-entrainment into the structure did not account for the persistent radon air levels in excess of EPA guidelines. The initial continuous monitoring data showed intermittent peaks in radon concentration characteristic of waterborne radon entry. Only when consideration was given to the off-gassing of radon from the components of the basement well water supply was the source of these radon levels discovered.

BUILDING INVESTIGATION

The detached single family ranch style home is approximately 30 years old and contains about 2,000 ft^2 of first floor living space. The basement walls are constructed of concrete block with a poured concrete floor. Some significant settling cracks to daylight were noted along wall mortar joints in the basement utility room.

A two car garage under the living space is adjacent to a utility room on one portion of the basement slab. The utility room contained laundry and storage facilities as well as a lavatory with toilet and shower. The garage and utility area are approximately 1,090 ft^2 in total area with an air volume of 10,163 ft^3.

The remainder of the basement contained a workroom area where the well water services were located, and a finished recreation room. An exterior sliding glass door provided above grade access to the outdoors. This portion of the basement measured approximately 917 ft^2 with a volume of 6,846 ft^3.

EVALUATION OF INITIAL MITIGATION WORK PERFORMED BY CONTRACTOR

The mitigation contractor had installed two separate combination SSD/BWD systems in the two different basement areas to the slab floor and block wall. The tops of the block wall had also been sealed with cement prior to installation of the BWD portion of the mitigation network.

Also in the basement, a Clearadon® STA radon in water reduction device had been installed to the well water supply. Radon in water measurements conducted of this well throughout the course of this investigation revealed an average radon level of 147,300 $pCiL^{-1}$ pre-mitigation and 5,400 $pCiL^{-1}$ subsequent to STA processing. An average 3.0 $pCiL^{-1}$ radium was present in this well water and remained in the effluent of STA process. The Clearadon® unit was installed without an auxiliary blower and its discharge duct routed through the band joist to the roof. The lack of an auxiliary blower, as recommended by the manufacturer, resulted in pressurization of the discharge duct. An examination of the STA system demonstrated that it did not account for the observed radon levels. Prevention of radon gas entry into the basement area from the existing floor drains had been accomplished with the installation of Drainjer® drain systems.

The SSD/BWD systems were constructed of 4" I.D. schedule 20 polyvinylchloride (PVC) pipe. This pipe was used throughout the inside of the structure, and also for exterior discharge of radon gas above the house. The blower for these mitigation systems were Fantech® fans, an R-175 located in the laundry/utility room, and an R-150 located in the work room area, were both located inside the basement. They were installed in a horizontal orientation, which may provide opportunity for condensation collection within the fan housing. The appropriate location of these blowers is, exterior to the house, vertically exhausting radon gas above the roof line.

Condensate drain holes were drilled on the elbow of an exterior run of PVC pipe adjacent to a basement window sill. These holes can allow radon gas exhausting from the ventilation system to re-enter a house when located near windows or other openings. When first examined by the authors during the early months of 1990, it was noted that one of these drain holes was effectively blocked with ice.

Interestingly, it was discovered (and overlooked by the contractor) that the house rain gutter downspout drained to in-ground clay tiles. The homeowner had no knowledge of the drainage details of this system. No tests were conducted to assess the feasibility of incorporating these drains into the mitigation strategy.

Subsequent to the installation of the air and water radon reduction devices as described above, radon measurements as taken with an At-Ease® radon monitor by the mitigator demonstrated that radon levels were less than EPA guidelines for the first floor living area (0.9-2.1 $pCiL^{-1}$). However, radon levels fluctuated in the basement as follows:

TABLE 1. Post-Mitigation Radon Levels

Basement Location	Radon Levels ($pCiL^{-1}$)
Garage	1.6
Utility Room	0.9 - 3.0
Finished Room	6.0 - 6.6
Work room on work bench	7.2 - 36.5
Work room near water tank	7.5 - 35.2

FURTHER HOUSE EVALUATION

The above information implied that the cause of the exacerbated radon in air levels was located in the work room area. Therefore, two Pylon® AB-5 continuous radon monitors were utilized to study radon fluctuations in this area. One of the monitors was set up upon a work bench about 1.3 m high and the second was set up on a dehumidifier (non-operating) about 0.8 m high. It was decided to observe radon levels in this area with both SSD/BWD systems operating, only one (of each of the) SSD/BWD systems functioning, and with both of the systems turned off. Figures 1, 2 and 3 represent readings taken from the workbench site under different mitigation conditions.

Figure 1. Radon Levels with Both SSD/BWD Systems Inoperative, 30 Minute Cycles

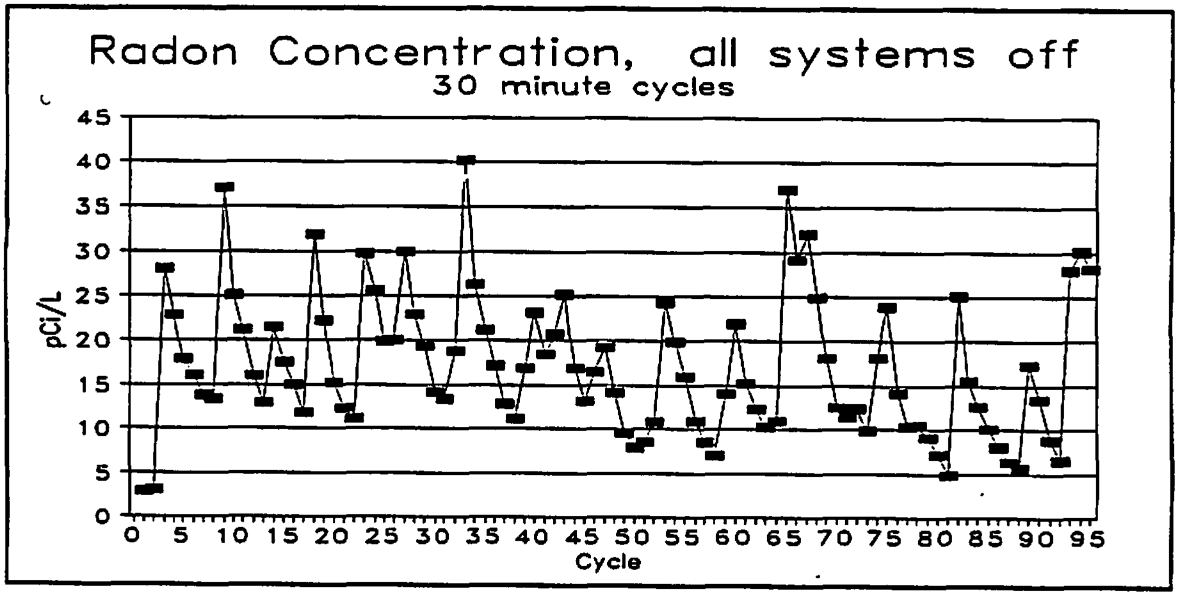


Figure 2. Radon Levels with each SSD/BWD System Operating alone, 30 Minute Cycles

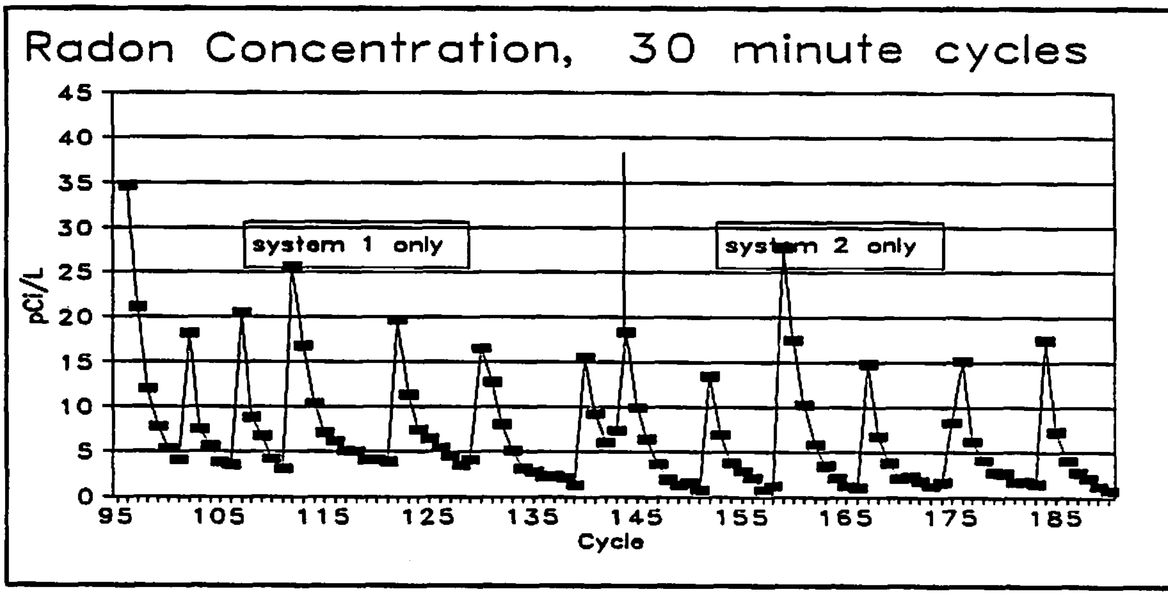
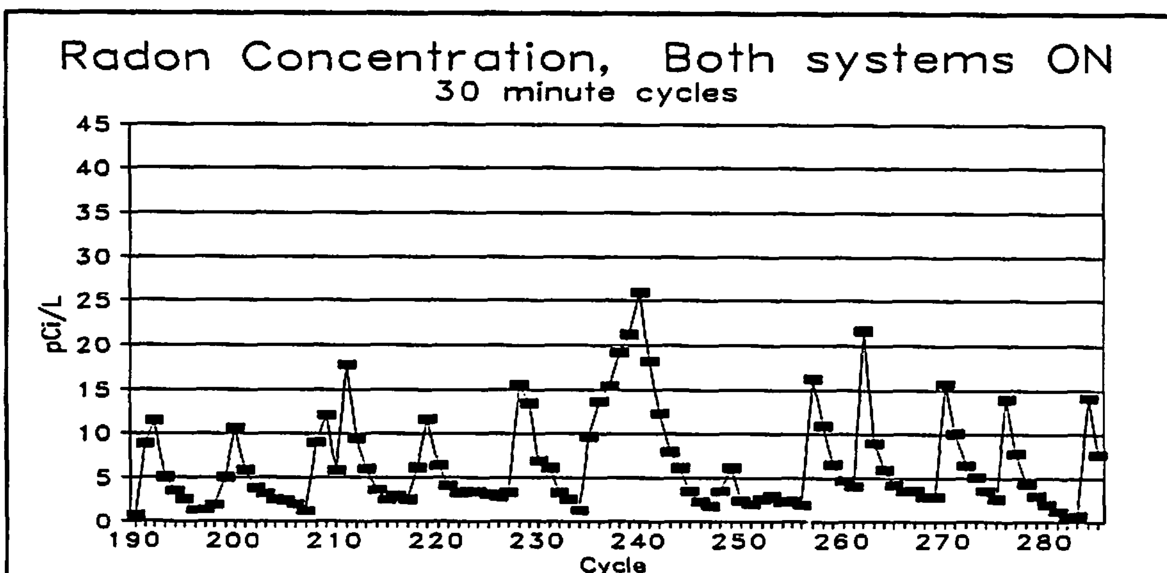


Figure 3. Radon Levels with both SSD/BWD Systems Operating, 30 Minute Cycles



Although the nature of the fluctuations in radon levels present in the basement work area were documented with these readings, the precise cause of the infiltration was not yet determined. A sniffer test of air bled from the hydro-pneumatic pressure tank indicated a high radon concentration in the tank's air volume. Therefore, charcoal radon monitors were utilized by placement in various basement areas along with sealing two of these monitors directly to the pressurized water tank with plastic sheeting and duct tape. The two monitors attached to the pressurized water tank were taped directly over air inlets present upon the tank. The results seen in Table 2 were obtained with these monitors:

TABLE 2. CHARCOAL RADON READINGS TAKEN IN BASEMENT WORK AREA

Location	Results ($pCiL^{-1}$)
Utility Room	0.5
Finished Room	3.7
Work Room Workbench	8.5
Work Room Near Pressurized Water Tank	10.8
Work Room on Top of the Clear-Radon® Unit	14.2
Lower Portion of Pressurized Water Tank	154.0
Top Portion of Pressurized Water Tank	1363.0

Based upon these measurements, it was hypothesized that the pressurized air tank was a significant source of the radon in air recorded in the basement work room. An understanding of the operation of the water supply system was necessary to explain the exact cause which would lead to solving the problem.

The following two diagrams of the water pump system show the valve and vent positions with the pump operating (Figure 4) and not operating (Figure 5).

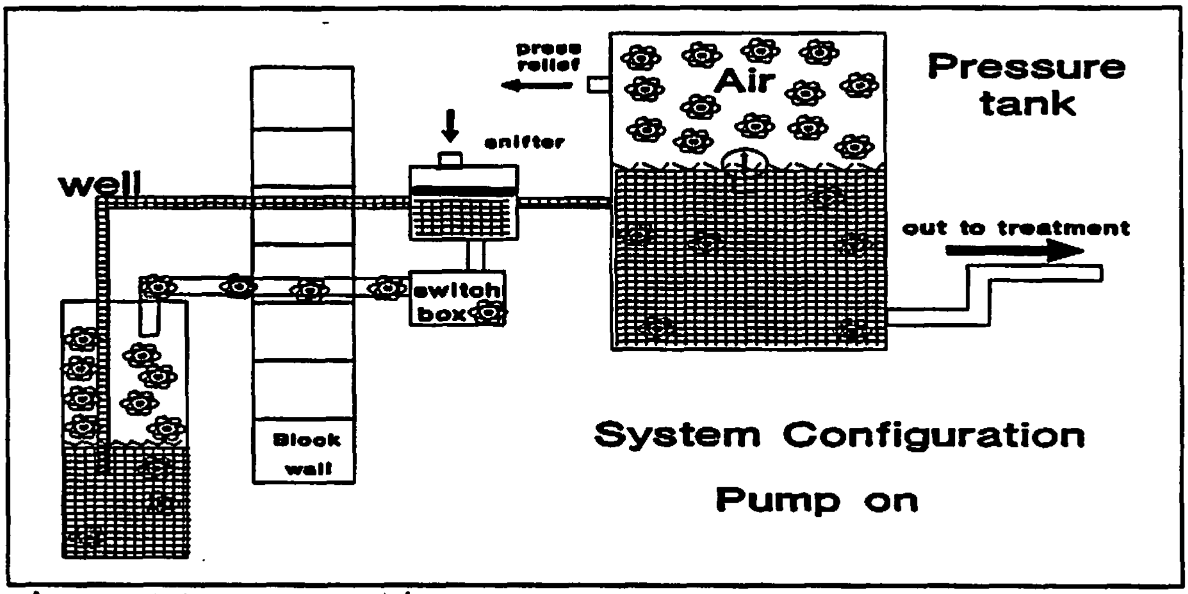


Figure 4 Pump Operating

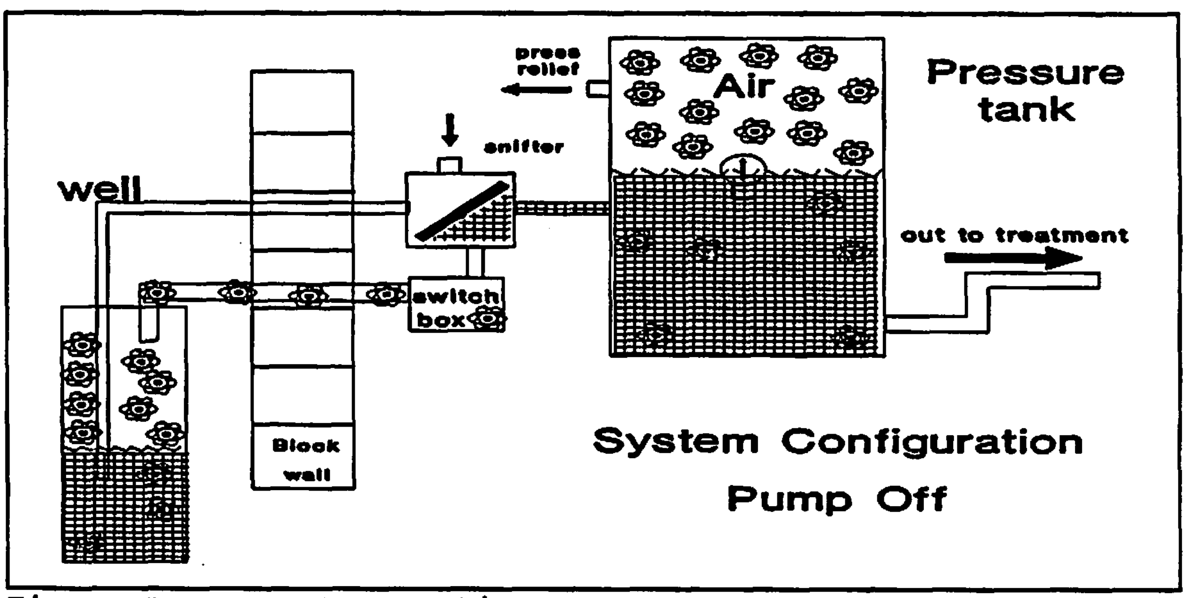


Figure 5 Pump not Operating

Upon cessation of pumping, a snifter valve, located near the switch box, allows basement air to enter the well water supply line acting like a vacuum breaker. Water in the line is replaced by house air back to the water level in the well. When pumping resumes, the air which now contains substantial quantities of radon gas is pumped into the pressurized storage tank. Ultimately, that radon laden air is purged from the tank to the indoor air via the pressure relief valve on the pressure tank.

In an effort by the contractor to correct the situation the relief valve on the tank air was removed so that it did not off-gas into the basement area. Subsequently, a Pylon® AB-5 radiation monitor was set in the vicinity of the pressurized water tank to continuously record radon concentrations. The intermittent peaks characteristic of brief introduction of high concentrations of radon gas continued.

DISCOVERY OF THE SECOND PATHWAY

During another site visit, the Pylon® AB-5 was utilized as a "sniffer" to help locate this additional radon entry pathway. It was noted that a one inch diameter conduit, containing electrical wiring running from the well to the pump's switch box in the basement, was an intermittent source for considerable concentrations of radon gas. Significant radon concentrations were detected beginning immediately after cessation of pumping and lasting only a few minutes. The duration of this infiltration is concurrent with the recovery of the well. Water which was removed from the well was replaced by air drawn through the well vent (in this case the electrical conduit). As the well refills (recovers), this air now containing high concentrations of radon gas, is forced back through the conduit into the switch box and then to the basement. Precise measurement of the air being off-gassed from this source and a study of the well mechanism revealed that when activated, the well would displace 15 gallons of air containing 58,000 $pCiL^{-1}$ into the basement area nearby. This well, which had average radon in water of 147,330 $pCiL^{-1}$, and a peak of 219,400 $pCiL^{-1}$ during a three month measurement period, was able to concentrate this enormous amount of radon in air and displace it into the basement during normal well operation.

The radon gas from this well vent was redirected to one of the SSD/BWD systems thereby preventing any radon gas which would emanate from entering the basement. Further readings taken with the Pylon® AB-5 radiation monitor, and both charcoal and alpha-track monitors, revealed that the radon concentration had been reduced to less than 0.3 $pCiL^{-1}$ in the basement.